Pre-Columbian Mining and Resource Production between Southern Peru and Northern Chile

An Analysis of the Exchange Processes Concerning Lithic and Metal Resources Used by the Pre-Columbian Cultures in the Andes

Benedikt Gräfingholt

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Cover Image
Mollaque Grande. Typical small-scale mining operations in the Andes. Adits following a Cu/Au mineralization in Mollaque Grande (photo: DBM, B. Gräfingholt).

Frontispiece
Mollaque Grande. Overview of the research area with adits following the curved mineralization running down the hill from south-west to north-east (photo: DBM, B. Gräfingholt).

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Content

Preface

The present work concludes essential parts of a research project that started more than 15 years ago in southern Peru. At the invitation of the Palpa Project and Dr Markus Reindel of the Bonn Commission for Archaeology of Non-European Cultures (KAAK), the Deutsches Bergbau-Museum Bochum was able to put out its first feelers into this highly fascinating cultural landscape and region in 2006. The region had been well known to German researchers since May Uhle's and Maria Reiche's work on the Nasca geoglyphs ("the so-called Nasca lines"). Unfortunately, these archaeological monuments have also led to all kinds of parascientific theses that have made Nazca famous far beyond the specialist world. The KAAK projects here have not only developed the scientific basis for the origin of the geoglyphs, but have also intensively researched the pre-Columbian settlement and cultural history, especially of the valley area around the southern Peruvian town of Palpa. In the course of the various excavations carried out at the Archaic, Paracas and Nazca culture sites, questions about the early extraction of raw materials have repeatedly come up. For example, the special location of Late Intermediate Period settlements, such as on the hill of Pinchango Alto, has fuelled the question of early gold extraction. In the meantime, it has become clear that the late pre-Inca settlement period represents a particularly favourable phase in terms of agriculture and population history, during which even marginal settlement zones were increasingly settled and used. Nevertheless, the numerous evidences of the use of metallic and lithic raw materials raised questions that made it rewarding for our house to become further involved here.

Initial investigations were able to begin during a short survey in 2006 (Stöllner and Reindel 2007; Stöllner 2009) and were subsequently expanded with help of a smaller DFG funding. The DFG's expert committees are to be thanked for this. As early as 2009, an extensive survey was carried out, which also laid the foundations for this work (Reindel, et al. 2013; Stöllner, et al. 2013) and subsequently enabled further investigations by the author of this book. The investigations, carried out for the first time as a systematic montane-archaeological survey, were laid out along the deposits of the coastal area of southern Peru and followed the deposit outcrops of the coastal valleys, the quebradas. The sparse vegetation enabled the discovery of numerous suspected sites for pre-Columbian mining, but also allowed interesting ethnographic insights through the numerous re-uses by modern artisanal small-scale mining. During these surveys, the DBM team was involved, along with the author of this foreword, Dr Guntram Gassmann and the then student Benedikt Gräfingholt. We were supported by Prof. Dr. Markus Reindel, Dr. Johny Isla Cuadrado, Prof. Dr. Günther A. Wagner and the driver and local expert Pablo Segura. The latter made it possible to visit even impassable extraction areas and shared a lot of local knowledge with us. I am very thankful to all these colleagues. The staff of Casa Blanca, the excavation house of the Palpa Archaeological Project (PAP) must also be included in the thanks. They made our work on site pleasant and also purposeful. Fascinating sites were also visited during the survey, such as Mina Primavera, which can be considered an outstanding pre-Columbian extraction site for red earth (ochre) (Eerkens, Vaughn and Linares Grados, 2009). The visit to the important obsidian deposit of Jichja Parco in the district of Ayacucho at almost 4000 m above sea level is also well remembered. The site, which has gone down in archaeological-archaeometric literature as Quispisisa (Tripcevich and Contreras 2013), must be considered one of the most important sources for the southern Altiplano and also the coastal areas between Palpa and Nasca. Here, too, this work was able to provide new and important evidence.

Benedikt Gräfingholt began his research immediately after the 2009 surveys, initially within the framework of a Master's thesis on "Obsidian projectile points in the Palpa region, Peru", which was completed in 2011 and already involved the initial attribution of the obsidian's origin. This basis allowed the studies to be expanded into a dissertation, which since 2012 has also been supported by the Konrad Adenauer Foundation (KAS), for which the DBM and the Ruhr University (RUB) are very grateful. It was also possible to convince the Research School PLUS of the RUB to carry out further investigations on site in 2014. Among other things, reliable evidence was obtained for the early extraction of gold-bearing ores during the early Paracas period in Mollaque Grande. There is similar evidence in the Viscas valley near Saramarca, but unfortunately without a secure stratigraphic context. This very important evidence clearly indicates the potential for further mining archaeological investigations, which, however, are becoming increasingly difficult due to modern extraction, especially irregular mining, which destroys many archaeological contexts. In this respect, the volume presented here provides numerous mining archaeological and archaeometric approaches to understanding the extractive landscape in the coastal region of Peru's south. It is to the author's great credit that he has dedicated himself to this not entirely easy task and has now compiled it into a fundamental work.

The present work was submitted as a dissertation in 2016. Numerous colleagues contributed to its supervision and, most recently, to its printing: In addition to the project partners, above all Dr. Johny Isla Cuadrado (Lima) and Prof. Dr. Markus Reindel (Bonn), the staff of the DBM research laboratory in Bochum, above all Dr. Michael Bode and Prof. Dr. Michael Prange, should be mentioned and thanked. Prof. Dr. Andreas Hauptmann has accompanied the work with benevolent criticism, just as we owe Dr. Petra Eisenach the supervision of the printing, editing and pagination. Bernd Lehnhoff once again took on the demanding editorial work, just as Jochen Pausch and Dr. Gisbert Puzicha were involved in the English proofreading. In conclusion, I hope that the work will be well received in the scientific world and that it will stimulate further research in the field of montane archaeology in the Andean region.

Prof. Dr. Thomas Stöllner, February 2022

Acknowledgement

My research project started in January 2012 and I am absolutely sure that since then countless people have supported and helped me finishing this PhD thesis one way or the other. I would like to thank all of them and apologize just in case I forgot to mention someone by name. First of all, I want to thank my supervisor Prof. Dr. Thomas Stöllner who encouraged me to follow my passion for the Americas and enabled me to commit my research efforts on South and Middle America. The support and constructive criticism he has given me over the years has always been extremely valuable and helped me to focus and enhance my research. His enthusiasm for mining archaeology and immense knowledge concerning prehistoric raw material exploitation worldwide has inspired me to focus my research efforts on these topics. From the beginning, my second supervisor Prof. Dr. Andreas Hauptmann has supported the interdisciplinary approach of this thesis, as he provided me with the knowledge needed to combine humanities and natural science. Because of his vigorous advocacy I was given the permission to take a pXRF device to Peru. I am fortunate to have Dr. Markus Reindel, German Archaeological Institute Commission for Archaeology of Non-European Cultures and director of the Palpa Project, as a third supervisor. He has welcomed me to his interdisciplinary team in Palpa and introduced me to the pre-Columbian cultures of South Peru. I could always rely on his advice and he constantly managed to give me valuable feedback concerning my research efforts in the Nasca-Palpa area.

Since I started my research in Peru in 2008 Dr. Volker Soßna has been a friend and colleague who supported and encouraged me with his knowledge about Peru in general and especially concerning the research area. It has been a great experience working with him and I am very thankful for the maps he designed to illustrate the research area. I want to express my gratitude to the following colleagues who advised me and deserve a great deal of credit include Herman Gorbahn, Moritz Jansen, Ingolf Löffler, Katrin Westner, Christian Mader and Daniela Oestreich. I especially want to thank Dr. Guntram Gassman who has laid the foundation for this study by the mining archaeological research conducted in the Nasca-Palpa area together with Prof. Dr. Thomas Stöllner.

In the course of my research stays in Peru Johny Isla Cuadrado supported me in many ways.I have tremendously benefited from his deep knowledge of the research area and learned a lot from his archaeological excavation skills. Above all he is responsible for the successful geochemical analysis of all obsidian and metal artifacts as he organized the access to the objects in Palpa, Ica and Lima. He and his team, especially Omar Quzjandria Jimenez, have made every stay in Palpa unique and worth remembering: Thank you very much! I am also very thankful for the support and interdisciplinary scientific discourse with all the researchers that I have had the chance to meet in the course of my work in Palpa. I hope that everybody who has supported my research in the course of our joined interdisciplinary work in Peru feels acknowledged. Still I owe a very warm and special gratitude to Pamela Castro de la Mata Guerra García and María Inés Velarde Dellepiane for supporting as they shared their results of the SEM analysis of the metal artifacts from the research area and provided access to the precious metal artifacts from the research area during my stay in Lima.

A very special acknowledgement goes to Rodolfo Contreras, Director of the Museo Augusto Capdeville in Taltal (Chile), who welcomed me to his museum and spontaneously guided me to the oldest mining site on the American continent. I would not have been able to reach the site without his help and it has been a tremendous inspiration for my thesis to have actually visited the so far most ancient mining site in the Americas.

For the time he took in educating me about geochemical analysis in general and especially about the application of the pXRF device on obsidian and copper-based artifacts I would like to thank Prof. Dr. Michael Prange, head of the material science laboratory at the Deutsches Bergbau-Museum Bochum. He and Dr. Michael Bode have given me the chance to follow an interdisciplinary approach by integrating the results of the pXRF into my PhD thesis. Dr. Michael Bode, material science laboratory of the Deutsches Bergbau-Museum Bochum, has continuously provided me with helpful suggestions and further information concerning my research. Because of the whole team of the material science laboratory at the Deutsches Bergbau-Museum Bochum I have had an extremely supportive working environment and always felt encouraged by the researcher who helped me with bits and pieces in the course of my project.

Dr. Wolfgang Homann (†), former director of the Naturmuseum Dortmund, supported me with his expertise on gold washing and helped to identifiy promission gold samples from the research area.

Furthermore, I want to thank Gergely Puzicha who has accompanied me during my fieldwork in Peru and was a tremendous help because of his mathematical knowledge and geological curiosity. Dr. Gisbert Puzicha, Dr. Petra Eisenach, Bernd Lenhoff and especially Jochen Pausch have supported me immensely when I needed advice concerning stylistic and idiomatic issues. My lifelong friend Mirco Befeld committed quite a bit of time and effort to solve technical problems I had while writing my thesis and fulfilled an incredible task to give me a deeper understanding of Excel. Come what may, he was always there to help.

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Last but not least, I want to thank Prof. Dr. Jürgen Kretschmann, President of the TH Georg Agricola University, for actively encouraging me to apply the knowledge I gained in the course of my scientific research and for sustainably persuading me to finish my PhD thesis by the end of June 2016. By working for him since February 2016 I have had the chance to integrate myself in the team of the TH Georg Agricola University of Applied Science and daily face new and challenging tasks in a familiar and encouraging working environment.

Finally, my parents deserve a special acknowledgement, as they have always believed in me and the path I have chosen. During the four and a half years it took to successfully complete my PhD thesis, I have always been supported, backed up, encouraged, pushed, advised and accompanied by my wife Katrin. She was there for me and actively contributed to the success of my thesis by traveling 3,500 km from Santiago de Chile up to Lima, in order to visit important pre-Columbian mining sites and conducting geochemical trace element analysis in Palpa and Lima. Her scientific knowledge and archaeological understanding tremendously helped me when I was unsure how to solve difficult issues.

I am absolutely sure that my thesis would have been completed slightly earlier if it was not for my daughter Amalia who constantly convinced me to discover the world with her!

Benedikt Gräfingholt
Bochum, November 2021

1 Introduction

For more than 12,000 years the people in the Andes mined the resources of their surroundings[1] and were irreversibly associated with mining.[2] The world´s largest copper (El Teniente, Northern Chile)[3], silver (Potosí, Bolivia) and tin (Llallagua, Bolivia) deposits[4] and one of the greatest gold deposits (Yanacocha, Peru) in the world are still located in the Andes[5]. "*In the most general sense mining can be regarded as extension of the search for natural materials that could be used for the fabrication of tools and weapons or as ornaments.*"[6] The desire and search for raw materials let to the evolution of a mining tradition in the Andes that used methods which allowed the pre-Columbian miners to extract ores and other resources such as obsidian and minerals with highly specialized tools that were produced using locally available resources, like stone and bone.[7]

This comprehensive analysis of an ancient mining district in the south of Peru in the region around Palpa highlights the long-lasting tradition of mining in the area and explains the origin of this tradition. Stöllner (2014, p.138) has defined the term mining district in the following way: *"A "district" should be understood as locally concentrated, intensive exploitation of a deposit: Generally, one could understand them as large and permanent production units. Often they are parts of an even larger unit, the so called "mining region" ("Montanlandschaften") that assembles different production and functional units on the larger scale of a landscape."*. A combination of mining archaeological methods (Stöllner, 2015) and modern geochemical analysis was used to discuss the question of how resource production was organized by the pre-Columbian cultures of southern Peru and northern Chile and to answer the question concerning the beginning of pre-Columbian mining and raw material consumption patterns in the research area. In order to address this question, a pre-Columbian mining district in the Palpa region is presented to reconstruct the duration of mining in the region and clearly identify the cultures involved in mining. By means of geochemical analysis resources mainly mined in the region were defined and exchange networks of locally produced ores and artifacts were identified.

In the past, as Shimada and Craig (2013, pp.3) outlined, archaeologists have concentrated their research on high-value artifacts that emerged during the Conquista and in later unorganized excavations and grave robbing activities with no contextual information. Due to the focus on precious artifacts, the reconstruction of the technological process (*chaîne d´operatoire*) was concentrated on the final stage. The whole multi-phase production process was never really accepted as worth investigating, resulting in the fact that previous generations of researchers never asked and tried to answer the question where the raw materials for those – in most cases – looted artifacts came from. An explanation may be that they were so overwhelmed by the richness of noble metals that were used by the pre-Columbian cultures in South America to produce such marvelous artworks.[8]

After the *Conquista* and the successful establishment of the Spanish rule over the conquered Inca Empire the first written documents of the chroniclers remarkably illustrated the rich mining tradition that existed in the subjected territory[9] and also highlighted the existence of alloys in the New World. Juan de Grijalva gave one of the earliest reports of alloy use in his account about a Spanish expedition to Yucatan in 1518: *"The Spaniards asked the Indians if they had any gold. […] They said 'yes' and brought some guanines which they put in their ears and some round discs of guanin and said they had no other gold than that...so that the reader may understand what guanines are … I may say that they are pieces of gilded copper, and if they contain any gold it is very little."*[10] The handed down descriptions of mining organization, mining techniques and social aspects of mining during the transition from the Inca rule to the Colonial times have to be regarded as eyewitness or oral tradition documents that cannot offer a glance beyond its time.[11] This written heritage is extremely important when dealing with Incaic mining[12] but an archaeological study which investigates pre-Inca mining districts should not concentrate too much on these written documents instead the archaeological

1 Salazar, et al., 2011b; Salasar, Borie and Oñate, 2013.
2 Shimada 2013, p.335.
3 Maksaev, et al., 2004, p.16.
4 Sillitoe, 2004, p.1.
5 Gustafson, et al., 2004, p.259.
6 Weisgerber and Pernicka, 1995, p.3.
7 Petersen, 2010, p.36; Salazar, et al., 2011b; Figueroa, et al., 2013.

8 Sáenz Samper and Martinón-Torres, 2011, p.245.
9 Shimada, 2013, p.348.
10 Wagner, 1942, p.94 cited in Root, 1951, p.7.6.
11 Shimada, 2013, p.348.
12 Cantarutti, 2013.

context on-site has to be interpreted in order to reconstruct the pre-Columbian mining environment.

The investigations conducted by Salazar in the mining district of *San José del Abra* offer a perfect example of this approach – although written sources would have been available.[13] Commonly cited advocates of the written heritage concerning mining tradition are Cieza de León "*Crónica del Perú*" (1553), Pedro Sancho de la Hoz secretary of Francisco Pizarro, El Inca Garcilaso de la Vega "*Commentarios reales de los Incas*" (1609) and Hernando de Santillán "*Relación del origen, descendencia, politica y gobierno de los Incas*" (1563). By looking at the medieval texts it becomes clear that – during Inca rule – mining was state organized. A labor program called *mita* – a sort of tax – assigned the common people to work for the state at different times of the year or all over the year in specialized working fields like agriculture, transport or mining.[14] This rotation system affected all inhabitants of the Inca Empire and once assigned to work the local people or even whole contingents of workers from other region exploited the state owned mines.[15] The raw material production was organized by Inca officials (*quipucamayocs*) who sent the men and women to work in the mines. If necessary, settlements were especially built for the people who attended for duty. One way or the other, when performing certain tasks continuously or because of a handed down family tradition, at one point specialization started and different craftsmen groups arose. Specialized miners´ professions are documented for silver (*colque camayoc*) and copper (*antay quilla camayoc*) mining.[16]

At the beginning of the 20th century, Lothrop (1937) and Root (1949) laid their research emphasis on the development of metallurgy in the New World and did not attempt to pinpoint the origin of the raw materials these artifacts were made of. Caley and Easby (1959) at a very early stage of metallurgical research speculated about the advanced mining techniques that might have been present in the Province of Ica in the Valle de Ingenio and proved that the pre-Columbian metal smiths mastered the smelting of sulfide copper ores. Lechtman (1976) with her macro-scale survey of ancient mines and metallurgical sites has to be regarded as a bridge builder between the pure metallurgical approach to the artifacts and mining archaeology. Mining archaeology is the investigation of ancient mining contexts and has the potential to identify the sources of the raw materials used in pre-Columbian times. By locating the mines and quarries used by the pre-Columbian cultures in the Nasca-Palpa area it will be possible to identify the sites were the raw material for the production of the metal artifacts excavated in the region was extracted.

Already in 1970, G. Petersen published a first comprehensive analysis of pre-Columbian mining, the use of resources and the rise of metallurgy in the Andes especially in Peru. This work also tried for the first time to give an encyclopedic overview of mining archaeology in Peru that naturally only encompassed a very limited selection of mining archaeological sites.[17] This publication could have been the initial spark for further research concerning mining archaeology,[18] but in spite of this a rich research tradition that deals only with the pre-Columbian metallurgical processes evolved,[19] mining archaeology in South America is still in the early stages. Several researchers have undertaken the task to widen the scope on pre-Hispanic mining in Peru. In the course of her metallurgical site survey in the Peruvian Andes, Lechtman tried to contribute a first comprehensive approach on trying to locate pre-Hispanic mines. Eventually she could not identify a single pre-Hispanic mine herself but correctly stated that the "*Europeans took over many of the Inca mines, greatly enlarging their scale of operations by exploiting Andean labor.*"[20] She also envisioned that copper was the basis for all Andean metallurgy and with this pre-Columbian copper mining had to be present somewhere.[21]

Craig and West (1994) undertook the quest to gather the avant-garde of archaeometallurgists and mining archaeologist working on research issues of pre- and post-Conquest periods in the Americas in the 1990s. Representatives of the upcoming type of mining archaeologists started to publish comprehensive results of pre-Conquest mining site in Mesoamerica and the Andean Region. Phil Weigand[22] dedicated his life to the research on turquoise mines and was able to locate the extraction sites of turquoise in the Southwest of the USA that was exported from there via long distance trade to the heartland of the Mesoamerican Civilizations. Additionally Mathien[23] comprehensively investigated the turquoise mining of the prehistoric Chacoans. In the chapter on Pre-Hispanic Mining Shimada (1994, pp.47-55) contributed to "*In Quest of Mineral Wealth. Aboriginal and colonial mining and metallurgy in Spanish America*" he demonstrated the lack of research in the field of mining archaeology in the Andean region and described his approach to locate ancient mines in the Lambayeque, La Leche and Zaña Valleys. An important argument for the underdeveloped field of mining archaeology in Peru is mentioned in this chapter as well – the problem of gaining access to ore deposits and the reopening of pre-Hispanic mining sites by modern miners. Promising sites are today worked on by *mineros artesanales* to extract gold.[24] Another aspect

13 Salazar, 2008; Salasar, Borie and Oñate, 2013, pp.91-92.
14 Stöllner, 2011, p.184.
15 Gonzáles, 2004, p.321.
16 Stöllner, 2011, p.184.

17 Petersen's work (1970) was later translated from Spanish to English and republished by W.E. Brooks (quoted in this study as Petersen, 2010).
18 Stöllner, 2009, p.393.
19 e.g. Lothrop, 1937; Root, 1949; Mujica Gallo, 1967; Bray, 1971; Lechtman, 1976; 1979; Benson, 1979; Lechtman, 1991; MacEwan, 2000; Gordon and Knopf, 2006; 2007.
20 Lechtman, 1976, p.8.
21 Lechtman, 1976, p.9.
22 Weigand, Harbottle and Syre, 1977; Weigand and Harbottle, 1993; Weigand, 1994; Weigand and Garcia de Weigand, 2001.
23 Mathien and Warren, 1984; Mathien, 2001.
24 Stöllner, et al., 2013, p.114.

clearly was the civil war 1980–2000[25] that devastated especially the Altiplano region and terrified its inhabitants. The violent conflict between the terrorists of the *Sendero Luminoso* also called *Movimento Tupac Amaru* and the democratically elected government and its armed forces left no secure place for archaeological investigations as the region was mostly inaccessible to foreign researchers. At first only the Altiplano region in Ayacucho was affected but the situation changed in the course of the conflict so that foreign archaeological research all over Peru declined. Nonetheless, a few projects continued their work but did not follow any mining archaeological approach. In this context it is obvious that archaeological investigations in Peru declined and especially surveys conducted by foreigners with a focus on mineral deposits and pre-Hispanic mining would not have been feasible.[26] Since 2000 the situation has dramatically changed not only in Peru but throughout South America as González (2004; 2008) has impressively outlined for the metallurgical development in Northeast Argentina. Salazar (2003-2004) impressively continued the work started by Núñez (1999; 2006) – who pioneered with first comprehensive investigations on mining and metallurgy in the South Andean region – as he described the mining archaeological beginnings in Chile, and Cruz and Vacher (2008) presented a summary of mining and metallurgy in the Andes. Just recently a thought provoking work by Tripcevich and Vaughn (2013) has presented an overview about mining archaeology in the Andes and basically summons all researches that are actually working on projects investigating prehistoric mining in the Andes. The same holds true for the 2013 special issue of the *Revista de Antropología Chilena*.[27] Just recently Salazar and Vilches (2014) summarized the progress mining archaeology has taken in the south-central Andes. In the Nasca-Palpa region, mining archaeological investigations have been conducted since 2006 in the course of interdisciplinary research projects led by the German Archaeological Institute.[28] Stöllner, et al. (2013, p.114) have discovered traces of early mining activities dating to the Paracas and Nasca culture and established a survey routine to locate ancient mines in the quebradas of the river valleys around Palpa. This work has laid the foundation for the current study and enabled the author to directly access already identified pre-Columbian mining sites in the research area. Nonetheless only a minimal proportion of sites located in the Andes has been investigated so far concerning the potential as mining archaeological sites, as to date the huge potential for the reconstruction of raw material consumption patterns has not been widely acknowledged. Therefore, the available scientific knowledge about mining activities and capacities of the pre-Columbian cultures still remains on a basic level, and comprehensive analyses of the mines and quarries that produced the lithic and metal resources that pushed the exchange processes in the Andes are still rare.

25 Shadle, 2013, p.285.
26 Burger, 1989, p.44.
27 Shimada, 2013, p.338.
28 Stöllner and Reindel, 2007.

1.1 Aim of this thesis

This mining archaeological study conducted in the Nasca-Palpa area seeks to contribute to the mining archaeological research, as this comprehensive investigation combines geochemical trace element analyses and mining archaeological methods to reconstruct the raw material consumption and extraction patterns in Southern Peru. Due to the fundamental research efforts that have been conducted in the Nasca-Palpa area since 1997 by interdisciplinary research projects[29] of the German Archaeological Institute which were implemented by Dr. Markus Reindel and Johny Isla Cuadrado on the one hand and on the other hand encouraged by the mining archaeological research that has been initiated in the course of these interdisciplinary projects by Prof. Dr. Thomas Stöllner[30] from the Deutsches Bergbau-Museum Bochum and the Ruhr University Bochum, this study accessed a comprehensive set of data that already defined the given parameters for the cultural development in the research area. In order to incorporate a wider perspective the given situation in the research area shall be compared to another identified core region of pre-Columbian mining in Northern Chile[31] to elaborate with the examples of obsidian, copper and gold mining operation a role model for the development of a small-scale mining district in the Nasca-Palpa region over the course of the whole span of pre-Columbian human occupation. Furthermore, this study will also contribute to the fundamental research on the direct application of pXRF in the field as this method has so far mainly been used in controlled laboratory environments[32] that totally ignore the huge potential of this highly effective non-destructive geochemical analytical method for the archaeological field research in an international context. The fundamental questions that shall be answered with this study can be summarized as follows:

29 Castro de la Mata Guerra García, et al., 2012; Eitel, et al., 2005; Eitel and Mächtle, 2009; Fehren-Schmitz, et al., 2009; 2010; 2011; Hecht, 2009; Herrmann, Reindel and Wagner, 2009; Isla Cuadrado, 2009; Isla Cuadrado and Reindel, 2002-2006; Mächtle, et al., 2009; Reindel, 1997; 2007; 2008; 2009a; 2009b; 2011; Reindel and Isla Cuadrado, 1999; 2000; 2001; 2003; 2009; Reindel, Isla cuadradi and de La Torre, 2004; 2005; Reindel, Isla Cuadrado and Linares Grado, 2006; Reindel, Isla Cuadrado and Tomasto Cagigo, 2001; 2002; Reindel, Solis Quinteros and Isla Cuadrado, 2008; 2010; Reindel, Stöllner and Gräfingholt, 2013; Reindel and Wagner 2009; Schlosser, et al., 2009; Stöllner, 2009; Stöllner and Reindel, 2007; Stöllner, et al., 2013; Tomasto Cagigao, Reindel and Isla Cuadrado, 2009; 2015; Unkel and Kromer, 2009; Unkel, et al., 2007; 2012.
30 Stöllner and Reindel, 2007; Stöllner, 2009; 2011; Stöllner, et al., 2013; Reindel, Stöllner and Gräfingholt, 2013.
31 Núñez, 1999; 2006.
32 Frahm and Doonan 2013, p.1429

When did the pre-Columbian cultures of the Nasca-Palpa area start to exploit the rich mineralization zones opened up by the quebradas in the river valleys and did the inhabitants of the research area only rely on the obsidian source Jichja Parco to satisfy their need for high quality obsidian?

1.2 Approach

In order to address this question, it is imperative to incorporate the above mentioned non-destructive geochemical analysis conducted by a pXRF device[33], mining archaeological excavation[34] on previously identified sites of supposed pre-Columbian mining and geochemical analysis of ore samples taken during surveys in the research area between 2008 and 2018. Especially two sites in the Nasca-Palpa area have been identified as promising locations to intensify the mining archaeological research because of previously conducted survey campaigns: Mollaque Grande[35] and Saramarca[36]. Mining archaeological test excavations which target the pre-Columbian extraction sites in the mineralization zones of the Nasca-Ocoña belt that were overprinted by recent mining activities have been conducted on these sites to identify the chronological frame of the initial mining operation in the Nasca-Palpa area. In this sense, *"mining archaeology (Bergbauarchäologie) can be described as the basic archaeological method to survey, excavate and evaluate ancient exploitation areas such as underground mines and quarries."*[37] So far, the questions concerning the origins of the mining technique used in the Nasca-Palpa area and the timeframe for the introduction of mining into the research area have not been solved.

Furthermore, in order to reconstruct the raw material consumption patterns it is imperative to apply geochemical trace element analysis to the pre-Columbian obsidian and metal artifacts found in the research area. On the one hand, the pXRF offers a unique chance to generate a data set for a provenance study on the basis of 365 obsidian objects from the research area and track the obsidian quarries that have been used by the pre-Columbian inhabitants of the research area. As provenance studies on obsidian artifacts using a pXRF in Peru have proven to be successful in the past[38], this approach has been successfully implemented. Furthermore, samples from the obsidian quarry Jichja Parco which were taken during a previous field survey in the research area[39] will be analyzed in order to create a reference sample collection. On the other hand, the generated data concerning the trace element composition of 199 metal artifacts – which will naturally only detect the surface enrichment[40] – shall be used to clarify the question concerning the access the inhabitants of the research area had to different raw materials and ore deposits over the whole span of human metal consumption in the research area. The assemblage of obsidian and metal artifacts that will be analyzed in the course of the current study have been excavated and found in the course of interdisciplinary international research projects conducted in the Nasca-Palpa area since 1997 by the German Archaeological Institute and the Peruvian Instituto Andino de Estudios Arqueológicos (INDEA).[41] Additionally 37 ore samples from the research area were taken for the determination of the ore content and the main, minor and trace element contents for possible provenance analysis. The approach chosen follows the methods of mining archaeology described by Stöllner[42] and combines natural science and mining archaeological methods, as both will contribute to the interpretation and understanding of pre-Columbian mining and resource production in Southern Peru and Northern Chile.

1.3 Chapter Organization

Mining archaeological research is only starting to become recognized as an important contribution to the reconstruction of social, economic and cultural aspects of pre-Columbian societies.

Chapter 1 – *Introduction* – has already outlined the pioneering work that has been conducted by various researcher and research groups in the field of mining archaeology on the American continent in the course of the past decades.

Chapter 2 – *Pre-Columbian Mining on the South American Continent* – contains five parts and summarizes in detail the research concerning mining archaeology

33 The Niton XL3t GOLDD used in the course of the current study has been provided to the author by the Deutsches Bergbau-Museum Bochum (DBM). The required knowledge to operate the device in the field and to interpret the received data has been imparted to the author by Prof. Dr. Michael Prange of the DBM/TH Georg Agricola University of Applied Science.

34 Stöllner, 2014, p.146.

35 Reindel, Stöllner and Gräfingholt, 2013, p.312.

36 Stöllner, et al., 2013, p.118.

37 Stöllner, 2014, p.144.

38 Craig, et al., 2007; Kellett, Golitko and Bauer, 2013.

39 Stöllner, et al., 2013; Reindel, Stöllner and Gräfingholt, 2013.

40 Dussubieux and Walder, 2015, p.170.

41 Castro de la Mata Guerra García, et al., 2012; Eitel, et al., 2005; Eitel and Mächtle, 2009; Fehren-Schmitz, et al., 2009; 2010; 2011; Hecht, 2009; Herrmann, Reindel and Wagner, 2009; Isla Cuadrado, 2009; Isla Cuadrado and Reindel, 2002-2006; Mächtle, et al., 2009; Reindel, 1997; 2007; 2008; 2009a; 2009b; 2011; Reindel and Isla Cuadrado, 1999; 2000; 2001; 2003; 2009; Reindel, Isla Cuadrado and De La Torre, 2004; 2005; Reindel, Isla Cuadrado, Linares Grados, 2006; Reindel, Isla Cuadrado and Tomasto Cagigo, 2001; 2002; Reindel, Solis Quintero and Isla Cuadrado, 2008; 2010; Reindel, Stöllner and Gräfingholt, 2013; Reindel and Wagner, 2009; Schlosser, et al., 2009; Stöllner, 2009; Stöllner and Reindel, 2007; Stöllner, et al., 2013; Tomasto Cagigao, Reindel and Isla Cuadrado, 2009; 2015; Unkel and Kromer, 2009; Unkel, et al., 2007; 2012.

42 Stöllner, 2014.

especially in Peru and Chile in part 1 and 2 and presents the latest scientific knowledge regarding one of the most important mining archaeological type groups: mining tools, in part 3. Furthermore, a cultural overview of the research area will be given in part 4 in order to introduce the cultures that flourished in the Nasca-Palpa area from the Archaic onward. Part 5 concentrates on the importance of obsidian projectile points in south Peru to demonstrate why this special artifact group has been chosen for the geochemical analysis in the current study.

Chapter 3 – *Palpa Archaeological Project (PAP)* – presents the previous archaeological research that has been conducted in the research area since 1997 in the course of interdisciplinary projects. These projects have documented more than 1600 archaeological sites of all pre-Columbian periods which have been used by various researchers as the basis for their fundamental groundwork to reconstruct climate, living and cultural developments in the research area over the course of 8 millennia.

Chapter 4 – *Geology and landscape of the Palpa area* – is divided in 5 parts. Part 1 concentrates on Palpa, at the outskirts of the Andean region and gives an introduction to the landscape and environment of the research area. Part 2 deals with the formation processes of the ores in the Andes to highlight the immense mineral deposits that were accessible to the pre-Columbian cultures in South America. Part 3 focuses in detail on the research area and gives an introduction on the Geology of the Nasca-Ocoña belt on the basis of previous research in the area. Consequently, Part 4 concentrates on the Altiplano and the high-quality obsidian quarries that can be found throughout South America in Peru, Ecuador, Chile and Argentina. Part 5 summarizes the insights of chapter 4 and leads to the next chapter.

Chapter 5 – *Obsidian – the swiss knife of Southern Peru* – gives a detailed analysis of the obsidian projectile point typology of the research area and presents a new 5 folded obsidian projectile point typology for Southern Peru. It is structured in 6 parts. Part 1 explains in detail the importance of obsidian as a raw material for the production of tools. Part 2 outlines the methodology applied to create the typology. Part 3 explains the data acquisition. Part 4 concentrates on the type classification. Part 5 presents a new obsidian projectile point typology and chronology. Part 6 summarizes the chapter and draws a comprehensive picture of obsidian consumption in Peru.

Chapter 6 – *PXRF in the field* – outlines the successful application of the geochemical trace element analysis with a pXRF on the given assemblage of obsidian and metal artifacts from the research area. It is structured in 5 parts. Part 1 and 2 are to introduce the method and give an insight into XRF analysis. Part 3 deals with the application of the geochemical trace element analysis on obsidian artifacts in general and presents the results of the application to the given assemblage of obsidian artifacts from the research area. Part 4 presents the advantages of the pXRF for the sourcing of metal artifacts and outlines in detail the results received from analysis of the body of metal artifacts that have been made accessible for the current study. Part 5 summarizes the results of both sample series and gives a first conclusion towards the raw material consumption patterns in the research area.

Chapter 7 – *Results and Analysis of test excavation and geochemical analysis* – is divided into 8 parts. Part 1 describes the location of the test pits in the mining district of the research area. Parts 2 to 5 are dedicated to the detailed presentation of the test excavation conducted on the pre-Columbian mining site of Mollaque Grande and Saramarca. Part 6 presents the geochemical analysis of ores taken from different stratigraphical layers in the two test pits. Part 7 focuses on the results from the geochemical analysis of the ore samples taken in the research area. Part 8 summarizes the results gained and outlines the importance of mining archaeological investigations in the research area.

Chapter 8 – *Discussion: Exchange processes in the Nasca-Palpa region and beyond* – discusses in two parts the complete results obtained in the course of the current study. Whereby, part 1 concentrates on the obsidian case and part 2 gives further insight into the cases of copper and gold.

Chapter 9 – *Conclusion: Raw material consumption in Southern Peru* – concludes by summarizing the raw material consumption patterns in Southern Peru and gives an overview concerning future research tasks.

Cerro Chucchurumi. Entrance to an artisanal gold mine in the Nasca-Palpa region (photo: DBM, T. Stöllner).

2 Pre-Columbian Mining on the South American Continent

Since humankind dwells on the South American continent, mining and the consumption of raw materials has played a tremendous role in the development of complex societies and long-lasting exchange processes throughout the Andes. The following chapter will present the scientific research that has so far been conducted in two core regions for the development of pre-Columbian mining and metallurgy in combination with the most important archaeological evidence documented concerning mining tools up to now. Furthermore, an overview of the pre-Columbian cultural development in the research area will be given to highlight the continuous occupation of this assumed focal area for pre-Columbian mining and the challenges the inhabitants of this region faced from the Archaic onward because of a constantly changing climate. Furthermore, the importance of obsidian projectile points for the early societies of southern Peru will be outlined, in order to introduce this tool type as a preferable subject for a provenance study, which has been conducted in the course of the current investigation.

2.1 Pre-Columbian Mining in Northern Chile

"In the Andes, human biogeographic expansion to high-altitude lands likely stemmed from adjacent areas in Peru, Chile, and Argentina. By ~13.5 to 12.1 ka or earlier, foragers had settled the Pacific coast and the Southern Cone, and by ~12.7 to 11.3 ka groups occupied caves at ~2600masl in central Peru and up to 3300 masl in the Atacama Desert of northern Chile. In northwest Argentina, multiple sites at 3400 to 3800 masl date to ~12.0 ka, possibly as early as ~12.8 ka, although most pre-Holocene occupations have only single, unreplicated radiocarbon ages."[43] These early inhabitants of the Americas not only settled in high altitude environments but also initiated mining on the continent. In this context pigments can be seen as a binder between the lithic and metal resources in the Andean region. Around the world traces of color pigment mining belong to the oldest documented mining exploitations so far.[44] For the Americas the groundbreaking works of Salazar, et al.[45] have documented the Paleo-Indian hematite mine San Ramon 15 as the oldest proof of pre-Columbian mining on the American continent (Fig. 1). So far, it was possible to distinguish two phases of Paleo-Indian mining operations. Mining activities started in the Pleistocene-Holocene transition (before 10200 cal BP).[46] For the Middle Archaic (8000–5500 cal BP) no in situ mining could be documented but in the Late Archaic (4300–3900 cal BP) the mining was reopened by the hunter-gather-fisher groups that populated the area, in order to extract the red pigments.[47]

Fig. 1: Taltal. Paleo-Indian hematite mine San Ramon 15 as the oldest proof of pre-Columbian mining on the American continent (photo: DBM, B. Gräfingholt).

This research clearly showed that mining techniques and mining tools were used unchanged over the course of millennia.[48] The extraction of the red pigments during the Late Archaic laid the base for the mining of other ores like copper, gold and silver not only in Northern Chile but also in the Central Andes in modern Peru.[49] The pigment mining exploitations, like in the old world[50], laid

43 Rademaker, et al., 2014, p.466.

44 Stöllner, 2011, p.186.
45 Salazar, et al., 2011b; Salasar, Borie and Oñate, 2013, p.139.
46 Salasar, Borie and Oñate, 2013, p.147.
47 Salasar, Borie and Oñate, 2013; Salazar et al., 2011b; 2013; Stöllner, 2011.
48 Salazar, et al., 2011b, p.470.
49 Salazar, et al., 2010a, p.20.
50 Wagner and Weisgerber, 1988; Weisgerber and Pernicka, 1995, p.159.

the foundation for a mining tradition that diversified over millennia and initiated the exploitation of other resource quarries.[51] Salazar, et al. (2011b) even proposed that due to similarities in technology and extraction techniques the site could be linked to the old world. This would imply that mining "*might constitute one of the most long-lasting and conservative activities among hunter-gatherers, and one that may relate Old and New World populations*."[52]

Despite the initial mining of pigments – as a local invention or introduced by populations from the old world – copper bearing ores have to be regarded as a key raw material for all further mining activities – especially in Northern Chile and the South Central Andes during the last 5,000 years.[53] The South Central Andes are according to Lechtman (2014, p.389) defined "*as an extensive zone that covers coastal and highland territory roughly from the latitude of the Moquegua River valley in southern Peru and the southernmost tip of Lake Titicaca in Bolivia (approx. 16.3◦ S) to approximately 30◦ S, just beyond the city of La Rioja in Northwest Argentina."* Today, more than 40% of the world's known copper deposits can be found in Chile and it has to be assumed that since 500 BC the ores were used by the pre-Columbian cultures to produce bracelets, earrings and weapons. Most of the artifacts were made of native copper or copper-rich minerals that were manufactured in the course of metallurgical processes.[54] It has been proposed that around 1500 BC the agropastoral inhabitants of the Loa and Atacama region have been actively involved in a transregional exchange network that traded cooper ores from the deposits of Salar de Atacama and smelted copper. This implies that copper ores were mined by these archaic groups in the Atacama region.[55] In the pastoralist communities of the Tilocalar dating to the Early Formative (1200–500 BC) gold and copper sheets have been documented that indicate an independent development of a mining metallurgical tradition in the South Central Andean in a pastoralist context.[56] Before the copper ores were actually mined for metallurgical purposes, the extraction of precious and semiprecious minerals and stones has to be viewed as an important driving force for mining activities.[57] During the early Formative (1200–500 BC) beads have been manufactured in the Antofagasta region using copper ores and it has been proposed that the origins of the metallurgical tradition in Chile derive from the region as well.[58] Long distance exchange networks had to be in place to dispatch those gemstones. In this context the copper deposits in Northern Chile must be regarded as extremely valuable for the pre-Columbian cultures though turquoise is often formed as a secondary mineral in primary copper deposits.[59] Such a quarry and a nearby cemetery were investigated in the Atacama Region in the mining district of El Salvador. At first described by Iribarren (1973) as a Inca exploitation site the *Mina La Turquesas* was later identified as a combination of mining settlement where turquoise was processed in a workshop that was extracted and crushed by the nearby mine starting in the *Formativo* (500 BC – 400 AD) and continued to be occupied up to the Late Intermediate Period (900–1450 AD).[60] The mine itself consists of three pits, a gallery, and additional infrastructure in the form of a carved stairway, a mineral crushing and processing area, a wood-and-stone slab bridge and an adit for light and ventilation.[61]After a spectacular discovery in 1899 the region of Antofagasta and especially the Chuquicamata mine has been well known for a pre-Columbian mining tradition that manifested in the mummified corpus of ancient miners.[62] After the discovery of the so called "Copper Man" in the Restauradora mine of Chuquicamata three additional mummified ancient miners were found in pre-Columbian adits in the Chuquicamata mining district.[63] This corpus of the "Copper Man" was preserved by copper salt and dryness after a mining accident around 550 AD in Chuquicamata.[64] The well preserved mining tools of the "Copper Man" enabled researchers to reconstruct the ancient mining methods and again proved the continuity of mining techniques running relatively unchanged from the Archaic up to the Inca domination of the Andean region.[65]

The results presented by Graffam, et al. (1996; 1997) for the Ramaditas site in Northern Chile highlight that metallurgy and mining were conducted on the site and in the surrounding *quebradas* during the first century BC. In the course of the recent exploitation of the porphyry copper ore deposit Chuquicamata it was possible to document other traces of ancient mining activities, e.g. small mines.[66] Nuñez, et al. (2003, p.30) described the site Chu-2 in the surroundings of Chuquicamata as a mining camp where copper ores from nearby mines were processed. In the course of the archaeological investigation of the site an occupation from at least the *Formativo Tardio* until shortly before the Inca conquest of the region (400–1400 AD) was proposed underlining the long-lasting mining tradition in the area. For Northern Chile, the regions around Antofagasta and Taltal have been identified as a hotspot for early pre-Columbian mining operation in the Americas. Not only the oldest mine of the American continent so far San Ramon 15[67] was found here but also a long lasting metallurgical tradition of *pescadores-mineros* (fisherman-miners) who settled in the area and produced copper fishing tools from locally available copper ores which leaves no doubt

51 Stöllner, 2011, p.186.
52 Salazar, et al., 2011b, p.470-471.
53 Figueroa, et al., 2013, p.61.
54 Maksaev, et al., 2007, p.179.
55 Nuñez, 2011, p.214.
56 Núñez, 1999, p.179
57 Salazar, 2003-2004, p.137.
58 Salazar et al., 2010a, p.10.
59 Stöllner, 2011, p.190.
60 Westfall and González, 2010, p.1076.
61 Figueroa, et al., 2013, p.75.
62 Stöllner, 2011, p.185.
63 Figueroa, et al., 2013, p.68.
64 Bird, 1979; Cradock, et al., 2003; Weisgerber, 2006; Stöllner, 2011.
65 Stöllner, 2011, p.199.
66 Salazar and Salinas, 2008.
67 Salazar, et al., 2011b; Salasar, Borie and Oñate, 2013.

that mining operation have been conducted here.[68] It is important to emphasize the point that these tools cannot be viewed in a ceremonial context but were clearly made for everyday life. A copper fishhook has been excavated in a layer that presumably dates to around 500 BC, but this chronological setting has been questioned as this type of tool does only appear frequently in the archaeological context around 800 AD.[69] Still there is evidence of an active metallurgical tradition in Northern Chile in the first century BC that concentrated on tools for the daily live in small communities such as Ramaditas. A slag fragment originating from this site proves that the local furnaces have been operated with temperatures close to 1,250° and that the local copper was manufactured into sheets on the site.[70] The copper used in the course of the metallurgical processes in Ramaditas was presumably mined near the site at the flanks of the Guatacondo valley, where small mines have been documented that may have supplied the site with copper ores such as brochantite and antlerite.[71] Though no further research has been conducted at these mining sites the origin of the smelted copper ores is still unclear. Occasionally objects made out of copper and gold start to appear mostly in burial contexts in Northern Chile during the Formative *"se trata fundamentalmente de adornos tales como placas, diademas, colgantes y fi guras antropomorfas y zoomorfas asociadas a las fases Formativas de Azapa (1.300-500 a.C.), Faldas del Morro (1.000-400 a.C.) y Alto Ramírez (500 a.C.-300 d.C.) para Valles Occidentales; y Tilocalar (1.400-400 a.C.), Toconao (300 A.C.-100 d.C.) y Sequitor (100-400 d.C.) para la Circumpuna de Atacama."*[72] During the Inca rule of Northern Chile the well-established mining tradition of the area was further specialized to intensify the extraction of precious ores. The mining complexes of *El Abra* and *Conchi Viejo* have at least three mineralization zones where deposits of chrysocolla, cuprite, antlerite, brochantite, pseudomalachite, hematite, native copper, turquoise as well as gold and silver occur.[73] These mining districts are an outstanding example of the change in the mining tradition where the emphasis was redirected from small-scale mining operation to an exploitation of ores that was supported by the state organized labor of the *mita* for the *Tawantinsuyu*[74] (literally, "land of the four quarters", the Inca name for their Empire)[75]. The whole operation was maintained to extract turquoise for the gemstone trade of the Inca Empire[76]as well as copper. The mines documented at San José del Abra "*include different kinds of open-cast pits and trenches, tailings, retention walls, and stock areas. Site AB-22/39 is the largest opencast mine yet known. Covering an area of approximately 3,000 m².*"[77] The archaeological investigation revealed a clear change from the pre-Inca mining operation to the state organized exploitation that intensified the work to maximize the output of turquoise from the mines of these complexes.[78]

Round about 1,000 lithic hammerstones produced out of local granodiorite and non-local andesite were documented at the site of El Abra on the surface and in secured archaeological contexts.[79] Of these artifacts, 500 hammerstones have been chosen for a detailed analysis. An important result of this study is the fact that both hafted and unhafted hammerstones were documented and that the shape and the size of the stones varied.[80] It was concluded that this was the result of differentiated mining activities conducted on the site.[81] A recent study showed no significant change in technologies and technical strategies in the mining district of El Abra after the Inca took over which implies that "*the state took advantage of several millennia of mining expertise by the local Atacamenian populations and reorganized it to fit imperial demands*."[82]

Other pre-Columbian mining sites exist throughout Chile, but they are sometimes hard to find even when they are published; only an endnote by Brown and Craig (1994, p.323 endnote 2) revealed the pre-Hispanic mining activities at the colonial silver mine *Huantajaya*. In 1992 two skeletons of pre-Hispanic miners were discovered in a collapsed adit together with a hafted stone hammer, small wooden wedges and a guanaco skin ore bag. Though this adit may be targeted a copper mineralization, it at least seems possible that either silver or copper ores were being extracted. A pre-Hispanic setting of the mining activities has to be assumed due to the documented hafted stone hammer which clearly belongs to the pre-contact period.[83] This assumption is also supported by early written documents stating that *Huantajaya* was an Inka mine valued for its native silver veins.[84] There is also scattered evidence of pre-Columbian mining and metallurgical processes in the San Bartolo Valley where multiple evidence for pre-Columbian occupation indicate that the rich native copper ores have been exploited and used by the inhabitants of the valley from the Periodo Intermedio Tardio (1200 AD) until after the Inca conquest of the region.[85]

68 Salazar, et al., 2010a, p.21; 2010b, p.38.
69 Salazar, et al., 2010a, p.15.
70 Graffam, Carevic and Rivera, 1997, p.57.
71 Graffam, Rivera and Carevic, 1996, p.104.
72 Salazar, et al., 2011a, p.124.
73 Salzar, 2008, p.44.
74 Salazar, 2008, pp.68-70.
75 Acuto, 2008, p.845.
76 Salazar, 2008, p.68-70.
77 Salasar, Borie and Oñate, 2013, p.258.
78 Salazar, 2008, pp.68-70.
79 Salasar, Borie and Oñate, 2013, p.259.
80 Figueroa, et al., 2013, p.72.
81 Salazar and Salinas, 2008, p.182.
82 Salasar, Borie and Oñate, 2013, p.270.
83 Brown and Craig, 1994, p.308 fig. 4.
84 Figueroa, et al., 2013, p.73.
85 Aldunate del S., et al., 2008, p.110.

2.2 Pre-Columbian Mining in Southern Peru

“In contrast to the northern coast of Peru and also to the central Andean Altiplano, southern Peru was never a focal area of metallurgical inventions or innovations.”[86]

Nonetheless, different research groups have so far successfully documented pre-Columbian mining activities in Southern Peru. Eerkens, et al. (2009) assumed that pre-Columbian mining was conducted on several pre-Inca sites in the Nasca region. Stöllner and Reindel (2007), Stöllner (2009) and later Stöllner, et al. (2013) prepared the ground for the study presented by the author with a comprehensive survey of the mining activities in the Palpa area and successfully pinpointed pre-Columbian extraction zones, which will later be discussed in detail.[87]

Especially the results presented for the Mina Primavera (Fig. 2) in the Ingenio valley[88] indicate a pre-Columbian mining operation that is similar to the oldest mine on the continent San Ramon 15 excavated by Salazar, et al. (2011b).

Fig. 2: Ingenio Valley. Mina Primavera (photo: DBM, T. Stöllner).

At this point, it seems clear that mining at the site of the Mina Primavera started approximately 2000 years ago during the peak of the Nasca culture and was concentrated on hematite that was processed on site in order to produce a red pigment. This red pigment was then most likely used as paint for the polychrome ceramic or to decorate the fine woven goods produced by the Nasca culture.[89] Due to similarities in technologies and technical strategies Salazar, et al. (2011b, p.470) proposed a transfer of the mining tradition from the oldest mine on the continent San Ramon 15 to the Nasca-Palpa area. The diagnostic ceramics of the Formativo (200 BC – 90 AD) and Intermedio Tardio (1000–1400 AD) documented in the excavations in the Mina Primavera[90] also suggest an earlier beginning and a longer duration of the mining operation, and therefore an introduction of mining techniques from north or south into the area is at least debatable. This is supported by the fact that the need for the valued iron-oxide ores did not start during the Nasca period, as the people of the Paracas culture clearly had a demand for hematite as well. Hematite (Fe_2O_3), also known as ocher, was called *tacu* or *taco* by the indigenous *Quechua* speaking people of the Andes.[91] An interesting fact is that San Ramon 15 and Mina Primavera, although separated by millennia and thousands of kilometers, nonetheless show a very similar mining technique that relied heavily on unhafted stone hammers. If a detailed analysis of the numerous stone tools found in the Mina Primavera were initiated, the results could lead to a comprehensive understanding of pre-Columbian mining traditions and techniques.[92] In recent years, Tripcevich and Contreras (2011; 2013) investigated the obsidian quarry Quispisisa/Jichja Parco (Fig. 3) in the Ayacucho region of southern Peru. This quarry was first mentioned by Petersen (2010; p.389) in connection with mining tools documented on this site. The extensive quarry pits, which were documented by two independent research groups,[93] prove a long-lasting mining tradition that covers millennia and cannot be linked to a single culture – instead this quarry was imprinted in the collective memory of the people who inhabited the Altiplano and coastal region of the Nasca-Palpa area. Similar words for obsidian in the indigenous languages, *quispi capa* or *kespi* in Quechua and *quispi* or *qhspi* in Aymara[94] underline the importance of this deposit as no other obsidian quarry in southern Peru is so unmistakable associated with obsidian.

Fig. 3: Jichja Parco. Obsidian mine wit open pit mining in the Huanca Sancos district (photo: DBM, T. Stöllner).

The mining and extraction of pigments and minerals most likely let to the discovery of the auriferous

86 Stöllner, et al., 2013, p.108.
87 Stöllner, 2011; Stöllner, et al., 2013; Reindel, Stöllner and Gräfingholt, 2013.
88 Vaughn, et al., 2013a, p.132.
89 Eerkens, et al., 2009; 2014; Vaughn et al., 2007; 2013a; 2013b.
90 Vaughn, et al., 2013a, p.135.
91 Petersen, 2010, p.7.
92 Stöllner, 2011, p.187.
93 Reindel, Stöllner and Gräfingholt, 2013, 308; Stöllner, et al., 2013, pp.114-116; Tripcevich and Contreras, 2011, pp.123-124; 2013, p.31.
94 Peterson and Brooks, 2010, p.8.

pyrite-quartz-carbonate veins of the Nazca-Ocoña belt.[95] These minerals – apart from being used for metallurgical process – were also frequently used for the polychrome ceramic of the Nasca culture as pre-fire slip-pigment paint.[96] Early examples of the use of extracted ores in a pre-metallurgical context are 33 small bags made out of rough cotton containing crushed ores which were found during excavations of the temple complex Pachacámac – the excavator assumed a connection to wall paintings documented on the temple wall as well.[97] A comparable bag with red pigments has also been excavated in the southern sector of Los Molinos in grave 2 dating to Nasca 5 proving a long lasting tradition of at least offering those bags as grave goods.[98] Judging from the red color of the mineral inside – which has not been analyzed so far – it is probable that it contains some sort of iron oxides such as hematite (Fe_2O_3), limonite (FeO) or magnetite (Fe_3O_4), as these minerals have been used to produce red colors.[99] It can be assumed that these ores probably derive from mining sites in the *quebradas* of southern Peru.

If the discovery of copper ores in southern Peru initiated metallurgy in the region as Van Gijseghem, et al. (2013, p.281) suggested or if metallurgy was introduced into the region and with that the knowledge of the metallurgical properties of the ores were being recognized, is debatable. Van Gijseghem, et al. (2013, pp.277-280) also argued that the ritual practices of mining which were documented in the ethnographic literature from Peru and Bolivia and by the Spanish chronicler for the Inca Empire reflect back in time. Although a considerable mining technological gap exists between Early Horizon mining organization, which concentrated on small-scale mines[100] and the Inca-period mines, which were gallery mines[101], winzes (vertical or steeply inclined shafts between different levels for access and/or ventilation) or stopes (step-wise excavations to extract ore from steeply inclined veins),[102] which require a comprehensive mining know-how. Therefore, the criticism expressed by Shimada (2013, p.348) in this context should be a guideline for future investigations. It is extremely problematic to directly apply handed down ritual practices and religious beliefs known only from ethno-historic and ethnographic sources – that only reach back as far as the Inca Empire – to the spiritual beliefs of Early Nasca and later Ica miners. In archaeological research one must be realistic and accept the fact that for some cultures, especially those with absolutely no written heritage, it will not be possible to reconstruct complex belief systems associated with mining. Especially so, since – at the moment – documented and excavated pre-Columbian mining sites are rare and so far no clear connection between ritual practice and mining could be drawn at these sites. Only by comparing Inca controlled mining, e.g. the Los Infieles Mining Complex[103] or in the Tarapacá valley[104] with the small-scale Paracas, Nasca[105] and Ica-culture mining[106] operations that were conducted in the southern Peruvian river valleys it becomes obvious that the dangers and threads those miners encounter differed to a great extent.

Therefore, Shimada (2013, p.348) must be strongly supported as he states that "*the invariability of beliefs and practices or 'general principles' needs better substantiation*."

So far, the origin of metallurgy, which clearly was independently invented in South America, is a very important research question that needs extensive international interdisciplinary efforts to be answered.[107] Southern Peru was no hotspot or driving force for developments in mining techniques – the foundations for mining and metallurgy were laid in the south and north of this region.[108] The question remains, by whom and at what point in time these techniques were introduced into Southern Peru.

Metals, or more precisely gold started to play an important role in the resource production of pre-Columbian cultures around 2000 BC. Nine cold-hammered native gold beads, which were found in an undisturbed Terminal Archaic burial context at *Jiskairumoko,* are so far the first objects made of metal in the Americas.[109] Indirectly these beads could be the first evidence of metal ore mining. Aldenderfer, et al. (2008, p.5004) suggest that the beads were produced out of quartz-vein native gold nuggets.

The finds from Waywaka in the northern Altiplano described by Grossman (1972a, p.155, pl.LXXIII, pl.LXXIV; 1972b, p.275) belong to the same metalworking tradition. The site dates roughly to the beginning of the second millennium BC (1890–1640). Here a gold-working tool kit consisting of anvils, stone hammers and some gold foils which were produced by cold-hammering was documented. Other metalworking tools made of stone were documented at the central coast of Peru.[110]

This picture of a cold-hammering metalworking tradition that laid the foundation for forging followed by true metallurgy in South America is completed by gold and copper artifacts documented at the Initial Period (1410–1090 cal BC) site Mina Perdida in the Lurín Valley on the central coast of Peru. The copper and gold foils were cold-hammered out of native metal. In the case of specimen 3357A a gold foil was manually attached to copper foil.[111] Here, the inhabitants of the Andean region used copper for the first time. Still, this is not concrete

95 Sillitoe, 2004, p.9.
96 Vaughn, et al., 2005, p.142.
97 Muelle and Wells, 1939, pp.268-270 fig. 3.
98 Reindel and Isla Cuadrado, 2001, p.262.
99 Brooks, et al., 2008, p.442; Carmichael, 1998, p.217.
100 Stöllner, et al., 2013, p.125; Rendel, Stöllner and Gräfingholt, 2013, p.319.
101 Saunders, 2004, p.126.
102 Shimada, 2013, p.340.
103 Cantarutti, 2013.
104 Zori, 2011; Zori, et al., 2013.
105 Reindel, Stöllner and Gräfingholt, 2013; Stöllner, 2009; 2011; Stöllner and Reindel, 2007; Stöllner, et al., 2013.
106 Van Gijseghem, 2013.
107 Lechtman, 2014, p.370.
108 Stöllner et al., 2013, p.108.
109 Aldenderfer, et al., 2008.
110 Lothrop, 1950, p.163 fig. 55.
111 Burger and Gordon, 1998, p.1109 fig. 4.

proof of mining activities, since no mines or extraction sites were documented in the Lurín Valley.

Another metal that was probably mined at a very early stage in the pre-Columbian history of Peru was mercury (Hg). The immense importance of this metal for the production of silver following the *conquista* is often forgotten. In fact, only the discovery of the "*patio*" amalgamation process by Bartolome Medina in Pachuca (Mexico) in 1553 enabled the large-scale silver production of the Viceroyalty of Peru stated in the 16th century.[112] Hints of exploitation of this metal can be traced back to around 1400 BC and thus predate the rise of the complex Andean cultures.[113] At this early stage cinnabar ores were probably used as pigments (vermillion) by the pre-Columbian inhabitants of the Huancavelica region.[114] Later on, during the Spanish rule, the Huancavelica mines would supply South America with the mercury needed for the amalgamation process in the New World's silver production.[115]

This supports the thesis that a basic knowledge of minerals, ores and the outcrop of the veins had to be present in the imprinted knowledge of the Andean societies from the Archaic onward. In the weathering zones, the blue, green and red minerals were clearly visible and were in reach for small-scale surface mining. Especially in southern Peru, it was relatively easy for pre-Columbian miners to access the mineral deposits as these were opened up at the mountainous flanks of the *quebradas* (river valleys).[116]

A driving force for the spread of metallurgy and the need to extract copper and gold bearing ores was clearly the rise and influence of the Chavín Horizon. So far, it seems as if copper was absent from Chavín but examples of gold-silver-copper ternary alloys start to appear in scientific literature.[117] From 800 BC the site Chavín de Huantar at the eastern flanks of the Andes next to the river Rio Mosna influenced the whole central Andean region. The ritual acts performed at Chavín de Huantar were probably related to water. This cult strongly influenced the rising Paracas culture with its center in the Ica valley.[118] The people of Chavín de Huantar had already developed outstanding skills in gold metallurgy, as Chavín-style gold artifacts impressively demonstrate.[119] Lothrop assumed that the "*technical processes represent local inventions by the talented creators of Chavín culture*."[120] Up to now, the finds from Jiskairumoko prove this assumption to be wrong. The knowledge of metal and especially gold working, forging and metallurgy did not appear out of the blue during the Chavín horizon but instead more than 1,200 years of experimenting enabled the metal smith of the Chavín horizon to create such marvelous gold objects and probably copper-based artifacts[121] as well.

Additional proof of this assumption can be found in the Nasca-Palpa area and Ica region. With the rise of the Paracas culture in southern Peru, copper metallurgy and with it gold and copper mining was present in the region.[122] Though the Paracas culture was directly influenced by the Chavín horizon which was manifested in an iconographic style that adopted elements of the Chavín iconographic on textiles and ceramics[123] a reimport of at least the knowledge of copper metallurgy and mining into the Chavín culture seems quite logical. It is a fact that from the end of the Chavín horizon and the beginning of the Early Intermediate Period copper became the dominating metal in the Andean region. All further developments in smelting and alloying techniques relied on this metal.[124]

The end of the Chavín Horizon around 200 BC marks the rise of local cultures, which flourished during the Early Intermediate Period (200B C – 600 AD) like the Moche in northern Peru[125] and the successor of the Paracas culture in southern Peru, the Nasca culture.[126] One can assume that due to the development of independent cultures during the Early Intermediate Period the processes of mining and metallurgy evolved in combination with the rise of the various cultures.[127] As Lechtman (2014, p.369) has emphasized "*Central Andean metallurgy was a three-component system. The elemental or material components are copper, silver, and gold. The system was set in place early in the Early Intermediate Period, as soon as these three metals were identified and used commonly by Andean metalworkers. The triad remained a physical and cultural reality up to and through the Late Horizon*." The diversification into different independent cultures was a boost for the metallurgical development and with it came the extraction of different metal bearing ores. An example of how the access to different ores influenced the production of copper alloys can be found in the Titicaca Basin. By the end of the Middle Horizon two kinds of alloys "*were used interchangeably for a wide variety of objects*", Cu-As-Ni bronzes and tin bronzes.[128] During Late Tiwanaku IV (650/700–850/900)[129] the inhabitants of the Titicaca Basin exploited the local rich cassiterite deposits and the supply of As-Ni ores declined forcing the metalsmiths to concentrate on the tin bearing ores.[130] These cassiterite deposits stretching from Lake Titicaca through the Altiplano into Northwest Argentina are some of the richest cassiterite deposits in the world and the only significant source of tin in the Andes. During the Middle

112 Wilson and Petrov, 1999, p.10.
113 Cooke, et al., 2009, p.8831.
114 Cooke, et al., 2011, pp.22-23.
115 Nriagu, 1994, p.174.
116 Stöllner, et al., 2013, p.114.
117 Lechtman, 2014, p.374.
118 *Reindel, 2011, pp.169-173.*
119 Lothrop, 1951, figs. 71-75, 77-78.
120 Lothrop, 1951, p.235.
121 Burger and Lechtman, 1996, pp.71-75.
122 Stöllner, 2009; Stöllner, et al., 2013; Reindel, Stöllner and Gräfingholt, 2013; Van Gijesghem, et al., 2013.
123 Reindel, 2011, p.170.
124 Lechtman, 1991, p.17; 2014, p.365.
125 Chapdelaine, 2011, pp.195-196.
126 Reindel, 2011, pp.171-172.
127 Stöllner, 2011, p.194.
128 Lechtman, 2003, p.258.
129 Isbell, 2008, p.732.
130 Lechtman, 2003, p.258.

Horizon and Late Intermediate Period these deposits were the supplier of tin for the whole Andean region.[131]

But before the tin bronzes dominated during the *Tawantinsuyu* rule – mostly because the Inca held the cassiterite deposits in Bolivia and Northwest Argentina under their control[132] – natural copper-arsenic alloys were widely used in the Andean region.[133] The most prominent and so far best documented complete production sequence of copper artifacts that runs from mining over smelting to casting has been investigated by Shimada, et al. for the last 30 years near Bátan Grande in the La Leche valley. Batán Grande up to now represents the only pre-Columbian copper ore mining district which has been intensively investigated during the last three decades. Cerro Blanco mine and the neighboring Cerro Huaringa-Cerro Sajino metallurgical complex were established during the Sicán culture (750/800–1375 AD) and further used by the pre-decessors during Sicán-Chimú (1375–1460/70 AD) and Sicán Inca (1460/70–1532 AD) in northern Peru.[134] After the incorporation of the Sicán culture into the Chimú, which were then in turn conquered by the Inca, the metallurgical production went on until the Spanish conquest.[135] The copper ores from Cerro Blanco Mine were probably processed during the pre-Columbian times in the Middle Sicán multicraft workshop at Huaca Sialupe around 950 to 1050 AD[136] and in the connected metallurgical centers of the Cerro Huaringa which also hosted permanent mining settlements.[137] After the Conquista mining on this site went on. The extremely rich and extensive deposit with "*high-grade malachite* $Cu_2CO_3(OH)_2$ *as well as a variety of weathered but high-grade (up to 25% concentration) copper sulfides, particularly chalcopyrite,* $CuFeS_2$*, and to a lesser extent, bornite,* Cu_5FeS_4*, and arsenopyrite, FeAsS*"[138] have been occasionally extracted until recent times. This extremely well organized mining district is a perfect example of long-lasting mining traditions that were passed on from one generation of miners to the next. Although a detailed chronology of the mines has not yet been established, the comparison with the workshops sites proves that these mines were being used since the Middle Sicán (900–1100 AD) with intensification during the Chimú Phase up to the Inca period.[139]

So far, it has not been possible to document ancient gold mining in the Andes. An often proposed assumption is that the pre-Columbian miners extracted the gold from alluvial gold deposits and did not actually exploit gold from mines.[140] Important alluvial gold deposits in the central Andean region from the Inca period are Patas in Northern Peru, the Rio Oropesa near Cuzco, Carabaya in the modern province of Sandia and the Altiplano region in the border territory of Chile, Peru and Bolivia.[141] The site Mollaque Grande, which will be further described in this study, has an important characteristic for pre-Columbian mining activities: small adits that follow mineralization. Peterson (2010, p.36) has perfectly described were to look for ancient mines as he states that "t*he ancient miner usually worked the softer rocks such as sandstone, lutites, and slates and rarely worked the igneous and metamorphic rocks. Wear on the mining tools was especially great in gravelly units. As a consequence of these limitations, the ancient miner typically opened many adits instead of opening a single deep adit. This is why numerous small mines are found on the slopes of Descuelga, Nevado Illimani, and Micuipampa."*

This description of an ancient mining site mirrors the situation documented at the site of Mollaque Grande (Fig. 4) in the Nasca-Palpa area, where the archaeological context revealed that this site was obviously intensively mined in pre-Columbian times.[142]

Fig. 4: Mollaque Grande. Typical small-scale mining operations in the Andes. Adits following a Cu/Au mineralization in Mollaque Grande (photo: DBM, B. Gräfingholt).

A previous study in the Nasca-Palpa area showed that the pre-Columbian miners had access to surface-near oxides and carbonides with high enrichments in copper and gold (up to 100 g per ton). The *quebradas* in the research area opened up these deposits of small but highly enriched veins, also called "*bonanzas*", which were exploited by the pre-Columbian miners. The exploited ores may have been used in the course of metallurgical processes to manufacture the rare metal artifacts found in the research area.[143] So far, it was not possible to identify pre-Columbian metallurgical sites in the Nasca-Palpa area as having been documented elsewhere in Peru[144] and Chile.[145] One explanation was offered by Stöllner

131 Stöllner, 2011, p.194; Lechtman, 2014, p.365.
132 Lechtman, 2014, p.413.
133 Stöllner, 2011, p.194.
134 Shimada and Craig 2013, p.4; Shimada, Epstein and Craig, 1982; Shimada and Merkel, 1991; Shimada, 1994; Goldstein and Shimada, 2007.
135 Shimada and Craig, 2013, p.15.
136 Goldstein and Shimada, 2007, p.45.
137 Stöllner, 2011, p.197.
138 Shimada and Craig, 2013, p.15.
139 Stöllner, 2011, p.196.
140 Sáenz-Samper and Martinón-Torres, 2011, p.246.

141 Stöllner, 2011, p.203.
142 Stöllner, 2011, p.203 fig. 31; Stöllner, et al., 2013; Reindel, Stöllner and Gräfingholt, 2013.
143 Stöllner, et al., 2013, p.123.
144 e.g. Swenson and Warren, 2012; Shimada and Merkel, 1991; Tereygeol and Castro, 2008.
145 e.g. Graffam, Rivera and Carevic., 1996; Nuñez, 2011; Salazar, et al., 2010a; 2010b; 2011a; Zori and Tropper, 2013.

(2011, p.204) who stated that the native gold was probably cold-hammered without the need to operate furnaces, which would have been identified in the course of the extensive archaeological surveys of the research area in the last years. Another assumption formulated by the author of the current study relates to the annual floods of the rivers in the research area. Not only in the town of Palpa, but throughout the Nasca-Palpa region these annual floods caused devastating damages in the river valleys depending on the amount of rain that fell in the highlands, until the river courses were straightened in recent years.[146] The force of theses annual floods could have destroyed all pre-Columbian traces of metallurgy, which may have been carried out near the rivers, still settlement related smelting activities may be documented in the course of future extensive mining archaeological excavations in the Nasca-Palpa area. A direct access to river water in the course of the metallurgical processing of the ores facilitated the working process, especially if the crushed ores had to be washed in order to extract the gold. Interestingly the lack of documented gold making tools and productions sites is ubiquitous in the Americas. The huge amount of archaeological objects made out of this precious raw material does not mirror in an *in situ* documented *chaîne opératoire* combined with archaeological evidence of this production sequence such as furnaces, crucibles or casting molds.[147] First archaeometallurgical investigations on the composition of gold used by the pre-Columbian cultures in Peru were conducted by Root (1949) and Marshall (1964). Root (1949, pp.13-14) analyzed 8 Paracas gold objects as well as 9 Nasca gold objects and defined two types of gold that were used to produce these objects. Type A consists of up to 95% nearly pure gold and less than 5% silver and type B was characterized as silver-rich gold with silver content between 15–30%.[148] Marshall (1965, Lista 1) later analyzed three objects that were found in the research area of the current study on the site Mollake during a campaign in 1957. His investigations supported the division into two types of gold that were used by the pre-Columbian inhabitants of the Nasca-Palpa region during the apogee of the Paracas and Nasca culture as sample 41156 (57/64a) belonging to type A characterized as *"oro y plata, mas o menos 50%; cobre menos del 10%",* sample 41148 (57158b) representing type B with a composition of *"oro más o menos 55%, plata 5 a 10%; el resto cobre" and* sample 41155 (57118b) defined as *"oro más o menons 60%. El resto cobre."* demonstrating the existence of copper metallurgy in the region.[149] Recently this assumption has been supported by comprehensive archaeometallurgical study on pre-Columbian gold consumption in Peru that incorporated metal objects from the research area[150] that have also been analyzed for the current study. Furthermore, the before mentioned study brought to light that only a few Paracas and Nasca objects were manufactured out of gold type A containing less than 10% silver.[151] In this context, it is important to take a closer look at the chemical modification that occurs during the transport of placer gold in rivers. The longer gold nuggets are transported in river water, the more water-soluble metals alloyed with the gold are washed out. In the end this often leads to a near chemical purity of alluvial gold of up to 95% to 99%, with very low contents of silver and copper.[152] This implies that the earlier defined gold type A is probably alluvial gold and that artifacts made out of gold type A have to be associated with a gold extracting industry that relied on alluvial gold deposits. On the other hand objects that are made out of gold type B, which are also present in the research area[153], should be related to natural gold/silver ores that were mined or intentionally alloyed in the course of the metallurgical production sequence.

Combined with the results of the excavations of the pre-Columbian mining districts Mollaque Grande and Saramarca, the conducted geochemical analyses of 199 metal objects in the course of the current study shall further clarify the picture of the metallurgical development in the Nasca-Palpa area. So far, the archaeological research in southern Peru has reconstructed the metallurgical development in the Nasca-Palpa region as a three-stage process. This process staggered over time with the development of metallurgy in the Americas as described above. At first thin gold plates were produced during the Paracas culture whereby this tradition of gold working was handed down to the Nasca culture and then to the Middle Horizon. During the Early Intermediate Period native copper was used on a regular basis,[154] but it can be assumed that the foundation for the copper metallurgy in the Nasca-Palpa area was already laid during the Paracas culture parallel to the introduction of the gold metallurgy.[155] This copper metallurgical tradition evolved cross-cultural over the centuries to the mastering of binary and trinary copper-arsenic alloys during the Middle Horizon.[156] It is obvious that the raw materials for the described metallurgical processes had to be mined somewhere by the inhabitants of the Nasca-Palpa region. The local gold deposits in the Nasca-Palpa area probably attracted the attention of the early inhabitants of the region. According to a recent analysis of gold ores from the Viscas and Acarí valley it seems most likely that these quartz-gold veins were exploited and the extracted ores were then used to produce Paracas and Nasca gold objects.[157] This corresponds with the results presented earlier by Stöllner

146 Personal communication with J. Isla Cuadrado in 2014.
147 Sáenz Samper and Martinón-Torres, 2011, p.247
148 Root, 1949, p.10.
149 Marshall, 1964, Examen metalográfico 28/1/64 nos.8-10.
150 Schlosser, et al., 2009, p.426.
151 Schlosser, et al., 2009, p.426.
152 Borg, 2014, pp.59-60.
153 Schlosser, et al., 2009, pp.427-428, fig. 24.5; Marshall, 1964, Examen metalográfico 28/1/64 nos.8-10; Root, 1949, pp.13-14, tabs.3-4.
154 Castro de la Mata Guerra Garciá and Vellarde Dellepiane, 2013, p.12.
155 Schlosser, et al., 2009, p.430.
156 Castro de la Mata Guerra Garciá and Vellarde Dellepiane, 2013, p.12.
157 Schlosser, et al., 2009, p.432.

et al. (2013) which indicate that the people who inhabited the Nasca-Palpa region extracted the raw materials they needed from the polymetallic veins which were opened up by the *quebradas* of the rivers in the research area. The current study will contribute to the mining archaeological research of the Nasca-Palpa area by presenting the results of the archaeological excavations in the pre-Columbian mining districts of Mollaque Grande and Saramarca as well as with the geochemical analysis of the 199 metal artifacts that were excavated in the research area during the foregoing archaeological projects of the German Archaeological Institute and its international partners.[158]

2.3 Mining tools

Mining tools, especially hammer stones must be regarded as the most valuable insights into pre-Columbian mining technology. The most prominent examples of mining tools from South America are the stone tools that were found with the so called "Copper Man" in an ancient adit in the mining district of Chuquicamata.[159] Nonetheless, the importance of this group of archaeological artifacts has not been widely recognized in South America in contrast to the old world where numerous studies underline the significant value of these artifacts to reconstruct the ancient mining techniques.[160] Different types of classifications for stone mining tools or "*mauls*"[161] have been proposed in Europe. Pickin (1988, p.18) started with a very rudimentary differentiation of the stone tools into four types: Unmodified Cobble Hammer, Notched Cobble Hammer, Notched and Cup-marked Hammer and Rilled and Cup-marked Hammer. As this earlier classification concentrated on stone hammers, following studies incorporated further classes of artifacts such as pestles, pounders and mortars in order to cover the whole assemblage of objects that were used by pre-historic miners.[162] It is important to emphasize that each mining district has a specific tool kit available depending on the knowledge transferred by the local miners, the abilities to produce accurate tools and of course the accessibility of raw materials for the tool production. Therefore, an analysis of mining tools first of all has to concentrate on the locally available assemblage of artifacts in order to reconstruct the mining techniques used.[163] An important aspect concerning stone hammers that were used for mining operation are the modifications and deliberated haft-modification. The actual process of hafting was time-consuming, but on the other hand facilitated the work by an increased impact. Furthermore, the advantage of a hafted tool over an un-hafted one is clearly the usability due to a reduced force working on the upper extremities.[164] A hafted stone tool needs to be prepared by certain modifications on the surface. At least one out of three basic indicators on stone tools should be present to prove that hafting was used: pecking, notching and grooving.[165] As demonstrated by Stöllner, et al. (2010, p.133) for the Sakdrisi mine in Georgia early miners at this site used a great variety of mauls. Four types of tools were defined: horizontally or vertically hafted flat hammers (type 1a/b), cylindrical hammers (type 2a/b), heavy hammers (type 3a/b) and flat picks (type 4a/b). An interesting fact is that the type 1a/b stone tools were either hafted horizontally or vertically which implies that the tools were especially modified for the space-restricted working environment in the mines by these hafting methods.

In comparison to the rich research history on stone mining tools in Europe such an analysis incorporating this type of artifacts has not yet been conducted for Southern Peru although Petersen (2010, p.36) has listed important types of tools. In Northern Chile Figueroa, et al. (2013) and Salazar, et al. (2011a) have already presented comprehensive studies concerning the mining ergology – corpus of everyday technical instruments and artifacts used by pre-Hispanic miners – and lithic mining tools.

The fundamental research effort on mining ergology in Northern Chile is groundbreaking for South America. The analysis of ethnohistoric documents and archaeological artifacts from the Atacama Region brought to light that a miner's tool kit would have been divided first of all into three groups of artifacts: working tools, transport material and personal effects. In the words of Figueroa, et al. (2013, p.75): "*An ideal model of the mining set would include hafted hammers and unhafted hammerstones, as well as wood and lithic shovels as the main working tools. Deer horns have also been mentioned as mining implements in Peruvian mines but have not yet been reported in Northern Chile. Transport Materials would be capachos, basketry, cords and textile bags. Finally, the Personal Effects of pre-Hispanic miners include ankle supports, loincloths, ponchos and hair braids.*" On the other hand Salazar, et al. (2011a) were able to document *in situ* 491

158 Castro de la Mata Guerra García et al., 2012; Eitel, et al., 2005; Eitel and Mächtle, 2009; Fehren-Schmitz, et al., 2009; 2010; 2011; Hecht, 2009; Herrmann, Reindel and Wagner, 2009; Isla Cuadrado, 2009; Isla Cuadrado and Reindel, 2002-2006; Mächtle, et al., 2009; Reindel, 1997; 2007; 2008; 2009a; 2009b; 2011; Reindel and Isla Cuadrado, 1999; 2000; 2001; 2003; 2009; Reindel, Isla Cuadrado and De La Torre, 2004; 2005; Reindel, Isla Cuadrado and Linares Grados, 2006; Reindel, Isla Cuadrados and Tomasto Cagigo, 2001; 2002; Reindel. Silis Quintero and Isla Cuadrado, 2008; 2010; Reindel, Stöllner and Gräfingholt, 2013; Reindel and Wagner, 2009; Schlosser, et al., 2009; Stöllner, 2009; Stöllner and Reindel, 2007; Stöllner, et al., 2013; Tomasto Cagigo, Reindel and Isla Cuadrado, 2009; 2015; Unkel and Kromer 2009; Unkel, 2006; Unkel, et al., 2007; 2012.

159 Bird, 1979; Cradock, et al., 2003; Weisgerber, 2006; Stöllner, 2011; Figueroa, et al., 2013.

160 Bogosavljevic, 1995; Craddock, 1990; Dutton, 1990, pp.11-14; Gale, 1990; 1995; Timberlake, 1990, pp.25-27; O´Brien, 2004; O´Brien and Brindley, 1994, pp.116-136; Pickin, 1988; 1990; Timberlake and Craddock, 2003; Stöllner, et al., 2010, pp.133-134.

161 O´Brien, 2004, p.338.

162 e.g. Dutton, 1990, p.13; Stöllner, et al., 2010, pp.119-120; de Nigris and Puche Riart, 2013.

163 Timberlake, 1990, p.26.

164 O´Brien, 1994, p.134.

165 Gale, 1990, p.48; 1995, p.48.

hammerstones from the Early Holocene layers of the so far oldest mine on the American continent San Ramon 15 near Taltal which was exploited in two phases during the Early Archaic (ca. 10500 cal BP) and during the Late Archaic (ca. 4300 cal BP) (Fig. 5).

Fig. 5: San Ramon 15. Hammerstone documented near the Archaic mining complex (photo: DBM, B. Gräfingholt).

A methodology was designed to analyze this corpus by concentrating on three variables: physical dimensions, raw material, and quantity and morphology of the active functional edges of the hammer. The results give a very important indication for future mining tool studies in South America. First of all the mining activities are not continuous from the Early to the Late Archaic – leaving a gap of approximately 4,000 years – the unhafted handheld stone tools that were used are equal and a technological continuity was assumed. The excavators proposed two diverging theories for this phenomenon.

On the one hand it may be possible that the Late Archaic miners found the tools used by their ancestors from the Early Archaic and incorporated the ancient technique into their workflow.[166] This would fit into the dynamics that have been described for early Bronze Age copper mining in Wales. At the mining site of Cwmystwyth 41% of the documented stone tools were re-used.[167] An even higher percentage was described at the site Alderley Edge where a high proportion of the stone tools was re-used.[168] On the other hand, the documented mining tools could support the theory of an existing long-lasting mining tradition among hunter-gatherer societies that was handed-down from the Early Archaic to the Late Archaic in Northern Chile and from there to the agropastoralist Early Intermediate Period societies in the Nasca-Palpa area in southern Peru. Especially the Mina Primavera excavations have brought to light comparable stone mining tools used for the exploitation of hematite.[169] It is obvious that there is a relatively wide gap of more than 2,500 years between the Late Archaic and the Earl Intermediate Period. But as this study will prove – the mining know-how was not forgotten until the Early Intermediate Period –, instead mining was present in the Nasca-Palpa area at least during the Early Horizon as has been proposed earlier.[170] This reduces the gap to approximately 2,000 years – only half the time the mining activities at the site San Ramon 15 in the Early and Late Archaic were suspended.

Huge advantages of these cited projects are clearly the remarkable conservation conditions in the Atacama Desert[171] but nonetheless as demonstrated by Stöllner, et al. (2013) other regions in South America – such as the Nasca-Palpa area – have the potential to contribute to the investigation of ancient mining tools and the overall mining archaeological research. In this context the Nasca mining operation that was documented by Vaughn, et al. in the Mina Primavera[172] and off course the mining districts of Mollaque Grande and Saramarca, which will be described in this study, must be regarded as a transition zone and link between the north and south for a handed-down mining tradition which manifest in the stone tools used by the pre-Columbian miners.

In this context it is interesting to note that Shimada and Craig (2013, p.17) mentioned that the pre-Columbian Sicán miners in Northern Peru which exploited the mines near Batan Grande from the Middle Sicán (900–1100 AD) up to the Inca conquest in the region did not use "*any special tools or techniques distinct from those found with the 'Copper Man' of Chuquicamata. Inside prospecting pits and larger workings at Cerro Blanco, we found roughly triangular and oblong stones (17-22cm long, 9-13cm wide, and 3-6cm thick), resembling the `hammers' found associated with the 'Copper Man'. The battered apices of the triangular stones and their heavy weight (around 0.5kg) support the notion that at least some of them served as picks or hammers to crack or batter ores into small pieces that could then be collected in bags or baskets much as Copper Man did*".

From the mining ergologic point of view this is one of the key findings of the whole campaign. Because these tools must be viewed in close relation – not only – to those found with the "Copper Man" but also to the ones that were documented in the mining district of Mollaque Grande in the Palpa area[173], the Mina Primavera near Nasca[174] (Fig. 6) and of course San Ramon 15 near Taltal[175].

166 Salazar, et al., 2011b, p.469-470.
167 Timberlake and Craddock, 2003, p.88.
168 Gale, 1990, p.48.
169 Vaughn, et al., 2013a, p.137 fig.5.
170 Reindel, Stöllner and Gräfingholt, 2013, p.312.
171 Figueroa, et al., 2013, p.76.
172 Vaughn, et al., 2007; 2013a; 2013b; Eerkens, et al., 2009.
173 Stöllner, et al., 2013, p.122 fig.19.
174 Stöllner, 2011, p.188 fig. 7; Vaughn, et al., 2013a, p.137 fig.5.
175 Salazar, et al., 2011b, p.427 fig. 7.

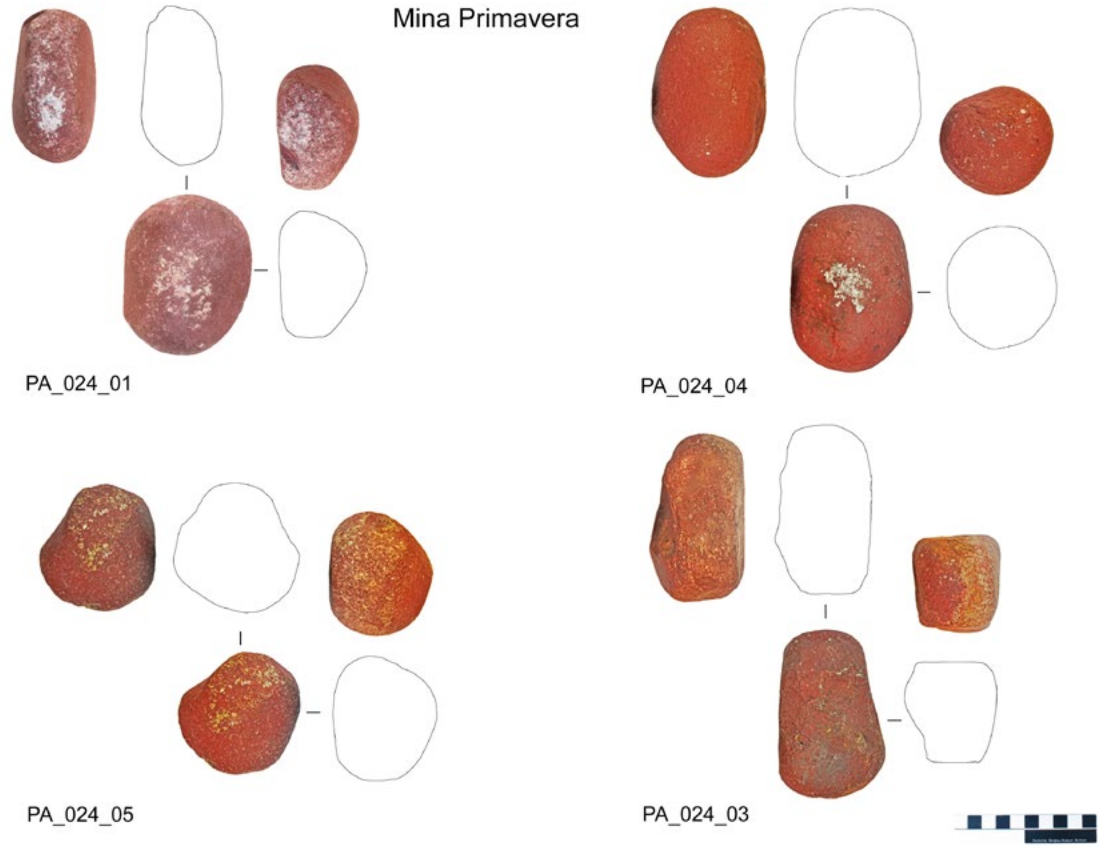

Fig. 6: Mina Primavera. Hammerstones found on the surface inside the mine (graphic: DBM, B. Gräfingholt after Stöllner 2011, 188 Abb. 7).

Additionally the hints concerning mining tools given by Petersen (2010, p.38) should be kept in mind although they basically represent research history. For these studies as well as for the Batan Grande mining complex[176] the research focus must be extended to the above-mentioned comprehensive analysis of mining ergology in the Atacama Region which demonstrated that specialized tools for mining have to be divided into three categories: working tools, transport material and personal effects.[177] To further differentiate these into sub-categories the proposed separation between raw materials by Petersen (2010, p.36) used for the production of mining tools could be worth considering. Future interdisciplinary mining archaeological projects in the Andean region must widen their focus in order to verify if this model is applicable to other region of the Andes as well and previous excavations must be revised in order to identify mining tools that so far have not been recognized as such.

176 Shimada and Craig, 2013, p.4; Shimada, 1981; 1994; Shimada, et al., 1982; Shimada and Merkel, 1991; Goldstein and Shimada, 2007.

177 Figueroa, et al., 2013, p.75

2.4 Cultural overview of the Nasca-Palpa area

For the South American archaeology a rough chronology dominates the scientific discourse which originated in the central Andean. It operates which two extremes "Horizon" and "Intermediate Period". All cultural developments in the Andean region were classified into one or the other. Horizons are always associated with a dominating culture or cult which affects all regions. In contrast to this centralization the Intermediate Periods were associated with decentralization and the rise of regional cultural and economic centers.[178] Lechtman (2014, p.368) summarizes the chronological scheme as followed "*Horizons were times of contact and exchange among peoples of different and often far-flung regions and from a variety of political contexts. […] Within this chronological framework, periods of time that do not manifest horizon features in the archaeological record are referred to as 'periods' or 'intermediate periods'. These exhibit a much higher degree of isolation between polities, when attention turned to local or regional affairs.*" Naturally, this concept can hardly be applied to all facets of Andean culture as regional developments, and

178 Reindel, 2011, p.162.

cultures do not always fit into this order. This holds true for the research area especially during the domination of the Paracas (800–260 cal BC) and Nasca culture (260 cal BC – 640 cal AD) in the region[179] – although diverging more conservative chronologies for these periods are postulated as well.[180]

From the beginning of the archaeological investigations in the Nasca-Palpa area researchers have tried to either press the regional developments into the guiding theme or just recently used ^{14}C methods and interdisciplinary projects to elaborate a differentiated chronology that combined archaeological investigations with the latest ^{14}C technologies.[181] More than 150 samples were collected in the research area covering a timeframe of pre-Columbian history extending 5,200 years.[182] Apart from this method, geo-archaeological studies proved a permanent alternation of settlement centers from the coast to the Altiplano region, which was triggered by climatic changes causing aridity and desertification in the coastal region of the research area in certain intervals.[183]

So far, it can be stated that the research area has been intensively populated from the Archaic Period (3300–3060 cal BC) onward. First permanent settlements were documented on the site Pernil Alto where a number of huts[184] with a round or oval layout and some graves were excavated[185] – ^{14}C dates indicate a continuous occupation during the Archaic Period.[186] It seems as if the site was then abandoned for more than 1,600 years. In the Initial Period (1460–840 cal BC) traces of human presence in the region again appear on the site Pernil Alto. This period is marked by the introduction and continuous use of pottery and cumulates in the dominance of the Chavín style in Southern Peru.[187] Obviously this period embedded the people in the river valleys of the Nasca-Palpa area and enabled the rise of the first sedentary culture – called Paracas culture.

This culture was defined by its ceramic that was first excavated by Tello[188] on the Paracas peninsula in the Pisco Valley. Additionally spectacular embroidered textiles and the ceramic that was influenced by the Chavín style defined the Paracas culture whereby the name Paracas derives from the Quechua word for sandstorm.[189] In the course of the excavation and later archaeological revision of the finds, a differentiation into different ceramic styles called Ocucaje – after the eponymous site near Ica – was proposed and is still common. Menzel, et al. (1964) elaborated a very fine relative chronology of the Paracas culture dividing the ceramics into Ocucaje 1 to 10; a lack of archaeological material has made the first 3 phases redundant.[190] This chronology has been outdated by recent investigation conducted by Unkel, et al. (2012, p.2301) as they proposed an absolute chronology that is purely based on ^{14}C dates which were interlinked with ceramic finds from undisturbed contexts associated with Ocucaje ceramic. Following this absolute chronology, the Paracas culture can be divided into Early Paracas (840–500 cal BC) associated with Ocucaje 3-4, Middle Paracas (500–380 cal BC) associated with Ocucaje 5, 6 and 7, and Late Paracas (380–260 cal BC) associated with Ocucaje 8 and 9. Important settlements of the Paracas culture that have been intensively investigated in recent years are Mollake Chico[191], Jauranga (PAP-150)[192] and Cutamalla[193].

In the course of nearly a millennium the Paracas culture evolved into the succeeding Nasca culture whereby the change from one culture to the next is mainly marked by a change in the ceramic style.[194] Two aspects of the Nasca became famous around the turn of the 19th to the 20th century: the fine polychromic ceramic[195] and the geoglyphs constructed in the Nasca desert[196]. Again for the ceramic a relative chronology was elaborated by Dawson together with his mentor Rowe who proposed a division of the ceramic into Nasca 1 to 9[197], due to the research undertaken in the Palpa area this relative chronology has been replaced by an absolute one.[198] Following this absolute chronology the Nasca culture can be divided into Initial Nasca (260 cal BC – 80 cal AD) associated with Ocucaje 10 and Nasca 1, Early Nasca (80–300 cal AD) associated with Nasca 2 and 3, Middle Nasca (300–440 cal AD) associated with Nasca 4 and 5, Late Nasca (440–640 cal AD) associated with Nasca 6(?) and 7. Important settlements of the Nasca culture that have been intensively investigated in recent years apart from Chauachi[199] are Estaqueria[200], Los Molinos[201], La Muna[202], Jauranga[203], Hanaq Pacha and Parasmarca.[204]

The decline of the Nasca culture due to a drastic climatic change – resulting in an extreme aridity of the coastal area – provoked a shift of the settlements towards the middle reaches of the valleys and to the Altiplano region.[205] Here the influence of the Wari culture in the

179 Unkel, et al., 2012; Stöllner, et al., 2013, p.108.
180 Proulx, 2008, pp.564-565; Vaughn, et al., 2013a, p.135.
181 Unkel, 2006; Unkel, et al., 2007; 2009; 2012.
182 Unkel, et al., 2012, p.2302.
183 Eitel, et al., 2005; Eitel and Mächtle, 2009; Mächtle, et al., 2009; 2010.
184 Comparable huts with a round or oval layout can be found in Chilca, Paloma or other settlements of the Archaic in Southern Peru (Reindel, 2011, p.164).
185 Reindel, 2009a, p.441.
186 Unkel, et al., 2012, p.2301.
187 Reindel, 2009a, p.443.
188 Tello, 1959; Tello and Mejía Xesspe, 1979.
189 Proulx, 2008, p.563.
190 Reindel, 2009a, p.445.
191 Tomasto-Cagigao, et al., 2015, p.70; Reindel, 2009a, p.445.
192 Reindel and Isla Cuadrado, 2003.
193 Reindel, 2008, p.299.
194 Proulx, 2008, p.572.
195 Proulx, 2006; Hecht, 2009.
196 Lambers, 2006.
197 Proulx, 2008, p.575.
198 Unkel, et al., 2012.
199 Silverman, 2002; Reindel, 2009a, p.452.
200 Reindel, 2009a, p.451.
201 Isla Cuadrado and Reindel, 2003.
202 Isla Cuadrado and Reindel, 2002-2006.
203 Reindel and Isla Cuadrado, 2001.
204 Unkel, et al., 2012, p.2297.
205 Stöllner, et al., 2013, p.106.

highlands marked the beginning of the Middle Horizon Loro/Chakipampa (640–790 cal AD).[206]

Due to a lack of archaeological material a research gap of nearly 400 years must be accepted. The following Late Intermediate Period (1180–1560 cal AD) is significantly better documented were an Inca and Spanish occupation of the sampled sites Chillo, Pinchango Bajo and PAP-650 to end of this period seem possible.[207] This reoccupation of the coastal region and western slopes of the Andes came along with improving climatic conditions that enabled the people to resettle the abandoned area.

By looking at this comprehensive analysis of the Palpa area proposed by the ongoing interdisciplinary research of the DAI, it becomes clear that a permanent interchange of goods, ideas, people and raw materials must have been in place over the millennia.[208] Of huge importance for the pre-Columbian culture that flourished in this area were obviously the resources they extracted from the river valley flanks and the Altiplano region. In this context it is a unique opportunity to further widen the scope of the research in this area to a mining archaeological perspective. The mining districts of Saramarca and Mollaque Grande as well as the obsidian projectile points found in the research which will be presented by the author in this study have the potential to reconstruct the long-distance exchange processes that were in place over the whole time period of human dwelling in the region.

2.5 The importance of obsidian projectile points in South Peru

More than 400 obsidian projectile points[209] have been found in the course of the archaeological investigations in the Nasca-Palpa area since 1997.[210] This artifact group has to be regarded as extremely valuable for provenance studies as the raw material can be easily linked to the quarries and due to the characteristics of the points a chronological setting of the raw material consumption can often be pinpointed. In the twentieth century, a tremendous intensification of archaeological research started in Peru. Beginning with the work of Max Uhle (1902) and J.C. Tello Rojas (1959) the foundation for the research in the Nasca-Palpa Region and beyond was laid. For the preceramic periods the stone tool industries were the main component in defining different cultural sequences. Especially projectile point typologies must be regarded as an important indicator for the dating of remote preceramic hunter-gatherer sites in the Andean region. There are no other index fossils that can be used to pinpoint the chronological sequence better than projectile points. Therefore, securely dated obsidian projectile points offer a unique chance to connect the raw materials that were exploited for the production of the artifacts with the cultures that used them and thereby reconstruct exchange processes for resources in the Andes. The geochemical trace element analysis conducted in the current study have been incredibly facilitated due to the previous typological and chronological investigation concerning obsidian projectile points in the Nasca-Palpa area[211] as due to this work the whole assemblage of obsidian projectile points found to this date in the region was dated and classified into a relative chronological frame. Consequently the investigation of stone tools has seen a tremendous increase during the last years, whereby the huge potential of this type of archaeological artifacts as an important cultural invention has been recognized since the first archaeological investigation in the Andes began and a connection between early cultures and their stone tool industries was already drawn by Uhle (1889). In the following decades stone tools and especially projectile points were used to define preceramic cultural sequences. First small investigations of rock shelter sites in the highland region of Peru started to unveil the huge potential that was buried in the Peruvian past.[212] Schroeder (1957) was able to do basic groundwork concerning the question of the first Americans and connected this question with the investigation of the early lithic industries of Peru.

At the same time – influenced by his previous work in the Nasca-Ica region – Engel (1957a) came forward with an investigation of the preceramic sites on the Peruvian Coast. Lanning and Hammel (1961) summed up the work that has been done on lithic industries in the first half of the 20th century and were able to combine the existing works for the preceramic periods in western South America. They proposed a cross dating for the defined periods in South America linking the continent via the use of special types of projectile points. Later Lanning (1963) successfully investigated the pre-agricultural occupation on the central coast of Peru. Again, projectile points were of great use in order to define cultural sequences. The projectile points collected on the surface of the site El Inga (Ecuador) further enabled the researchers to connect the early preceramic cultures of South America.[213] Ravines (1972) impressively defined projectile point types for the Archaic Period in South Peru based on his research in the rock shelter Toquepala.

As outlined before, the 1980s suffered a tremendous decline in archaeological research in the Peruvian Andean region because of the terrorist movement of *Sendero Luminoso*.[214] Nonetheless, for the high Andean region the work that was carried out by Rick (1980; 1996) marked an important step in these research efforts on preceramic

206 Reindel, Stöllner and Gräfingholt, 2013, p.301; Reindel, 2011, p.174; Buzon, et al., 2012, p.2627-2628.
207 Unkel, et al., 2012, p.2302.
208 Reindel, Stöllner and Gräfingholt, 2013, p.302.
209 This chapter has partly been taken from the master thesis of the author (Gräfingholt, 2011, pp.6-18) and has been updated to the latest scientific research.
210 Gräfingholt, 2011, p.3.
211 Gräfingholt, 2011.
212 Tschopik jr, 1946.
213 Mayer-Okes, 1966.
214 Burger, 1989, p.44.

projectile points. Dillehay, et al. (1992) commenced with a differentiated investigation of the earliest hunters and gatherers of South America. During the 1980s, Engel published a stone typology for Peru, which incorporated projectile points from the Nasca-Palpa region, but failed to describe the actual archaeological context.[215] Stone (1983) convinced with a comprehensive lithic analysis of all lithic material found in Huari but failed to publish the few projectile points found in the limits of the research area.

The 1990s investigation of Telarmachay defined a projectile point typology for the preceramic period in the *puna* based on the results of the excavations.[216] Kink and Aldenderfer (2005) were successful in establishing a preceramic typology of projectile points in combination with a chronology for the Lake Titicaca region, this work was later extended by Klink (2007) and covered all sorts of lithic artifacts. Only recently Briceño Rosario (2010), Maggard (2010) and Stackelbeck (2008) proceeded with research efforts addressing the very first inhabitants of Peru represented by the fishtail (ca. 11100–10100 BP) and Paijan-projectile point groups (10800–9000 BP)[217]. Maggard´s approach (2010, p.331) to characterize the projectile points in his work by focusing on the haft element seems very promising and will help to further differentiate the diffuse picture of the earliest projectile points. So far, the cultural affiliation of the fishtail projectile points shows a transcontinental distribution represented by artifacts from archaeological contexts stretching from Mexico down to Chile.[218] However, the great variation in shape and form of these early projectile points is still not fully understood and further investigations will help to differentiate the picture of the early preceramic periods in Peru.[219]

In contrast to the extensive work that has been carried out for the preceramic periods, it is obvious that as soon as the ceramic steps in as a chronological marker, only a few attempts have been made to establish a projectile point typology for the ceramic periods.[220] Gero (1983, p.112) as an early example investigated the Formative highland site of Huaricoto and its lithic culture. On this site a fair amount of projectile points was found, but only less than 10 points were manufactured using obsidian. Overall, the lack of any image showing obsidian projectile points makes it impossible to further classify the finds and incorporate them into a wider regional context.[221] There are of course attempts to define certain types of projectile points for different cultures. Burger (2007) was able to pinpoint the obsidian lithic industry of Animas Altas during Ocucaje 9. This investigation followed his earlier work that was concentrated on the provenance of obsidian tools used during all time periods in Peru and Northern Bolivia. In his work, he gave an excellent overview of projectile points used during the ceramic periods, but without the definition of specific types.[222] A comprehensive work investigating the lithic cultures of the Wari and Tiwanaku empires was written by Benic (2000, pp.98-99,107-108). The small assemblage of projectile points recovered from Iwawi and Conchopata could be divided into a Tiwanaku type and a Wari type. Giesso (2003) investigated the production of lithic tools including Tiwanaku style projectile points and could demonstrate that the production of these tools took place on a household basis. Detached from projectile points Downey (2010) was able to show that expedient lithic technologies can be differentiated for complex societies and help to understand daily life and resource utilization. Recently DeLeonardis and Glascock (2013) published a comprehensive analysis of a Paracas obsidian assemblage from the lower Ica valley, which indicates that the obsidian used in this region derived from the obsidian source Quispisisa/Jichja Parco in the highland region, which may imply that the obsidian from the research area was also extracted from this quarry. Just recently the author established an Obsidian projectile point chronology for the Nasca-Palpa area using a collection of securely dated and documented obsidian artifacts of the PAP (Fig. 7).

Fig. 7: Pernil Alto. Oldest securely dated obsidian projectile points found at the site Pernil Alto dating to the Archaic Period. Type 7A (graphic: DBM, B. Gräfingholt).

215 Engel's (1983) typology incorporated points from all time periods but failed to give a chronological setting for the points. Only site names are given which do not reveal the archaeological context.
216 Lavallee, et al., 1995.
217 Maggard, 2010, p.329-330; Malpass, 1986.
218 Briceno Rosario, 2010, pp.84-155.
219 Maggard, 2010, p.289.
220 Burger, 2007, p.477.
221 Gero, 1983.
222 Burger, Mohr Chavez and Chavez, 2000.

Throughout the whole research area which stretches from the coast up into the Altiplano region obsidian projectile points were found either in excavated contexts or during surveys in the region.[223] After the successful establishment of an obsidian projectile point chronology these artifacts were again used for the current study in order to reconstruct the exchanges processes between the highland region and the coastal settlements using geochemical methods to pinpoint the ancient obsidian quarries and the exchange networks that existed throughout pre-Columbian times in the Nasca-Palpa area and beyond.

Survey work in the valley Sol de Gaz using the Pickup-4wheel-drive as an ideal place for identifying suspicious field formation (photo: DBM, B. Gräfingholt).

[223] Gräfingholt, 2011.

Blick über das Palpa-Tal nach Südosten, im Vordergrund die Geoglyphen von Palpa-Sacramento (photo: DBM/RUB, T. Stöllner).

3 Palpa Archaeological Project (PAP)

The present study of the pre-Columbian research production and raw material extraction was developed out of a joint research effort between the German Archaeological Institute Commission for the Archaeology of Non-European Cultures and the research department of the Deutsches Bergbau-Museum Bochum which started in 2006.[224] of the Nasca-Palpa area in southern Peru. The research area encircles the town of Palpa and the nearby slopes and plateaus as well as the upper and lower reaches of the river valleys Rio Grande, Rio Palpa and Rio Viscas.[226] In recent years this area has been extended and now stretches on a transect line from the coastline up into the Altiplano. More than 1,600 settlements starting in the Archaic up to the Late Intermediate Period and Late Horizon were identified along this transect line located at the south coast of Peru (Fig. 8).[227]

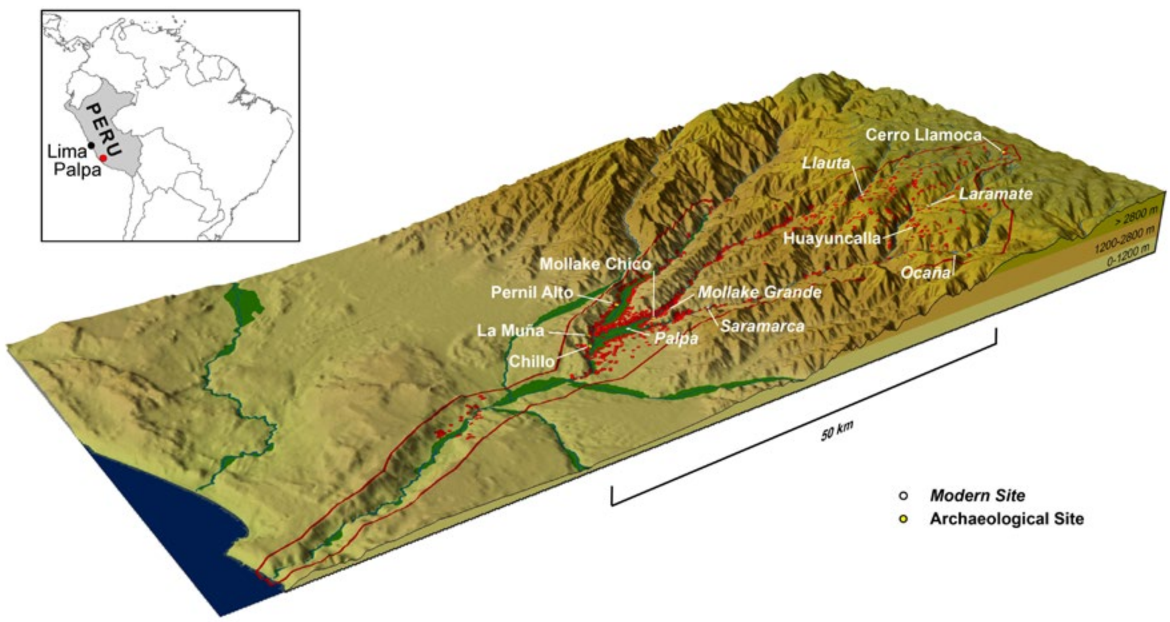

Fig. 8: Research area of the Andean Transect project indicating pre-Hispanic settlements and important locations mentioned in the text (graphic: KAAK, V. Soßna).

In 2009 a fundamental mining archaeological survey conducted by an interdisciplinary team further narrowed the view on the potential of the Nasca-Palpa area as a hotspot for pre-Columbian mining activities and identified several pre-Hispanic mines and processing sites.[225] The main survey area was concentrated on the research area that has been comprehensively investigated since 1997 in the course of the Palpa Archaeological Project headed by Dr. Markus Reindel and Johny Isla Cuadrado. Multiple projects concentrated on the interdisciplinary investigation

224 Stöllner and Reindel, 2007, Stöllner, 2009.

225 Stöllner, 2011; Stöllner, et al., 2013; Reindel, Stöllner and Gräfingholt, 2013.

226 Unkel, et al., 2012, p.2295.

227 Castro de la Mata Guerra García, et al., 2012; Eitel, et al., 2005; Eitel and Mächtle 2009; Fehren-Schmitz, et al., 2009; 2010; 2011; Hecht, 2009; Herrmann, Reindel and Wagner; Isla Cuadrado, 2009; Isla Cuadrado and Reindel, 2002-2006; Mächtle, et al., 2009; Reindel, 1997; 2007; 2008; 2009a; 2009b; 2011; Reindel and Isla Cuadrado, 1999; 2000; 2001; 2003; 2009; Reindel, Isla Cuadrado and De La Torre, 2004; 2005; Reindel, Isla cuadrado and Linares Grados, 2006; Reindel, Isla Cuadrado and Tomasto Cagigo, 2001; 2002; Reindel, Solis Quintero and Isla Cuadrado, 2008; 2010; Reindel, Stöllner and Gräfingholt, 2013; Reindel and Wagner, 2009; Schlosser, et al., 2009; Stöllner, 2009; Stöllner and Reindel, 2007; Stöllner, et al., 2013; Tomasto Cagigao, et al., 2009; 2015; Unkel and Kromer, 2009; Unkel, et al., 2007; 2012.

The research area is part of the region known as the south coast of Peru in archaeological literature. It can be defined as the part of Peru lying between the Cañete valley in the north stretching down south to the valley of Acarí. This region forms the heartland of the famous Nasca-culture (260 cal BC – 640 cal AD) that created the Nasca Lines as well as high quality polychrome ceramic that can be found in museums worldwide.[228] Here on the northern offshoot of the Atacama Desert, one of the driest places on earth, the investigation of the mysterious Nasca Lines marked the beginning of the PAP.[229] Agriculture and the development of complex societies in this dry area was only possible because of the rivers Rio Santa Cruz, Rio Grande, Rio Palpa, Rio Viscas, Rio Ingenio and Rio Nazca that run down from the highlands and annually secured the flow of the most precious resource in the arid Nasca-Palpa region: water.[230] As soon as the water flow was interrupted because of climate changes that occurred in the course of the millennia, cultures diminished and people had to migrate into more fertile regions in the highlands where a continuous occupation was present during all time periods.[231] The chronological frame of the PAP is therefore not only limited to the Nasca-culture, instead it investigates the ceramic possessing semi-nomadic settlements of the coastal region, the cactus belt and in the highland region during the Initial Period, continuing with the antecedents of the Nasca-culture, the Paracas Culture and following the climate change at the end of the Nasca-culture and looking at the cultures that were formed during the Middle Horizon, rounding up this work with a close look at the cultural changes that occurred during the Late Intermediate Period.[232]

In the course of the rise and fall of the different cultures that flourished in the region the people had a need for the resources they found and mined in the area. On the one hand, hunters and warriors relied heavily on projectile points made out of obsidian.[233]

On the other hand, metal smith and common people demanded ores and objects made of them. The research carried out since 1997 by the PAP covered the Archaic Period as well and continued through all ceramic bearing periods of the region. Archaeological sites from the Archaic/Initial period like Pernil Alto[234] to huge Paracas and Nasca sites like Los Molinos[235] and Jauranga[236] were investigated as well as settlements of the Middle Horizon like Huayuncalla in the highlands. The project also included extensive surveys of LIP and Inca sites in the research area (Fig. 9).[237]

The interdisciplinary PAP combined archaeological fieldwork with the newest methods and techniques of natural science in order to draw a complete picture of the Nasca-Palpa region and establish a securely dated and comprehensively investigated example of interdisciplinary archaeological fieldwork.[238] The present study tries to focus on the pre-Columbian resource production and the exchange of raw material and objects between the coast and the Altiplano in the research area during the time periods until the Late Horizon. In order to highlight the importance of resources for the development of cultures especially in the arid and semi-arid climate of the Nasca-Palpa area it is important to put an emphasis on the main resources that were used by the cultures during all time periods. By looking at the whole body of excavated artifacts, it becomes clear that on the one hand obsidian projectile points were used extensively by all pre-Columbian cultures in the Nasca-Palpa area[239] and on the other hand that metal artifacts became available to the people during the Early Horizon at the peak of the Paracas culture.[240] Therefore, this comprehensive analysis of the raw materials, their origin and exchange will further contribute to the interdisciplinary research activities that have been carried out in the Nasca-Palpa area by the PAP.

228 Reindel and Wagner, 2009, p.8.
229 Reindel, 2007, p.330.
230 Eitel and Mächtel, 2009, p.20.
231 Mächtel, et al., 2009, p.40.
232 Eitel and Mächtel, 2009, p.35; Unkel, et al., 2012.
233 Gräfingholt, 2011, p.11.

234 Reindel, 2011, p.164; Reindel and Isla Cuadrado, 2009.
235 Reindel and Isla Cuadrado, 2001.
236 Reindel and Isla Cuadrado, 2003.
237 Soßna, 2014.
238 Hermann, Reindel and Wagner, 2009.
239 Gräfingholt, 2011, p.109.
240 Tello, 1959; Tello and Xesspe, 1979; Uhl, 1913.

YEARS	PERIODS	CULTURES	PHASES	CERAMIC STYLE	SITES	RAW MATERIALS
1535 AD	LATE HORIZON	Inca/Ica		Inca/Ica		
1180 AD	LATE INTERMEDIATE PERIOD	Ica		Ica	Chillo, Montegrande	copper (Cu-Sn), gold, silver obsidian
1130 AD 850 AD						(Jichja Parco, Callejones)
790 AD 690 AD	MIDDLE HORIZON	Wari		Chakipampa	Huayuncalla, Primavera, Lucriche	copper (Cu-As; Cu-Sn; Cu-As-Ni), gold, silver,
660 AD				Loro	Montegrande	obsidian (Jichja Parco)
620 AD 470 AD	EARLY INTERMEDIATE PERIOD		Late	Nasca (6?), 7		gold, copper (Cu; Cu-Ag)
410 AD 340 BC		Nasca	Middle	Nasca 4, 5	La Muña	obsidian (Jichja Parco, Cerro Huenul, Lisahuacho)
270 AD 110 AD			Early	Nasca 2, 3	Saramarca, Mollaque Grande, Primavera, Montegrande	gold, copper (Cu), obsidian (Jichja Parco)
40 BC 130 BC	TRANSITION	Initial Nasca		Nasca 1 Ocucaje 10		gold, copper (Cu) obsidian (Jichja Parco)
330 BC 360 BC	FORMATIVE PERIOD		Late	Ocucaje 8, 9	Saramarca, Mollaque Grande, Montegrande, Jauranga, Cuttamalla	gold, copper (Cu), obsidian (Jichja Parco, Puzolana, Cerro Huenul, Callejones)
400 BC 440 BC		Paracas	Middle	Ocucaje 5, 6, 7		gold, copper (Cu?), obsidian (Jichja Parco, Cerro Huenul)
560 BC 800 BC	EARLY HORIZON		Early	Ocucaje 3, 4		gold, obsidian (Jichja Parco)
900 BC 1500 BC	INITIAL PERIOD			Puerto Nuevo Disco Verde Hacha	Pernil Alto, Ocoro, Cuttamalla	obsidian (Jichja Parco), silex
2960 BC 3760 BC	ARCHAIC			no ceramics	Pernil Alto	obsidian (Jichja Parco), silex
8000 BC					Cerro Llamoca	obsidian (Jichja Parco), silex

Fig. 9: Pre-Columbian chronology and raw material consumption in the pre-Columbian periods of South Peru according to Stöllner, et al., 2013 (graphic: KAAK, M. Reindel, modified by B. Gräfingholt).

Panoramic view of Valle Ingenio in direction south-east 2009, in the fore-ground: remnants of buildings from the Late Intermediate Period (photo: DBM/RUB, T. Stöllner).

Mollaque Grande. Overview from the first survey campaign in 2009 showing modern artisanal mining which overprinted the pre-Columbian mines (photo: DBM, T. Stöllner).

4 Geology and landscape of the Palpa Area

4.1 Palpa, at the outskirts of the Andean Region

In 1979 Petersen (1979, p.3) stated that for earth scientists "the challenges in South America are exciting and ongoing." This still holds true, not only for earth scientist, but also for all scientists working in the Andean Region. The term Andean Region was defined by Murra (1984) and encircles a topographical landscape that spans from northern Ecuador to central Chile. This region marks the political and social construct of the Inca Empire that established a stable rule in the Andean Region from 1438 to 1525 AD. During the apogee of the Inca Empire, Tawantinsuyu, this territory stretched over 4,200 km from north to south and incorporated the coastline and parts of the highlands of modern nations Ecuador, Peru, Chile, Bolivia and Argentina. Due to its high-stress environment of extremes the Andean mountain range is seen as the dominating factor in the western limits of South America[241] and has been perfectly defined by Petersen (1965, p.362) as he outlined that "broadly speaking the Andes represents in cross-section a large anticlinorium complicated by a series of faults and intrusions. The flanks of this superstructure are made up of the Coastal Mesozoic and the Eastern Mesozoic belts, in both of which Mesozoic sediments occupy topographically low positions. The core of the superstructure is composed of the Central Andean Mesozoic and the Eastern Paleozoic belts. In these, the Paleozoic rocks attain comparable elevations above sea level due to the combined effect of general upwarping, folding and longitudinal faults along which the Cordilleran units have been raised. The main difference in surface geology results from the fact that in the Eastern Paleozoic Belt most of the Mesozoic sediments have been stripped by erosion being preserved only in occasional infolds or down-dropped fault blocks. In the Central Andean Mesozoic Belt Paleozoic rocks crop out at elevations above 4,000 m at Cerro de Pasco, Malpaso, Yauli and Julcani. The 1,000–4,000m thick Mesozoic cover is preserved in this belt largely due to its high topography." The processes that lead to the formation of the Andean chain started approximately 150 million years ago.[242]

[241] Lechtman, 2014, p.362.
[242] Stöllner, 2011, p.181.

Since then the Nasca-Plate is constantly moving 63 mm per year towards the South American Plate, forming in the subduction zone of the Nazca plate the 8,000 m deep Atacama Graben.[243] The metallogenic activity enhanced the formation of Cu, Au and Zn deposits which concentrate on the overriding plate above the Nazca Ridge which sweeps southward along the coast of South America[244]. The mountain chain of the Andean can be roughly divided into the North-, Central-, and South Andean.[245] An important factor in this geological landscape is the division of these geological zones from west to east by three distinct orogens, the Cordillera Occidental (western), the Cordillera Central (center) and the Cordillera Oriental (eastern).[246] As a result of this division the cultures living in the described landscape had to adapt and constantly redefine their way of living in this high-stress environment – "the net result of this challenging environment has been to isolate communities from one another. Movement, communication, and exchange through mountain passes along a west–east trajectory, critical to the subsistence viability of highland populations and to their economic wealth, were the norm and practiced traditionally. The impediment to expansion, of whatever kind, lay in the near-insurmountable obstacle presented by the north–south axis of the Andes chain."[247] The pre-Columbian "Pan Americana" that boosted the interaction of the different cultures over the ages in the Andean region and which was used to transport people, raw materials and ideas from north to south was clearly the Altiplano. Lechtman (2014, p.389) impressively highlights the importance of this region as she states that "throughout this terrain—in northern Chile, on the Bolivian altiplano, in the high intermontane valleys (the valliserrana) of Northwest Argentina—people mined and smelted metallic ores, produced a variety of bronze alloys, and moved metal objects via caravans of llamas among coastal and highland communities." During the Middle Horizon and Late Horizon the inhabitants of the Altiplano developed a certain trade pattern that has been characterized by Browman (1981, pp.416-417) as the "Altiplano mode." He defined the need of the inhabitants of the Altiplano to specialize in a certain way as followed "Because all Altiplano

[243] Haupmann, 2011a, p.23.
[244] Rosenbaum, et al., 2005, p.24.
[245] Stöllner, 2011, p.182.
[246] Lechtman, 2014, p.362.
[247] Lechtman, 2014, p.362.

communities produced roughly the same commodities, trading with these goods alone would not yield immediate access to required resources from other ecozones. Thus many communities have traditionally specialized on certain products such as pottery or textiles or in metal mining and fabrication. The Altiplano individual had to become either an expert trader, acquiring goods through his entrepreneurial skills or an accomplished craftsman, exchanging his marketable skills for desired commodities."[248] It has been assumed that this long-distance exchange networks have been mostly concentrated on "relatively portable goods of limited geographical availability such as peppers, herbs, dried fruit, salt, and obsidian were conveyed in regular and perhaps seasonal schedules that likely interfaced with annual festivals and rituals."[249]

Located between Cordillera Central (center) and the Cordillera Oriental (eastern) the intermountain plateau of the Altiplano (Fig. 10) reaches a height of up to 4,500 m asl.[250]

Fig. 10: Huanca Sancos. Altiplano region near the Obsidian quarry Jichja Parco in April after the annual rainfalls (photo: DBM, B. Gräfingholt).

The plateau extends from the Lake Titicaca for a distance of 965 km to the southwest end of Bolivia. From west to east it measures about 150 km, being part of southern Peru, Bolivia, northern Chile, and Northwest Argentina. It is characterized by high, cold, and arid, tundra-like environment.[251] According to the prevailing research opinion the Altiplano uplift to an average height of 3,800 m a.s.l. occurred during the Miocene.[252] The Palpa region is located in the Central Andean which today corresponds to the states of Ecuador and Peru.[253] Mineralization zones that formed rich ores deposits are mainly located in the Central Andean region making it a hot-spot for mining archaeology as it is for industrial mining today.[254] Massive porphyry copper deposits appear in clusters here and are related to specific fracture/fault zones.[255] A unique characteristic for the Nasca-Palpa area is a desert strip, which stretches for more than 90 km from the coast to the foot zone of the Andes, which is 10 to 30 km wider then further up north between Ica and Lima. The reason for this phenomenon is the Cordillera de la Costa, which basically blocks the coastal humidity from the Ica-Nazca depression – where Palpa is located – as it extends for 170 km from north to south and reaches an altitude of 1,500 m. This manifests in a 20 km broad and only up to 500 m a.s.l high basin – the hyperarid Nazca-Ica depression (Fig. 11) – that formed between the Cordillera de la Costa and the Andean Cordillera Occidental a sharp increase to more than 4,000 m a.s.l.

Fig. 11: Santa Lucia. The hyperarid Nazca-Ica depression from the town of Santa Lucia at 2,800 m a.s.l. facing east towards the Pacific (photo: DBM, B. Gräfingholt).

In these harsh environmental conditions only the river valleys that have perennial runoffs can support permanent human settlements. In the past the rivers Rio Grande, Rio Palpa and Rio Viscas in the research area provided the fresh water that was necessary for agriculture in this hyperarid climate.[256] Due to the climatic changes that occurred in the research area over the last millennia the desert margin has constantly shifted – forcing the people who dwelled in the region to adapt constantly.

The center of the research area is the town Palpa, which is located on the left margin of the river Palpa at 383 m a.s.l.[257] So far, the archaeological investigations in the Nasca-Palpa area have proven that during the Paracas period, characterized by generally more humid conditions than today, the population density shifted from the highlands to the coastal area. This situation manifested during the early and middle Nasca period and was only reversed in late Nasca period – caused by a climatic change – when settlements were relocated to the middle reaches of the valleys and to the highlands. As reconstructed from the

248 Browman, 1981, p.415.
249 Tripcevich, 2009, p.64.
250 Stöllner, 2011, p.182.
251 Lechtman, 2014, pp.363-365.
252 Bissig, et al., 2015, p.344.
253 Lechtman and MacFarlane, 2005, pp.7-8.
254 Stöllner, 2011, p.182.
255 Petersen, 1979, pp.4-5.
256 Eitel and Mächtel, 2009, pp.18-19.
257 Montoya, Garcia and Caides, 1994, p.9

archaeological record it must be assumed that during the Middle Horizon the coastal area was nearly deserted because of the harsh environmental condition that did not support permanent human occupation. After a renewed climatic change during the Late Intermediate Period the environmental condition again became humid and supported human settlements and agriculture on the coast and the river valleys.[258] Completely new settlements like the Ciudad Perdida were established during this period.[259]

As the desert margin sporadically shifted from the coast to the highlands and back,[260] the people who lived in the area and exploited the resources had to modify their living strategies, in order to access the precious raw materials that were mined in the research area. The situation described perfectly illustrates that a "constant movement between the highlands and the coast took place over the centuries/millennia and that presumably people had constant contact and moved or exchanged goods between these regions to obtain the raw materials for their economic activities."[261] In the highlands, they had access to the interregional exchange networks that operate on the Altiplano and used llama caravans to export the goods from one destination to the other.[262] Up to now the desert margin is located at round about 1,200–1,800 m a.s.l. more than 60 to 90 km away from the coastline – this region is distinguished botanically from the arid desert strip by the emerging cactus belt.[263]

4.2 Formation of the ores

During earth's history an immense variety of metal ore deposits developed in the Andes. These deposits formed during different periods in the past 70 million years in the course of the subduction of the Nazca Plate, which converged with the South American Plate. Roughly 160 km from the western margin of South America the process of subduction has shaped the ocean floor resulting in the formation of the Peru-Chile Trench[264] (8,065 m) in the Pacific Ocean, which runs parallel to the South American continent.[265] The trench must be regarded as the geological frontier between the Nazca plate in the west, which is basically the ocean floor, and the South American plate. This geological process has resulted in dense volcanic activities and the formation of a great variety of ores.[266]

The effects of this trench had a long-lasting impact on the coast, Andean foot and the Western Cordillera and had a sustainable influence on the development of the pre-Columbian cultures that flourished in this region.[267] Mankind was probably driven to extract the minerals from these deposits since the landfall on the South American continent around 15000 BP.[268] Geologically the Peruvian Andes are divided into several morphostructural zones: coastal zone, Western Cordillera, inter-Andean Altiplano, Eastern Cordillera and the sub-Andean zone.[269]

Within these zones four geographically different ore lead isotope provinces (I, II, IIIa and IV) as well as an additional compositional group (IIIb), which is not connected geographically were identified in the course of ongoing investigations.[270] These investigations clearly documented that the lead isotope provinces run parallel to the Peru-Chile trench and that the lead isotopic compositions changes from west (lead isotopic province I) to east (lead isotopic province III) – but it is not the altitude of a deposit that determines the lead isotopic composition instead it is the distance from the trench, resulting in the fact that the important pre-historic and modern mining districts of Chuquicamata (2,600 m a.s.l.) and Collahuasi (5,000 m a.s.l.) belong to the costal lead isotope province I.[271] As MacFarlane and Lechtman (2014, p.12) have stated the "lead isotope ratios of ore deposits in the central and south-central Andean zone display a distinctive, large-scale pattern which reflects the interaction of the major lead reservoirs in the crust and mantle in the generation of metal ores." It is most likely that the porphyry copper and epithermal gold deposits were the main targets of pre-Columbian exploitation as they are today.[272] The geological processes that formed the southern Andean were outlined recently by Hauptmann (2011a; 2011b) and Moreno and Gibbons (2007). For the Central and South Central Andean zones Lechtman (2014, p.265) has impressively described the copper deposits that were exploited by the pre-Columbian miners, when she states that "these copper ores have been exploited heavily from prehistory to the present. The Central Andean zone is particularly rich in the tetrahedrite–tennantite [$Cu_{12}Sb_4S_{13}$–$Cu_{12}As_4S_{13}$] copper sulfarsenide ore solid solution series, sometimes referred to as fahlerz or grey ores. These ores of copper, arsenic, antimony, and sulfur and their weathered products are abundant from southern Ecuador to northern Bolivia and are also represented in

258 Stöllner, et al., 2013, p.106.
259 Mächtel, et al., 2009.
260 Eitel and Mächtel, 2009, p.35.
261 Reindel, Stöllner and Gräfingholt, 2013, p.302.
262 Tripcevich, 2009, p.64.
263 Eitel and Mächtle, 2009, p.20.
264 It should be noted that the denomination for the Peru-Chile trench is reversed into Fosa Chile-Peru by authors writing especially for a Chilean audience, e.g. Lechtman and MacFarlane, 2006, p.513.
265 MacFarlane and Lechtman, 2014, p.6-7.
266 Lechtman and MacFarlane, 2005, p.513.
267 MacFarlane and Lechtman, 2014, p.7.
268 Every now and then new theories come up. Bradly and Stanford (2004) have suggested that a migration from Europe during the Solutrean-Culture could be part of the first migration into the new world. Straus, Melzer and Goebel (2005) have passionately argued against this theory. For now, the scientific community has agreed that the first migration whether by land or sea took place between 15000–10000 BP as proposed by Dillehay (2008; 2009).
269 Gunnesch, Baumann and Gunnesch, 1990, p.1384-1385.
270 MacFarlane, et al., 1990; Petersen, MacFarlane and Danielson, 1993; Kamenov, MacFarlane and Riciputi, 2002; Lechtman and MacFarlane, 2006; MacFarlane and Lechtman, 2014.
271 Lechtman and MacFarlane, 2006, p.513.
272 Sillitoe, 2004, p.1; Bertrand, Guillou-Frottier and Loiselet, 2014.

significant deposits in Northwest Argentina and central Chile. Enargite [Cu_3AsS_4], one of the purest mineral types in the series, occurs in an important group of deposits stretching the length of the Central Andes, from Pilzhum in northern Ecuador to Laurani in northern Bolivia. The largest and richest of these deposits are in central Peru." Porphyry Cu-Mo deposits stretch from north to south in six longitudinal belts along the Andes of northern Chile, each stands for a discrete metallogenic period. The porphyry belts are: Late Paleozoic-Triassic (298–230 Ma), Early Cretaceous (132–97 Ma) Paleocene-early and late Miocene (60–50 Ma), late Eocene-early Oligocene (43–31 Ma), and late Miocene-early Pliocene (12–4.3 Ma). From the mining point of view, the two youngest porphyry copper deposits must be regarded as the richest and most profitable. The late Eocene-early Oligocene deposits have formed local clusters in equigranular dioritic to granodioritic plutons where the copper-bearing stocks were enclosed. The above mentioned pre-Hispanic mining districts El Abra, El Salvador, La Escondida and of course Chuquicamata are all part of this late Eocene-early Oligocene Cu-Mo belt.[273] Additionally Sillitoe (1988, p.100) has stated that "in the central Andes, nearly all major copper deposits, principally of porphyry type but also including skarns and enargite-bearing replacements in Peru, are restricted to the three well defined Cenozoic sub-belts: Paleocene-early Eocene (66-52 Ma), late Eocene-early Oligocene (42-31 Ma), and middle Miocene-early Pliocene (16-5 Ms). These three sub-belts account for more than 90 % of Andean copper resources."

4.3 Geology of the Nasca-Ocoña belt

For the Nasca-Palpa area the rich mineralization zones of the Nazca-Ocoña belt must be regarded as a main force for modern and pre-Columbian mining operations. The Nazca-Ocoña belt – an iron oxide copper gold (IOCG) mineralization[274] – is dominated by auriferous pyrite-quartz-carbonate veins[275]and epithermal or hydrothermal veins[276], which are formed in a subduction setting. In the geological research and exploitation ventures IOCG deposits have only recently been recognized. In the context of the pre-Columbian mining operation it is important to note that beside the high grade of Cu and Au content this class of deposit also contains low-Ti iron oxide (magnetite and/or hematite). From the IOCG deposits gold can be extracted in three forms: native gold, electrum, and gold–bismuth–antimony–tellurium alloy. During pre-Columbian times probably the main focus was on native gold and electrum, which commonly occurs as inter-granular particles and tiny inclusions in sulfide, hematite and gangue minerals (quartz, calcite, barite and siderite) in these deposits.[277] In the Nazca-Ocoña belt mineralization's bearing gold or copper are mainly the "Batolito de la Costa" and the "Complejo Bella Union". The metal deposits run parallel to the western cordillera and are enclosed by either Jurassic or Cretaceous volcanic or sedimentary-volcanic host rocks. Lower amounts of noble metals, lead and zinc can be found in the copper deposits as well as native gold-silver fine disseminated in hydrothermal quartz veins. Especially these veins, which can be localized relatively easy at the flanks of the quebradas attracted modern and pre-Columbian miners. The central Andean region is considered a zone of widespread gold and polymetallic ore deposits that were exploited very early on, particularly in northern Peru. The origin of the deposits is roughly generalized and attributed to major plate tectonic events, whereby the relatively heavier oceanic lithosphere plate (Nazca Plate) is pushed (subducted) several kilometers below the relatively lighter continental plate of the mainland. The contact zone thereby becomes a so-called active continental margin, which is characterized by high seismic activity and particularly explosive volcanism, but also has a considerable potential for deposits of various (polymetallic) ores. Particularly in the Palpa-Nazca district, an ore belt running parallel to the mountains is found, which is due to a huge intrusive body (coastal batholithes) in the subsoil, which was formed during subduction in the deeper underground from converging melts. Due to its influence, mineralizations could accumulate at tectonic fault zones. Hydrothermal vein fillings and gold and quartz veins were formed. The individual ore veins sometimes have enormous gold and copper contents, which in the case of gold can amount to several hundred grams/ton and more.

Fig. 12: Saramarca. Quebrada of the Rio Viscas facing north. The rich mineralization zones are opened up by the river valleys and enabled the localization of these deposit in pre-Columbian times (photo: DBM, B. Gräfingholt).

273 Maksaev, et al., 2007, pp.181-182.
274 Stöllner, 2009, p.401; Sillitoe, 2004, p.2.
275 Sillitoe, 2004, p.9.
276 Stöllner, et al., 2013, p.106.
277 Zhu, 2016, pp.37-38.

In some cases, rich “bonanza” veins of gold and copper and iron oxide ores can be found in this mining zone.[278] The topographical circumstances of the research area enhanced the access to ores as the quebradas over the ages cut through the weathered upper portion of the ore veins (Fig. 12). Therefore the pre-Columbian miners could exploit native metals as well as the secondary copper carbonates, which enhanced the metallurgical process as theses ores “promoted the discovery of smelting and served as the first major source of copper because it can be smelted from such ores by simple reduction with charcoal, while smelting copper metal from primary sulfide ores is a highly complicated technical process.”[279]

4.3.1 Extraction zone in the Nasca-Palpa area

Possible pre-Columbian extraction zones have been identified in the course of intensive surveys in the region in 2009 and 2018.[280] Results have been published so far by Reindel, Stöllner and Gräfingholt (2013), Stöllner, et al. (2013), Stöllner (2011) and in this study. The 2018 survey concentrated on the ore region around Palpa and the north of the Nazca province in the valleys of the Rio Santa Cruz, Rio Grande, Rio Palpa, Rio Viscas and Rio Ingenio. The ore zone in the south of Nazca was avoided on the advice of Jonny Isla Cuadrado, the local cooperation partner and state monument protector for the Nazca-Palpa region, because at the time of the prospecting campaign a conflict over mining rights of various interest groups is being fought there, sometimes with the use of firearms. At present, a partial legalization of the previously prohibited wild ore mining is underway in Peru. This is accompanied by conflicts over the cutting of the awarded claims. It seemed sensible to avoid dangerous regions. The search for sample material was initially carried out by visiting already known sites at the edge of river valleys, which could be reached by four-wheel-drive off-road vehicle and on foot. Other mining sites, which were visible from afar in the arid climate, were also targeted and also sampled. In 2009, starting from the ore deposits in the Nasca-Palpa area punctually deposit-orientated surveys were conducted to get an overview of the existing reservoir of ore deposits. In the beginning, a major problem occurred during the search for old mining activities in the form of modern artisanal mining. The operations conducted by the mineros artesanales have been comprehensively described by Kuramoto[281] and the situation has continued to be relevant for the mining archaeological research as demonstrated by Stöllner and Reindel (2007), Reindel, Stöllner and Gräfingholt (2013), Stöllner, et al. (2013) and in the course of the present study. These modern mining superimposed the assumed ancient mining traces. In the course of a forerunning survey[282], which established the basis for the author’s work in Mollaque Grande and Saramarca, which will be outlined later, a routine was established that allows the localization of ancient mining and clearly separates this operation from the modern extraction activities.

Especially in pre-Columbian settlements located near the outcrops of mineralization zones it was possible to document handheld stone tools and characteristic beneficiation mills. These mills were mostly scattered on small terraces in combination with crushed ores. Stone mills were partly used by modern mineros, therefore a positive sighting of such an artifact does not give a clear hint for ancient mining. On some sites it was nonetheless possible to document traces of ancient mining activities in the form of old waste dumps with characteristically conchoidal fractured stones representing the main waste of a crushing mining with stone tools. It was possible to localize those waste dumps with ancient pottery shards and small wild corncobs that were plastered with waste of modern mining activities.

4.3.1.1 Valle de Rio Grande, La Muña

In the vicinity of the large tomb of La Muña (Middle Nazca period, ca. 340–420 AD) extensive modern mining activities have been documented, which already strongly intervene in the archaeological findings on site. The site is more or less protected by the local authorities. The surrounding slopes, where isolated pre-Hispanic mining tools as well as mining operations have been documented, are however strongly endangered by modern mining. Sample material from ore excavations was taken.

4.3.1.2 Valle de Lomas, Acarí

Located in the south of the previous survey area the Valle de Lomas (Fig. 13) is accessible from the coastal plain via the village Acarí.

Fig. 13: Valle de Lomas (photo: DBM, B. Gräfingholt).

278 Stöllner, et al., 2013, p.106-107.
279 Patterson, 1971, p.289.
280 The following site description is partly taken from Prof. Dr. Thomas Stöllner’s survey diary of 2009.
281 Kuramoto, 2001.
282 Stöllner, et al., 2013; Reindel, Stöllner and Gräfingholt, 2013.

The ore-bearing zones are located inward near the village Huanca. The veins are cut by the quebradas and have been exploited by artisanal mining in the recent past. Important to note about Huanca are the boulder fields. Here big granite erratic can be found to produce the well-known quimbaletes. Those stones have been used as mills to crush gold bearing ores and are still in use in the area of Saramarca.[283] Sub-assemblies are found everywhere as well as used ones thrown away. The village itself seems to have a long-standing tradition of gold processing, maybe as far back as into early colonial times. Further proofs of this assumption were documented at a mine in a valley north-east of Huanca (site PB004). The mine is located at the north-east valley side. An old track connects the mine with the town and has been used by pack animals and mineros. No dynamite was used to open up the mine, only traces of metal tools – probably a pick dug – were found. Hence, a colonial period extraction should have taken place, in recent times an artisanal mining used the old shaft mine. The exact date of the mine cannot be determined, but some hints exist. First of all, a pottery shard (Paracas) was found on the track leading to the mine, therefore it may be possible that the colonial mining activity had a forerunner in pre-Columbian times. The mineros working in the area underlined the potential of the valley and pointed to other mines in the valley further up in the highlands. It is reasonable to assume that those mines are more easily accessible via the highland tracks.

4.3.1.3 Valle de Las Trancas

Further north the Valle de Las Trancas was investigated earlier by an American team.[284] A basic result of this survey was the documentation of a smelting site near Media Luna.[285] Hence, it seemed reasonable to investigate the valley closer, because it has been impossible so far to locate smelting sites from pre-Inca periods in southern Peru. Starting from the outcrops near the village of San Nicolas de las Trancas, it was possible to document pre-colonial settlements. At the exit of the valley the well-known cemetery of Chauchilla (PC008), is another cemetery attached in the south of the river Trancas, which runs some 100 m on a terrace from west to east. The north of the river is dominated by large Middle Horizon to LIP settlements (PC007; PC020) (Fig. 14).

Fig. 14: Las Trancas Valley. LIP settlement PC007 (photo: DBM, B. Gräfingholt).

A first survey was conducted near the modern Mina de los Inca that did not bring to light any traces of ancient mining. Probably this mine has its roots in colonial times; an older extraction history was not found so far and seems improbable because of the long distance to known ancient settlements. Much more promising finds were made in the east. At the opening of the valley near the villages S. Lucia and S. Nicolas one ancient mine (Pb007) could be identified. The mine is located near the agricultural terraces and consists of some open pit mines that followed the ore veins. Stone tool fragments and mortar stones used to process the ores are unmistakable evidence for ancient mining. The mine itself is supported by a terrace construction at the portal with large pieces of material concentrated on the waste dump at the entrance. Again, pottery sherds were found in the waste dump. Similar open pit mines were also found further west. Some bear traces of ancient extraction and should be associated with pre-colonial mining as well. Other examples of open pit mining sites can be found were dynamite was used showing modern mining activity (Site Pc017).

Open pit extraction supported by a terrace construction can also be found at the south side of the valley. Following the hint of a local miner part of the mountain range of the Cerro Negro in the south was investigated. Here an ancient mining site was documented (Pc014). The diagnostic ceramic placed the site into the Nasca Period. The ores sampled at the site showed an enrichment of 3% Cu comparable to results received on other sites of artisanal mining in the area.[286] No ancient settlements are known in this area. Furthermore, an arid climate is a characteristic of the zone and today it is located 2 km away from the fertile edge of the valley. Hence, a relocation of the pottery to a later date can be excluded.

On the other sites in the Trancas valley, charcoal piles were documented, for example near the settlement of S. Lucia (Pc017) and close to the mentioned site of Media Luna (Pc010-Pc013). Four piles were located near the LIP settlement. Following the dating of Eerkens, Vaughn

283 Stöllner, 2009, p.405; Stöllner, 2011, p.206.
284 Eerkens, Vaughn and Linares Grados, 2009.
285 Eerkens, Vaughn and Linares Grados, 2009, p.774.
286 Stöllner, et al., 2013, p.125 tab.1.

and Linares Grados (2009), the piles were used in early colonial times (15^{th} – 16^{th} century) and can be considered as proof of a denser tree population. The site was at no time used for smelting, no slag was found, only a small copper plate from the LIP settlement. Together with the pastels, metalworking can be considered.[287]

4.3.1.4 Valleys and the area surrounding Nasca

Valle de Aja, Mina Sol de Oro, Urupalla Valley. These sites located in the north of the Trancas valley were surveyed for some days; previous surveys conducted by Eerkens et al highlighted the potential of the area. But the sites Minas Vetilla and Pataraya published by Eerkens, Vaughn and Linares Grados (2009, p.738, p.1) could not be localized in the field. Another site mentioned by Eerkens, Vaughn and Linares Grados (2009, p.738 figs.1, 5-6), La Ballena situated on the north side of the Aja-valley at the exit of the Quebrada de Pongo, was described as mining camp. Other temporary settlements are mentioned, but so far a clear interpretation is missing. For now, it has been impossible to verify any ancient mining activity and raw material processing on the sites. The area around the river oasis in Nasca, which is fed by the rivers Aja and Tierras Blancas, must be seen as the heart of the Nasca culture. Cahuachi, one of the largest Nasca settlements is situated in the area. Vaughn, et al. (2005; 2007) highlight the significance of Cahuachi as pottery center in the region. In the light of previous investigations, it was clear that the area had potential for further surveys. Near the modern mine Sol de Oro smaller pits were identified in the surrounding quebradas. On Site Pc002-004 it was possible to document near-surface mining operations. The mineralization occurred in the form of a quartz vein, which had been worked with metal axes. This type of mining should be associated with early 20^{th} century exploration conducted by the mineros of the modern Sol de Gaz mine. Nevertheless, a colonial origin of the exploration cannot be excluded. These traces can be found at numerous locations as reported by local mineros. Much more information was gathered while working in the Aja valley near the site described earlier by Eerkens, Vaughn and Linares Grados (2009). Especially the mountain ranges located between the Aja and Tierras Blanca valley show a tremendous potential for mining. Metalliferous veins are located near the valley floor and can be reached without much effort from the populated zones. Such a site was found on site Pg001-003.

Fig. 15: Aja Valley. Ancient near-surface small-scale mining operation penetrating gold-bearing quartz veins (photo: DBM, T. Stöllner).

It was possible to document a near-surface small-scale mining operation here that penetrates the possible gold-bearing quartz veins. A small subsurface heading, as well as a quarry in combination with a small extraction hole were documented (Fig. 15). It was also possible to find some stone tools – especially hammer tools – in the waste dump situated below the mine. The waste dump itself must be viewed as erosion, a phenomenon covered by pre-Inca mining operations. The stone tools give a clear hint to support such a dating, although no diagnostic ceramic was found.[288] So far, it seems obvious that ancient mining operations were basically concentrated near the populated zones of the Paracas and Nasca culture. A very dry quebrada located north of Nasca, the Urupalla valley, showed no traces of ancient mining only modern small-scale mining and exploration mines like the Mina Condor (Pf004) attempted to exploit the deposit. Ancient mining in this area can be ruled out because of the unfavorable vegetation and settlement situation. Today the valley is relatively inaccessible.

4.3.1.5 Valle de Ingenio

This valley could only be investigated in parts. A special emphasis was laid on a valley running north south called the Ayapana valley and a zone located at the opening of the Ingenio valley in the north near the village San Jose. This zone was surveyed for two days and showed an enormous potential. Recent and sub-recent small-scale mining was documented in the Ayapan valley alongside ancient settlement complexes of the Paracas and Nasca period (Ocucaje 7-8, Initial Nasca). One site could be dated to a Middle Horizon context. Sites Pa006-009 in combination with the cemetery Pa010 must be seen as temporary settlement of the same time. Although gold and copper deposits are common in this mineralization zone, no clear traces of mining were found. Better results were received going out of the valley near the village San Jose and in the quebradas located in the north of the Ingenio

287 Reindel, Stöllner and Gräfingholt, 2013, p.309.

288 Reindel, Stöllner and Gräfingholt, 2013, p.310.

valley. First of all remains of Geoglyphs (Pa013) were documented on the 50,000 year old pediment zones at the opening of the valley. Further south it was possible to locate near-surface mining with a striking example of pre-colonial mining in the form of an 8m long partial extraction. Fire setting was verified to date by the soot-blackened ridge. The quartz/Fe mineralization is sitting in a cretaceous rock (calcareous rock/marls) that has been exploited for gold. This mine located near a dry riverbed is within the reach of a mountain range that was occupied by a LIP fortification. Here some building, fortifications and a water basin were found. (Pa019, 021-022) The highlight in this zone is clearly the Mina Primavera.[289]

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Fig. 16: Mina Primavera. Entrance to the mine with a modern archaeological test pit excavated by Vaughn, et al., 2007 (photo: DBM, T. Stöllner).

The site is located within the area of a former iron-barite mine from the 1960s and has been published recently by K. Vaughn, M. Linares Grados, J.W. Eerkens.[290] Used as a powder magazine in the portal area the whole mine was conserved very well. In the back of the mine two headings were documented, which reach up to 20 m into the solid rock– one is running southwest, the other souths east. These headings were driven with a crushing stone tool technique (Fig. 16). Heaps of used hammer tools were scattered on the mine floor mixed with the waste. Overall hammer tools are mostly unmodified belonging to a roller type made of stones from the river. Characteristic signs of use can be found on both ends. The mine was constructed following hematite enrichment between two geological layers (one hanging andesitic layer, one lying barite layer). To date it is still possible to see the excavation trenches of the previous investigation in the portal zone of the rock shelter like a mine. This area was mainly used as a place for recovery and for the processing of the ochre mined in the mine. So far the picture received from the investigations has led to the assumption that the red pigments have been used as ceramic paint at least since the Nasca period.[291] Without a doubt the Mina Primavera represents one of the best preserved examples of ochre mining on the South American continent. In 2018 the modern gold mine Mina Rita near Tulin was visited, but it is already abandoned. There was no evidence of old mining, so no samples were taken. In the whole valley there is currently a lot of activity with busy roads and some tent sites. A well-guarded processing plant is visible from afar, also near Tulin. The valley is dominated by modern mining. Old traces of settlement can only be found in the lower part of the valley near the mina perdida.

4.3.1.6 Valle de Viscas, Saramarca

Previous investigation in the Palpa area in 2006[292] led to no clear picture of this zone. The results received in 2009 brought to light a differentiated overview that was mainly received because the survey was concentrated around the known ancient settlements. From here the ore deposits in the surrounding area were easy to reach and showed some promising traces of ancient mining activity. Evidence was found in form of workshops for the ore processing process. In situ stone tools like anvil, pastels and plates were documented that were used to refine the ores. Ceramic found nearby indicated a pre-colonial context.

Fig. 17: Saramarca. Slopes of the quebradas with ancient mines that were overprinted in the last decades (photo: DBM, B. Gräfingholt).

The overall situation presented in the Viscas valley near Saramarca impressively demonstrates that the opening to the inner valley was blocked by settlements (Pe010-013) located on the mountain ranges. The center of the valley just ahead of the modern mining village Saramarca is dominated by an ancient fortified terraces settlement (Pe014-018) located on a hill slope with a cemetery nearby. On the south side of the valley and further north some small settlements were found. In one case a processing and mining site (Pe029-031) was documented next to the settlements Pe028 and Pe031 that have direct accesses to the mine. Further into the valley

289 Site description is taken from Prof. Dr. Thomas Stöllner's survey diary.

290 Eerkens, et al., 2014; Vaughn, et al., 2007; 2013a; 2013b; Eerkens, Vaughn and Linares Grados, 2009.

291 The dating of the mine is only based on the living and processing area near the entrance, therefore it seems reasonable to assume that a comprehensive excavation of the whole mine will clarify the picture.

292 Stöllner, 2009.

more sites were found, but failed to reveal traces of ancient mining. Similar patterns as documented elsewhere can be assumed, the mining was conducted near the settlements not far away from the habitable zones. In the Viscas valley it was possible to document a new type of processing site Pe002 and Pe031. Terraces like construction were found here that showed remains of the processing of ores as well as ceramic fragments. Judging from the ceramic sherds this site was first used during Late Paracas (Ocucaje 7/8) and later flourished during Late Nasca. These sites are therefore very good indicators of ancient mining activities in the region. It may not be possible to always locate the actual mine, or as seen on site Pe029 where overprinting in sub recent times occurred and made it difficult to date the site (Fig. 17).

Further into the valley modern mines dominated the landscape but because of the remains of heaps of old quimbaletes and the clear identification of dynamite use on sites Pe007-008 in the north a colonial period extraction can be assumed. The Nasca settlement (Pe006) located on a fluvial terrace may indicate that the documented colonial mining had a predecessor in ancient times. No traces of ancient mining could be found though the colonial mining and modern mining overprinted the whole site. Nonetheless on some sites it was possible to distinguish surface near extraction with hammering traces from underground galleries worked with iron tools.[293] One ore sample taken from the site showed an Au enrichment of 1000 ppm highlighting that high-grade ores where the reason mining started in the area.[294] In order to clarify the picture of the ancient mining district of Saramarca, the author excavated one trench at the opening of an assumed pre-Columbian mining operation at the flank of the valley, where a Cu/Au mineralization was detected. The old processing mill in Saramarca, which was still in operation in 2009, fell victim to a severe flood in 2014, so today's settlement pattern was only created afterwards. Some sample material was collected from abandoned modern mining sites on gold-bearing quartz veins on the right side of the valley. In 2009, mining was still going on there. A looted cemetery extends below. On the opposite side of the valley some copper ore, maybe gold, was found. A modern prospecting above a burial ground aims at an ore vein, which, in addition to copper mineralization, also opens up a gold-bearing quartz vein.

4.3.1.7 Valle de Palpa

This valley as all other feeders of the Rio Grande is squeezed between interglacial pediment zones and the mountain ranges of the Andes foot. It was obvious that the erosion process should have opened up the economically interesting mineralization long before. Therefore, it was assumed that ancient mining had to be found within close range to major population centers. In the course of the survey in the Valle de Palpa it was possible to prove this assumption and locate pre-colonial mining sites near the site Mollaque Grande, a site previously investigated by the Nasca-Palpa survey. The first hint was given by modern artisanal mining that exploited the mineralization (quartz veins with Au, Cu and Fe_2O_3) on the site that had been mined before. The ores of the processing site Pj001 showed Cu contents of 5% and may indicate ancient copper mining.[295] In total the documented area left no doubt and must be viewed as the most prominent pre-colonial mining site documented during the survey 2009.

Fig. 18: Mollaque Grande 2009. Overview of the site with the ancient adits that follow the mineralization (photo: DBM, T. Stöllner).

Therefore, the site Mollaque Grande was chosen by the author to conduct additional excavations on the site, which will be outlined later. Following the N-S running mineralization, it was possible not only to locate the modern mine, but also a pre-Hispanic mining operation. The modern extraction opened up the existing pre-colonial mine. On the waste dump it was possible to find stone tools characteristic for pre-Columbian mining. Late Paracas ceramic dominated the assemblage found and mark the site (Pj005, 007, 011) as one of the oldest mining districts documented so far in the Nasca-Palpa area. Together with the ceramic it was possible to locate mining tools in the ancient waste dumps that were covered by sub-recent waste.[296] On the platforms used for the processing of the ores it was also possible to relate the documented Paracas and Nasca ceramic to the mining activities. A LIP settlement (Pj008) lying above the mine on the mountain range could not be linked to the extraction operations as well as no signs of ancient mining have been found in connection with LIP so far in the area. Therefore, the documented stone tools and mills in the settlement must be treated with special interest, though they may represent LIP tools. In total, Mollaque Grande must be viewed as a pre-colonial mining district with enormous potential for further investigations (Fig. 18). The site Mollaque Grande, as it coincides with a listed settlement area, was found

293 Stöllner, et al., 2013, p.118.
294 Reindel, Stöllner and Gräfingholt, 2013, p.316 fig.14.17.
295 Stöllner, et al., 2013, p.125 tab.1.
296 Reindel, Stöllner and Gräfingholt, 2013, p.313 fig.14.14.

largely unchanged in 2018, but unauthorised underground interventions are currently taking place, which could be problematic for the future.

Broadly speaking, in 2009 and 2014 it was determined that Mollaque Grande is one of the oldest known ore mining zones in Peru. So far, the beginning of mining here could be dated to the Paracas period (800–330 BC). Currently, the ore deposit is being approached by mineros artesanales, who, according to their own statements, sometimes extract several kilograms of gold underground. Above ground, the site has not been significantly altered since 2014. The pre-Hispanic mines, which were recently overprinted, are still preserved and a mining terrace, which lies on the opposite slope, has been documented. Sample material was taken from the modern stockpiles. The site Pinchango Alto is located opposite to Mollaque Grande the other site of the Rio Palpa. Here, in the immediate vicinity of a settlement of the late interim period (LIP ca. 1200 AD), a copper mine (Fig. 19), abandoned in the 1960s, was sampled.

Fig. 19: Pinchango Alto. Mouth hole of recent copper mining with remains of pre-Hispanic mining (photo: DBM, B. Gräfingholt).

4.3.1.8 Valle de Santa Cruz

This valley located at the north-western end of the investigation zone is part of the river oasis around Nasca-Palpa and is fed during the rainy season by the Rio Grande river. Near the village Locari approximately 8 km away from the Pan-American at the entrance of the valley ore deposits and ancient settlements were known. In the light of the previous results, a positive identification of ancient raw material extraction was very probable in this zone. Starting from the farm of Armando Rochas it was possible to access waste dumps with concentrations of malachite at the flanks mixed with erosion material that were clear hints of mining. Ore samples taken on the site showed an enrichment of 19% Cu (sample Pd001).[297] A content that would have been worth extracting in pre-Columbian times as well as today. After a first inspection the hillside itself revealed near surface extraction activities. Following the ore mineralization, small pits were dug into the slope (Pd004). Furthermore, waste dumps and stone tools were found indicating a pre-Columbian mining industry. The mines are probably connected to the Nasca settlement (Pd007) located above on the mountain plateau where stone tools were found. Stone quarries and younger LIP graves complete the ensemble. The close connection of the ore processing and the populate area was even clearer in the south on a larger settlement (Pd010-Pd016). Site Pd011 and Pd013 were identified as workshops, where hematite was processed using stone tools. Located on the mountain plateau between the Valle de Santa-Cruz and Valle de Rio Grande the terrace settlement had a strategic overview of the surrounding area. The site showed continuous occupations at least since Early Nasca with traces of Middle Nasca, Middle Horizon and LIP being present as well. At the transition – located between settlement 1 and the complexes 2 to 5 – connecting the two valleys more undated mines (Pd017-018) were found. Judging from the ore geochemistry Cu seemed the desired raw material mined at the site.

The fieldwork conducted was especially successful to document numerous sites of ancient ore extraction concentrated on Cu, Au and Hematite in a relatively short time. In the ancient settlements the localization of the workshops where the ores were processed enabled Stöllner, et al. (2013, p.120) to postulate an organization model of the ancient ore production directly next to the extraction zones. Traces of actual smelting remained in the shadows. Two reasons may explain this fact; the south Peruvian costal metallurgy during the Nasca period was probably based on a smelting process concentrated on high-grade Cu ores from the oxidation zone (Malachite, Azurite) that only leaves small amounts of slag. Au-metallurgy traditionally produces small amounts of waste material especially when it is concentrated on free Au deposits as in the Nasca-Palpa area. Furthermore, the fact that the settlements of the ancient periods have only been investigated to a very small proportion concerning remains of metallurgy (crucible), leaves some room for speculation. It has been correctly stated by Graffam, Rivera and Carevic (1996, p.108) that "when dealing with relatively infrequent or small-scale efforts at reduction, the evidence of sme1ting is scarce. Metallurgical slag is

297 Stöllner, et al., 2013, p.125 tab.1.

not commonly searched for by most excavators, and it can easily be discarded from the screen, if encountered." Still the location of the possible mining districts near the populated areas is not surprising, though the mineralization zone of the Nasca-Ocoña belt runs alongside the settlements from Northwest to Southeast. The previous mining archaeological research[298] conducted in the region proved that beside the LIP other periods like the Paracas and Nasca period also played an important part in the ancient regional resource extraction. The current study was only made possible because of these results and will further investigate the pre-Columbian raw material extraction in the research area. A second visit to the valley in 2018 revealed that extensive cemeteries and associated settlements on both sides of the Rio Santa Cruz exist, but old mining is only preserved within the settlement area near Locari in the form of mining terraces and old slagheaps. The old mining area above a hut, which was investigated in the previous campaign of 2009, is now completely covered by a new slagheap. There are new dwellings of gold prospectors everywhere, which characterize the landscape. Nevertheless, some copper and gold quartz mineralization, perhaps related to pre-Hispanic mining, has been sampled. On the other side of the valley near El Carmen, cavities appeared in the rock, which turned out to be modern but already abandoned tunnels. In plastic bags supposed ore remains were found, which were selectively sampled. Further upstream there are two looted cemeteries, and in the rummaged overburden a heavy stone tool was found, which was presumably used to extract ore (Fig.20).

Above the settlement areas of Locari at the transition to the Rio Grande, there are indications of old slag heaps, but also modern open-pit copper ores that were discarded. Selective samples were taken. At the bottom of the valley there is a modern gold mine, which could not be visited for safety reasons. At the transition to the valley system of the Rio Grande, extensive settlement terraces were found on the hills with associated cemeteries along the Rio Santa Cruz.

Fig. 20: El Carmen. Heavy equipment approx. 12 kg (Photo: DBM, B. Gräfingholt).

298 Stöllner and Reindel, 2007; Stöllner, 2011; Stöllner, et al., 2013; Reindel, Stöllner and Gräfingholt, 2013.

4.4 Geology of the Altiplano

4.4.1 Formation of Obsidian

Obsidian is formed at the outer rims of a lava stream, which consists of high viscous lava that has a high silica and alumina level.[299] Therefore the chemical composition of obsidian is varying between 70-75% SiO_2, 10-15% Al_2O_3, 3-5% Na_2O, 2-5% K_2O und 1-5% Fe_2O_3 + FeO.[300] The trace elements make up less than 1%.[301] During the forming of the obsidian the trace elements are separated and scattered between the liquid and solid states. This is the main reason why it is possible to determine the provenance of obsidian sources and artifacts with the aid of trace elements analysis. Obsidian is mostly black or grey depending on the chemical composition of the material – other colors are possible.[302] The formation of the obsidian takes place near the tectonic margin. Here in the upper mantel the silicic volcanism originates and forms magma where the solid materials and the trace elements are distributed between the liquids and solids. As the magma evolves, fractional crystallization takes place. In the course of the crystallization, trace elements such as Co, Cr, Ga, and Ni are consumed by the solid phases. Other trace elements such as Ba, Cs, Rb, Sr, Hf, Nb, Ta, and Zr are incompatible with the solid phase and are enriched in the liquid. Therefore, the variety of incompatible elements within each obsidian source is unique – enabling researchers to use trace element analysis of obsidian objects to pinpoint the provenance of the artifacts.[303]

4.4.2 Obsidian in Peru

For the past 40 years obsidian has been a major research issue in the Americas[304] Intensive research concerning the provenance of obsidian primarily with Neutron Activation Analysis (NAA)[305], X-Ray fluorescence (XRF)[306]and other

299 Glascock, Speakman and Burger, 2007, p.525.
300 Glascock, Braswell and Cobean, 1998, p.18.
301 Glascock, Speakman and Burger, 2007, p.525.
302 Glascock, 2002, pp.611-612.
303 Glascock, Speakman and Burger, 2007, pp.526-527.
304 Asaro, et al., 1994; Burger and Asaro, 1977; Burger, 1980; Burger and Glascock, 2000; Burger, Mohr Chavez and Chavez, 2000; DeLeonardis and Glascock, 2013; Eerkens, et al., 2008; Glascock, 2002; Glascock, Braswell and Cobean, 1998; Healan, 1997; Rees and De Souza, 2004; Riciputi, et al., 2002; Rogers, 2008; Seelenfreund, et al., 1996; Shackley, 1998a; 1998b; Stanish, et al., 2002; Stevenson, Stross and Heizer, 1971; Tenorio, et al., 1998; Vaughn and Glascock, 2005; Yacobaccio, et al., 2004.
305 Glascock, 2002, pp.613-615; Glascock, Speakman and Burger, 2007, p.531; Glascock, Speakman and Neff, 2007; Knight, et al., 2011; Popelka-Filcoff, et al., 2007; Santi, Renzulli and Oddone, 2010.
306 Burger, 1980, p.258; Craig, et al., 2007; Glascock, Speakman and Burger, 2007, pp.527-528; Knight, et al., 2011; Stevenson, Stross and Heizer, 1971.

chemical analysis[307] led to the characterization of the major obsidian quarries during the last decade.[308] In the south of Peru and northern Bolivia ongoing archaeological and archaeometric studies have been able to characterize and to locate twelve obsidian sources, which were used in the past: Alca (Cotahuasi)[309], Chivay (Colca)[310], Puzolana (Ayacucho)[311], Jampatilla (Puquio)[312], Lisahuacho (Andahuaylas A)[313], Aconcagua (Puno)[314], Potreropampa (Andahuaylas B)[315], Soro Soro (Bolivia)[316], Laguna del Maule (Central Chile), Capiapó (Northern Chile)[317], Macusani[318] and Quispisisa (Ayacucho)[319]. The results of these studies indicate an intensive long distance trade between the lowlands and the highlands,[320] which is manifested in the form of more than 90% of obsidian used in the Andean region coming from the Quispisisa, Chivay and Alca quarries.[321] Similar words for obsidian in the indigenous languages, quispi capa or kespi in Quechua and quispi or qhspi in Aymara[322] support the assumption that obsidian has to be viewed as an important force for long distance trade in the Andean. During pre-Columbian times, obsidian was highly valued because of its material properties.[323] It was mainly used to produce tools like projectile points. A detailed analysis of the Obsidian projectile point assemblage of the Palpa region showed that Obsidian was used from the Archaic up to the Late Horizon.[324] Probably all of the so far geo-chemically characterized quarries have been used by pre-Columbian cultures to extract obsidian.[325] After the geochemical characterization of some of these obsidian quarries it was possible to pinpoint the beginning of the extraction process as well as to identify the mining methods used.[326] So far, the existing results indicate intensive exchange relations between the inhabitants of highland region in the Altiplano as producer of the obsidian and inhabitants of the coast as consumers and end-consumers of this highly valued product.[327] Similar terms for obsidian in the indigenous languages Quechua (quispi capa or kespi) and Aymara (quispi or qhspi)[328] further highlight this transregional exchange network. Above all the quarries Chivay, Alca and Quispisisa must be viewed as the primary mines for obsidian in the central Andean region. Approximately 90% of all archaeological obsidian artifacts deriving from Peru and northern Bolivia analyzed with either NAA or XRF have been mined from these three quarries.[329] Latest research undertaken in the highland region of Huanca Sancos underlined the major importance of the obsidian quarry Quispisisa. Independently two research groups[330] investigated the lava flow Quispisisa and were able to clearly identify the exact location of the Obsidian extraction at the mine of Jichja Parco. At this location 40m long extraction pits with a depth of 4m were documented (Fig. 21). In the surroundings workshops and stone tools made out of river stones were found and proved the in situ processing of the obsidian.[331]

Fig. 21: Jichja Parco. Open pit obsidian quarries at the pre-Columbian mine of Jichja Parco (photo: DBM, T. Stöllner).

On the one hand samples from Jichja Parco were analyzed in Berkeley using a XRF device. The results indicated a clear connection with the quarry until then called Quispisisa. Furthermore, proof of an extensive mining of obsidian in pre-Columbian times at this quarry was documented in form of the multiple mining pits.[332] On the other hand samples from Jichja Parco as well as obsidian flakes from archaeological excavation of the Andentransect Project were analyzed geochemically using the NAA. The results indicate that Jichja Parco

307 Glascock, Speakman and Burger, 2007, p.527; Eerkens, et al., 2010.
308 Aldenderfer, 1999; Brooks, Glascock and Giesso, 1997; Burger, et al., 1998; Burger and Glascock, 2000; Burger, Mohr Chavez and Chavez, 2000; Craig et al., 2010; Glascock, Speakman and Burger, 2007, p.537; Seelenfreund, et al., 2002, p.18; Stöllner, 2011, p.191; Tripcevich, 2009.
309 Burger, et al., 1998.
310 Tripcevich, 2009.
311 Burger and Glascock, 2000.
312 Burger, Mohr Chavez and Chavez, 2000.
313 Glascock, Speakman and Burger, 2007, p.537.
314 Aldenderfer, 1999.
315 Glascock, Speakman and Burger, 2007, p.537.
316 Brooks, Glascock and Giesso, 1997.
317 Seelenfreund, et al., 2002, p.18.
318 Craig, et al., 2010.
319 Burger and Glascock, 2000.
320 Stöllner, 2011, p.191.
321 Craig, et al., 2010, p.569.
322 Peterson and Brooks, 2010, p.8.
323 Glascock, 2002, p.611.
324 Gräfingholt, 2011.
325 Alca (Cotahuasi): Burger, et al., 1998; Chivay (Colca): Tripcevich, 2009; Puzolana (Ayacucho): Burger and Glascock, 2000; Jampatilla (Puquio): Burger, et al., 2000; Lisahuacho (Andahuaylas A): Glascock, Speakman and Neff, 2007, p.537; Aconcagua (Puno): Aldenderfer, 1999; Potreropampa (Andahuaylas B): Glascock, Speakman and Burger, 2007, p.537; Soro Soro (Bolivien): Brooks, Glascock and Giesso, 1997; Laguna del Maule (Central Chile), Capiapó (Northern Chile): Seelenfreund, et al., 2002, p.18; Macusani (Puno): Craig, et al., 2010; Quispisisa/Jichja Parco (Ayacucho); Burger and Glascock, 2000; Reindel, Stöllner and Gräfingholt, 2013; Stöllner, 2011; Stöllner, et al., 2013; Tripcevich and Contreras, 2011.
326 e.g. Jennings and Glascock, 2002; Stöllner, et al., 2013; Tripcevich and Contreras, 2011.
327 Stöllner, 2011, p.191.
328 Petersen, 2010, p.8.
329 Craig, et al., 2010, p.569.
330 Tripcevich and Contreras, 2011; Stöllner, 2011; Reindel, Stöllner and Gräfingholt, 2013; Stöllner, et al., 2013.
331 Stöllner, 2011, p.193.
332 Tripcevich and Contreras, 2011, p.15.

must be viewed as the main supplier of Obsidian in the Nasca-Palpa region. Starting in the Archaic up to the Middle Horizon the quarry was continuously used by the ancient inhabitants as the main source for obsidian.[333] For the present study 365 obsidian projectile points excavated and found in the PAP were analyzed using a pXRF of the Deutsches Bergbau-Museum Bochum and as a geological reference 40 samples from the quarry Jichja Parco were additionally measured with the same device. The samples were taken during the previous field campaign and are currently stored in the Deutsches Bergbau-Museum Bochum. Therefore, this study will present a method for the geochemical characterization of obsidian in the field, which will facilitate provenance studies and will prove long lasting obsidian mining traditions and raw material consumption patterns in the Nasca-Palpa area during the pre-Columbian periods.

4.4.3 Obsidian in Ecuador

Ecuador is divided into three topographically distinct regions, which are clearly separated from each other by altitude and climate – Costa (the coastal plains), Sierra (the mountainous highlands of the Andes), Oriente (the eastern lowlands, leading to Amazonia).[334] In comparison to the research carried out in southern Peru on obsidian provenance and the characterization of obsidian sources that have been exploited in pre-Hispanic times, Ecuador trails behind. This is due to a considerable gap in archaeological research in this region, which has so far only concentrated on obsidian in some sourcing studies.[335] Nonetheless obsidian has been recognized as a raw material, which was used from Paleo-Indian periods onward to produce tools such as scrapers, burins, projectile points, flake knives and retouched blades. During the Regional Development Period (300 BC – 500 AD) obsidian reached its apogee of usage and was documented in coastal, highland and even rainforest sites. The postulated non-existence of obsidian tools on Inca sites has to be regarded as a direct consequence of the ignorance concerning lithic studies on ceramic sites until the early 90ies of the last century in Ecuador.[336] Therefore the provenance studies on obsidian carried out by Burger (1994) and Asaro, et al. (1994) can be regarded as a direct consequence of this ignorance that was first highlighted by the initial obsidian studies published by Bigazzi, et al. (1992) and Salazar (1992). Because of this research in the last decades, it was possible to characterize the most important obsidian sources that were exploited during the pre-Hispanic area. For the archaeological research and provenance studies the area of the large (≈ 32 ×20 km) Chacana caldera[337] is most important as the three main obsidian deposits, which have so far been identified as suppliers of obsidian for the pre-Hispanic cultures in Ecuador and beyond, are located in this complex. The first source Mullumica, which was created by an unfinished merging of two different magmas in the same chamber,[338] in the Sierra de Guamaní located on the 370 km long Cordillera Real[339] has been intensively mined during the pre-Hispanic area.[340] It is also the largest deposit identified in Ecuador so far[341] and runs along the flanks of the glacial valley of Mullumica for 5 km. This volcanic effluvium is located at around 4,000 m a.s.l. in the Cordillera Real.[342] This source was not only a supplier for raw materials on a local level, but obsidian from this quarry has been documented on the site of Saraguro 400km to the south of the source[343] as well as in the Tumbes region in Peru some 450 km away from the quarry[344]. Additionally a flake manufactured from Mullumica obsidian was found on the Pubenza site in Colombia approximately 400 km to the north of the source[345] indicating a widespread consumption pattern for obsidian from the Mullumica source in a radius of at least 400km around the obsidian quarry. A second source, which actually consists of two chemically indistinguishable deposits that can be found within a distance of 5 km is the Yanaurco-Quiscatola source.[346] Both obsidian sources outcrop near the tips of the mountains Cerro Yanaurco Chico and Quiscatola[347] at an elevation of approximately 4,000 m a.s.l. and form part of one volcanic complex that erupted at the same time.[348] Because of this both deposits have an identical geo-chemical composition and are therefore referred to as the Yanaurco-Quiscatola source. The total numbers of artifacts found on archaeological sites in the highlands and coastal area that have so far been assigned to sources in Ecuador, indicate that the Yanaurco-Quiscatola and Mullumica sources account for the overwhelming number of obsidian artifacts.[349] The two breccia deposits are located on top of an ancient volcanic succession that was mainly formed by andesitic lavas. Furthermore, the fact that these two obsidian deposits are located only 10km away from each other facilitated the extraction of raw material from these sources in pre-Hispanic times.[350] The Callejones flow has to be regarded as the third source in Ecuador that is important in the archaeological context. This obsidian flow is not as big as Mullumica but has similar characteristics. In total this lava flow stretches over a distance of 3 km and probably erupted at the same time as the Mullumica

333 Reindel, Stöllner and Gräfingholt, 2013; Stöllner, et al., 2013.
334 Valdez, 2008, p.866.
335 Ogburn, 2011, p.98.
336 Bigazzi, et al., 1992, p.24.
337 Bellot-Gurlet, Dorighel and Poupeau, 2008, p.273.
338 Asaro, et al., 1994, pp.268-269.
339 Bellot-Gurlet, Dorighel and Poupeau, 2008, p.273.
340 Ogburn, 2011, p.100.
341 Bellot-Gurlet, Dorighel and Poupeau, 2008, p.273.
342 Asaro, et al., 1994, p.258.
343 Ogburn, 2011, p.113
344 Moore, 2010, p.406
345 Gudiño, et al., 2001, p.8.
346 Ogburn, 2011, p.100.
347 Bigazzi, et al., 1992, p.24.
348 Asaro, et al., 1994, p.258.
349 Ogburn, 2011, p.100.
350 Burger, et al., 1994, p.231.

flow.[351] According to the published date, the given similarity of the geo-chemical composition of the Mullumica and the Callejones source is a result of the “incomplete magmatic mixing before the eruption”[352]. Due to the limited number of obsidian artifacts that has so far been assigned to this source, it appears that the Callejones deposit was only sporadically used as a supplier of raw material.[353] Apart from these three quarries that could be linked with the production of pre-Hispanic obsidian tools only one other deposit of obsidian in Ecuador could be identified as supplier of obsidian to the pre-Hispanic cultures – the Carboncillo source.[354] This quarry is located at an elevation of approximately 3,000 m a.s.l. near the modern towns of Paquishapa and Oña. “The name of Carboncillo derives from the local obsidian, meaning essentially “little piece of charcoal,” indicating that the material was prevalent and distinct enough to be of note to local inhabitants.”[355] Other obsidian sources that have been identified in Ecuador[356] do not seem to have been mined during pre-Hispanic times probably because of the insufficient quality of the raw material for tool production.[357]

4.4.4 Obsidian in Chile and Argentina

As in other parts of the Americas, obsidian played an important role as raw material for the stone tool production used by the pre-Hispanic cultures in Chile and Argentina.[358] Due to an increased interest in obsidian studies starting in the 90ies with a first study of obsidian provenance by Seelenfreund, et al. (1996) the awareness for this raw material was awakened. In the course of multiple studies a comprehensive understanding of the raw material consumption of the pre-Hispanic cultures of Chile and Argentina was generated and the main sources of obsidian sources were identified in different topographical regions: Cordilleran sources, Non-Cordilleran sources, Unknown sources. “A total of six sources were located, the first three in the Cordillera region: Laguna del Diamante (with two subsources—Arroyo las Numeradas and Arroyo Paramillos); Las Cargas and Laguna del Maule (with three subsources—Laguna del Maule, Arroyo El Pehuenche and Laguna Negra) and the remaining three sources are located in the oriental plains (Cerro Peceño, Payún Matrú and Cerro Huenul).”[359] In the Cordillera del Límite near the springs of the Diamante River the obsidian source Laguna del Diamante was localized at 3,200 m a.s.l.[360] In the High Cordillera the vast volcanic complex of the Laguna del Maule with three subsources Laguna del Maule, Arroyo El Pehuenche and Laguna Negra is located at an elevation of approximately 3,000 m a.s.l. at the headwaters of the Maule River[361] and covers an extension of 900km².[362] The obsidian found at this complex has perfect flaking properties and excellent quality.[363] The las Cargas source was documented at approximately 2,350 m a.s.l. on the border between Argentina and Chile. The raw material is very easy to access at this deposit and can be found in blocks of up to 0.5 m². Because the obsidian at this site is of high quality, it is no surprise that signs of knapping activities were documented.[364] Apart from the described Cordilleran sources three other sources have been documented. Located near the volcanos Payún Matrú and Payún Liso, which both altitudes of approximately 3,600 m a.s.l.[365] the Payún Matrú source was used relatively late as a supplier of raw material only during the Late Holocene. Furthermore, this type of obsidian is rarely found in the archaeological context probably because of its poor quality.[366] On the northwestern flank of the El Nevado volcano, which is a volcanic system of huge dimensions and an altitude of more than 3,500 m a.s.l., the El Peceño source is located at around 1,450 m a.s.l., where two types of obsidian deposits were documented.[367] Probably the most interesting source is the Cerro Huenul. This deposit is located next to the Colorado River in northern Neuquén, near the modern town of Buta Ranquil in Argentina.[368] Cerro Huenul belongs to the so-called Tilhué Formation consisting of three obsidian outcrops, which are scattered over a distance of approximately 45 km. The geochemical composition of these three outcrops is similar and therefore does not allow a further differentiation.[369] This probably explains the slightly different element concentrations measured by XRF with have been published by two independent research groups.[370] Although not many artifacts made of this type of obsidian have been documented in archaeological contexts,[371] the raw material from this site seems to have a very wide distribution: it can be stated that it has a supra-regional distribution especially from 3000 BP to 1000 BP, as artifacts from different archaeological site have been assigned to the source in a distance of up to 680 km.[372] As an example three archaeological sites – two in the north and one in the south – have been chosen to highlight this proposed supra-regional distribution of the Cerro Huenul source. One of the most distant samples of Cerro Huenul obsidian was alleged to be documented

351 Bigazzi, et al., 1992, p.24.
352 Bellot-Gurlet, Dorighel and Poupeau, 2008, p.282.
353 Ogburn, 2011, p.101.
354 Ogburn, Connell and Gifford, 2009, p.743.
355 Ogburn, 2011, p.102.
356 Compare: Bigazzi, et al., 1992; Asaro, et al., 1994; Burger, et al., 1994; Bellot-Gurlet, Dorighel and Poupeau, 2008.
357 Ogburn, Connell and Gifford, 2009, p.742.
358 Giesso, et al., 2011, p.1.
359 Giesso, et al., 2011, p.5.
360 Duran, et al., 2004, p.31.
361 Seelenfreund, et al., 1996, p.9.
362 Giesso, et al., 2011, p.6.
363 Duran, et al., 2004, p.30.
364 Giesso, et al., 2011, p.6.
365 Duran, et al., 2004, p.28.
366 Giesso, et al., 2011, p.16.
367 Duran, et al., 2004, p.30.
368 Giesso, Berón and Glascock, 2008, p.17.
369 Barberena, Hajduk and Gil, 2011, p.30.
370 Barberena, Hajduk and Gil, 2011, p.30 tab,3; Giesso, et al., 2011, p.8 tab.1.
371 Giesso, et al., 2011, p.15.
372 Barberena, Hajduk and Gil, 2011, p.33.

some 600 km away from the source in the Intihuasi cave (San Luis, Argentina).[373] But the artifacts from grupo 2 found at Intihuasi (San Luis, Argentina), which were associated with the Cerro Huenul source[374] were affixed falsely to the source because they do not match with the element concentration and standard deviations for obsidian from the Cerro Huenul source.[375] The Zr (ppm) concentrations published for grupo 2 (around 200 ppm)[376] are more than double the element concentration published for the Cerro Huenul source (71 ppm) in the latest research.[377] The data does also not match with the results received by the oldest research on obsidian provenance in Chile and Argentina, where only one artifact from the Cerro Huenul source was analyzed with an element concentration of 65 (ppm) for Zr[378], which on the other hand matches perfectly with the latest published element concentration and standard deviations for the obsidian compositional group of Cerro Huenul in the Mendoza region measured by NAA and XRF.[379] Although the presence of Cerro Huenul raw material at this site has to be denied, the source has to be regarded nonetheless as a supplier for distant sites! At the site Tapera Moreira in the Western Pampas of Argentina Cerro Huenul obsidian was identified in the earliest and middle occupation layers. This implies that the inhabitants of Tapera Moreira had access to the Cerro Huenul source from 3000 to 1200 BP. Though the geochemical composition of the samples perfectly matches with the published data for the Cerro Huenul source, it can be assumed that this source was somehow incorporated into a system of long distance exchange.[380] A driving force for this was probably the high quality raw material present at this quarry combined with an easily accessible location, which could be reached without obstacles all over the year.[381] Furthermore, the immense outcrop of high quality obsidian at this site and the possibility to exploit – even today – more than 50 kg of raw material within one hour of work[382] must be considered as a driving force for the exploitation of this site during pre-Hispanic times. The use of obsidian from the Cerro Huenul was probably initiated during the Late Holocene at Cañada de Cachi (3200–2200 BP) and later appeared in the archaeological record in northern Mendoza at the La Manga site around 1100 BP. It has been argued that the limited distribution of Cerro Huenul raw material might be related either to the territorial boundaries or difficulties to access the deposit from the north as the Colorado River might be a natural border.[383] Both assumptions must be denied, though the documented examples so far of obsidian far away from the source prove that an access was possible and though other samples have been documented in the course of this study, which were distributed beyond the imagined limits, the Cerro Huenul source should be refocused into the archaeological investigation in order to clarify the importance of this raw material supplier during the pre-Hispanic period in South America.

373 Giesso, et al., 2011, p.15.
374 Laguens, et al., 2007, p.12.
375 Giesso, et al., 2011, p.8.
376 Laguens, et al., 2007, p.12.
377 Giesso, et al., 2011, p.8.
378 Seelenfreund, et al., 1996, p.14.
379 Giesso, et al., 2011, p.8; Barberena, Hajduk and Gil, 2011, p.30.
380 Giesso, Berón and Glascock, 2008, p.17.
381 Giesso, et al., 2011, p.16.
382 Duran, et al., 2004, p.31.
383 Giesso, et al., 2011, p.16.

4.5 Discussion

As demonstrated with this chapter, the raw materials and the access to them played an enormous role for the pre-Columbian cultures of Peru and Chile.[384] The knowledge concerning the exact location of the raw material deposits of obsidian and polymetallic ores have probably been handed down through generation of pre-Columbian miners who have exploited the sites since humankind arrived in the New World.[385] On the one hand the need for obsidian as a raw material for tool production was omnipresent during the whole span of human occupation in the Americas.[386] Due to the geological formation processes high quality obsidian can only be found at certain locations in the Andes – in South America mostly in the Altiplano – and therefore forced the early consumers to establish stable and probably cross-cultural exchange networks. In order to reconstruct the raw material consumption of the inhabitants of the Nasca- Palpa region it is imperative to know the geochemical trace element composition of the quarries that were used as suppliers of raw material in per-Hispanic times. Due to the fundamental research that has been

384 e.g. Benson, 1979; Bird, 1979; Bray, 1971; 1978; Cesareo, et al., 2010; Childs, 1994; Craig and West, 1994; Cruz and Vacher, 2008; Eerkens, et al., 2009; Giesso, et al., 2011; Grossman, 1972; Figueroa, et al., 2013; Maldonado and Rehren, 2011; Merkel, Shimada and Doonan, 1994; Ogburn, 2011; Petersen, 2010; Rehren and Temme, 1994; Rehren, 2011; Reindel, Stöllner and Gräfingholt, 2013; Salazar, Borie and Oñate, 2013; Shimada and Merkel, 1991; Stöllner, et al., 2013; Tripcevich and Vaughn, 2013; Zori, Tropper and Scott, 2013.
385 Dillehay, 2008; 2009; Dillehay, et al., 2003.
386 e.g. Asaro, et al., 1994; Bellot-Gurlet, Dorighel and Poupeau, 2008; Bigazzi, et al., 1992; Brooks, Glascoch and Giesso, 1997; Burger, 1980; 2006; 2007; Burger and Asaro, 1977; Burger and Glascock, 2000; Burger, et al., 1994; 1998; 2000; Cecil, et al., 2007; Craig, et al., 2007; 2010; DeLeonardis and Glascock, 2013; Duran, et al., 2004; Eerkens, et al., 2008; 2010; Giesso, Berón and Glascock, 2008; Giesso, et al., 2011; Glascock, 1994; 2002; Glascock and Giesso, 2012; Glascock, Speakman and Burger, 2007; Gräfingholt, 2011; Healan, 1997; Hirth, et al., 2013; Jennings and Glascock, 2002; Kellett, Golitko and Bauer, 2013; Klink, 2007; Knight, et al., 2011; Millhauser, Rodriguez-Alegría and Glascock, 2011; Nazaroff, Prufer and Drake, 2010; Ogburn, 2011; Ogburn, Connell and Gifford, 2009; Popelka-Filcoff, et al., 2007; Riciputi, et al., 2002; Salazar, 1992; Santi, Renzulli and Oddone, 2010; Seelenfreund, et al., 1996; 2002; Shackley, 1998b; Stanish, et al., 2002; Tenorio, et al., 1998; Tripcevich, 2007; 2009; Tripcevich and Contreras, 2011; 2013; Tripcevich, Eerkens and Carpenter, 2012; Tripcevich and Mackay, 2011; Vaughn and Glascock, 2005; Yacobaccio, et al., 2004

conducted in the Andes in the past 40 years concerning the provenance of obsidian it is now possible to access a wide corpus of geochemical data and compare these results with newly obtained trace element analysis from pXRF of archaeological artifacts excavated in the Nasca-Palpa area which have been conducted in the course of this study. On the other hand, a detailed description of possible pre-Columbian extraction sites for polymetallic ores in the research area is given in this chapter, in order to highlight the huge importance of the Nasca-Palpa region as a center for early mining. Raw material mining is the foundation for all further metallurgical processes that in the end lead to the overwhelmingly rich metallurgical tradition of the Andes. When the inhabitants of the Americas started to experiment with metallurgy in the second millennia BC, the foundation for a metallurgical tradition was laid that would later on produce the precious pre-Columbian artifacts that were documented during archaeological research and which have also been illegally acquired since the conquista in the 16th century.[387] The processes described started with the extraction of ores in order to use these raw materials as ornaments or paint[388], later the metallurgical properties were recognized and the techniques evolved from simple hammering of the ores and native metal to annealing and forging of complex works of art. This cultural heritage of the Andean inhabitants can be found in public and private collections worldwide and illustrates how highly the cultures in South America valued the metallurgical products made of mined ores. A comprehensive understanding of the exchange processes that enabled the inhabitants of the Nasca-Palpa region to participate in the trade and exchange of obsidian and polymetallic ores, which were probably mined in the research area, shall be outlined in the following chapters by presenting the results of geo-chemical trace element analysis from pXRF conducted on obsidian and metal artifacts from the PAP.

Documenting pre-Columbian pottery during field-work 2018 in the Palpa-Region (photo: DBM/RUB, G. Gassmann).

387 Aldenderfer, et al., 2008; Angiorama and Becerra, 2010; Boone, 1996; Burger and Lechtman, 1996; Craig and West, 1994; Desaulty, et al., 2011; Dussubieux and Walder, 2015; Dussubieux, et al., 2008; Eeckhout and Owens, 2015; Fields, Zamudio-Taylor and Beltrán, 2001; González, 2010; Hörz and Kallfass, 2000; Lechtman, 1991; Lothrop, 1951; MacFarlane and Lechtman, 2014; Martinón-Torres, et al., 2012; Sáenz Samper and Martinón-Torres, 2011; Scott and Meyers, 1994.

388 e.g. Eerkens, et al., 2014.

5 Obsidian Consumption in Peru

5.1 Obsidian – the swiss knife of Southern Peru

Throughout the entire prehistory of the Andean region the obsidian quarries in the Obsidian Belt that stretches from the north in Ecuador to the south in Chile, were the main source for raw material that was used to produce working tools out of volcanic glass. For the south coast of Peru the obsidian source known as Quispisisa plays a tremendous role as supplier of this valued resource.[389] The properties of obsidian facilitate the processing; obsidian can be shaped into tools relatively easy by flaking, cutting or polishing.[390] For the past 30 years obsidian has been a major research issue in the Americas.[391] Intensive research concerning the provenance of obsidian primarily with Neutron Activation Analysis (NAA)[392], X-Ray fluorescence (XRF)[393] and other chemical analyses[394] led to the characterization of the major obsidian quarries during the last decade.[395] In addition, extensive research has been carried out for preceramic stone tools and projectile points in South America especially in Peru.[396] But so far no typology exclusively for obsidian projectile points has been proposed. While numerous other projectile point typologies exist, the fishtail projectile points only mark the beginning of intensive hunting and stone tool production in the Andean region.[397] Since 1997 archaeological fieldwork has been carried out in the Palpa Region. In the beginning the Swiss-Liechtenstein Foundation for Archaeological Research Abroad (SLSA) in cooperation with the DAI (Deutsches Archäologisches Institut), centered on the geoglyphs of the Nasca culture. 2002 saw the start of the Nasca-Palpa project “Entwicklung und Adaption archäometrischer Techniken zur Erforschung der Kulturgeschichte” (development and adaption of archaeometric techniques for the investigation of cultural history) funded by the German Ministry for Education and Science (BMBF). Since 2008 until now the Andean-Transect Project (Proyecto Arqueológico Palpa) has continued the research started in 2002.[398] Over 400 bifacial obsidian tools from the PAP have been documented since 1997 (Fig. 22).

In the South-Central Andes obsidian was mainly used to produce bifacially flaked projectile points, apart from this tool group other tools such as knives and scrapers can also be identified in the archaeological context.[399] In the PAP 371 bifacial tools have been identified as projectile points, 151 of these projectile points have been excavated from securely dated contexts. “Projectile points are manufactured through systematic primary, secondary, and tertiary bifacial flake removal (using hard- and soft-hammer percussion and pressure flaking). The systematic flaking results in a longitudinally asymmetrical form with a haft element (typically includes a stem and notching) on the proximal end and parallel lateral margins that converge to form a pointed distal tip. Latitudinally, the form is generally symmetrical and typically thin (in relation to width and length) in cross-section.”[400] Projectile points can be used on arrows, spear thrower darts, spears, lances and in form of ceremonial artifacts of those objects. This study will not differentiate between these different types of tool groups, but regardless of the assigned names for the types de-fined, it is obvious that a different size automatically implicates a different purpose for the projectile point.[401] The aim of this analysis is in the first step to establish a projectile point typology that will be relevant for the Nasca-Palpa Region. Obsidian projectile point types proposed in this analysis should be regarded as index fossils for this region only, though chronologies that try to include an area that goes beyond the borders of one homogenous cultural sphere

389 Tripcevich and Contreras, 2011.
390 Glascock, 2002, p.611.
391 Asaro, et al., 1994; Burger and Asaro, 1977; Burger, 1980; Burger and Glascock, 2000; Burger, Mohr Chavez and Chavez, 2000; Eerkens, et al., 2008; Glascock, 2002; Seelenfreund, et al., 1996; Shackley, 1998; Stanish, et al., 2002; Stevenson, Stross and Heizer, 1971; Vaughn and Glascock, 2005.
392 Glascock, 2002, pp.613-615; Glascock, Speakman and Burger, 2007, p.531; Glascock, Speakman and Neff, 2007; Knight, et al., 2011; Popelka-Filcoff, 2007; Santi, Renzulli and Oddone, 2010.
393 Burger, 1980, p.258; Craig et al., 2007; Glascock et al., 2007, p.527-528; Knight, et al., 2011; Stevenson, Stross and Heizer, 197.1
394 Glascock, Speakman and Burger, 2007, p.527; Eerkens et al., 2010.
395 Aldenderfer, 1999; Brooks, et al., 1997; Burger and Glascock, 2000; Burger, Mohr Chavez and Chavez, 2000; Burger, et al., 1998; Craig, et al., 2010; Glascock et al., 2007; Seelenfreund, et al., 2002, p.18; Stöllner, 2011, p.191; Tripcevich, 2009.
396 Rick, 1980; Klink and Aldenderfer, 2005; Klink, 2007; Briceno Rosario, 2010; Maggard, 2010.
397 Briceno Rosario, 2010, p.1.
398 Reindel and Wagner, 2009, p.10.
399 Tripcevich, 2007, p.268.
400 Maggard, 2010, p.329.
401 Van Buren, 1974, p.4.

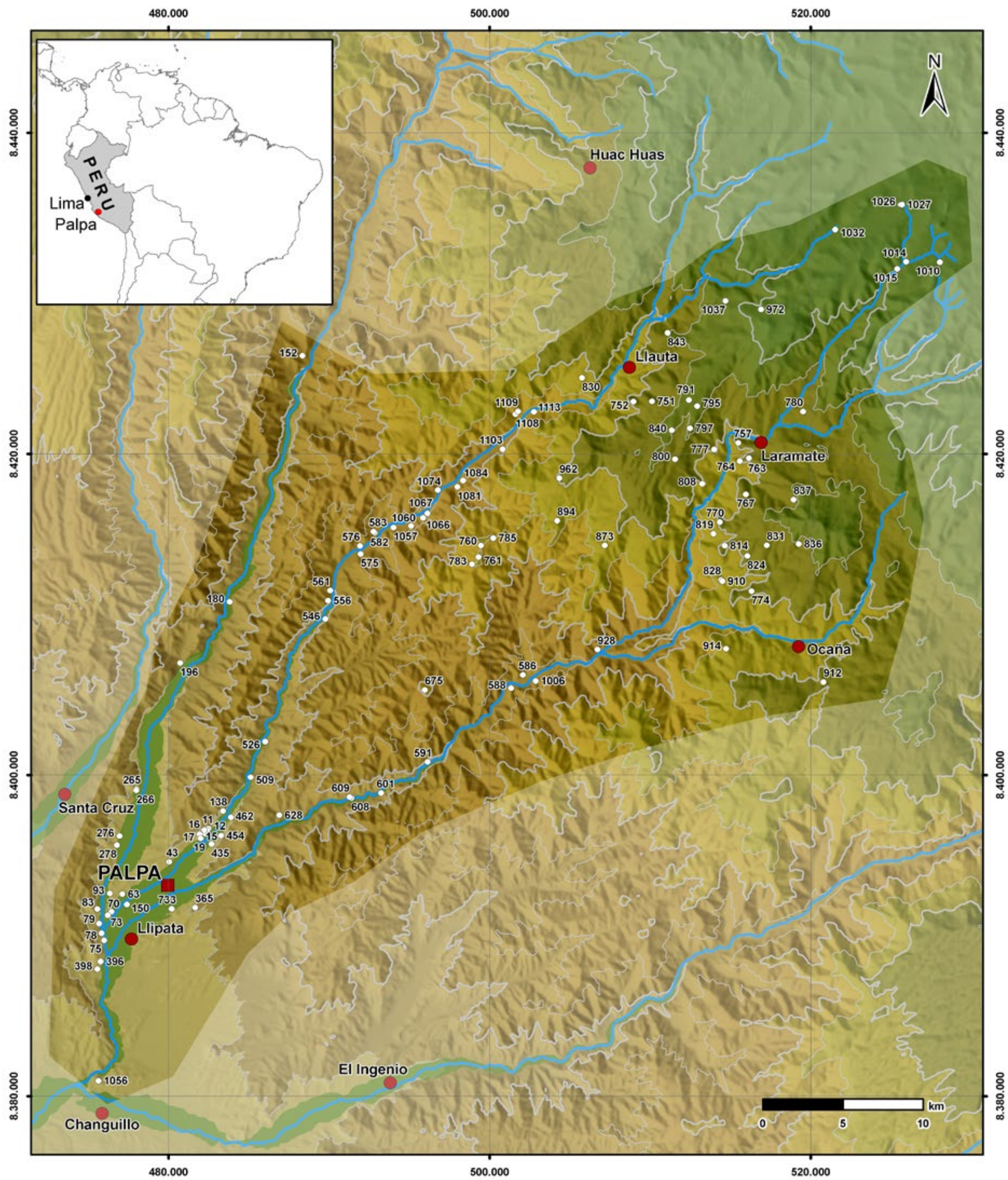


Fig. 22: Archaeological sites in the PAP where Obsidian projectile points have been found (graphic: KAAK, V. Soßna).

tend to be rather imprecise.[402] Therefore, the emphasis in the second step will be laid on the implementation of a chronology for the obsidian projectile points that can be used as a guideline to date pre-Columbian ceramic sites and archaeological contexts in the research area. Beyond this thesis, the possibilities of an obsidian projectile point typology for ceramic processing cultures have been widely ignored because of the ceramic as a chronological marker.[403] In the Nasca-Palpa region a differentiated ceramic chronology for all ceramic possessing cultures exists, beginning with the Paracas-culture[404] and Nasca-cultures[405] and continuing in the Middle Horizon[406] and

402 Stöllner, 1999, pp.198-199.

403 Burger, 2007, p.477.

404 Isla Cuadrado and Reindel, 2006; Menzel, Rowe and Dawson, 1964; Wetter, 2005.

405 Hecht, 2009; Proulx, 2006; Unkel and Kromer, 2009.

406 Isbell, 2008.

the Late Intermediate Period[407]. The existing chronology has been combined recently with samples from secured archaeological contexts that have been dated via 14C dating in order to establish an absolute chronology for the Nasca-Palpa region.[408] Although all these different cultures used obsidian as an important resource for tool making[409] no typology for obsidian projectile points has been proposed for the Nasca-Palpa region so far. Obsidian is mostly black or grey but other colors are possible depending on the chemical composition of the material.[410] In Quispisisa/Jichja Parco the nearest obsidian quarry in the region black, grey, red, brown and yellow obsidian could be identified.[411] The projectile points in the PAP basically represented this color composition but a few remarkable exceptions were documented. Obsidian projectile points played an important role as lithic tools used on a daily basis by the ancient inhabitants of the area. Beside the actual finds the practical use of these artifacts is represented by paintings on numerous ceramic vessels and textiles found during excavations and surveys in the Andean region.[412]

5.2 Methodology

In order to give a detailed classification of all obsidian projectile points found in the PAP, an analytic approach was chosen that combined different earlier methods to establish an obsidian projectile point typology and chronology for the Nasca-Palpa region. A comparable approach was chosen in the Titicaca region for preceramic projectile points.[413] This analysis is primarily based on three prior investigations about projectile points, Van Buren (1974), Rick (1980) and Klink and Aldenderfer (2005). Well-founded by these earlier approaches the result of this analysis will provide a guideline to date open-air archaeological sites from the Archaic Period to Late Horizon sites, were no ceramic can be localized. Enhancing researchers in the future to classify newly found obsidian projectile points in situ via a visual inspection of the artifact. The assemblage of obsidian projectile points investigated in this analysis derives from the clearly defined area of the PAP. What has been postulated for the preceramic is even more relevant for the ceramic bearing cultures of the South Coast. “Because the numbers of individual points recovered from sites are typically very low and often fragmentary, few studies have attempted or had the opportunity to examine intra-type variability in detail.”[414]

407 Menzel, 1976; Conlee, 2003.
408 Unkel, et al., 2012.
409 Burger, Mohr Chavez and Chavez, 2000, p.348.
410 Glascock, 2002, p.611-612.
411 Reindel, Stöllner and Gräfingholt, 2013
412 Tripcevich, 2007, pp.872-874.
413 Klink and Aldenderfer, 2005.
414 Maggard, 2010, p.329.

5.3 Data Acquisition

All obsidian projectile points that have been found since 1997 in PAP were located using the database of the project. In order to facilitate the research undertaken since 1997, a database of all archaeological features, sites, chemical analysis and artifacts found in the course of the project was established. “Within the Nasca-Palpa project, excavations were conducted in several settlement sites of the Palpa area and numerous additional test pits were documented. During excavation special attention was paid to the stratigraphic relationships between the excavated contexts. All materials were catalogued with reference to their stratigraphic context, so a comprehensive database of stratigraphically related pottery is now available.”[415] After an archaeological feature has been fully documented in the field, the finds are registered in the field laboratory in Palpa where photos, drawings and find descriptions were made. The whole archaeological information is then combined in the database, in order to have a direct access to all relevant archaeological information of certain sites, contexts or artifacts and can be used by researchers investigating the ancient cultures in the Palpa region. Projectile points that derive from the same archaeological context were differentiated by numbers added to the feature number. As guideline for the preparation of the drawings and the cross-section of the projectile points the work of Hahn (1993) was used.

5.4 Type classification

In order to classify the given assemblage of obsidian projectile points, a way to differentiate between the different types was chosen that tries to incorporate a sufficient amount of diagnostic characteristics. Several types and type variants consist of less than three specimens. This may be seen as an “atomization”[416], but because of the defined archaeological context of these specimens and the possibility to compare these artifacts with projectile points from neighboring regions the creation of types and type variants with such a small amount of objects seemed rational. Furthermore, this analysis must be seen as a fundamental groundwork for obsidian projectile points in the region. Neighboring archaeological projects in the Ica-Palpa-Nasca area can further differentiate this work and propose similar typologies for the existing but not yet published assemblage of obsidian projectile points. The diagnostic characteristics used to classify the obsidian projectile points of this analysis were taken from Van Buren (1974), Rick (1980) and Klink and Aldenderfer (2005). The diagnostics characteristics are different for each type or type variant of obsidian projectile points defined in this

415 Hecht, 2009, pp.210-211.
416 Stöllner, 1999, p.199.

work. Therefore 3 to 5 characteristics were chosen in order to characterize the type or type variant. The following diagnostic characteristics were chosen for this analysis: projectile point form, base form, blade form, cross section, weight, maximal width, length, thickness, tool length/width product, bifacial or unifacial and flaking[417]. In general, two techniques of flake production can be identified in the lithic stone tool industries: Percussion and pressure flaking. They differ in the way the force is applied to the stone tool, in order to shape it. Pressure flaking uses a slow or static load, where percussion flaking is characterized by a dynamical punch.[418] Therefore, different ways of flaking can be identified in the archaeological context. Percussion flaking will be applied first, in order to shape the blanks or preforms. A finished projectile point is further worked by pressure flaking to manufacture the desired shape. In some cases only a little rework is done to sharpen the edges and points, this pressure flaking method is called retouch.[419] The flaking techniques used to manufacture the obsidian points in the Nasca-Palpa region are: Random flaking; Random flaking with retouched edges, Random flaking with retouched edges, and Basal thinning, Irregular flaking, Regular pressure flaking, Chevron flaking. Earlier works summarized the techniques and methods to produce projectile points and other stone objects as well as other approaches to define projectile point typologies.[420] In order to assign the documented obsidian projectile points to different time periods the archaeological context was studied using the excavation reports of the PAP for the securely excavated obsidian projectile points. Surface finds were roughly combined with the affiliated cultural context of the site, which were documented in the excavation and survey reports of the PAP. Though some of the sites are located in a very remote area, projectile points can be found on the surface of these sites that derive from completely different cultures than the documented site. Therefore, the given cultural affiliation of surface finds was not considered for the chronological setting of point types. All securely dated contexts were associated with diagnostic ceramics, the different ceramic styles especially for the Paracas and Nasca-culture were defined using the work of Rowe (1960), Menzel, Rowe and Dawson (1964), Menzel (1976), Proulx (2006) and Hecht (2009). The next step was to compare the documented obsidian projectile points with other published examples of projectile points in bordering regions as well as in regions where the cultural influence of the Nasca-Palpa region could be identified. To complete the research undertaken by this work, the entire data was combined and a chronological setting for each type was proposed, when sufficiently secure dated specimens were documented. Whenever an exact chronological setting into a certain cultural period can be proposed, these cultural periods will be defined according to the phases proposed by Reindel and Wagner (2009) in cooperation with Unkel and Kromer (2009), which has been modified by Unkel, et al. (2012).

417 Van Buren, 1974; Klink and Aldenderfer, 2005.
418 Speth, 1972, p.37.
419 Van Buren, 1974, p.86.
420 Andrefsky, 2009; Buchanan and Collard, 2010; Buchanan, et al., 2011; Cheshier and Kelly, 2006; Downey, 2010; Flenniken and Ramond, 1986; Grant MacCurdy, 1900; Johnson, et al., 1978; Rick, 1980; Lanning and Hammel, 1961; León Canales, 2007a; 2007b; Mourre, Villa and Henshilwood, 2010; Odell, 1996; 2001; Sellet, 2004; Spence, 1967; Speth, 1972; Stevens and Codding, 2009.

5.5 Typological and chronological classification

Five major type groups could be clearly differentiated: triangular (type group 1), lanceolate (type group 2), foliate (type group 3), diamond (type 4) and small triangular (type 5). In these groups the different types and their variants were then further differentiated according to more detailed traits of the points.[421]

5.5.1 Type group 1 triangular form

Type group 1 (Fig. 23) is characterized by a triangular form, an average length less than 40 mm and a maximal width of 31 mm.

In total 95 obsidian projectile points were used to define this type group. The type group was subdivided into 11 types ranging from type 1 A-K and some variants of certain types. Type 1 F and its variant I were perhaps produced using a special type of transparent obsidian either known as Rare Type 9 obsidian or Macusani obsidian. This type of obsidian is associated with Early Horizon settlements, e.g. in Taraco, a major early settlement in the northern Late Titicaca Basin as well as with Archaic projectile point forms.[422] But only a chemical analysis of the artifacts could reveal their exact provenance and may link Pernil Alto directly to the Lake Ticitcaca region or even further south to the Macusani source. The transparency of this type of obsidian must be viewed with special emphasis because “transparent elements were viewed as mediators between different cosmological worlds”[423] in the Andes. This assumption was further supported by archaeological and ethnographic evidence from the region.[424] By comparing type 1 F and type 1 F variant I a clear continuity can be stated. This type and also in part the same material of transparent obsidian was first used during the Initial Period in Pernil Alto and continued to be produced through Late Paracas up to the Late Nasca period. Obsidian projectile points exclusively used by the Paracas culture are type 1 G and its variant I. Types 1 B and 1 C represent a lithic technology that was used from the Paracas culture due

421 Rick, 1996, p.252.
422 Craig, et al., 2010.
423 Giesso, 2003, p.368.
424 Tripcevich, 2007, p.287.

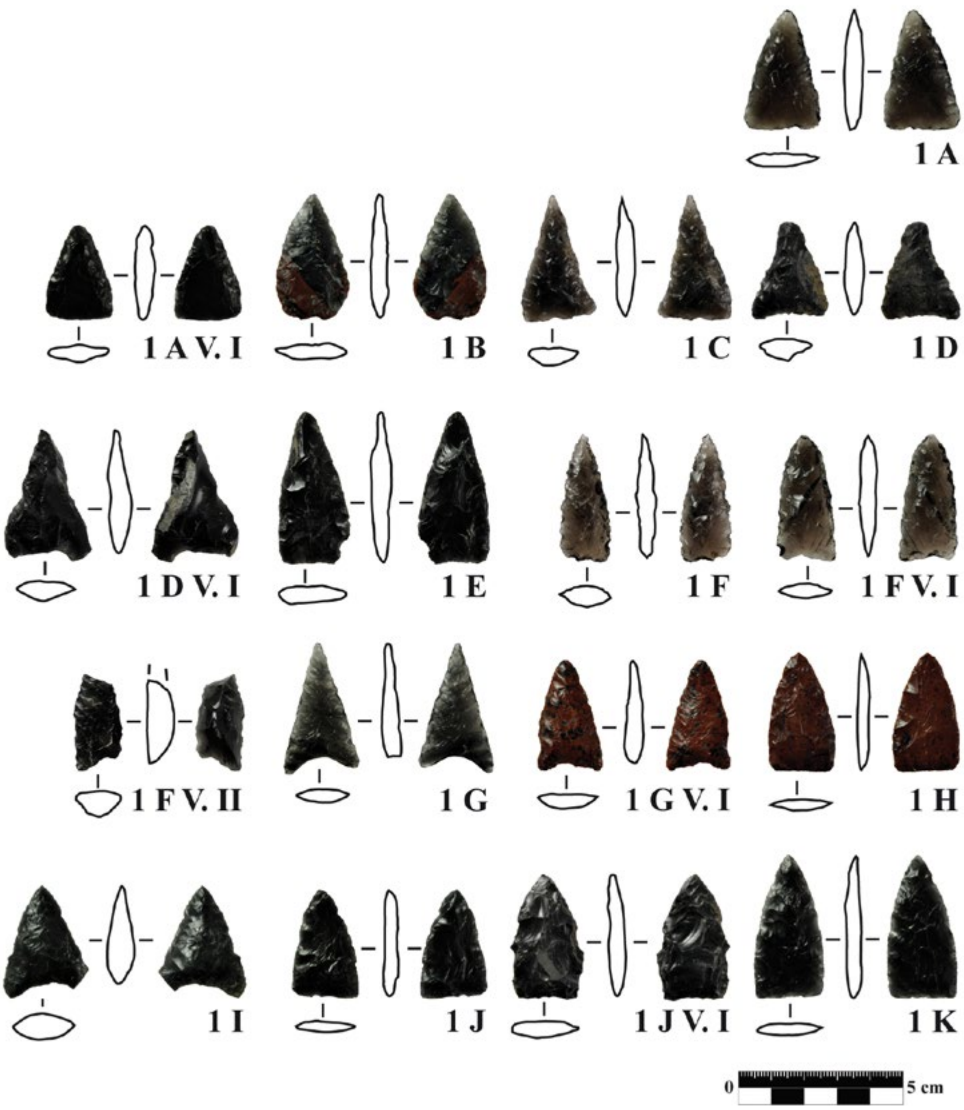


Fig. 23: Type group 1 "triangular form"(graphic: DBM, B. Gräfingholt).

to the Nasca culture. All other types in this group derive from surface finds or disturbed archaeological contexts and should not be used as diagnostic markers.

5.5.2 Type group 2 lanceolate form

Type group 2 (Fig. 24) is characterized by a lanceolate form, an average length of more than 50 mm and a maximal width of 55 mm.

In total 92 obsidian projectile points were used to define this type group. The type group was subdivided into 12 types ranging from Type 2 A-L and some variants of certain types. Type 2 A has to be viewed with a special emphasis, though so far "Obsidian products, particularly finely-made bifacial tools, were perhaps one of a series of items that served to differentiate status-seeking individuals in early transegalitarian contexts, but with later crafts investment obsidian appears to have been assigned a relatively specific role for projectile point production and for cutting implements".[425] In contrast to this assumption, type 2 A seems to be a tool type that is mostly associated with an elite Paracas burial and has to be viewed as a diagnostic marker for Late Paracas contexts. Therefore obsidian tools should not only be viewed as ordinary tools but also as precious burial gifts for members of the ruling elite of the Late Paracas society. Types 2 B, 2 C variant I, 2 C variant II, 2 D, 2 H variant II, 2 H variant III, 2 H variant IV, 2 I variant I, 2 K "Cutamalla" and 2 L can also be viewed as diagnostic markers for the Paracas culture. Interesting to note is that certain types can be used to link the coast and the highland clearly demonstrating the movement of goods and people from one region to the other. Type 2 F "Jauranga" from the coast and type 2 F "Jauranga" variant I from the highland represent a lithic technology that was used during the Late Paracas period, the same holds true for 2 H variant IV from the coast and 2 H variant III from the highland. Types and type variants that connect the Paracas and Nasca cultures are: 2 A variant I, 2 H, 2 H

425 Tripcevich, 2007, p.284

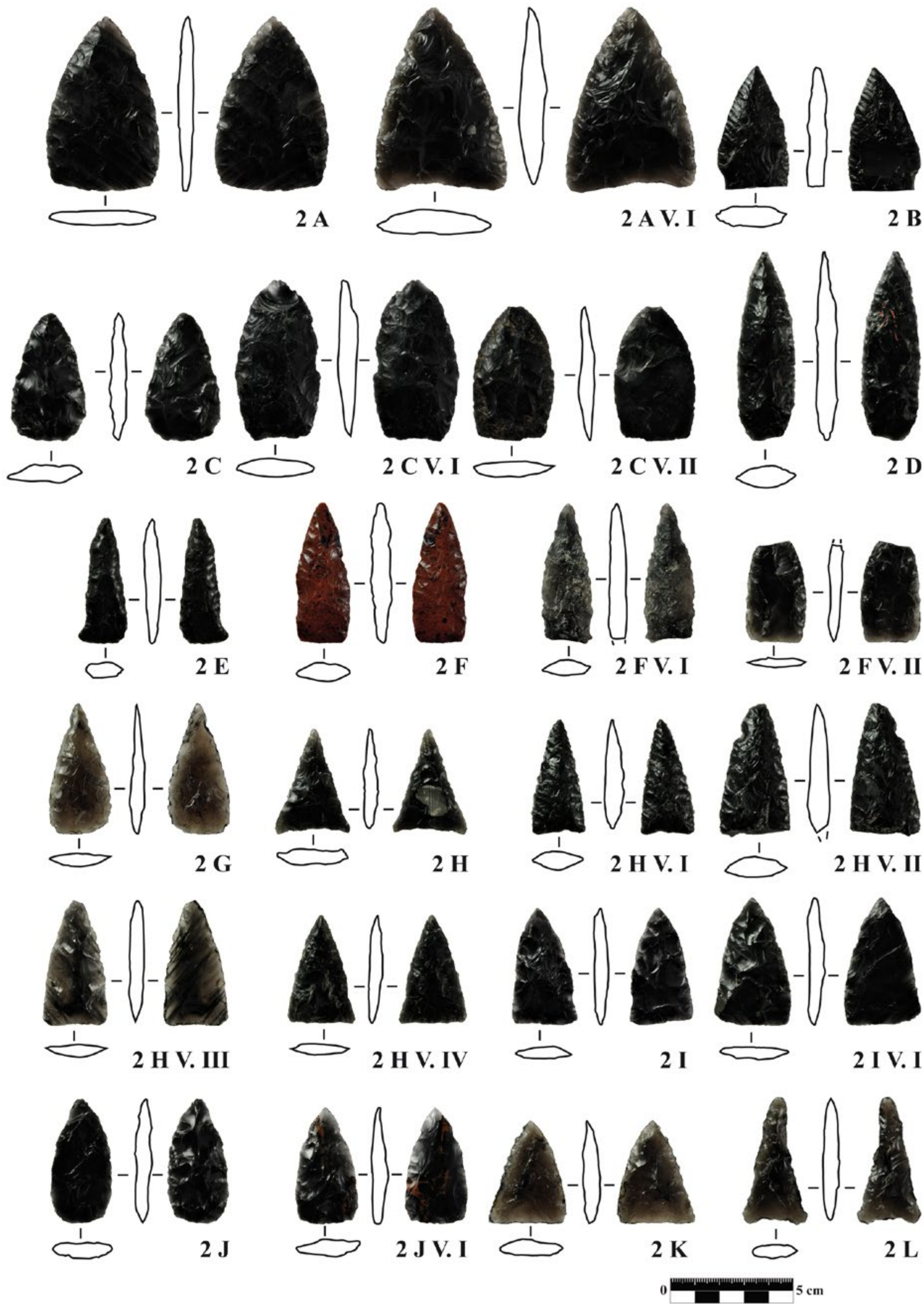


Fig. 24: Type group 2 "lanceolate form" (graphic: DBM, B. Gräfingholt).

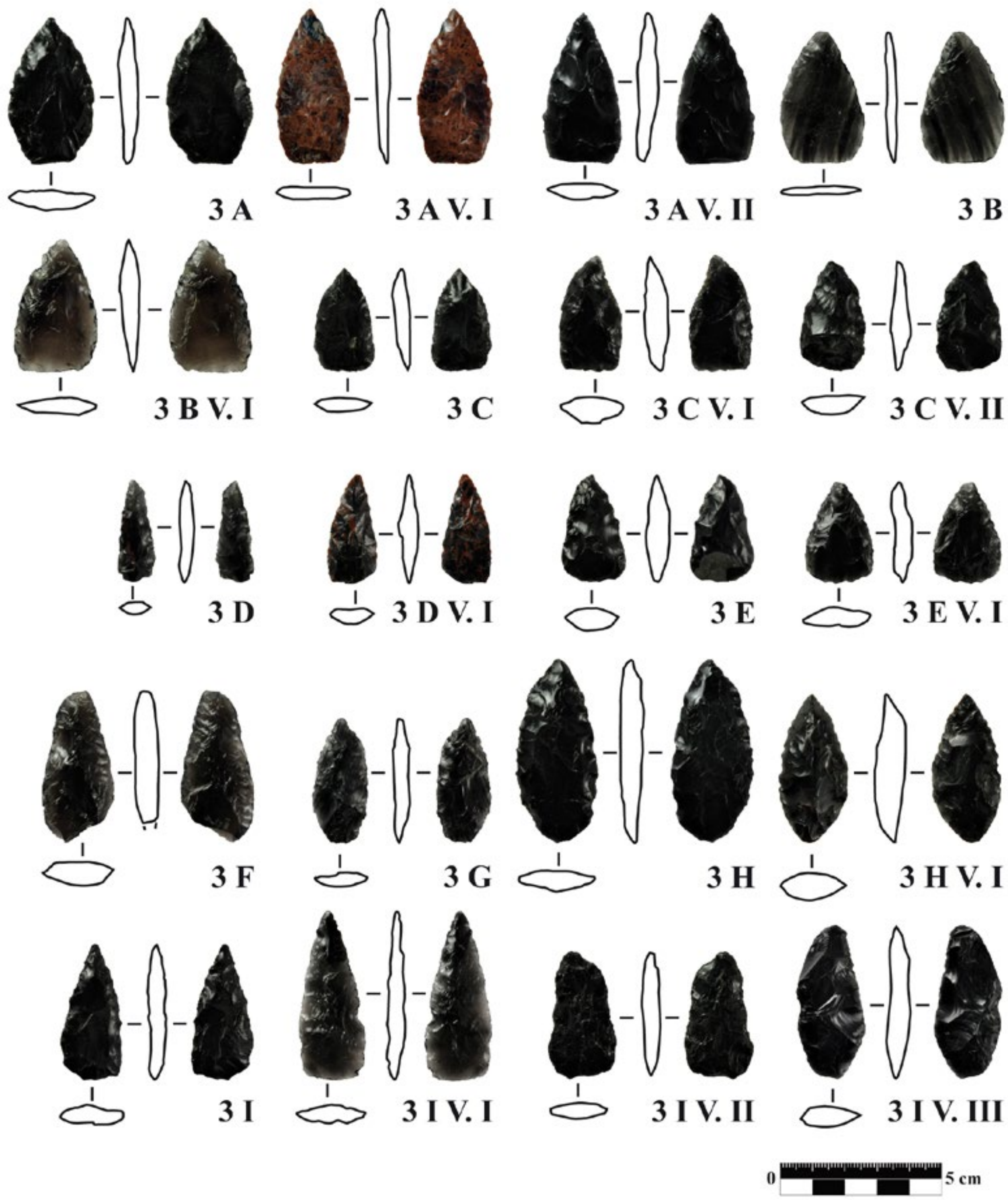


Fig. 25: Type group 3 "foliate form" (graphic: DBM, B. Gräfingholt).

variant I and 2 J. Near Carhua in Ica an obsidian projectile point was found stuck in an arm muscle.[426] Though only the distal end of the point is visible the classification into type 2 H ms be treated with care. This example shows that projectile points were not only used as tools for hunting but also in warfare and violent disputes between humans. Only type 2 J variant I could be exclusively linked to the Nasca culture. Type 2 C must be seen as an obsidian projectile point type being used during the Nasca culture and also during the Middle Horizon in the highland area. All other types in this group derive from surface finds or disturbed archaeological contexts and should not be used as diagnostic markers.

[426] Engel, 1966, p.212.

5.5.3 Type group 3 foliate form

Type group 3 (Fig. 25) is characterized by a foliate form, an average length around 40 mm and a maximal width of 30 mm. In total 94 obsidian projectile points were used to define this type group. The type group was subdivided into 9 types ranging from type 3 A-I and some variants of certain types. The Paracas culture was associated with type 3 F and 3 H. Type 3 G connects the Paracas and Nasca culture. Only type 3 A variant II could be linked to the Nasca culture. With type 3 E the bonds between the Nasca-Palpa region and the highland during the Middle Horizon were demonstrated. Most important for this type group was the classification of type 3 A "Huayuncalla", 3 A "Huayuncalla" variant I, 3 B "Wari" and 3 C. These types derive from Middle Horizon contexts, therefore representing a lithic technology that was introduced into the Nasca-Palpa region by the Wari Empire. A projectile point base fitting the diagnostic characteristics of type 3 B was recovered on the surface of the Middle Horizon Wari center Cerro Baúl, Moquegua Valley.[427] Other complete projectile points were also found in the ruins of the Wari citadel that can clearly be associated with type 3 B "Wari".[428] Interesting to note in this context is the special location of Cerro Baul on the Tiwanaku frontier.[429] In the region surrounding this outpost three projectile point sharing the diagnostic characteristics of type 3 B "Wari" were found during a survey in the Osmoro drainage. These points were classified as "Wari style" projectile point.[430] In the ancient Wari city of Conchopata, 10 km away from the Wari capital in the Sierra, an obsidian projectile point was excavated that shares the diagnostic characteristics of type 3 B "Wari". The point was described by the author as nearly identical to the points found in Cerro Baul.[431] Obsidian projectile points of these types should be viewed as a diagnostic marker for the Wari culture flourishing in the highland region during the Middle Horizon.[432] The stemmed projectile point forms that are typical for the Tiwanaku area[433] are completely absent in the Nasca-Palpa area showing that the Wari domination excluded Tiwanaku style weapons in the area. All other types in this group derive from surface finds or disturbed archaeological contexts and should not be used as diagnostic markers.

5.5.4 Type group 4 diamond form

Type group 4 (Fig. 26) is characterized by a diamond form which is mostly associated with the preceramic periods.

In total 11 obsidian projectile points were used to define this type group. The type group was subdivided into 2 types ranging from type 4 A-B. Type 4 A should be regarded as a projectile point type that has its main distribution in the highland region and a clear connection to the preceramic periods. The same holds true for type 4 B, which represents a very small amount of projectile points and has to be seen in a greater context. Comparable specimens were found outside of the PAP research area and therefore a link to the Titicaca region must be drawn.[434]

5.5.5 Type group 5 small triangular form

Type group 5 (Fig. 27) is characterized by a small triangular form, an average length less than 25 mm and a maximal width of 24 mm. Indicating a bow and arrow use in the region.

In total 69 obsidian projectile points were used to define this type group. The type group was subdivided into five types ranging from type 5 A-E and some variants of certain types. The Paracas culture is represented by type 5 A, 5 A variant I and 5 C variant II. Type 5 C must be placed into the transition period between the Nasca culture and the beginning of the Middle Horizon. All other types in this group derive from surface finds or disturbed archaeological contexts and should not be used a diagnostic markers. Type 5 B for example can only be viewed as a chronological marker for the late preceramic and early ceramic bearing periods of the whole research area until further securely dated projectile points are found and published.

5.6 Discussion and Conclusion

The main research object of this analysis was to create a typology and chronology of obsidian projectile points. Therefore, the given assemblage of specimens was analyzed, in order to differentiate the obsidian projectile points into type groups, types and type variants. Special emphasis was laid on the practical use of this typology, in order to enable researchers in the field to roughly date open air sites. Here comparison with objects found in other regions helped to place the projectile point types into a wider context and in the same step incorporated other areas into this analysis. It became clear that some types should be viewed in a transregional context and can be used to link the Nasca-Palpa region with cultures in the highlands. Here the classification of different types of projectile points was used to outline the various approaches during pre-Columbian times to create part of a weapon that was used on a regular daily basis during hunting or as a high-tech weapon during warfare or armed disputes between neighbors as shown by the examples provided by type 2 H that was found in a human lumbar vertebra.[435] The 42 obsidian projectile point types and their variants represent the bright spectrum of lithic technologies that was used since the Archaic Period in Southern Peru. So far, this aspect of the complex societies has been widely ignored. Hence, this analysis should be viewed as a first step in order to recognize the huge potential of lithic analysis for the complete time span of human occupation in Peru. Downey has shown that lithic analysis for complex societies will be of great use for further researchers and that a concentration on ceramic might miss important aspects of daily life during the Andean past.[436] In the course of this analysis, several types and type variants of projectile points could be identified as chronological markers for certain time periods. The Paracas culture should be associated with the following types and type variants: 1 G, 1 G variant I, 2 A, 2A variant I, 2 B, 2 C variant I, 2 C variant II, 2 D, 2 H variant II, 2 H variant III,

427 Burger, Mohr Chavez and Chavez, 2000, p.335 fig.13 (a).
428 Contisuyo, 1997.
429 Williams, 2001.
430 Owen and Goldstein, 2001, fig.11b,c,f.
431 Benic, 2000, p.108 fig.17a.
432 Isbell, 2008.
433 Giesso, 2003, p.380-381 figs.15.13-14.
434 Klink and Aldenderfer, 2005; Lavallee, et al., 1995.
435 Raviens, 1967, pp.230-231.
436 Downey, 2010, pp.78-80.

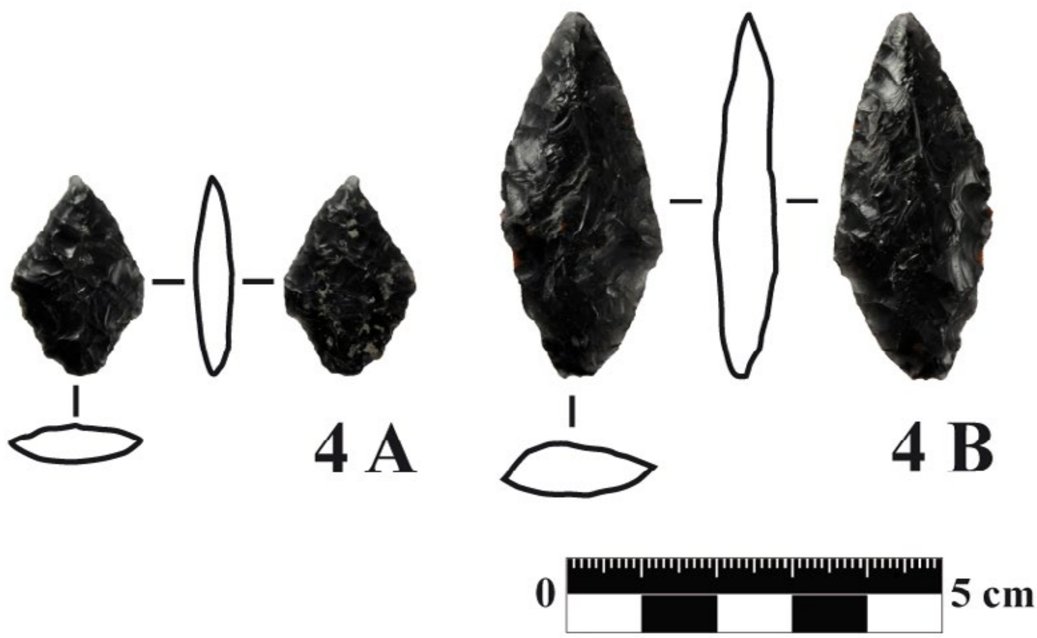


Fig. 26: Type group 4 "diamond form" (graphic: DBM, B. Gräfingholt).

2 H variant IV, 2 I variant I, 2 K, 2 L, 3 F, 5 A, 5 A variant I and 5 C variant II. Type 2 F from the coast and type 2 F variant I from the highland represent a lithic technology that was used during the Late Paracas period, the same holds true for 2 H variant IV from the coast and 2 H variant III from the highland. Type 3 H derives from a coastal context with a Late Paracas affiliation. The Nasca culture could be clearly associated with types 2 J variant I and 3 A variant II. The Middle Horizon cultures should be associated with the following types and type variants: 2 I, 3 A, 3 A variant I, 3B "Wari" and 3 C. Some types and type variants must be seen as representatives of an enduring lithic tradition that can be traced through the ages and connected the different cultures that were defined in the past through their ceramic tradition. Types and type variants that connect the Paracas and Nasca cultures are: 1 B, 1 C, 2 A variant I, 2 H, 2 H variant I, 2 J, 3 G. Types that connect the Nasca culture with the highland area and the Middle Horizon are: 2 C, 3 E, 5 C. Interesting to note in this context is that some lithic tradition only link the Paracas culture to the Nasca and others were handed down from the Nasca culture to the Middle Horizon. Although a ceramic style change is documented from the Paracas to the Nasca culture, the people living in this area made this change and represent a population continuity that developed

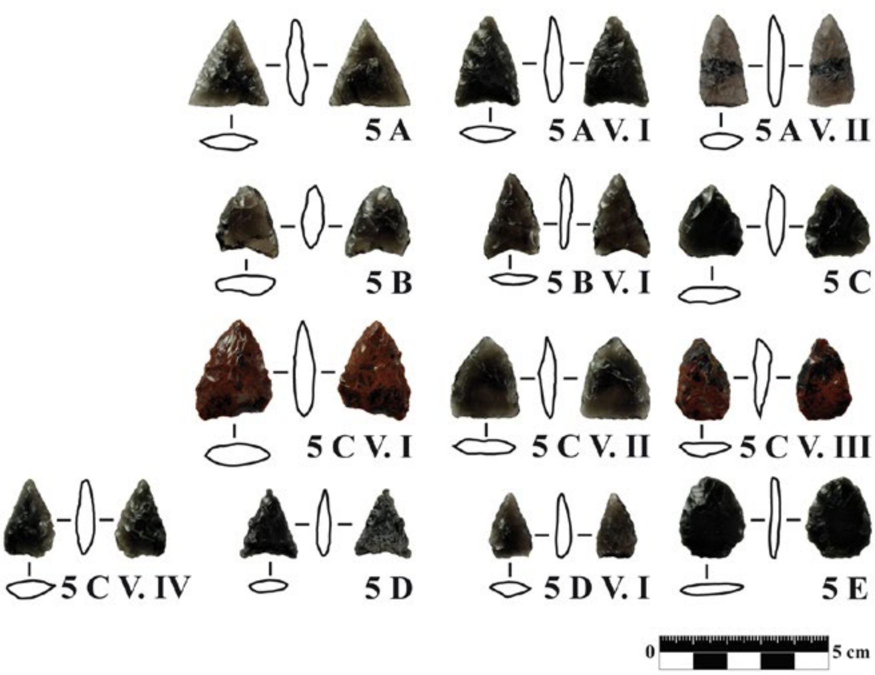


Fig. 27: Type group 5 "small triangular form" (graphic: DBM, B. Gräfingholt).

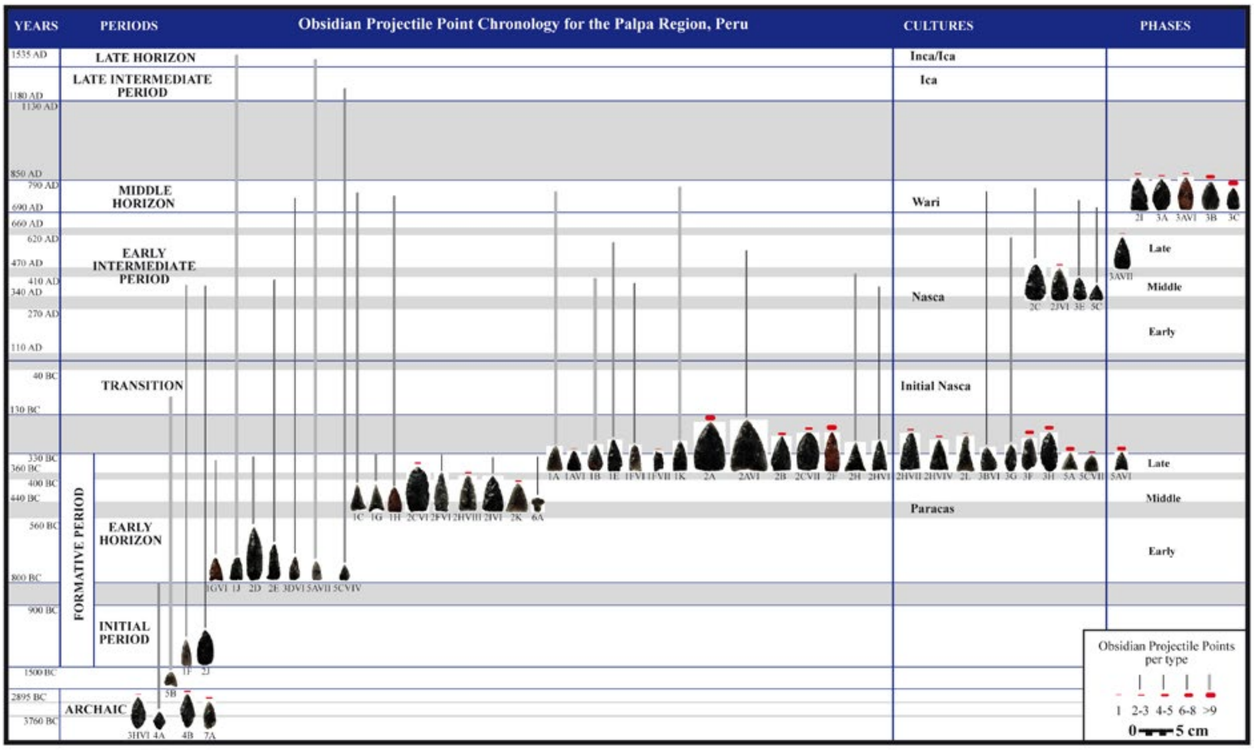


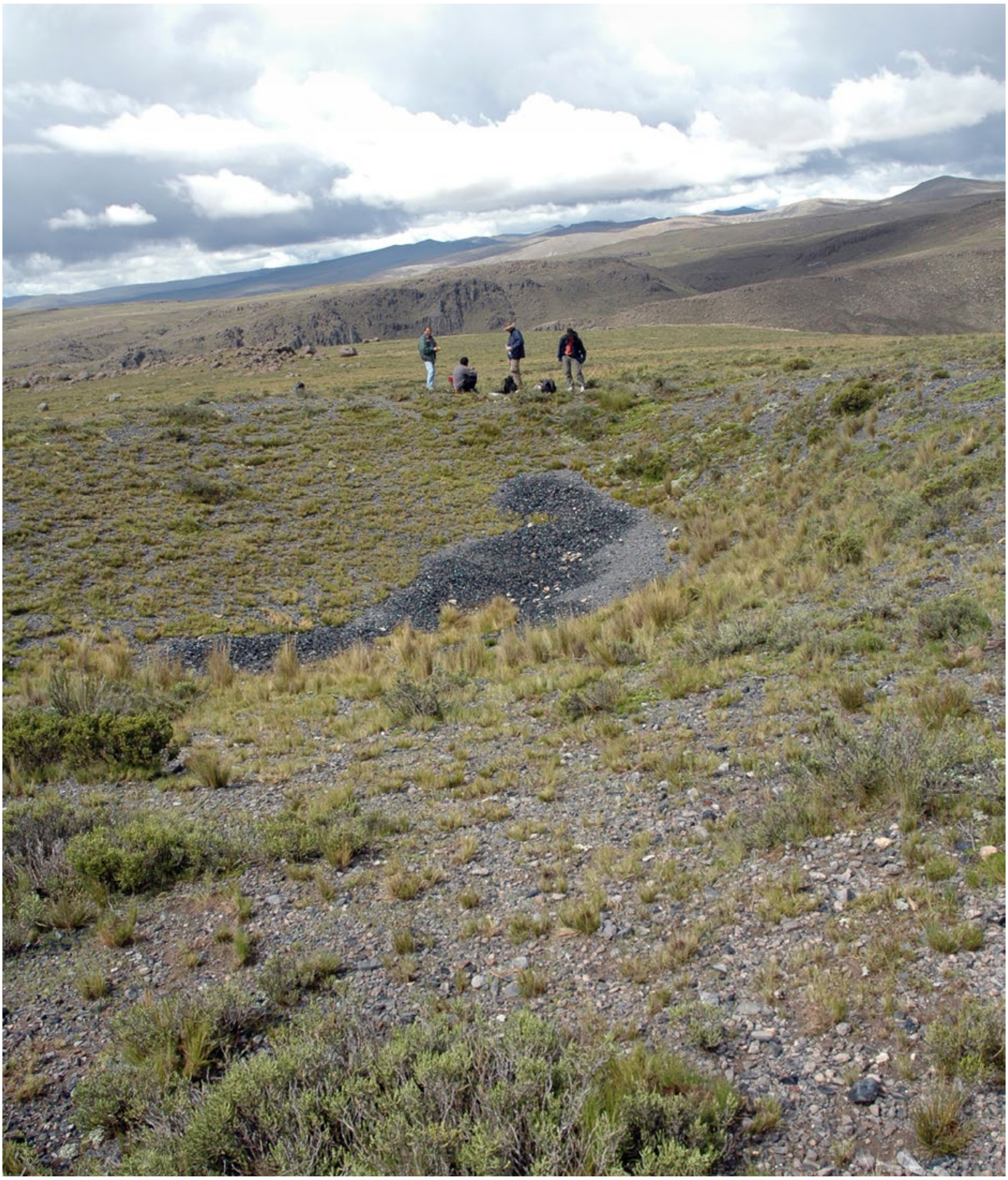
Fig. 28: Obsidian point chronology for the PAP (graphic: DBM, B. Gräfingholt).

into a complex society.[437] This assumption was further supported by DNA analysis that proved a dense population stability in the region.[438] Obsidian projectile point types that connected these two cultures in their lithic technologies underline the continuity of Paracas cultural traditions into the Nasca period. The dramatic climate changes that occurred at the end of the Nasca period during the 7th century AD followed by a partial migration of the people living at the coast into the highland region is reflected in the continuity of distinct lithic tradition documented in this analysis.[439] Furthermore, some obsidian projectile point types defined in this analysis could be clearly associated with the Wari culture of the highland during the Middle Horizon. These lithic traditions introduced into the study area by the time of the Wari domination of the region reflect the cultural interaction that occurred between the people from the region and those that came from highland Wari centers.[440] Obsidian projectile point types that can be associated with the ceramic bearing cultures from the Early Horizon to the Middle Horizon or even up to the Late Horizon in the region like types 1 A, 1 C, 1 H, 1 J, 1 K, 3 D variant I, 5 A variant II and 5 C variant IV, represent a lithic tradition that endured unchanged for millennia. Types 4 A and 5 B are in so far special as they mark the transition of projectile point types from the preceramic into the ceramic bearing periods of the Early Horizon. Type 1 F and type 1 F variant I may indicate a long-distance trade[441] undertaken by camelid caravans[442] or down the line trade[443] that took place in the region during the Initial Period when complex societies were not yet present and the semi-nomadic hunter and gatherer bands dominated the area and that those links to the distant obsidian sources that produced the valued transparent obsidian artifacts remained intact until the Nasca period. The proposed link to the Macusani obsidian quarry[444] cannot be proved until a provenance study reveals the origin of those specimens. Therefore a chemical analysis of the obsidian projectile points belonging to this group seems imperative in order to determine the provenance of the obsidian used to produce these projectile points. All types defined in this thesis that could be classified into certain time periods should be regarded as index fossils for further investigations in the region and will help to date open-air sites as well as other archaeological contexts without diagnostic ceramic. For the future, the identification of projectile points found in the Nasca-Palpa area will be facilitated through the results of this analysis. Researchers are now enabled to use the proposed obsidian projectile point typology and chronological setting of the types characterized in this analysis to date archaeological contexts during fieldwork. The proposed types will enhance the archaeological fieldwork to be more independent of ceramic artifacts, in order to date sites, inasmuch as a clear connection between the pre-Columbian cultures and some obsidian

437 Van Gijseghem, 2006.
438 Fehren-Schmitz, 2009, p.170.
439 Eitel, 2007, pp.312-313.
440 Conlee, et al., 2009, p.6; Schreiber, 2000.
441 Dillian and White, 2009.
442 Tripcevich 2007, pp.297-300.
443 Maus and Evans-Pitchard, 2016; Tripcevich, 2007, pp.293-298.
444 Craig, et al., 2010.

projectile point types deriving from the region could be drawn in this analysis. The results achieved underline the significance of lithic studies that have so far only played a minor role in the investigation of the ancient cultures in the Andean. According to the results of this study it is now possible to propose a comprehensive obsidian point chronology for the PAP (Fig. 28).

In order to comprehend the prehistoric cultures of South America a detailed analysis of all aspects of daily life is necessary. Therefore, lithic and other less recognized groups of archaeological finds have to gain their part in the research efforts in the region. For the Nasca-Palpa region the first step to comprehend the daily life of the ancient cultures has been done by the PAP, but this area only counts for a very small part of the huge South American continent, where numerous ancient cultures wait to be explored in detail.



Cerro Jichja Parco. Pre-Columbian open pit obsidian mining site in the Altiplano (photo: DBM, T. Stöllner).

Vale de Ayapana. Pre-Columbian obsidian projectile point type group 4 found during the initial survey in 2009 (photo: DBM, B. Gräfingholt).

6 pXRF in the field

6.1 pXRF for sourcing of raw materials

In the last decades the application of portable X-ray fluorescence (pXRF) was highly debated in the archaeological community whereby a lack of confidence in the analytical performance and application of the instrument seemed to be dominating the discussion. “Mobile instruments, employing both radioisotope and X-ray tube excitation together with liquid-nitrogen-cooled semiconductor (silicon) detectors (requiring vehicle transport), were developed at Oxford by the early 1970s by E. T. Hall and colleagues, in pioneering archaeological applications of this technology.”[445] Starting from these rudimentary beginnings of pXRF instruments designed by Hall, Banks and Stern[446] the devices have become highly portable handheld devices in recent years that enable researchers to conduct the chemical analysis of archaeological objects in situ rather than taking the artifacts first into laboratories. The combination of a highly portable analytical instrument which can analyze archaeological artifacts non-destructively motivated researchers to widen the range and scope of archaeological provenance studies. A result of the analytical measurement is instantly accessible to the researcher. Enhancing archaeologists to immediately alter their fieldwork and sampling strategies during the excavation campaigns instead of obtaining the chemical analysis months after the fieldwork has finished. Currant pXRF devices generate relatively accurate compositional data that enables researchers to characterize lithic quarries especially for glassy or fine-grained volcanic materials such as obsidian.[447] Just recently Prange, Modaressi-Tehrani and Demant (2016, p.255) have successfully demonstrated with a preliminary test series using 28 copper/copper alloys from a Bronze age cemetery in Slovakia that pXRF produces results that match to nearly 80% with the data produced using ICP-MS and EDXRF. As stated by Pollardand Bray (2014, p.220) “XRF is particularly well suited to metal alloy identification and quantification, as the majority of alloys used in antiquity (gold–silver/electrum and the bronzes and brasses) are primarily made up of heavy metals which show up well under XRF.” Nonetheless the term pXRF needs further explanation though a review of 200 articles by Frahm and Doonan (2013) brought to light that half of the instruments named “portable” XRF were in fact multi-component systems limited to museums, laboratories and field houses. If this assumption holds true then most of the instruments are not used in the course of archaeological excavations or during surveys but rather in controlled laboratory like environments or as a cheap alternative for labXRF. As outlined by Frahm and Doonan (2013, p.1426) the term pXRF has varied definitions, ranging from “being able to be carried by porters” to “handheld”. Four types of instruments labeled pXRF were identified in their study: benchtop-type pXRF, components-type pXRF, museum-type pXRF and handheld pXRF. Benchtop-type pXRF systems are theoretically transportable but normally remain fixed in a museum or laboratory surrounding. A smaller version of these instruments is labeled museum-type pXRF. These systems are also commonly operated in museums. In a way the components-type pXRF are truly portable devices as the single components can be transported and reassembled in museums or field houses. In reality these systems lack the characteristic of being portable due to the missing internal energy source. Hence, the only truly portable systems were those labeled handheld pXRF (HHpXRF). HHpXRF instruments are designed to be operated in the field and the reduced dimensions of the analyzer enables researchers to operate these devices on site without external energy sources. The Niton XL3t GOLDD used in this study is an instrument of the HHpXRF category and was supplied by the Deutsches Bergbau-Museum Bochum (DBM) to the author.

Reducing the performance of the analyzers in contrast to tabletop systems made the extreme portability possible. This means that the devices are equipped with “less-than-ideal geometric arrangements of miniaturized, low power components that run on batteries and the processing of X-rays is done by on-board electronics and software rather than external systems.”[448] Apart from the laboratory-based XRF (labXRF), which is used in archaeological research since the 1960, the first application of a truly portable XRF in archaeological science was undertaken during a

445 Williams-Thorpe, 2008, p.175.
446 Hall, 1960; Hall, Banks and Stern, 1964.
447 Goodale, et al., 2012, p.833.
448 Frahm, 2013a, p.1080.

survey of the DBM for copper smelting sites in Oman.[449] Since then the number of scientific investigations that relied on pXRF as an instrument for the geochemical characterization of museum art and archaeological objects has increased dramatically.

But nonetheless only 4% out of 199 studies used HHpXRF in a field house to analyze archaeological artifacts on-site[450]. Therefore, the results presented in this study must be viewed as exceptional and will help to establish a routine for future investigations with HHpXRF. As the term HHpXRF is not commonly used, the author has decided to go along with the wider abbreviation pXRF to be used in this study also for the analysis conducted with the handheld portable XRF Niton XL3t GOLDD.

6.2 Behind pXRF

The fundamental discovery of the X-ray emissions by Wilhelm Conrad Röntgen (1845–1923) in 1895 prepared the ground for the development of pXRF devices. In an additional step he established the foundation for the identification of elements in X-ray spectroscopy by comparing the relationship between frequency and the atomic number.[451] Modern pXRF devices are based on his groundwork. When applying the XRF analyses on archaeological artifacts the fact that the individual atoms emit X-rays when excited by an external source of radiation is used to identify the chemical composition of the sample.[452] During the analytic procedure a gamma- or sufficiently energetic X-ray hits an atom on the sample material and probably ejects an electron of the inner-shell of the atom. Immediately (less than 10^{-20} s) an electron from the higher energy shell fills this empty space. This electron replacement between the two different energy shells can be measured in the form of X-ray radiation. The fact that each element (atom) emits a specific and unique energy the characterization of chemical elements by the XRF analysis is made possible. An X-ray Fluorescence Spectrometer or Analyzer with three basic components is necessary for the task: an isotope or X-ray tube as source for exciting radiation, a means for reproducible sample presentation, and a detector equipped with a multichannel analyzer and analytic software.[453] Clear advantages of the pXRF devices are the pre-installed fundamental parameter (FP) calibrations. By using the FP approach the conventional coefficients to diminish the matrix effects can be left aside. An emphasis is laid on the mathematical description of instrument conditions (e.g. tube emissions, detector efficiency) and instrument-independent parameters of the individual element (e.g. fluorescence intensities, absorption coefficients, absorption edges).[454] These specifications are combined in an algorithm that solves a range of nonlinear equations determining the interconnections between the emission intensities and the elemental concentrations.[455] As a result, the correction coefficient is peerlessly defined for each element in the course of the measurement. PXRF devices have pre-installed metals, soil, mineral and plastic modes where only the general material type must be known in order to generate robust datasets. In archaeological science the use of pXRF for obsidian sourcing is well established – caution is required when analyzing other material.[456]

As numerous chemical elements mostly with their common abbreviation are mentioned in this study, an overview of all chemical elements´ given name can be found in the following table (Tab. 1).

449 Hauptmann, 1985.
450 Frahm and Doonan, 2013, p.1429.
451 Shackley, 2011, p.7.
452 Pollard and Bray, 2014, p.219.
453 Piorek, 2008, p.107.
454 Frahm and Doonan, 2013, p.1427.
455 Thomsen, 2007 cited in Shugar and Mass, 2012, p.30.
456 Frahm and Doonan, 2013, p.1427

H	Hydrogen
He	Helium
Li	Lithium
Be	Beryllium
B	Boron
C	Carbon
N	Nitrogen
O	Oxygen
F	Fluorine
Ne	Neon
Na	Sodium
Mg	Magnesium
Al	Aluminum
Si	Silicon
P	Phosphorus
S	Sulfur
Cl	Chlorine
Ar	Argon
K	Potassium
Ca	Calcium
Sc	Scandium
Ti	Titanium
V	Vanadium
Cr	Chromium
Mn	Manganese
Fe	Iron
Co	Cobalt
Ni	Nickel
Cu	Copper
Zn	Zinc

Ga	Gallium
Ge	Germanium
As	Arsenic
Se	Selenium
Br	Bromine
Kr	Krypton
Rb	Rubidium
Sr	Strontium
Y	Yttrium
Zr	Zirconium
Nb	Niobium
Mo	Molybdenum
Tc	Technetium
Ru	Ruthenium
Rh	Rhodium
Pd	Palladium
Ag	Silver
Cd	Cadmium
In	Indium
Sn	Tin
Sb	Antimony
Te	Tellurium
I	Iodine
Xe	Xenon
Cs	Cesium
Ba	Barium
La	Lanthanum
Ce	Cerium
Pr	Praseodymium
Nd	Neodymium

Pm	Promethium
Sm	Samarium
Eu	Europium
Gd	Gadolinium
Tb	Terbium
Dy	Dysprosium
Ho	Holmium
Er	Erbium
Tm	Thulium
Yb	Ytterbium
Lu	Lutetium
Hf	Hafnium
Ta	Tantalum
W	Tungsten
Re	Rhenium
Os	Osmium
Ir	Iridium
Pt	Platinum
Au	Gold
Hg	Mercury
Tl	Thallium
Pb	Lead
Bi	Bismuth
Po	Polonium
At	Astatine
Rn	Radon
Fr	Francium
Ra	Radium
Ac	Actinium
Th	Thorium

Pa	Protactinium
U	Uranium
Np	Neptunium
Pu	Plutonium
Am	Americium
Cm	Curium
Bk	Berkelium
Cf	Californium
Es	Einsteinium
Fm	Fermium
Md	Mendelevium
No	Nobelium
Lr	Lawrencium
Rf	Rutherfordium
Db	Dubnium
Sg	Seaborgium
Bh	Bohrium
Hs	Hassium
Mt	Meitnerium
Ds	Darmstadtium
Rg	Roentgenium
Cn	Copernicium
Nh	Nihonium
Fl	Flerovium
Mc	Moscovium
Lv	Livermorium
Ts	Tennessine
Og	Oganesson

Tab. 1: List of chemical elements[457] (table: DBM, B. Gräfingholt).

457 CIAAW. Atomic weights of the elements 2020. Available online at www.ciaaw.org. (18.09.2021)

6.3 pXRF for the sourcing of obsidian

Especially in the last couple of years pXRF analyses have proven to be a significant support for provenience studies of obsidian.[458] A number of studies around the world have applied pXRF for the sourcing of obsidian and demonstrated the reliability of this method.[459] Outstanding objects or large collections of artifacts can often not be transferred from the excavations or museums to the lab to conduct the necessary analysis due to juridical restrictions and national cultural heritage laws.[460] In these cases, the portable X-ray fluorescence equips researchers with a unique analytical instrument that clearly presents advantages over other chemical analysis. Moreover, the instant results of the chemical composition of objects and artifacts provided by pXRF in the field enable researchers to use this non-destructive device in an archaeological context.[461] A non-destructive and in situ analysis of major and minor elements can be conducted on site without even touching the objects.[462] Here the pXRF provides a research method to scientists working with delicate objects, where a destructive method is forbidden and only non-destructive methods are allowed.[463] Previous studies that cross-checked the data obtained by pXRF with other instruments proved that – although pXRF measures less elements than laboratory based instruments[464] – the results of pXRF are precise and can be used for provenience studies of obsidian.[465]

6.3.1 Application of pXRF to archaeological obsidian studies in Peru

One would assume that due to the described advantages of pXRF and the positive reception concerning obsidian studies countless researchers would implement pXRF in their research. In fact, only very low percentage has applied pXRF to analyze obsidian.[466] In Peru, geochemical investigation of obsidian artifacts started in the early 1970s with the employment of neutron activation analysis (NAA)[467] and later in that decade, in 1977, it was applied by Burger and Asaro.[468] In the past decade numerous studies employed laboratory XRF – which in this context includes pXRF used in laboratory contexts[469], neutron activation analysis (NAA)[470] or Inductively Coupled Plasma Mass Spectrometer (ICP-MS)[471] to analyze obsidian but a comprehensive non-destructive pXRF analysis of archaeological obsidian artifacts has only been conducted once in the field so far.[472] Therefore, the study presented will further highlight the huge potential of pXRF for archaeological obsidian studies in Peru.

6.3.2 Sampling strategy

Due to the unique circumstance established by the research of the German Archaeological Institute (DAI) in Nasca-Palpa region (Peru) and its projects which have been conducted in the area since 1997[473] it was possible to access a large body of obsidian projectile points that represent the whole period of human occupation in the Nasca-Palpa area. Apart from the projectile points countless obsidian flaks were excavated as well but due to the time restrictions of the fieldwork in Peru only the complete and securely dated obsidian projectile points were selected for pXRF analysis. In a study conducted by the author an assemblage of 365 obsidian projectile points was used to establish a typology and chronology of obsidian projectile points in the Nasca-Palpa area.[474] This previous study was the basis for the sampling of the obsidian projectile points. Nearly all of the points mentioned before were included into this study as well as additional points that were excavated between 2011 and 2013 in the research projects of the DAI in the Nasca-Palpa area.

6.3.3 Archaeological artifacts

These obsidian projectile points derive from secure excavation contexts as well as from surface finds in the Nasca-Palpa region. The main focus of the research in the Nasca-Palpa area was put on the valleys of the rivers Grande, Palpa, and Viscas of the Palpa province, in the northern part of the Nasca drainage and up to the upper

458 Dussubieux and Walder, 2015, p.170.
459 Cecil, et al., 2007; Craig et al., 2007; Phillips and Speakman, 2009; Jia, et al., 2010; Nazaroff, Prufer and Drake, 2010; Burley, Sheppard and Simonin, 2011; Sheppard, et al., 2011; Millhauser, Rodriguez-Alegría and Glascock, 2011; De Francesco, et al., 2012; Forster and Grave, 2012; Glascock and Giesso, 2012; Goodale, et al., 2012; Williams, Dussubieux and Nash, 2012; Ferguson, 2012; Kellet, Goletko and Bauer, 2013.
460 Williams, Dussubieux and Nash, 2012, p.75.
461 Potts, 2008, p.1.
462 Shugar and Mass, 2012, p.17.
463 Williams, Dussubieux and Nash, 2012, p.75.
464 Craig, et al., 2007.
465 Craig, et al., 2007; Forster and Grave, 2012; Frahm, 2013b; Jia et al., 2010; Williams, Dussubieux and Nash, 2012.
466 Phillips and Speakman, 2009; Craig, et al., 2010; Jia, et al., 2010; Nazaroff, Prufer and Drake, 2010; Sheppard, et al., 2011; Burley, Sheppard and Simonin, 2011; McCoy, et al., 2011; Millhauser, Rodriguez-Alegría and Glascock, 2011; Forster and Grave, 2012; Goodale, et al., 2012.
467 Glascock, Speakman and Burger, 2007, p.529.
468 Glascock, 1994, p.118.
469 e.g. Craig, et al., 2007; Kellett, Golitko and Bauer, 2013.
470 e.g. Burger, et al., 1998; Burger and Glascock, 2000; Burger,Mohr Chavez and Chavez, 2000; Jennings and Glascock, 2002; Craig, et al., 2010.
471 e.g. Eerkens, et al., 2010; Williams, Dussubieux and Nash, 2012; Kellett, Golitko and Bauer, 2013.
472 Williams, Dussubieux and Nash, 2012.
473 Reindel and Wagner, 2009, p.10.
474 Gräfingholt, 2011.

courses of the rivers at an elevation of about 2,000 m.[475] During the fieldwork in Palpa 365 obsidian projectile points, partly incorporated in a previous chronological investigation[476], were analyzed using an pXRF of the Deutsches Bergbau-Museum Bochum (Tab. 3). These points represent the whole variety of cultures that flourished in the research area from the Archaic up to the Late Intermediate Period, representing 4,000 years of human occupation of the area (Fig. 29). Due to the research conducted by the DAI in the area a focus lies on obsidian projectile points produced by the Paracas and Nasca cultures.[477]

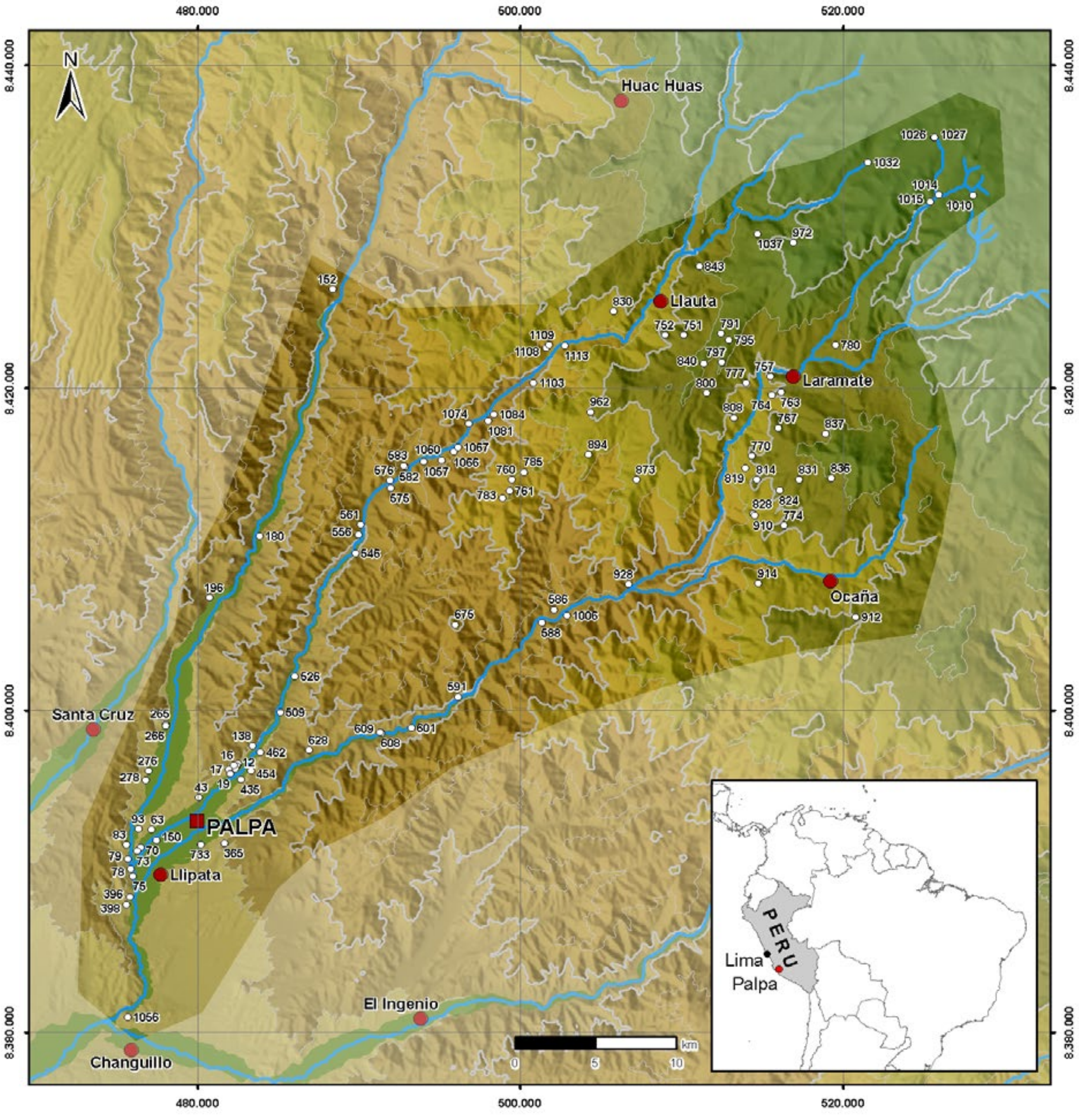


Fig. 29: Research area. Palpa Archaeological Project that encircles the town of Palpa and the nearby slopes and plateaus as well as the upper and lower reaches of the river valley of the river Rio Grande, Rio Palpa and Rio Viscas, as well as the Altiplano region around Laramate, Llauta and Ocoña (graphic: KAAK, V. Soßna).

475 Reindel and Wagner, 2009, p.13.
476 Gräfingholt, 2011.
477 Unkel, et al., 2012.

6.3.4 Geological reference collection

In addition to the archaeological artifacts 40 samples from the main obsidian source in the region – Jichja Parco[478] – were analyzed. These obsidian samples were taken at the obsidian quarry site of Jichja Parco during a survey in 2009.[479] In order to compare the geochemical signature of the projectile points to a reference source the geochemical signature of the samples from Jichja Parco was measured – in the laboratory of the Deutsches Bergbau-Museum Bochum – using the same pXRF and analytical procedure that was used during the fieldwork in Peru. Furthermore, the results for the main obsidian sources in Peru presented by Glascock, Speakman and Burger (2007, pp.540-541), the main obsidian sources characterized by different teams in Ecuador[480] and the main obsidian sources in Chile and Argentina presented by Giesso, et al.[481] were combined – when necessary – with the results received to clarify the origin of certain obsidian objects in this study. Due to the fact that laboratory XRF was used by Glascock et al., Giesso et al, and most of the teams in Ecuador to characterize the obsidian quarries the results are much more precise than those of the pXRF used in this study. Nonetheless by combing the results it is possible to locate the supposed transregional origin of the obsidian objects from the Nasca-Palpa region if Fe/Rb, Sr/Rb and Zr/Rb plots overlap.

6.3.5 Analytical instruments for the pXRF analysis

In the course of the fieldwork in Peru and during the test series in Germany a Niton XL3t GOLDD was used. The X-ray source of the analyzer was a 40-kV tube with Ag anode target, the detector was a Peltier-cooled Si-PN diode covered by a 20-mm detector window. For the analysis the soil mode with the Light Element Analysis Program (LEAP) and an aluminum filter for the determination of elements in light matrix samples was chosen. The voltage was 40 kV and the current 20 mA. In order to generate accurate data during the measurement the mineral modus of the device was selected. This setting allows analysis down to phosphorus and the measurement of 25 elements (Sb, Sn, Cd, Pd, Ag, Mo, Nb, Zr, Sr, Rb, Bi, As, Se, Au, Pb, W, Zn, Cu, Ni, Co, Fe, Mn, Cr, V, Ti).[482] Total measurement time was 120 s. So far, no common measurement time has been established in the published pXRF sourcing studies. Durations of test sequences have varied from 60[483] to 300s[484] of X-ray counts so far. Although the precision depends on the number of X-ray counts and the stability of the instrument[485] – due to the large number of objects and the limited time in the field an irradiation of 120s for each test sequence was chosen for this study. If an pXRF with a silicon drift detector (SDD) had been available the measurement time could have been reduced to 10s as demonstrated in a recent study.[486] Quantitative results are calculated, using fundamental parameters, by the software provided with the device. The aperture of the instrument is approximately 1 cm² and was totally covered by the sample.[487] As demonstrated before, the irregular surface of bifacial projectile points can be analyzed with pXRF without further preparation of the sample.[488] All obsidian projectile points were cleaned after excavation; no further preparation of the objects was conducted.

6.3.6 Results

As the previous study conducted by the author has differentiated the given assemblage of obsidian projectile points[489] – it is possible to present the results for the pXRF analysis staggered according to the chronological setting of the obsidian projectile points. The typology used for the classification of the projectile points follows the previous study of the author, all reference concerning the typology refer to this study from 2011. After reviewing the literature published concerning provenance studies of obsidian it has to be stated that different trace elements combination or principal component analysis (PCA) have been used to characterize obsidian, inter alia: Sr, Rb and Zr;[490] Ba, Ce and La;[491] Fe, Rb, Sr, Y, Zr and Nb (PCA);[492] Sr and Rb;[493] Rb and Zr;[494] Rb, Fe, Mn, Zn and Zr;[495] Y, Zr and Sr;[496] Mn, Fe, Co, Ni, Cu, Zn, Ga, Pb, Th, Rb, Sr, Y, Zr and Nb (PCA);[497] Ba and Mn;[498] Fe and Rb;[499] Nb and

478 Tripcevich and Contreras, 2011; Reindel, Stöllner and Gräfingholt, 2013; Stöllner, et al., 2013.
479 Reindel, Stöllner and Gräfingholt, 2013; Stöllner, et al., 2013.
480 Asaro, et al., 1994; Bigazzi, et al., 1992; Ogburn, 2011; Ogburn, Connell and Gifford, 2009; Bellot-Gurlet et al., 2008.
481 Giesso, et al., 2011; A slightly different element concentration for the Cerro Huenul source was published by Barberena, Hajduk and Gil (2011) but though the difference was within the standard deviation of the before mentioned investigation the author chose to concentrate on the data presented by Giesso ,et al. (2011, p.8 tab.1).
482 Personal communication with Prof. Dr. Michael Prange, 2015.
483 Golitko, Meierhoff and Terrell, 2010.
484 Nazaroff, Prufer and Drake, 2010; McCoy, et al., 2011; Forster and Grave, 2012.
485 Frahm, 2013a, p.1084.
486 Frahm, et al., 2014, p.337.
487 A comparable protocol was used by Williams, Dussubieux and Nash (2012, pp.76-77).
488 Frahm, 2013a, p.1091.
489 Gräfingholt, 2011.
490 Goodale, et al., 2012.
491 Kellet, Golitko and Bauer, 2013.
492 Forster and Grave, 2012.
493 Glascock, Speakman and Burger, 2007; Craig, et al., 2007; Phillips and Speakman, 2009; Craig, et al., 2010; Burley, Sheppard and Simonin, 2011; Glascock and Giesso, 2012; Williams, Dussubieux and Nash, 2012.
494 Cecil, et al., 2007; Nazaroff, Prufer and Drake, 2010; Sheppard, et al., 2011.
495 Millhauser, Rodriguez-Alegría and Glascock, 2011.
496 McCoy, et al., 2011.
497 Jia, et al., 2010.
498 Glascock, Speakman and Burger, 2007.
499 Glascock, Speakman and Burger, 2007.

Rb;[500] Sr and Mn;[501] Mn and Fe;[502] Eu and Rb;[503] Nb, Sr and Zr;[504] and Zr and Sr.[505] The quoted variety perfectly illustrates that no common approach concerning trace elements combinations for the provenance of obsidian has been defined. In order to follow a more or less often used approach scatterplots of Rb and Sr were used as well as scatterplots of Fe and Rb. In the cases where both approaches failed to present comparable results a third scatterplot of Zr and Rb was used to clarify the picture. A complete overview of the analyzed obsidian objects clearly proves that the main obsidian source for the inhabitants of the Nasca-Palpa region in the course of nearly four millennia was located in the Huanca Sancos region and was characterized earlier as the Quispisisa obsidian lava flow[506] – ongoing investigations in the lava flow at the site Jichja Parco[507] have identified open pit mining areas and the samples from the geological reference collation have been taken at this site. There can be no doubt that this site was continuously frequented by miners seeking to exploit the rich obsidian source of Jichja Parco. The trace element concentration for Quispisisa as presented by Glascock, Speakman and Burger (2007, p.540) and later confirmed by Tripcevich and Contreras (2011, p.127) matches with the results achieved for the geological reference collection from Jichja Parco presented in this study. When comparing the results for the Quispisisa/Jichja Parco obsidian source from Glascock, Speakman and Burger (2007, p.540), Tripcevichand Contreras (2011, p.127) and the present study it becomes obvious that this source has a greater variety of trace element concentration than projected by Glascock, Speakman and Burger (2007, pp.548-549) and must be further refined by the results of the current study (Fig. 21 and Fig. 22). As the resolution of the pXRF is not as precise as other methods, more than one sample can have the same geochemical signature. Therefore, the following plots, exspecially for Sr/Rb, often present sample concentrations of more than one on one single spot. Perfect examples are the following figures (Fig. 30 and Fig. 31). Samples from 365 obsidian projectile points and 40 samples from the source Jichja Parco are combined with other source to present an overview.

As the majority of the analyzed objects in both plots clearly derive from the Quispisisa/Jichja Parco lava flow there is no doubt that this source must be viewed as the main supplier of obsidian. Still, there are clearly indications that at certain points of time other sources were exploited as well. Therefore, a differentiation according to the chronological setting of the obsidian artifacts seems important to highlight the different approaches of raw material consumption in the region. If necessary, external obsidian sources were taken into consideration.

500 Ferguson, 2012.
501 Williams, Dussubieux and Nash, 2012; Kellett, Golitko and Bauer, 2013.
502 Craig, et al., 2010.
503 Glascock and Giesso, 2012.
504 De Francesco, et al., 2012.
505 Phillips and Speakman, 2009.
506 Burger and Glascock, 2000
507 Tripcevich and Contreras, 2011; Tripcevich and Contreras, 2013; Stöllner, et al., 2013.

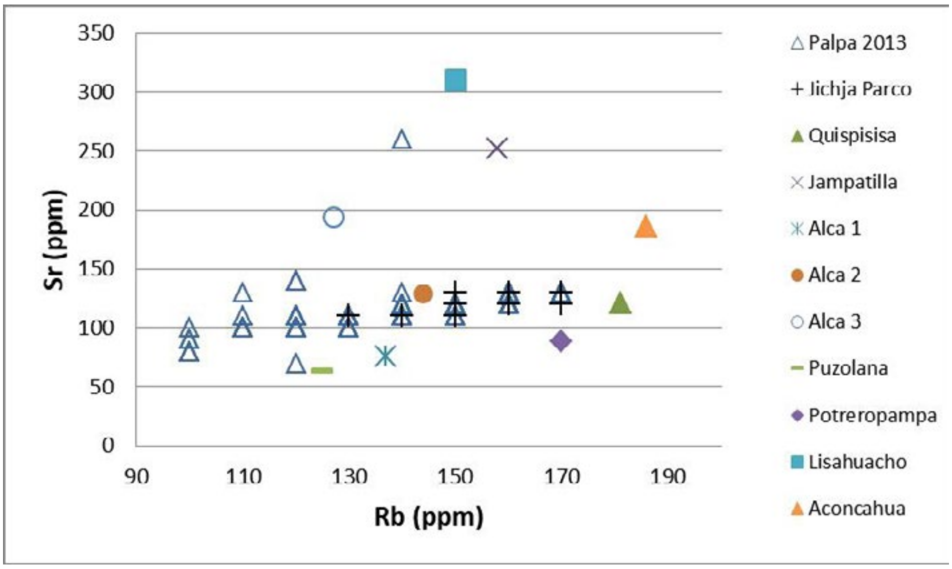


Fig. 30: Plot of Sr (ppm) versus Rb (ppm) for 365 obsidian artifacts from the PAP and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the XRF results for the obsidian quarries in Peru presented by Glascock, et al., (2007) (graphic: DBM, B. Gräfingholt).

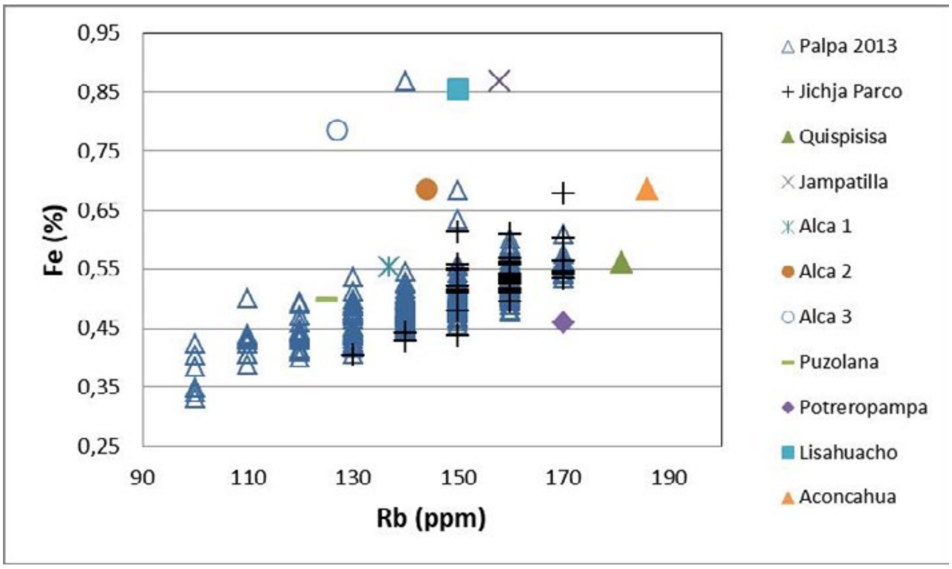


Fig. 31: Plot of Fe (%) versus Rb (ppm) for 365 obsidian artifacts from the PAP and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the XRF results for the obsidian quarries in Peru presented by Glascock, Speakman and Burger (2007) (graphic: DBM, B. Gräfingholt).

6.3.6.1 Archaic

Specimen 3801_2 from Botigiriayoq A (PAP-784) a projectile point of type 3 H variant I[508] from the Archaic was analyzed and combined with the results of the 40 samples from Jichja Parco (Fig. 32 and Fig. 33).

The artifact falls within the range of the obsidian quarry Jichja Parco and derives from this location. Therefore, the inhabitants of the Nasca-Palpa area exploited this obsidian source from the Archaic Period onward. Specimens 3167 and 4375 represent the oldest securely dated objects in the whole assemblage of obsidian artifacts that were analyzed (Fig. 34). Point 3167 derives from layer D U U.A.2B R Entierro 10. This grave represents the classic archaic context in Pernil Alto and was dated using C14:

508 Gräfingholt, 2011, p.80.

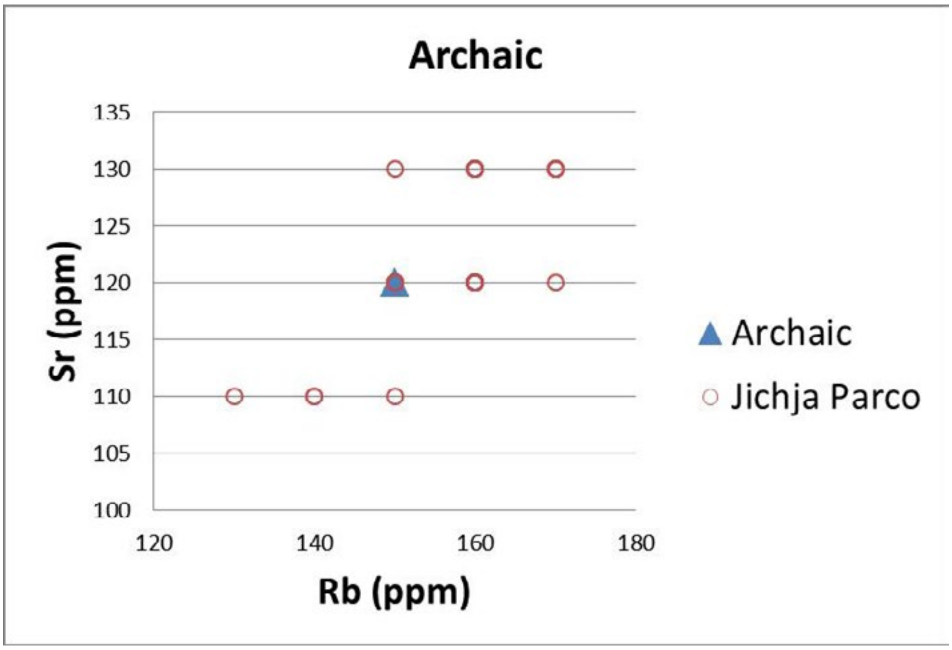


Fig. 32: Plot of Sr (ppm) versus Rb (ppm) for specimen 3801_2 PAP 784 and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

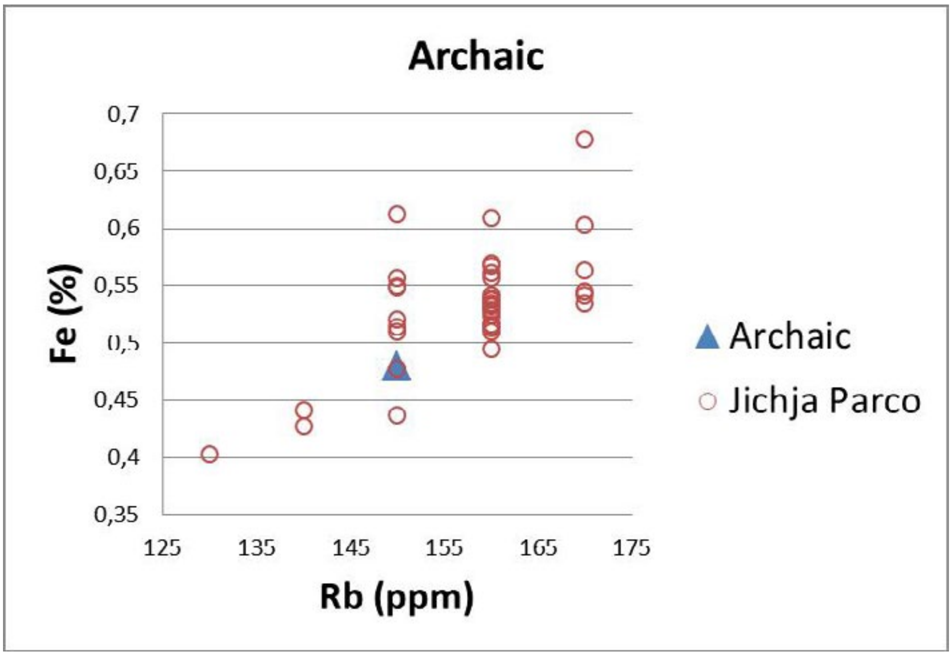


Fig. 33: Plot of Fe (%) versus Rb (ppm) for specimen 3801_2 PAP 784 and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

4776+-42, cal sig1 3650–3380; 4930+-44, cal sig1 3705-3640; 5008+-43, cal sig1 3800–3670. Specimen 4375 was excavated in layer H U AQ-46 that could be dated using C14 to around 3500–3150BC.[509]

The raw material for both artifacts was definitely extracted at the site Jichja Parco as demonstrated by the Fe/Rb and Sr/Rb plots (Fig. 35 and Fig. 36).

A long-distance exchange process between the highland region of Huanca Sancos and the coast had to be in place since that time. The obsidian quarry of Jichja Parco was therefore recognized by the inhabitants of the coast as early as the Archaic Period and attracted the first semi-nomadic inhabitants of Pernil Alto to extract their raw materials at this location in the highlands.

[509] Gräfingholt, 2011, p.103.

Fig. 34: Pernil Alto. Oldest securely dated obsidian projectile points found at the site Pernil Alto dating to the Archaic Period. Type 7A (graphic: DBM, B. Gräfingholt).

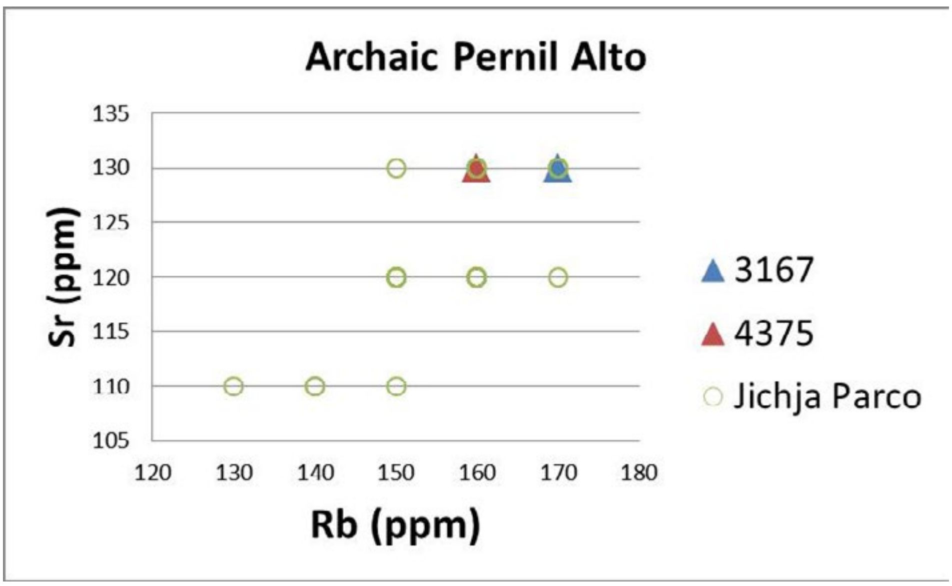


Fig. 35: Plot of Sr (ppm) versus Rb (ppm) for specimen 3167 and 4375 from Pernil Alto and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

6.3.6.2 Archaic/Initial Period

Eight obsidian projectile points of Type 4 A[510] – mainly found in the highland region – which represent the Archaic and Initial Period were combined with the data for Jichja Parco (Fig. 37 and Fig. 38).

The combination of the Fe/Rb and Sr/Rb plot perfectly illustrates that the seven obsidian projectile points that were found in the highland region on sites of Ocoro (PAP-751), Cutamalla (PAP-767), PAP-1032, PAP-785 and PAP-783, fit into the range of the obsidian source Jichja Parco and prove the continuous access to the source during the Archaic and Initial Period by the people inhabiting the highland region. The inhabitants of the highland region used the source for the extraction of raw materials for the tools they needed in their daily life. An exception is the obsidian artifact found in Jauranga (PAP-150). The artifact may be a hint at the long-distance exchange processes that were active in the region between the coast and the highlands, but though this point was excavated in Jauranga in a layer dating to Middle and Late Paracas, no such assumption can be made.

6.3.6.3 Initial Period/Transition

Ten obsidian objects belonging to the projectile point types 5 B[511] and 5 D variant I[512] which can be regarded as chronological markers for the Initial Period up to the Transition Period between the Paracas and Nasca Culture were combined with the pXRF results for Jichja Parco and the results presented by Glascock, Speakman and Burger (2007) for the site of Puzolana (Fig. 39 and Fig. 40).

510 Gräfingholt, 2011, pp.84-85.

511 Gräfingholt, 2011, pp.90-91.

512 Gräfingholt, 2011, pp.100-101.

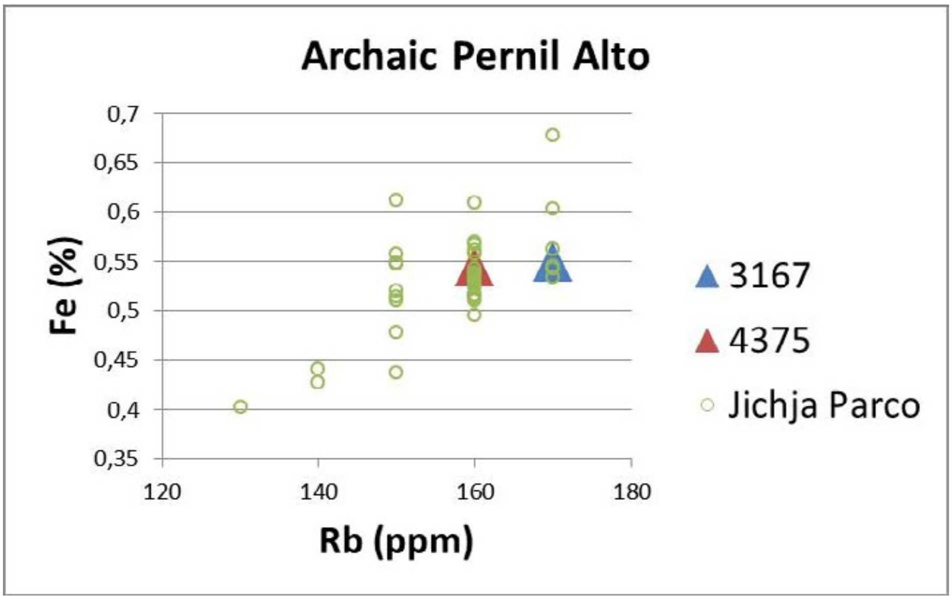


Fig. 36: Plot of Fe (%) versus Rb (ppm) for specimen 3167 and 4375 from Pernil Alto and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

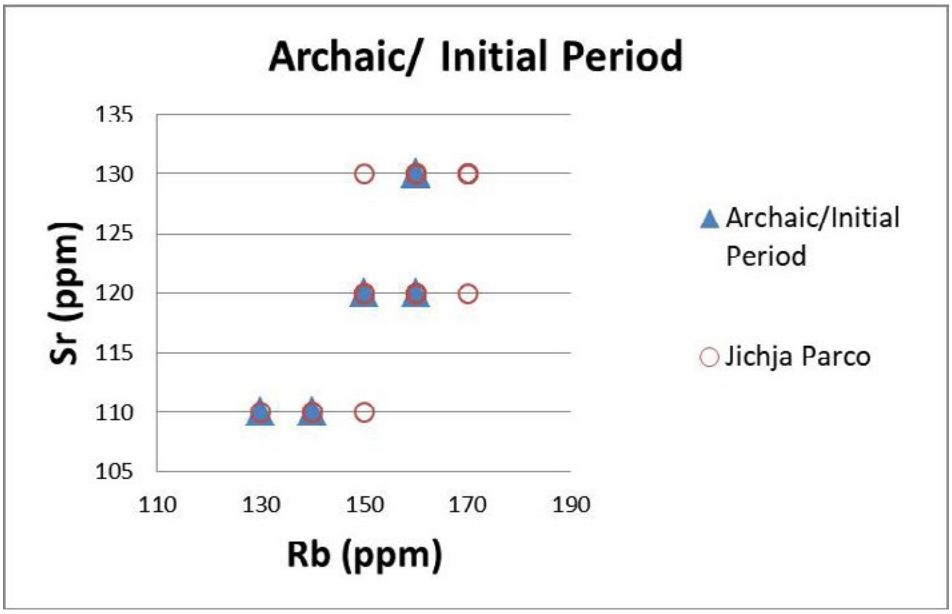


Fig. 37: Plot of Sr (ppm) versus Rb (ppm) for eight obsidian projectile points and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

The Puzolana source is located in the highland region of Ayacucho and obsidian from this source is rarely found in archaeological excavations outside of Ayacucho.[513]

Nine out of ten specimens clearly derive from the Jichja Parco source. Only specimen 770_5 (Fig. 42) from Qechqalla (PAP-770) associated to Middle or Late Paracas context in the highlands[514] does not fall within the chemical trace element concentration that is characteristic for Jichja Parco. The Fe/Rb and Sr/Rb plots indicate that an origin of this artifact from the rarely found obsidian source Puzolana[515] is not possible. But in the Sr/Rb plot the geochemical trace element composition of this artifact perfectly matches with the results presented for the Cerro Huenul obsidian source in Northern Argentina.[516]

Although the results presented in the Fe/Rb plot do not match exactly with Cerro Huenul, by adding a third plot (Zr/Rb) it becomes obvious that this artifact derives

513 Glascock, Speakman and Burger, 2007, p.536.
514 Tomasto Cagigao, Reindel and Isla Cuadrado, 2007, pp.280-283.
515 Glascock, Speakman and Burger, 2007, pp.535-536.
516 Giesso, et al., 2011, p.8.

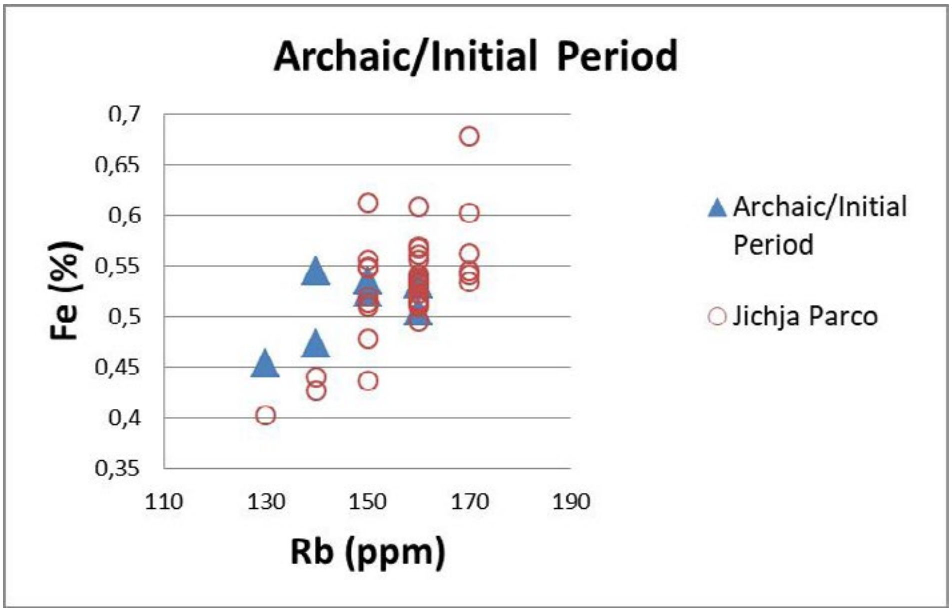


Fig. 38: Plot of Fe (%) versus Rb (ppm) for eight obsidian projectile points and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

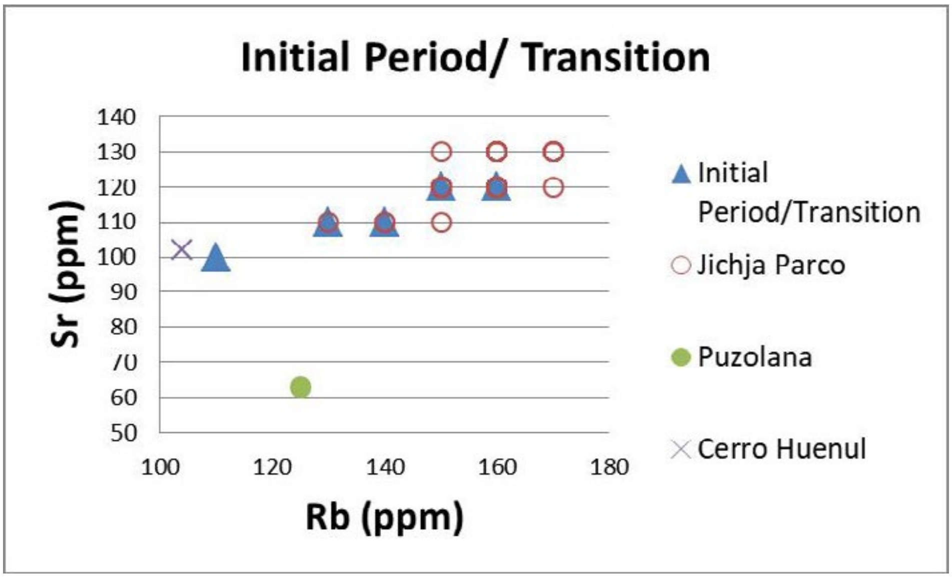


Fig. 39: Plot of Sr (ppm) versus Rb (ppm) for ten obsidian projectile points and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana source from XRF presented by Glascock, Speakman and Burger (2007) (graphic: DBM, B. Gräfingholt).

from the southern source Cerro Huenul (Fig. 41). Proving that during Middle to Late Paracas raw material from that source reached the Nasca-Palpa area. It is most likely that not only the raw material reached the Nasca-Palpa area but due to the unique production sequences of this specimen – which has only been documented for this point[517] – it may be possible that the finished artifact was handed down to the Nasca-Palpa area from that region. An obsidian projectile point with comparable characteristics – lacking the saw teeth on the edges – has been found at the site Pausa 15 km east of the obsidian source Chivay and was dated to the Late Formative (334–534 AD).[518] This small type of projectile point has been considered to be linked to the introduction of bow and arrow into the hunting techniques of the populations in Southern Peru around 3700 BP.[519] Therefore it may be possible that

517 Gräfingholt, 2011, p.91.

518 Tricevich and Mackay, 2011, p.274 pl.1.

519 Klink and Aldenderfer, 2005, p.52; Gräfingholt, 2011, p.93.

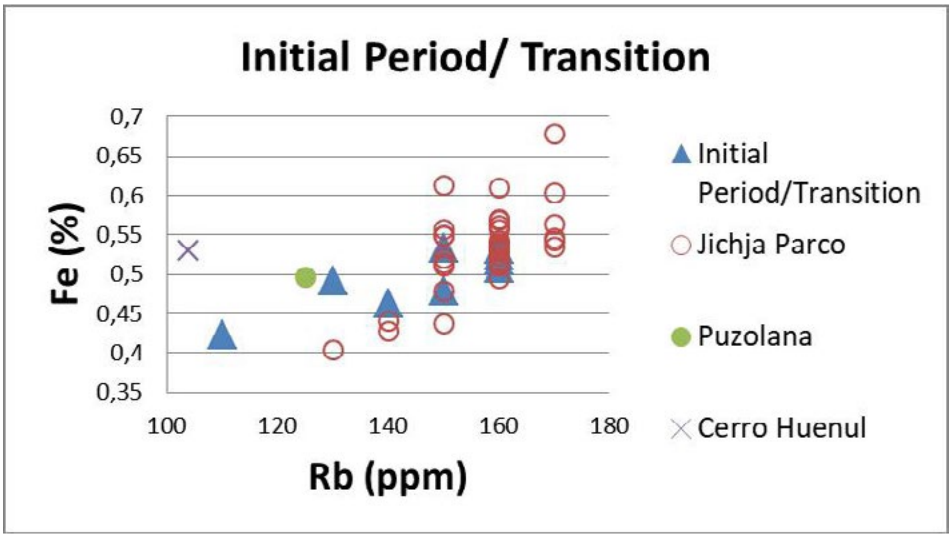


Fig. 40: Plot of Fe (%) versus Rb (ppm) for ten obsidian projectile points and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana source from XRF presented by Glascock, Speakman and Burger (2007) (graphic: DBM, B. Gräfingholt).

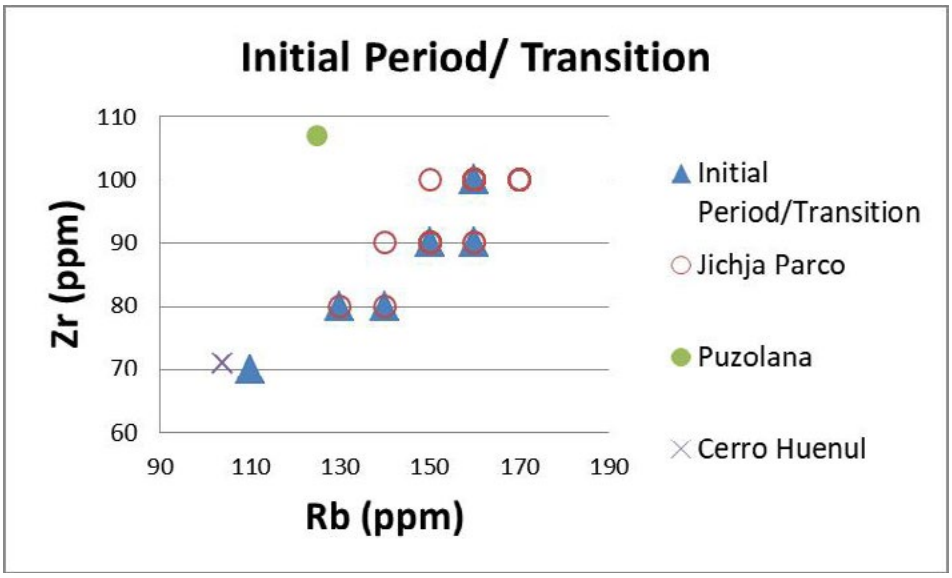


Fig. 41: Plot of Zr (ppm) versus Rb (ppm) for ten obsidian projectile points and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana source from XRF presented by Glascock, Speakman and Burger (2007) and the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

hunter-gathers from the south traveled a considerable distance for finally using the point in the research area.

Apart from this the remaining objects prove a constant access to the obsidian source Jichja Parco during the Initial Period up to the Transition by the inhabitants of the Nasca-Palpa region as the artifacts that were analyzed derive from coastal as well as highland sites.[520]

6.3.6.4 Middle Paracas

Twelve specimens belonging to the obsidian projectile point types 1 D, 2 C variant I [521], 2 H variant III[522], 2 I variant I, 2 K "Cutamalla"[523] and 3 D were analyzed using the pXRF. Furthermore, one scraper was tested as well. Except for point 2430_2 from Jauranga (PAP-150) excavated in layer

520 Gräfingholt, 2011, p.91.

521 Gräfingholt, 2011, p.47.
522 Gräfingholt, 2011, p.58.
523 Gräfingholt, 2011, p.63.

Fig. 42: PAP-770. Obsidian projectile point 770_5 a surface find from PAP-770 dating to the Paracas period and deriving from the Cerro Huenul obsidian source in Argentina (graphic: DBM, B. Gräfingholt).

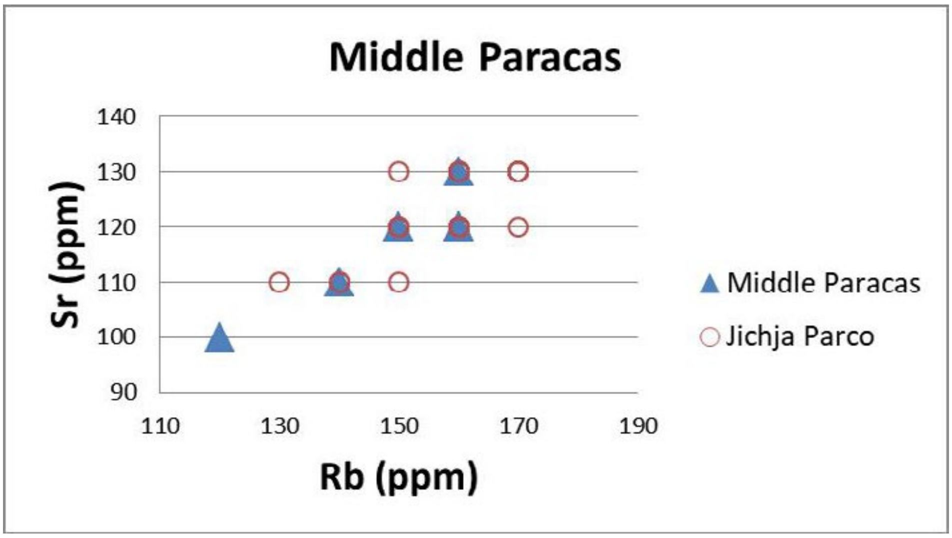


Fig. 43: Plot of Sr (ppm) versus Rb (ppm) for 12 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

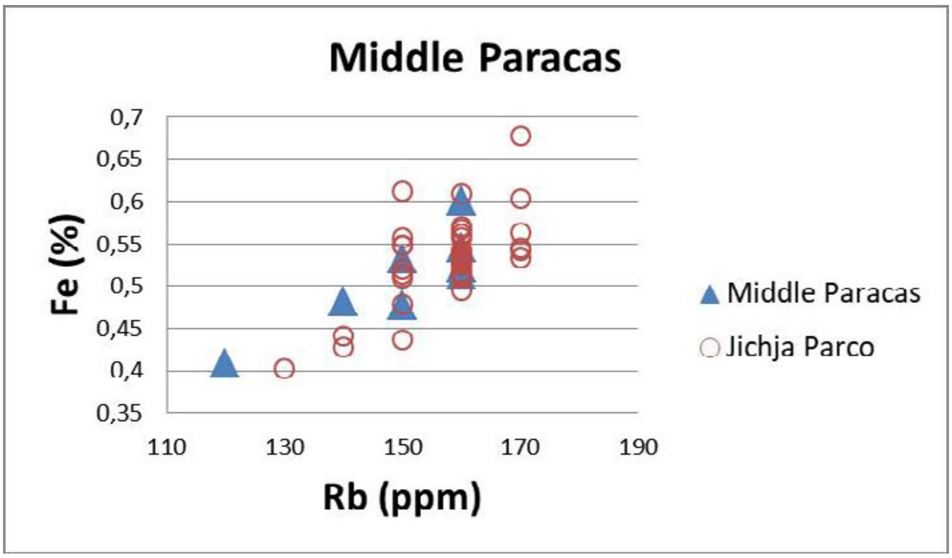


Fig. 44: Plot of Fe (%) versus Rb (ppm) for 12 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

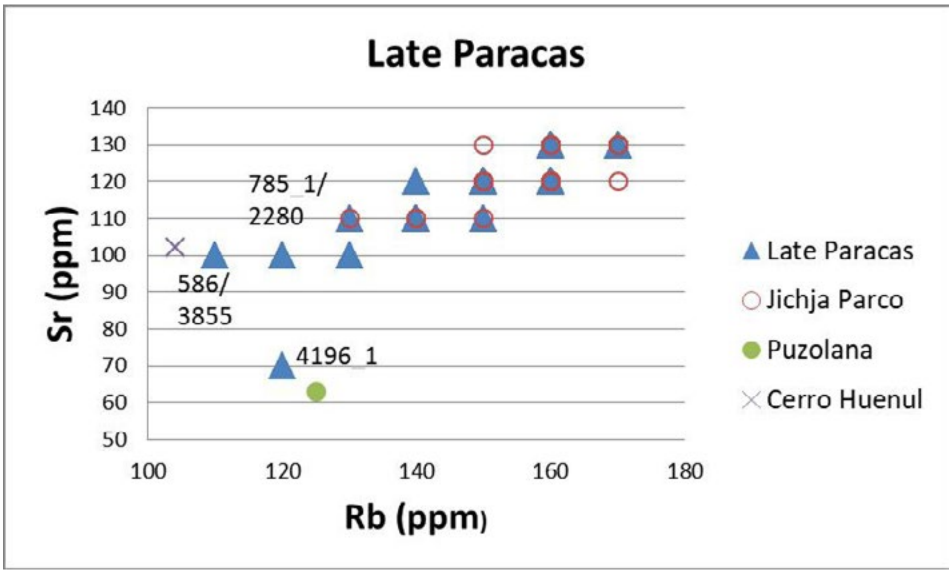


Fig. 45: Plot of Sr (ppm) versus Rb (ppm) for 64 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana sources from XRF presented by Glascock, Speakman and Burger (2007) and with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

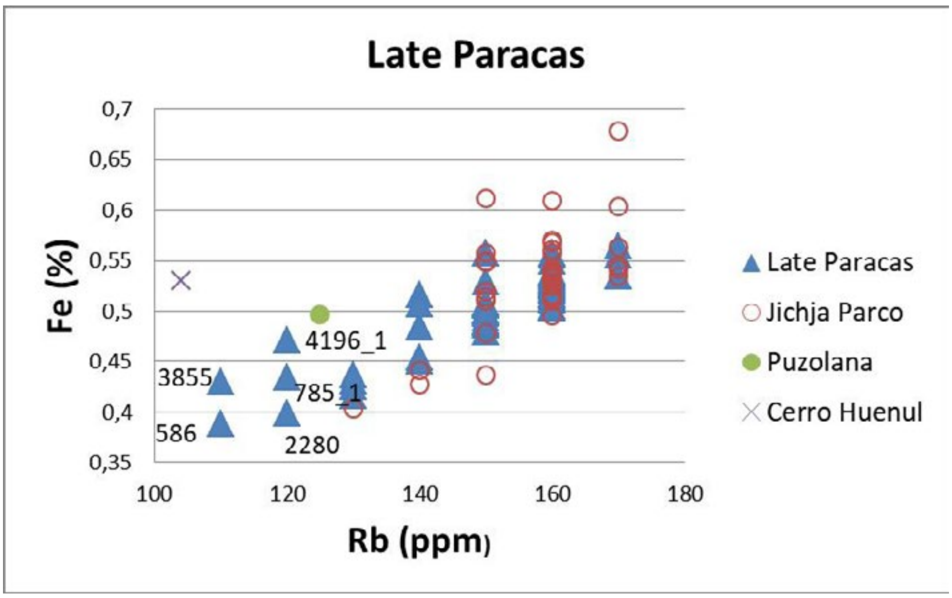


Fig. 46: Plot of Fe (%) versus Rb (ppm) for 64 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana from XRF presented by Glascock, Speakman and Burger (2007) and with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

H U TP3[524] all other objects derive from Middle Paracas highland sites, inter alia Cutamalla, a huge settlement with D structure dating to the Paracas culture.[525] The results were compared to the data obtained for the 40 samples of the obsidian source Jichja Parco from the pXRF analysis (Fig. 43 and Fig. 44).

The plots presented leave no doubt that during the Middle Paracas the access to the obsidian source Jichja Parco was well established and that the inhabitants of the highland region continuously exploited the sources. Only specimen 3823_2 excavated in Cutamalla (PAP-767) in layer A-1 U 1 R Hallazgo 1[526] shows a slight deviation from the trace element composition of Jichja Parco in both plots and cannot be securely assigned to that source.

524 Reindel, Isla Cuadrado and De La Torre, 2004, Appendix IV, p.5.
525 Reindel, 2009b, pp.347-348.
526 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.122.

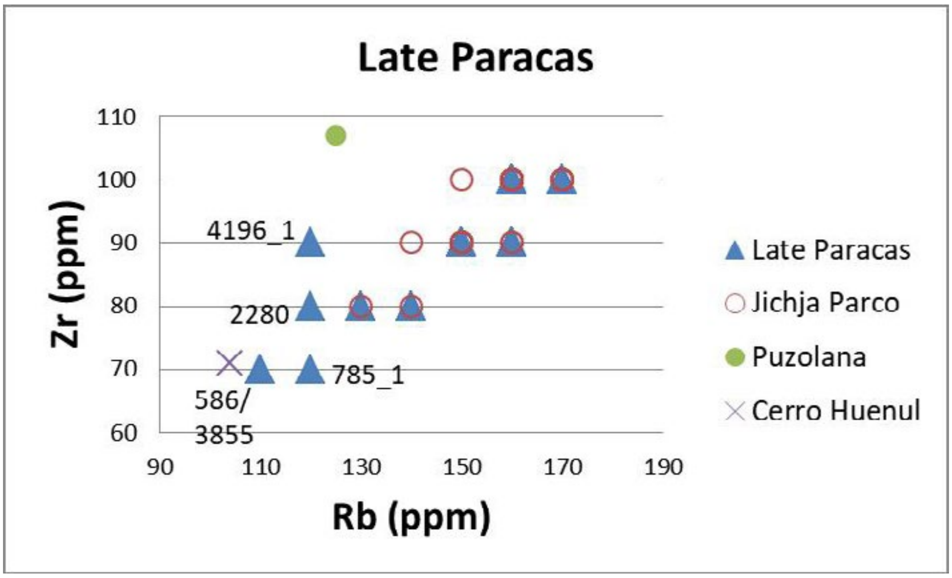


Fig. 47: Plot of Zr (ppm) versus Rb (ppm) for 64 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana from XRF presented by Glascock, Speakman and Burger (2007) and with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

Fig. 48: Specimen 3855 from PAP-767, PAP-586. Obsidian projectile points dating to Late Paracas. The raw material for these artifacts was probably exploited at the Cerro Huenul obsidian deposit in Argentina (graphic: DBM, B. Gräfingholt).

6.3.6.5 Late Paracas

Sixty-four artifacts belong to this assemblage of analyzed Late Paracas obsidian objects. The artifacts are differentiated into 15 obsidian projectile point sub-type (1 A variant I, 1 F variant II, 2 A, 2 A variant I, 2 B, 2 C variant II, 2 F, 2 H variant II, 2 H variant IV, 2 L, 3 F, 3 H, 5 A, 5 A variant I, 5 C variant I)[527] groups and basically represent the whole range of projectile points found in the region except for the type groups 4, 6, 7 and 8 which are very rare. Additionally eight obsidian scrapers were

527 Gräfingholt, 2011, pp.25, 33, 42, 44, 45, 48, 51, 57, 59, 63, 76, 79, 86, 88, 97.

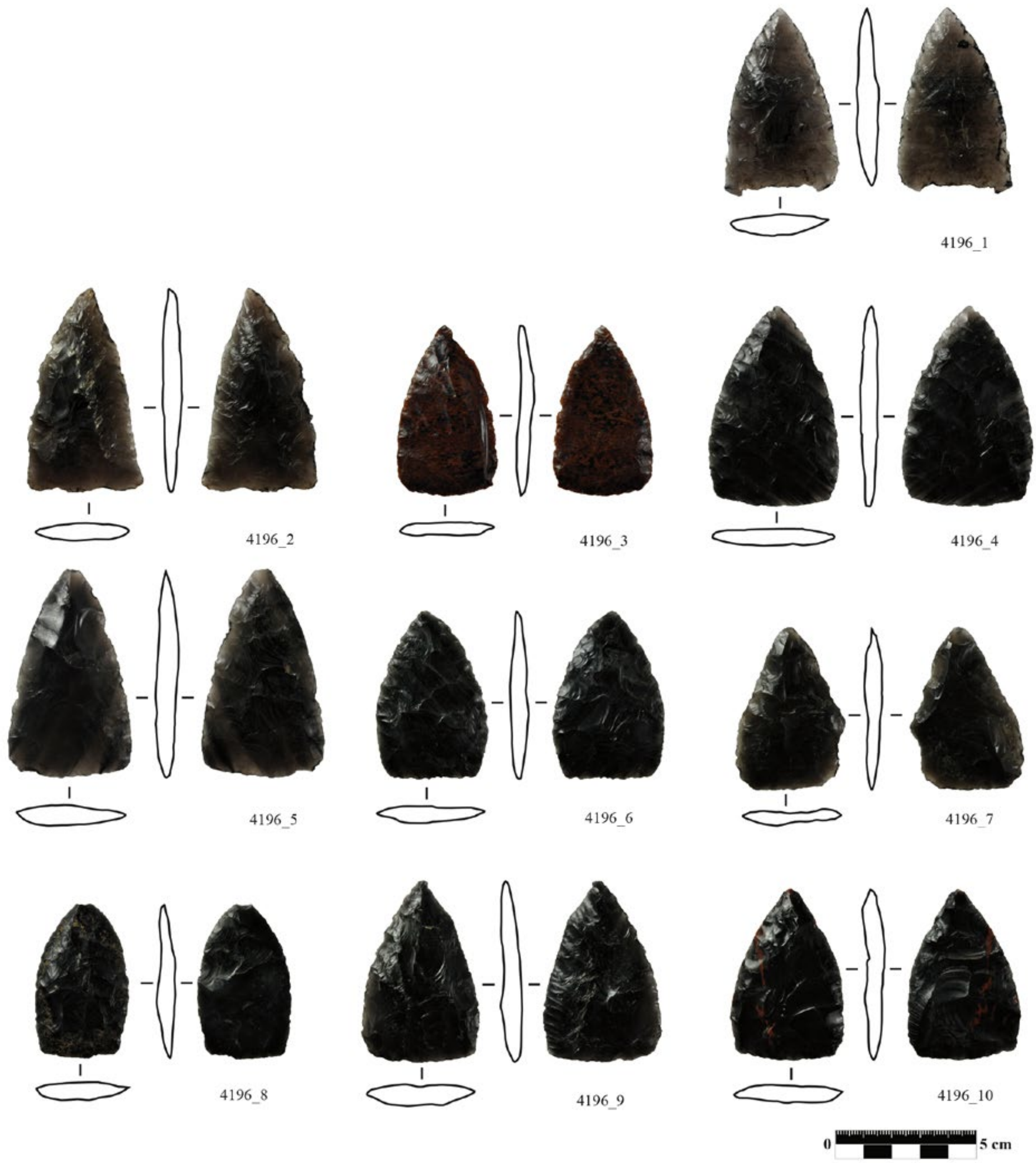


Fig. 49: PAP-454. Ten obsidian projectile points from a looted Ocucaje 8 burial on site PAP-454 (graphic: DBM, B. Gräfingholt).

analyzed. Therefore the results of the pXRF analysis of the Late Paracas objects combined with the data Jichja Parco results offer a deep understanding of raw material access during Late Paracas in the Nasca-Palpa region and how the exchange networks operated in that area at this point of time (Fig. 45 and Fig. 46).

Two obsidian artifacts do not fall within the trace element concentration of Jichja Parco and cannot be securely assigned to the Cerro Huenul source. Point 785_1 is a surface find from PAP-785[528] and point 2280 derives from Jauranga where it was excavated in layer E

528 Gräfingholt, 2011, p.77.

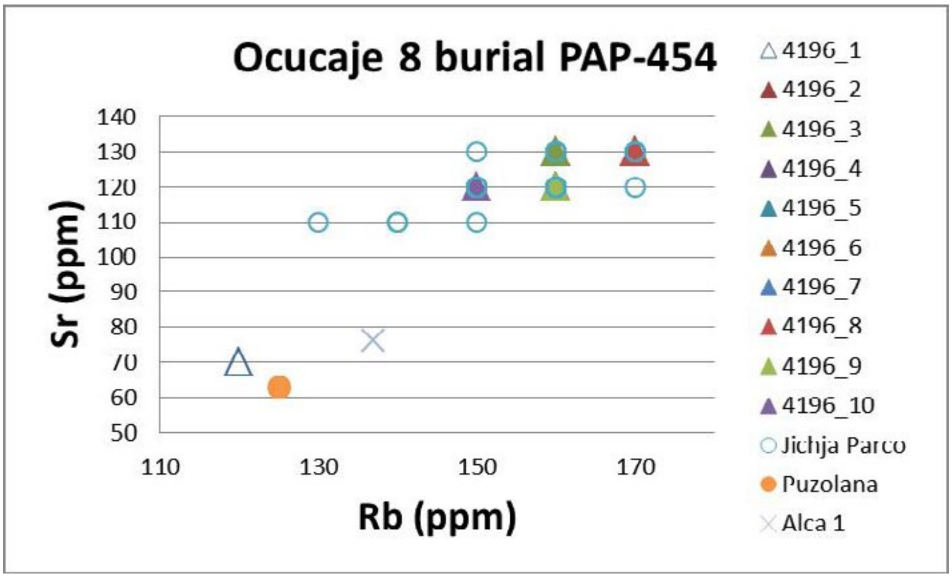


Fig. 50: Plot of Sr (ppm) versus Rb (ppm) for 10 obsidian projectile points dated to Ocucaje 8 and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana and Alca 1 sources from XRF presented by Glascock, Speakman and Burger (2007) (graphic: DBM, B. Gräfingholt).

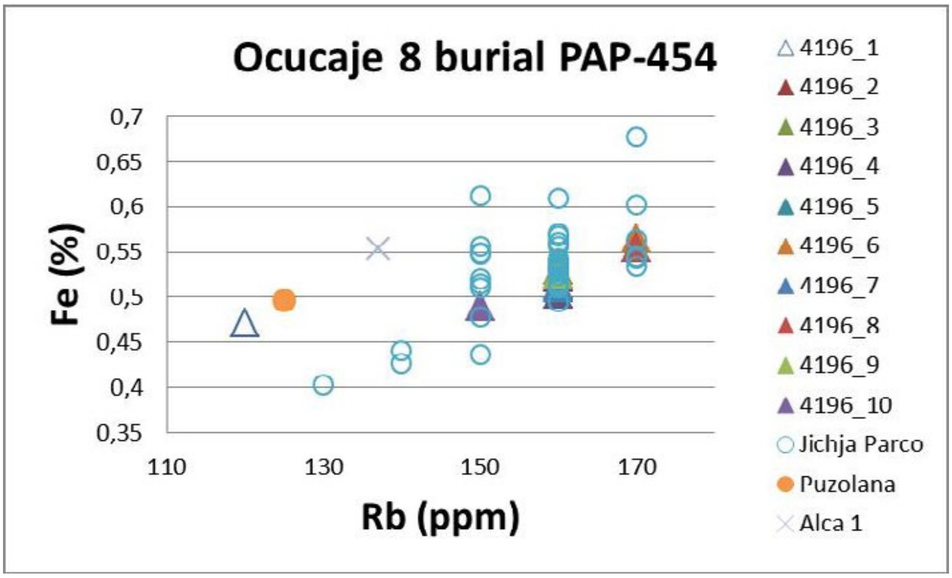


Fig. 51: Plot of Fe (%) versus Rb (ppm) for 10 obsidian projectile points dated to Ocucaje 8 and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana and Alca 1 sources from XRF presented by Glascock, Speakman and Burger (2007) (graphic: DBM, B. Gräfingholt).

U 2 R U.A. 3 that was dated using Ocucaje 8 ceramic.[529] It may be possible that the raw material for these two artifacts was exploited from a source that has not been characterized so far. According to the Sr/Rb plot the raw material used to produce point 586 – found on the surface of PAP-586[530] – and specimen 3855 – excavated in layer A U 4 S B that was dated using Ocucaje 6-7 ceramic in Cuttamalla (PAP-767)[531] – may derive from the Cerro Huenul source in Argentina (Fig. 48). Though the Fe/Rb

529 Reindel, Isla Cuadrado and De La Torre, 2004, p.21.

530 Gräfingholt, 2011, p.51.

531 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.135.

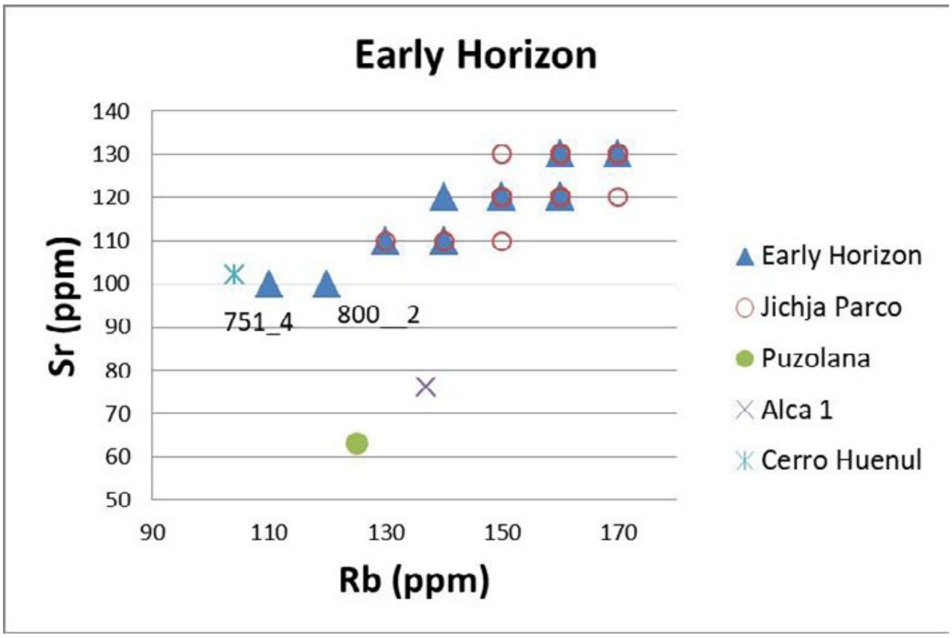


Fig. 52: Plot of Sr (ppm) versus Rb (ppm) for 23 obsidian projectile points and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana and Alca 1 sources from XRF presented by Glascock, Speakman and Burger (2007) and with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

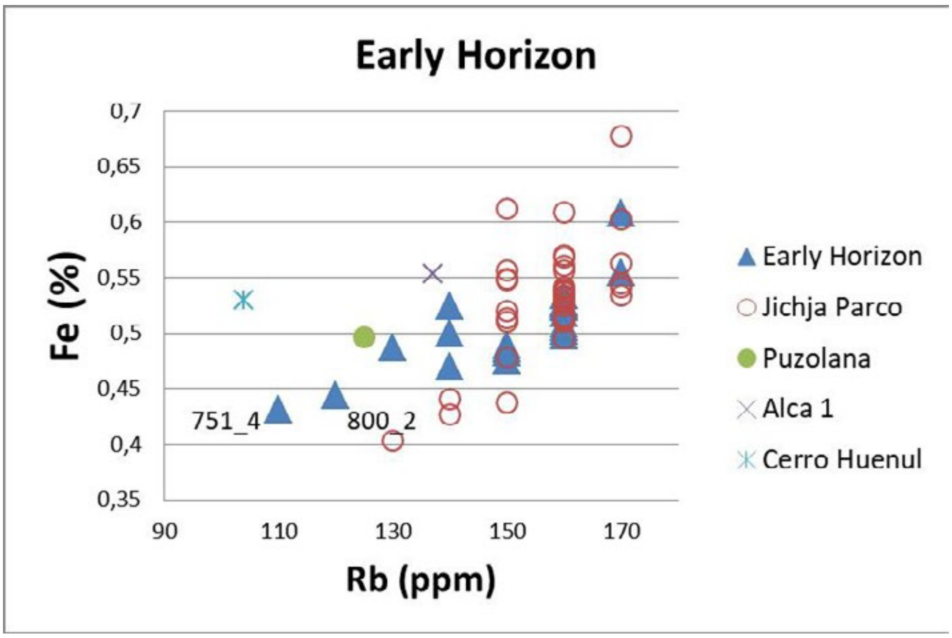


Fig. 53: Plot of Fe (%) versus Rb (ppm) for 23 obsidian projectile points and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana and Alca 1 sources from XRF presented by Glascock, Speakman and Burger (2007)and with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

plot diverges from this assumption a third plot (Zr/Rb) was taken into consideration (Fig. 47).

According to this plot both specimens fall within the geochemical trace element composition of Cerro Huenul proving that the raw material used to produce these artifacts was exploited at the deposits in Argentina. Specimens 785_1 and 2280 fail to match with either source and can therefore not be assigned to a known obsidian quarry.

Special emphasis must be laid on specimens 4196_1 to 4196_10. (Fig. 49) These ten obsidian projectile points are a unique assemblage and were found in a looted Ocucaje 8 burial on site PAP-454.[532]

It demonstrates that obsidian was highly valued by the people during Late Paracas who deposited these

532 Tomaste Cagigao, Reindel and Isla Cuadrado, 2009, p.141.

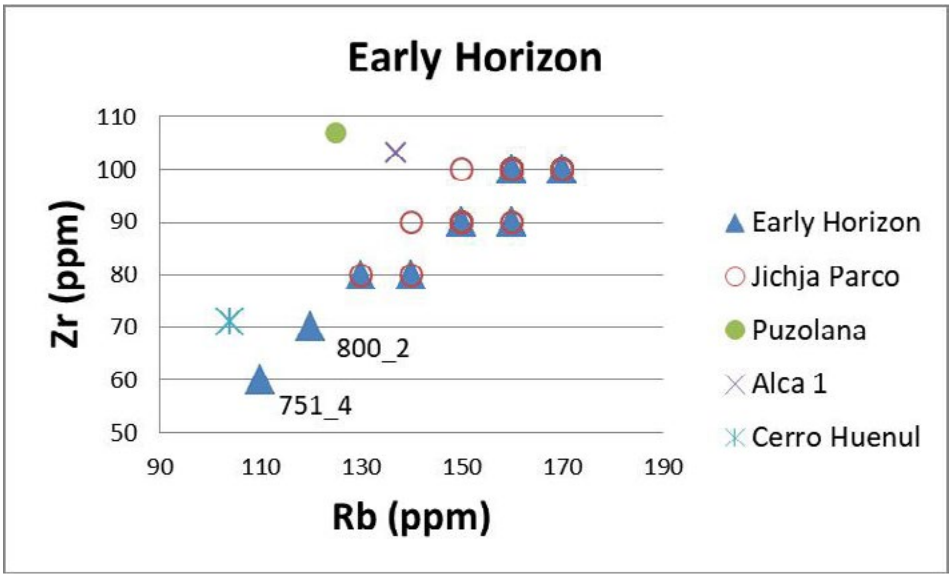


Fig. 54: Plot of Zr (ppm) versus Rb (ppm) for 23 obsidian projectile points and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana and Alca 1 sources from XRF presented by Glascock, Speakman and Burger (2007) and with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

outstanding examples of precious obsidian burial gifts. Tripcevich (2007, p.284) postulated that "Obsidian products, particularly finely-made bifacial tools, were perhaps one of a series of items that served to differentiate status-seeking individuals in early transegalitarian contexts, but with later crafts investment obsidian appears to have been assigned a relatively specific role for projectile point production and for cutting implements." This extraordinary find proves that in contrast to this statement obsidian projectile points were used by the Paracas culture as a status object and were not reduced to its pure functions as a tool made out of a raw material widely available.

Instead, as demonstrated by the Fe/Rb and Sr/Rb plots (Fig. 50 and Fig. 51), this burial contained objects made of obsidian from different obsidian sources – namely Jichja Parco and Puzolana. Due to the high quality of the obsidian projectile points and differences in color it can be assumed that the raw material for these objects was intentionally chosen – implying that the people were aware of the different origin of the raw material. It is remarkable that raw material from the obsidian source Puzolana was used to produce specimen 4196_1. Glascock, Speakman and Burger (2007, p.536) postulate, "it is unlikely that Puzolana was ever involved in a long-distance exchange network, perhaps due to the small nodule size." The data presented prove that the raw material from Puzolana was actually exchanged during Ocucaje 8 into the Nasca-Palpa area. The raw material was probably recognized as something valuable due to the long distance it had to be transported from the source. This is assumptions is further supported because of the unique assemblage of obsidian projectile points the object from Puzolana was combined with as a burial offer. The other nine objects derive from the Jichja Parco obsidian source in the Altiplano Region near Huanca Sancos demonstrating that a constant flow of obsidian was brought into the Palpa area during Late Paracas.

6.3.6.6 Early Horizon

Objects that could not be assigned to a certain Paracas period were summarized under the Early Horizon group. Twenty three artifacts belonging to the obsidian projectile point types 1 G[533], 1 G variant I[534], 2 D[535] and 2 F "Jauranga" variant I[536] were analyzed using the pXRF (Fig. 52 and Fig. 53). These projectile points derive from Early Horizon sites in the research area.

According to the plots, 16 out of 21 artifacts clearly derive from the Jichja Parco obsidian quarry. The remaining five objects may have different origins. Following the Sr/Rb plot the raw material for projectile point 777_2 from Tombuya[537] appears to be mined at the Puzolana source. Judging from the Fe/Rb plot specimens 3830_1 found in layer C-3 U 1 S B at the site Cutamalla which was dated to Ocucaje 6-7[538] and specimen 4153_2 found at Huayuncalla (PAP-814) in layer B U TP1 R U.A.1[539] may derive from the Alca 1 obsidian quarry which would be an outstanding result because of the long distance that the raw material for these artifacts would have been transported during the Early Horizon. The Alca quarry is located 3km southwest of the village Alca in the Cotahuasi Province, Arequipa. This quarry was rediscovered by Paul Trawick in 1984 on

533 Gräfingholt, 2011, p.34.
534 Gräfingholt, 2011, p.35.
535 Gräfingholt, 2011, p.48.
536 Gräfingholt, 2011, p.52.
537 Gräfingholt, 2011, p.34.
538 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.135.
539 Tomasto Cagigao, Reindel and Isla Cuadrado, 2009, p.164.

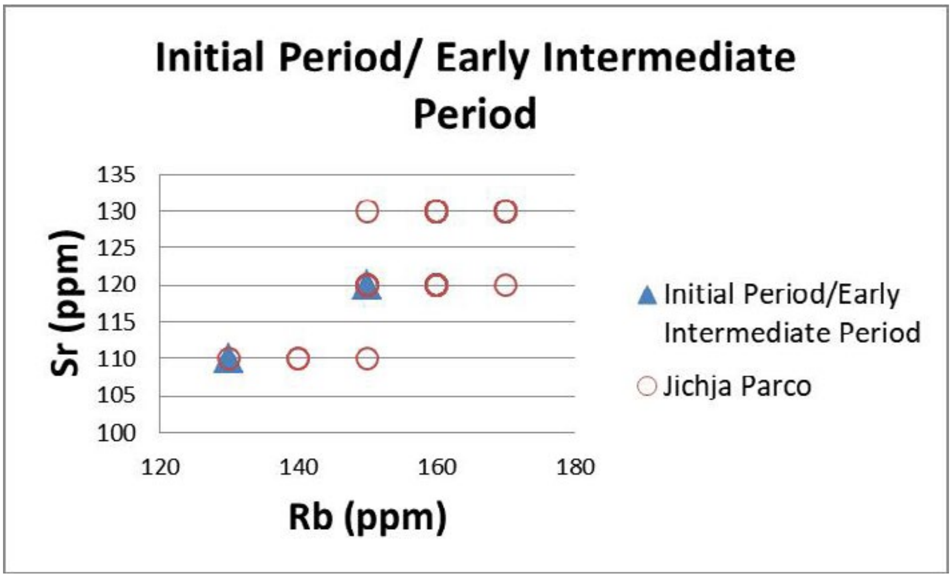


Fig. 55: Plot of Sr (ppm) versus Rb (ppm) for specimens 556_2 and 2955 and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

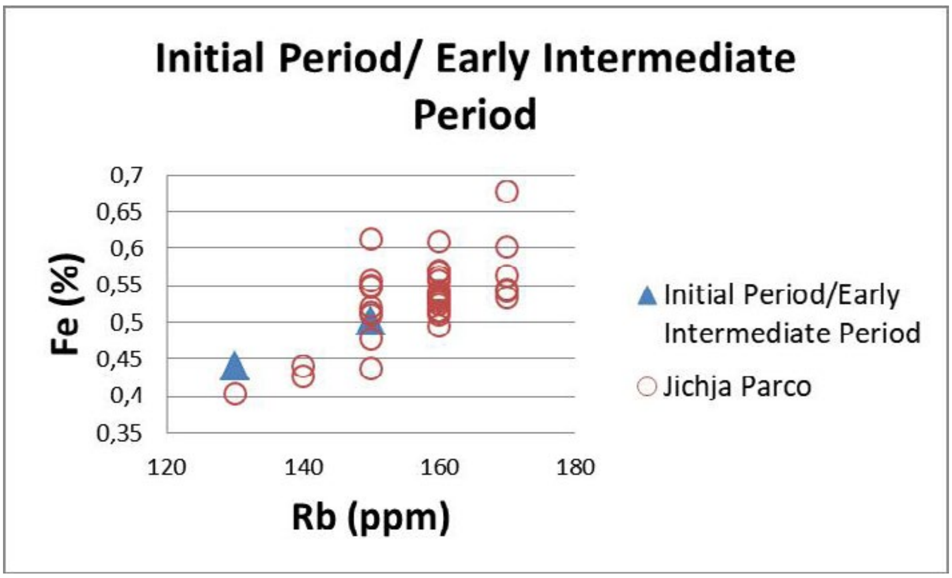


Fig. 56: Plot of Fe (%) versus Rb (ppm) for specimens 556_2 and 2955 and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

the Cerro Santa Rosa at 4,600 m a.s.l. overlooking the Cotahuasi River valley.[540] Specimens 800_2 a surface find from Cabracancha (PAP-800)[541] that was dated to Middle Paracas[542] and specimen 751_4 from Ocoro (PAP-751)[543] which can be associated with a Middle Horizon context[544] do not fall within the trace element concentration of an obsidian source in southern Peru – instead an origin from the Cerro Huenul source in Argentina seems possible. According to the Sr/Rb plot all objects – except for specimens 800_2 from Cabracancha (PAP-800) and specimen 751_4 from Ocoro (PAP-751) derive from Jichja Parco. But due to the diverging Fe results an origin from Cerro Huenul cannot be postulated without taking into account a third plot showing Zr/Rb (Fig. 54). An origin of specimens 777_2, 3830_1 and 4153_2 from Alca 1 seems unlikely because of the check against the Sr/Rb plot.

The Zr/Rb plot – first of all – proves the origin of all artifacts from Jichja Parco except for the two in question. In conclusion, their origin from Cerro Huenul seems possible, but the slight deviation of the trace element composition of the two artifacts does not allow a certain allocation to the source, although no other known source would match with these two artifacts.

540 Glascock, speakman and Burger, 2007, p.532.
541 Gräfingholt, 2011, p.34.
542 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.164.
543 Gräfingholt, 2011, p.36.
544 Tomasto Cagigao, Reindel and Isla Cuadrado, 2009, p.55.

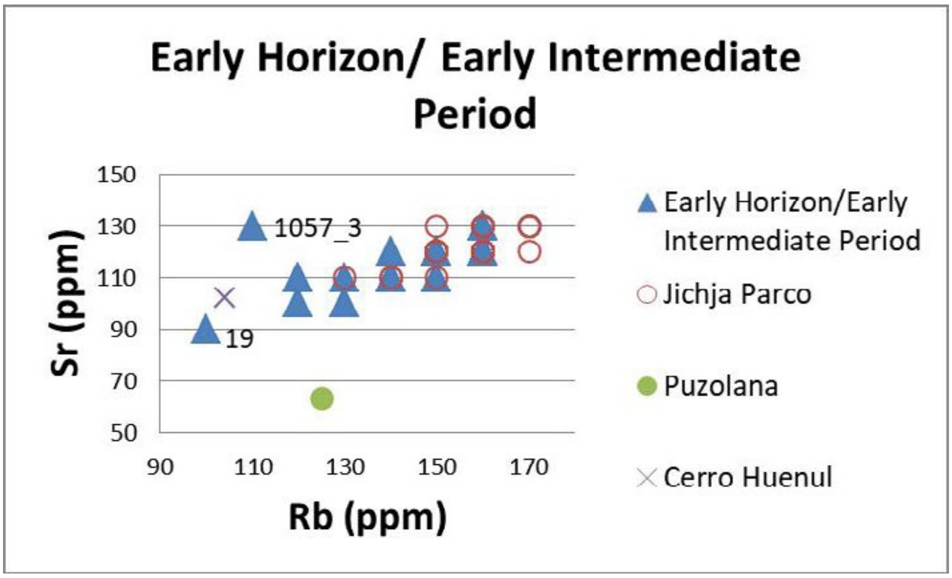


Fig. 57: Plot of Sr (ppm) versus Rb (ppm) for 45 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana source from XRF presented by Glascock, Speakman and Burger (2007) and the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

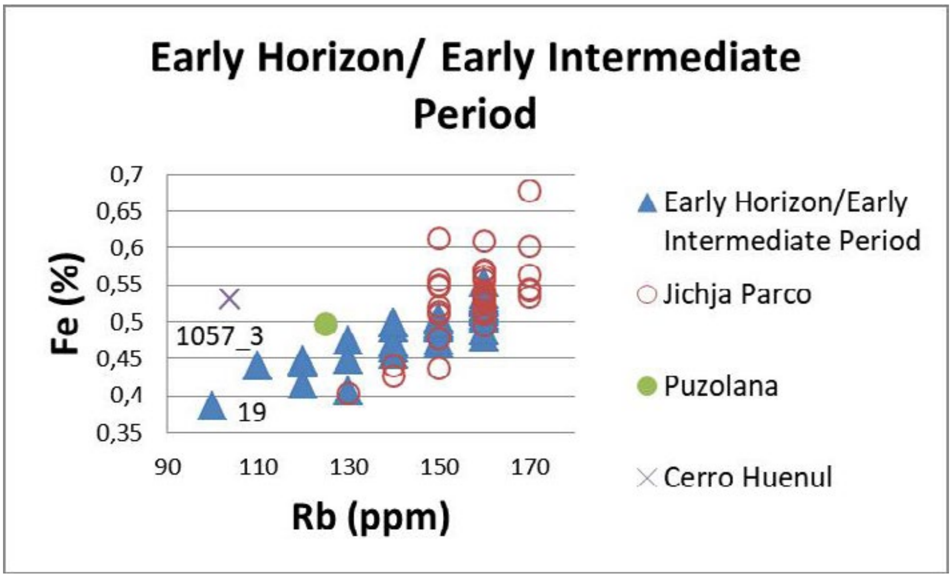


Fig. 58: Plot of Fe (%) versus Rb (ppm) for 45 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana source from XRF presented by Glascock, Speakman and Burger (2007) and the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

6.3.6.7 Initial Period/ Early Intermediate Period

Only two specimens belonging to obsidian projectile point type 1F were analyzed for this chronological setting. Point 556_2 – a surface find from a Nasca domestic/ cemetery site PAP-556 – and point 2955, which was found in layer CU 10B R Piso 2, was dated to the Initial Period (1000–900 BC).[545] This specimen was a rather outstanding object, because it was made of transparent obsidian. Therefore, an origin from the Macusani source[546] was postulated for this specimen by the author before the geochemical analysis was conducted using the pXRF.[547]

Both specimens fall within the trace element composition of Jichja Parco (Fig. 55 and Fig. 56). Therefore, the postulated origin of specimen 2955 from the Macusani source was not verified and can definitely be ruled out. A long-distance trade during the Initial Period as far as the Macusani source at the western flanks of the Andes was not in place. Instead, the inhabitants of the Nasca-Palpa region constantly used the obsidian source Jichja Parco.

545 Reindel, Isla Cuadrado and Linares Grados, 2005, p.156.
546 Craig, et al., 2010.
547 Gräfingholt, 2011, p.32.

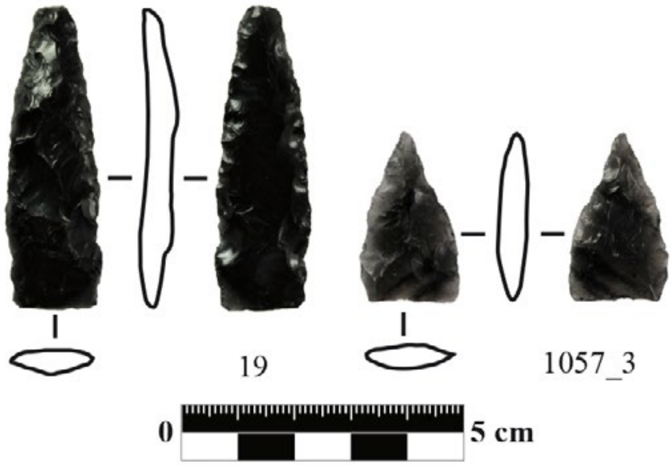


Fig. 59: PAP-19, PAP-1057. Both specimens were found on the surface and no cultural affiliation could be assigned (graphic: DBM, B. Gräfingholt).

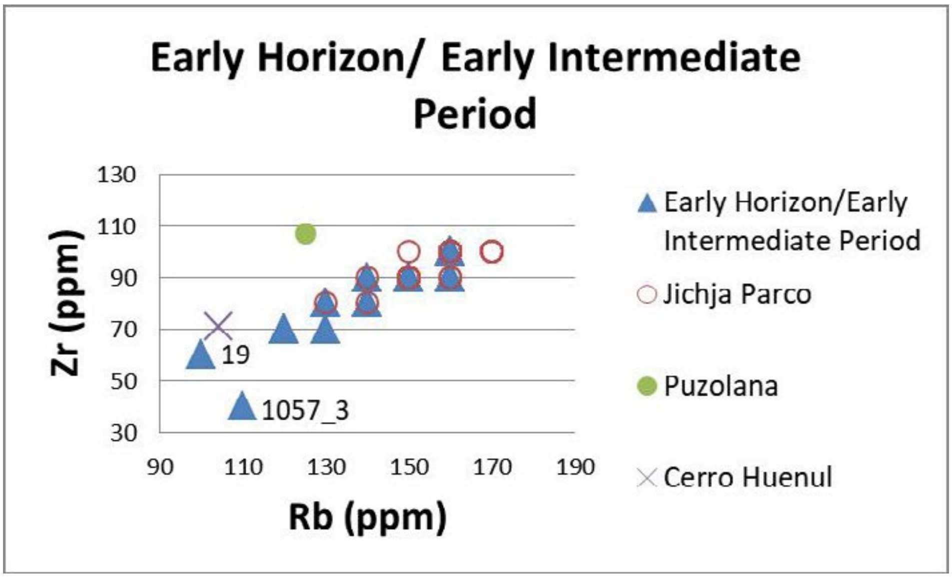


Fig. 60: Plot of Sr (ppm) versus Rb (ppm) for 45 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Puzolana source from XRF presented by Glascock, Speakman and Burger, (2007) and the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

6.3.6.8 Early Horizon/ Early Intermediate Period

Forty-five obsidian objects belong to this assemblage of analyzed Early Horizon/Early Intermediate Period specimens. The artifacts are differentiated into 12 obsidian projectile point sub-type groups (1 B, 1 E, 1 F variant I, 2 A variant I, 2 E, 2 G, 2 H, 2 H variant I, 2 I variant I, 3 G, 4 B, 8 A[548]) and one obsidian scraper and represent a great variety of projectile points found in the region. Therefore, the results of the pXRF analysis of the Early Horizon/ Early Intermediate Period objects are combined with the results for the pXRF analysis from Jichja Parco samples, in order to highlight the raw material consumption of the Paracas and Nasca culture in the Nasca-Palpa region. Furthermore, the XRF data for the obsidian quarries Puzolana presented by Glascock, Speakman and Burger (2007, p.540) and Cerro Huenul presented by Giesso, et al. (2011) were added to the plots (Fig. 57 and Fig. 58).

According to these results it is possible to reconstruct the exchange networks that operated in the region during the apogee of Paracas and Nasca cultures. In the Fe/Rb and Sr/Rb plots specimens 19 and 1057_3 are remarkably

548 Gräfingholt, 2011, pp.26, 30, 32, 44, 50, 54, 56, 60, 77, 84, 103.

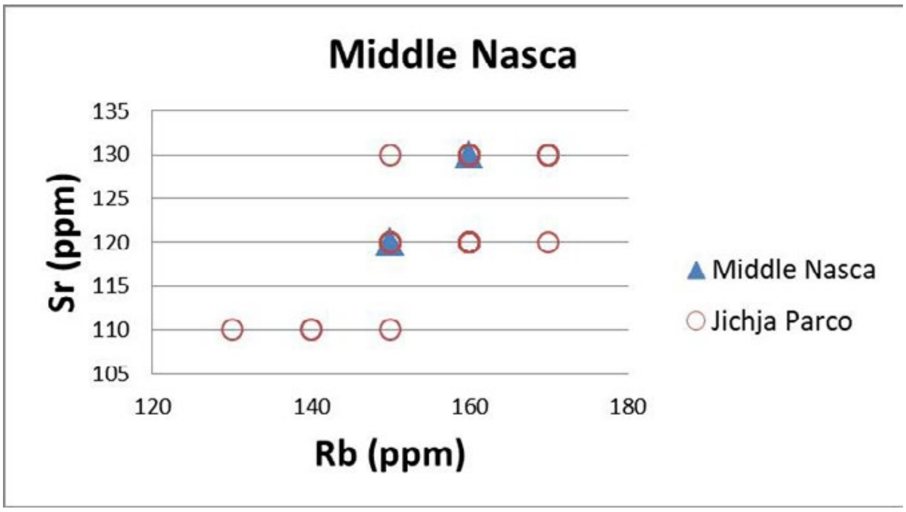


Fig. 61: Plot of Sr (ppm) versus Rb (ppm) for 5 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

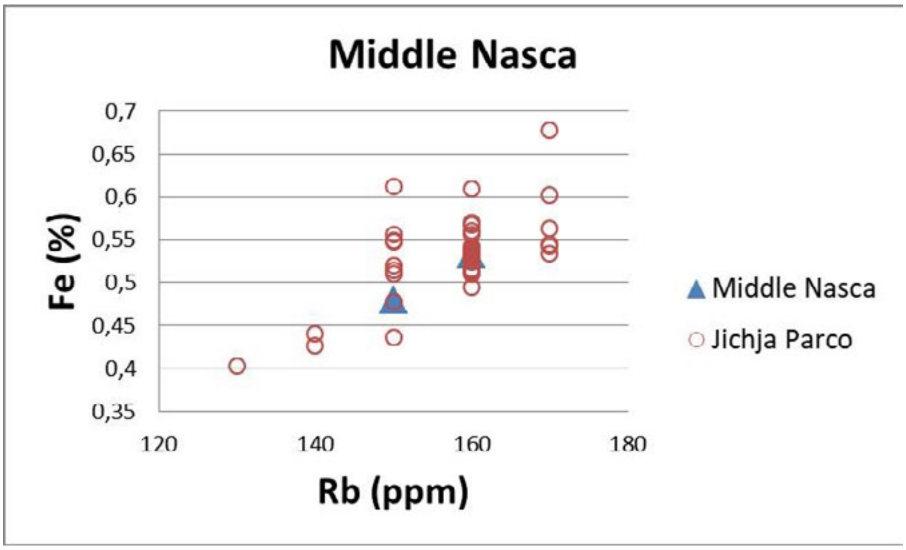


Fig. 62: Plot of Sr (ppm) versus Rb (ppm) for 5 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

different than the other 43 analyzed obsidian objects that clearly derive from Jichja Parco (Fig. 59).

Both projectile points are surface finds found during surveys in the valley of the Rio Palpa. Specimen 19 was found during a survey on PAP-19 where apart from the projectile point mainly Nasca ceramic was found.[549] Point 1057_3 was found during a survey on site PAP-1057 where overall Late Paracas and Early Nasca occupation was found.[550] The geochemical trace element concentrations of three Ecuadorian obsidian sources Mullumica[551], Yanaurco-Quiscatola[552] and Callejones[553] were taken into consideration, but failed to match with the given data for these artifacts. Due to the geochemical composition of these artifacts, the results for the Cerro Huenul source were added to the plots. Because the Fe/Rb plot and the Sr/Rb plot did not overlap, a third plot (Zr/Rb) was taken into consideration (Fig. 60).

This plot highlights that the raw material for all artifacts except for those two in question derives from the Jichja Parco obsidian source. An origin of the raw material that was used to produce specimen 19 from the Cerro Huenul source seems probable. Projectile point 1057_3 does not fall within the trace element concentration of a known source of obsidian in the Andean region; therefore, it is not possible to locate the deposit where the raw material for this artifact was exploited.

549 Reindel, 1998, Appendix III, p.31.
550 Gräfingholt, 2011, p.43.
551 Burger, et al., 1994.
552 Asaro, et al., 1994.
553 Bigazzi, et al., 1992.

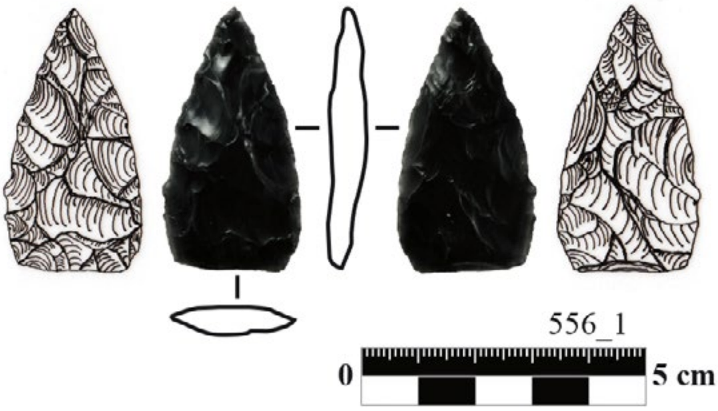


Fig. 63: PAP-556. Late Nasca obsidian projectile point 556_1 type 3A VII (graphic: DBM, B. Gräfingholt).

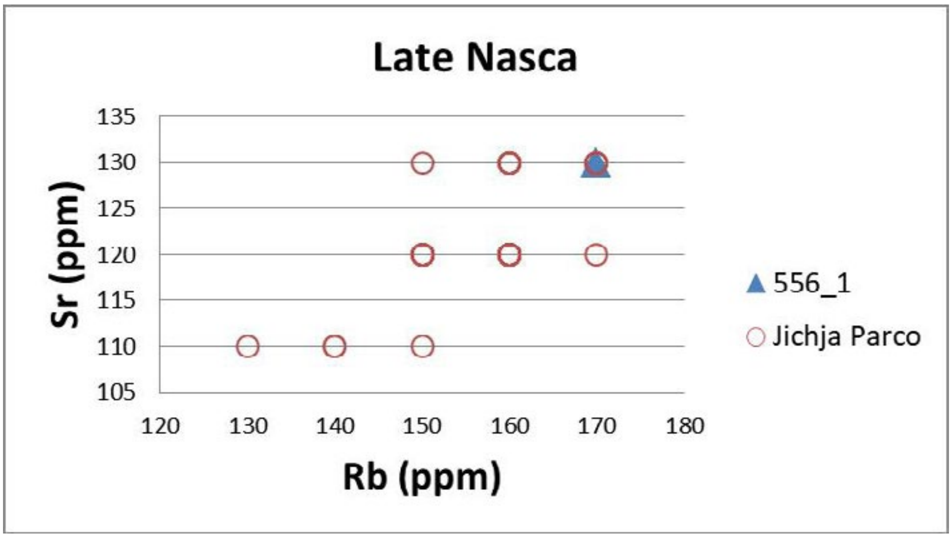


Fig. 64: Plot of Sr (ppm) versus Rb (ppm) for obsidian projectile point 556_1 and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

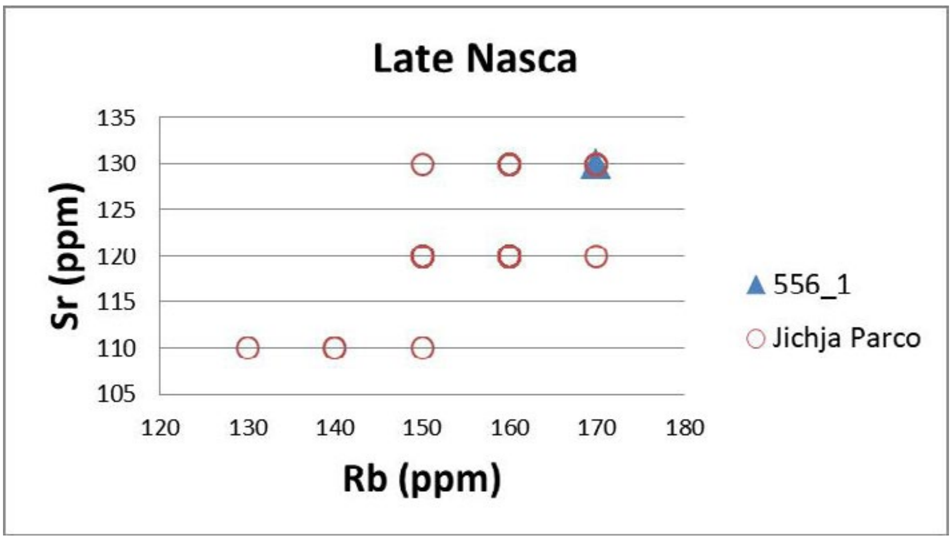


Fig. 65: Plot of Fe(%) versus Rb (ppm) for obsidian projectile point 556_1 and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

As outlined before the postulates geochemical composition of the Quispisisa/Jichja Parco source by Glascock, et al. (2007, p.540) has to be redefined according to the results received by Tripcevich and Contreras (2011, p.128) and the presented study.

6.3.6.9 Middle Nasca

Only five obsidian artifacts could be assigned to Middle Nasca – three projectile points belonging to the sub-type groups 2J VI[554] and 3E VI[555]; two objects were defined as scrapers.

According to the Sr/Rb and Fe/Rb plots there can be no doubt that during that period Jichja Parco was used by the Nasca to extract the raw material for their tools (Fig. 61 and Fig. 62). Due to the limited assemblage of objects dated to Middle Nasca a final consideration of the raw material consumption during that time has to be postponed until further Middle Nasca material has been analyzed.

6.3.6.10 Late Nasca

Just specimen 556_1 belonging to the obsidian projectile point sub-group 3A VII[556] was dated securely to Late Nasca (Fig. 63).

It derives from site PAP-556 in the valley of the Rio Palpa. The Sr/Rb and Fe/Rb plots prove that the raw material for this point was exploited at Jichja Parco in the Altiplano (Fig. 64 and Fig. 65).

Still this unique specimen dating to Late Nasca does not demonstrate that Jichja Parco was exclusively used be the people during Late Nasca to satisfy their need for obsidian.

6.3.6.11 Early Horizon/ Middle Horizon

Forty-eight artifacts belong to this assemblage of analyzed obsidian objects that cover a relatively long period of time – incorporating three cultures: Paracas, Nasca and Wari. The artifacts are differentiated into 6 obsidian projectile point sub-type groups (1A[557], 1C[558], 1H[559], 1K[560], 3B VI[561], 3D VI[562]). The geochemical analysis revealed that three of the artifacts do not derive from Jichja Parco – whereas the rest of the specimens do (Fig. 66 and Fig. 67).

Specimen 2411 (Fig. 68) was excavated in Jauranga (PAP-150) in layer E2 U TP3 where Early Nasca ceramic was documented.[563] Both plots indicate that the raw material for this point was exploited at the Lisahuacho source – demonstrating that an access to that source existed during Early Nasca.

Lisahuacho is located 42 km southwest of Chalhuanca at 3978m a.s.l.in the Aymara's region.[564] Obviously a connection between Jauranga and the Aymara's region existed during Early Nasca on at least one occasion as demonstrated by specimen 2411. As indicated by the Sr/Rb plot the two other artifacts which do not derive from Jichja Parco can be linked to the Cerro Huenul obsidian source in Argentina. The Zr/Rb plot (Fig. 69) impressively supports this as well as the origin of specimen 2411 from Lisahuacho.

Obsidian projectile point 828_4 derives from the surface of PAP-828 in the highlands where Ocucaje 6-7, Nasca 5 and LIP occupation were documented.[565] On the surface near geoglyph 468 PAP-17 – that was probably constructed during the Early Intermediate Period – specimen 17 was found.[566] Though both points belong to the projectile point type group 3 D variant I[567], it seems probable that the raw material for these points was introduced into the Nasca-Palpa region at the same time (Fig. 70).

6.3.6.12 Early Intermediate Period/ Middle Horizon

Sixteen obsidian projectile points belonging to the subtype groups 2 A[568], 2 C[569], 3 E[570] and 5 C[571] represent the assemblage of obsidian artifacts that covers the Early Intermediate Period and the Middle Horizon. Additionally one scraper was analyzed. According to the Fe/Rb and Sr/Rb plots all but one specimen derive from the Jichja Parco obsidian source (Fig. 71 and Fig. 72).

Point 751_7 found at the site Ocoro (PAP-751) in the highlands which is associated with a Middle Horizon occupation[572] does not exactly match with the trace element concentration for Jichja Parco in both plots. But due to the calculated error it is more than probable that this point also derives from Jichja Parco. All other points can be traced back to the Jichja Parco obsidian source demonstrating the permanent access to the site during the Nasca and Middle Horizon.

6.3.6.13 Wari

Thirty artifacts belong to this assemblage of analyzed Wari obsidian objects. These artifacts are differentiated into 6 obsidian projectile point sub-types (2 I[573], 3 A[574], 3 A variant

554 Gräfingholt, 2011, p.62.
555 Gräfingholt, 2011, p.75.
556 Gräfingholt, 2011, pp.65-66.
557 Gräfingholt, 2011, p.23.
558 Gräfingholt, 2011, p.27.
559 Gräfingholt, 2011, p.36.
560 Gräfingholt, 2011, p.40.
561 Gräfingholt, 2011, p.68.
562 Gräfingholt, 2011, p.72.
563 Reindel, et al., 2004, Appendix IV, p.4.
564 Glascock, et al., 2007, p.537.
565 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.181-182.
566 Reindel, 1998, Appendix III, p.31.
567 Gräfingholt, 2011, p.72.
568 Gräfingholt, 2011, p.42.
569 Gräfingholt, 2011, p.46.
570 Gräfingholt, 2011, p.73.
571 Gräfingholt, 2011, p.94.
572 Reindel, Solis Quintero and Isla Cuadrado, 2010, p.63.
573 Gräfingholt, 2011, p.59.
574 Gräfingholt, 2011, p.64.

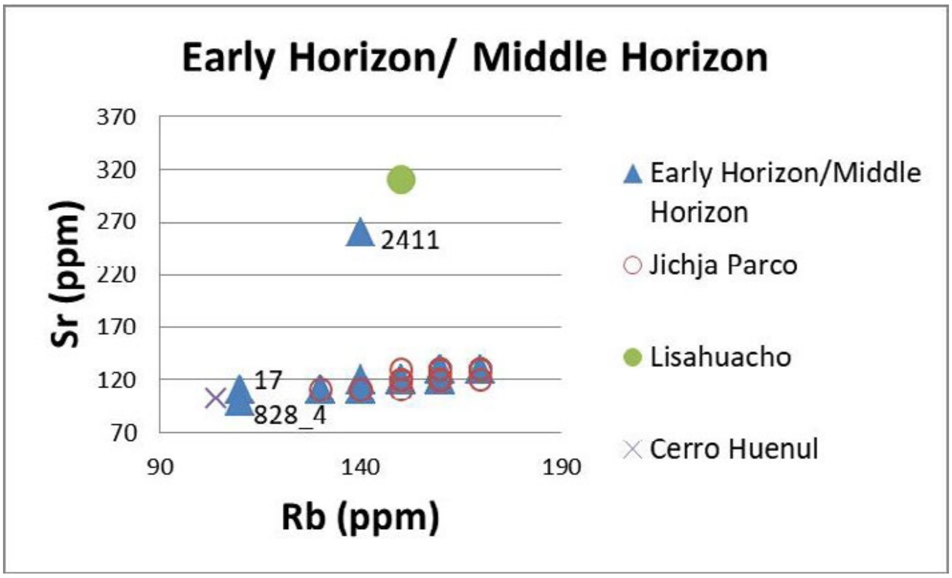


Fig. 66: Plot of Sr (ppm) versus Rb (ppm) for 48 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Lisahuacho source from XRF presented by Glascock, Speakman and Burger (2007) and with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

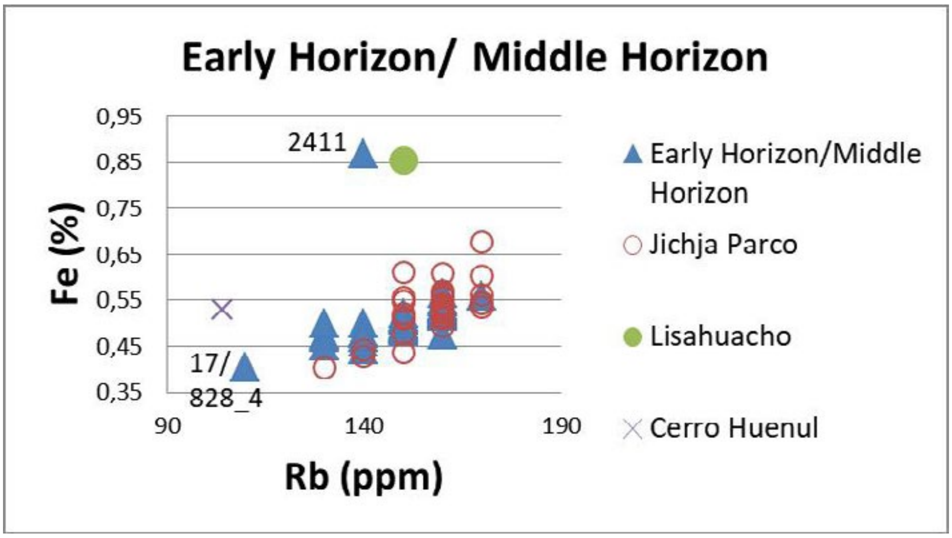


Fig. 67: Plot of Fe (%) versus Rb (ppm) for 48 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Lisahuacho source from XRF presented by Glascock, Speakman and Burger (2007) and with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

I[575], 3 B[576], 3 C[577], 3 I variant I[578]) groups which represent the typical obsidian projectile points used by the Wari culture in the Nasca-Palpa region (Fig. 73). Additionally three obsidian scrapers were analyzed. Twenty-seven objects derive from sites in the highlands and three objects are surface finds documented around Palpa.

According to the Fe/Rb and Sr/Rb plots (Fig. 74 and Fig. 75) all analyzed obsidian artifacts associated with the Wari culture in the Nasca-Palpa region derive from the obsidian source Jichja Parco.

There seems to be a slight deviation in the Fe/Rb plot but though the Sr/Rb plot – when taking into account the calculated error for the results – doubtlessly demonstrates the origin of the artifacts; Jichja Parco can be regarded as the main supplier of obsidian raw material for the people who inhabited the highland region in the Nasca Palpa region during the Middle Horizon.

575 Gräfingholt, 2011, p.65.
576 Gräfingholt, 2011, p.66.
577 Gräfingholt, 2011, p.68.
578 Gräfingholt, 2011, p.81.

Fig. 68: Jauranga (PAP-150). Early Nasca obsidian projectile point 2411 deriving from the Lisahuacho source (graphic: DBM, B. Gräfingholt).

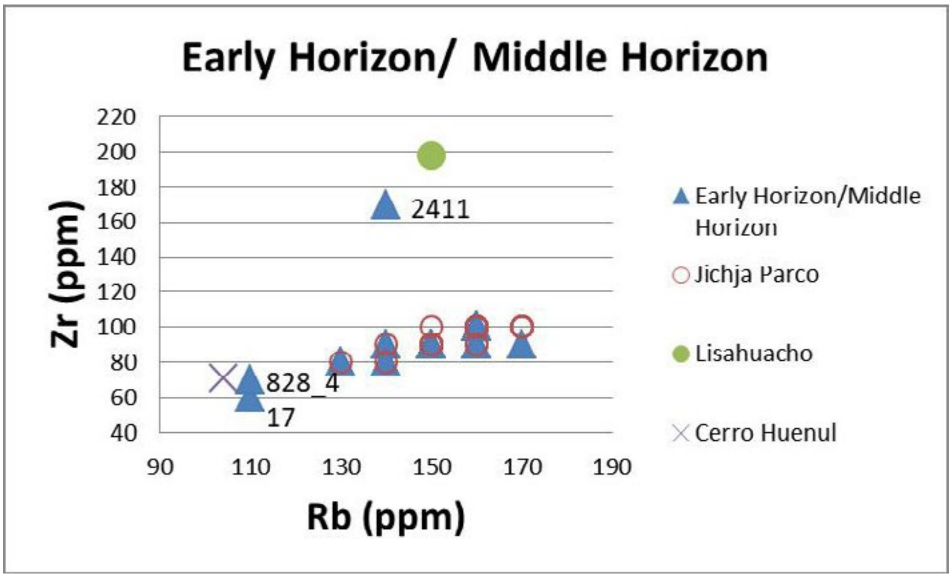


Fig. 69: Plot of Zr (ppm) versus Rb (ppm) for 48 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Lisahuacho source from XRF presented by Glascock, Speakman and Burger (2007) and with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

Fig. 70: PAP-828, PAP-17. Obsidian projectile points of type 3 D variant I that derive from the Cerro Huenul obsidian source in Argentina (graphic: DBM, B. Gräfingholt).

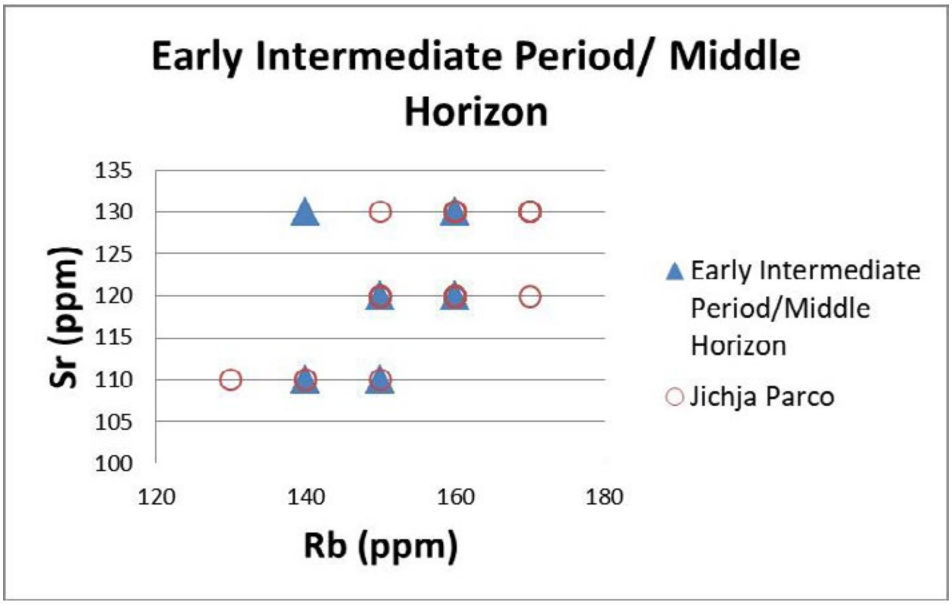


Fig. 71: Plot of Sr (ppm) versus Rb (ppm) for 16 obsidian objects and 40 samples from the Jichja Parco obsidian quarry (graphic: DBM, B. Gräfingholt).

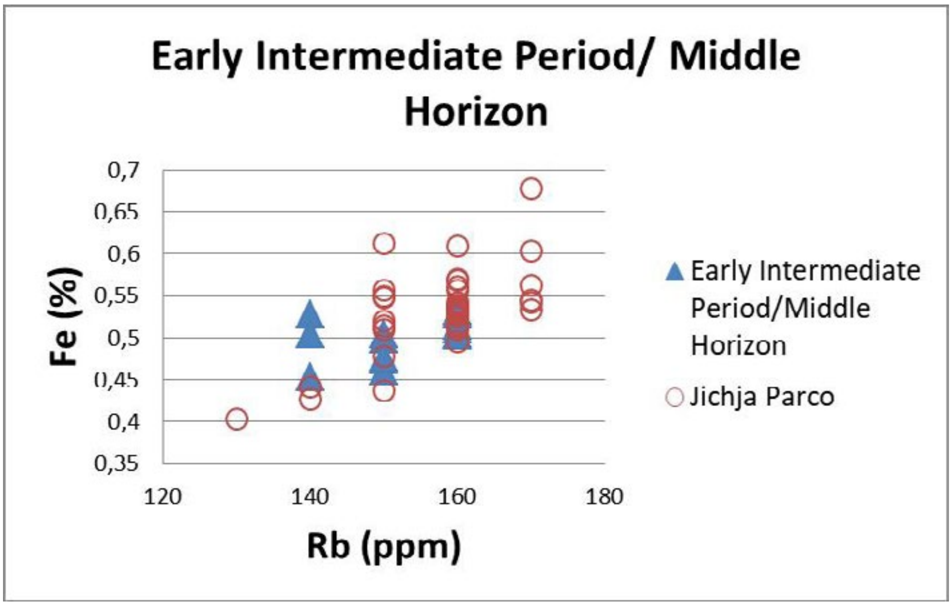


Fig. 72: Plot of Fe (%) versus Rb (ppm) for 16 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: M, B. Gräfingholt).

6.3.6.14 Early Horizon/ Late Horizon

Seventeen obsidian projectile points belonging to the sub-type groups 1 J[579] and 5 A variant II[580] were analyzed using the pXRF. These specimens could not be assigned to a certain culture in the Nasca Palpa region instead only a rough association to the ceramic bearing periods in the region could be carried out. The trace element plots of Sr/Rb and Fe/Rb for this series are not consistent. (Fig. 76 and Fig. 77)

On the one hand the Fe/Rb plot may indicate an origin of five specimens from a so far not know obsidian source. On the other hand, the comparison to the Sr/Rb plot does not support this hypothesis because here all but one artifact seem to derive from Jichja Parco.

Point 1108 (Fig. 78) – a surface find from PAP-1108 which is associated to Late Paracas[581] – does not fall into the geochemical composition of Jichja Parco in both plots. Neither can it be associated to another known source of obsidian in Southern Peru. In order to highlight

579 Gräfingholt, 2011, p.38.
580 Gräfingholt, 2011, p.89.
581 Reindel, Solis Quintero and Isla Cuadrado, 2010, p.327.

Fig. 73: Obsidian projectile points used by the Wari culture in the Nasca-Palpa region (graphic: DBM, B. Gräfingholt).

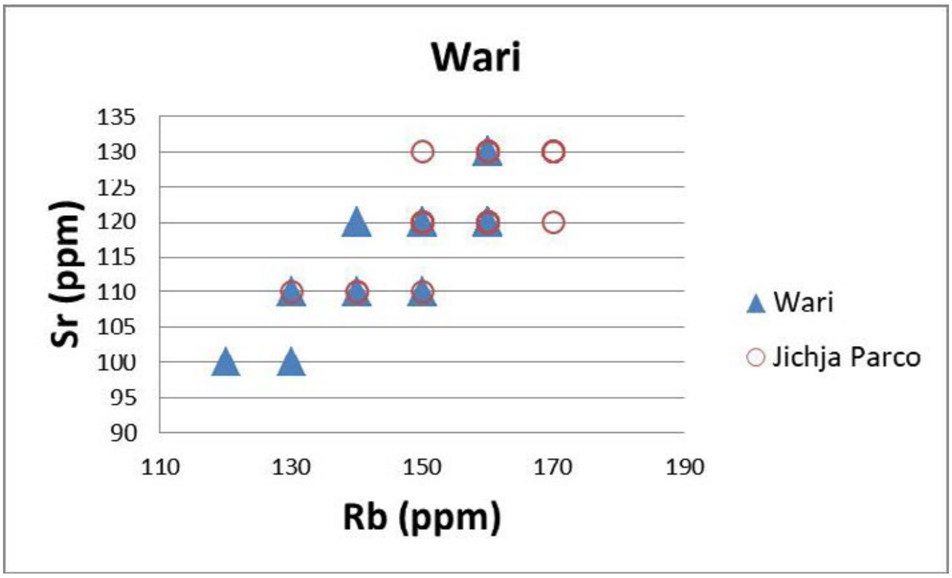


Fig. 74: Plot of Sr (ppm) versus Rb (ppm) for 30 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

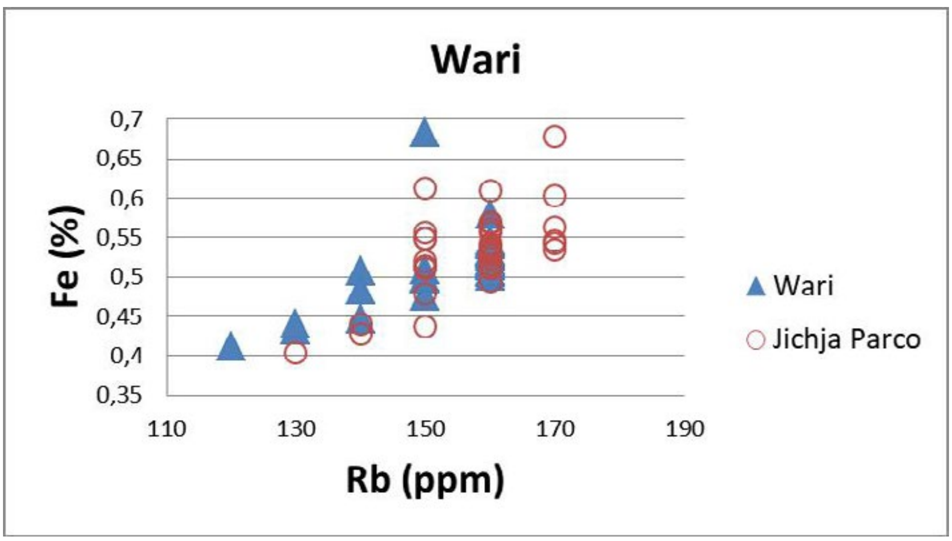


Fig. 75: Plot of Fe (%) versus Rb (ppm) for 30 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

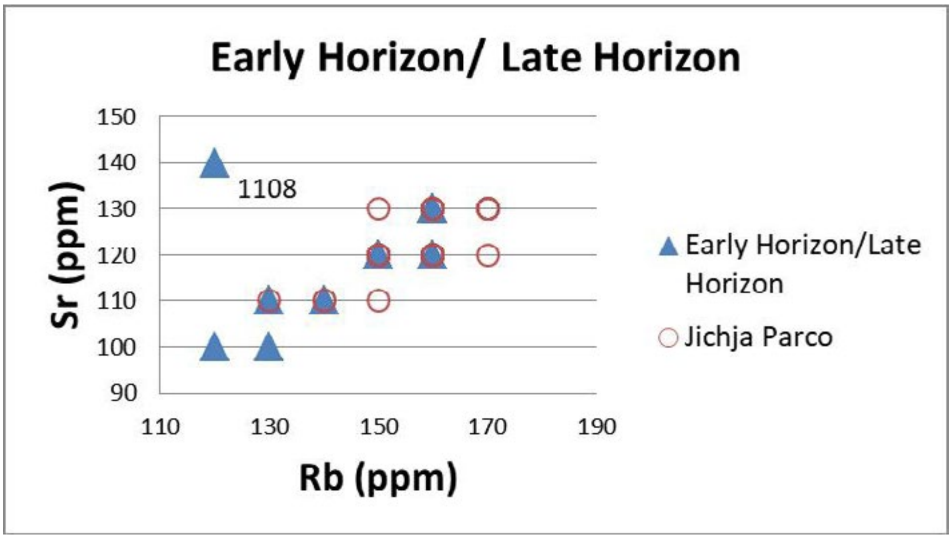


Fig. 76: Plot of Sr (ppm) versus Rb (ppm) for 17 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

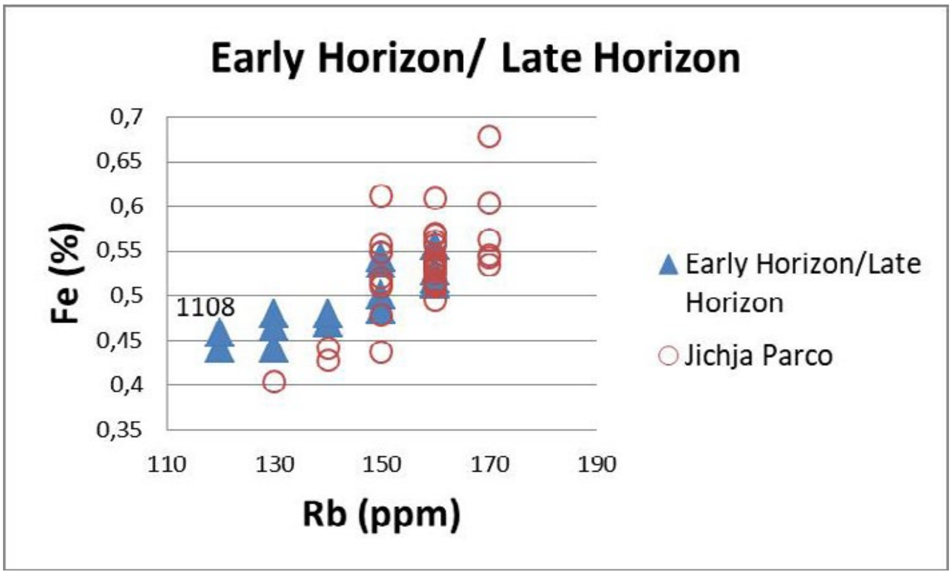


Fig. 77 Plot of Fe (%) versus Rb (ppm) for 17 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (Graphic: DBM, B. Gräfingholt).

Fig. 78 PAP-1108. Obsidian projectile point 1108 from the surface of PAP-1108 where no diagnostic ceramic was found (graphic: DBM, B. Gräfingholt).

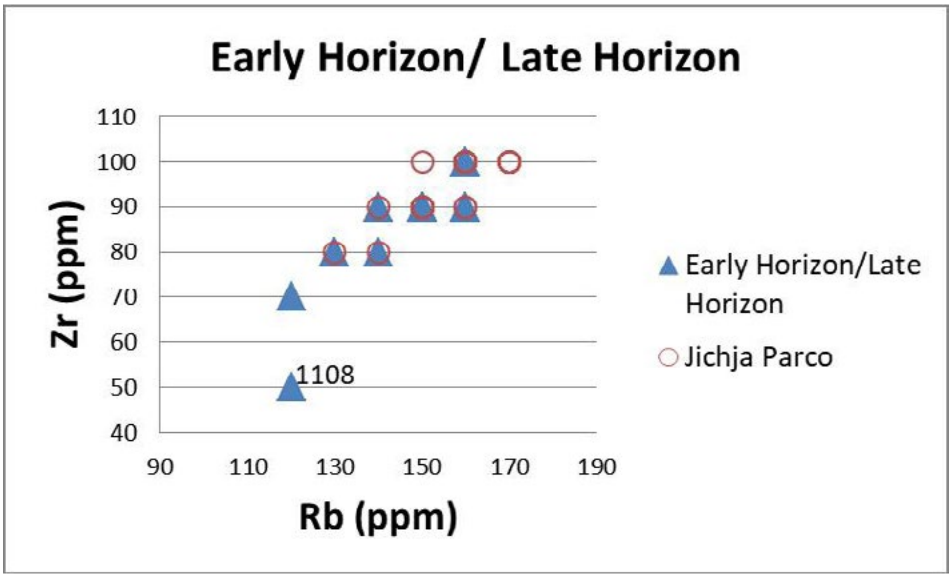


Fig. 79: Plot of Zr (ppm) versus Rb (ppm) for 17 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

the deviation of specimen 1108 a third plot of Zr/Rb was taken into consideration (Fig. 79).

Though this point derives from a highland site a chronological setting into the Inca period seems possible. Therefore, the trace element concentration of three Ecuadorian obsidian sources Mullumica[582], Yanaurco-Quiscatola[583] and Callejones[584] were compared. These deposits are located in the Sierra de Guamaní at an altitude of 3,900 to 4,200 m a.s.l. and can be found within a 15 km radius away from each other.[585] The trace element compositions presented for the Mullumica[586] and Yanaurco-Quiscatola[587] deposits clearly indicate that an origin from these sources can be excluded. According to the Sr (ppm) and Fe (%) data presented by Ogburn (2011, p.110) and Ogburn, et al. (2009, p.749) the third source mentioned – Callejones – could be a possible origin of the raw material used to produce specimen 1108. Nonetheless the Zr (ppm) element concentration of the artifact ranges below the given data for the source. Therefore, further analysis of this artifact seems imperative to clarify the proposed origin of the raw material from the Ecuadorian source.

6.3.6.15 Early Horizon/ Late Intermediate Period

Only five obsidian projectile points belonging to type 5C VIV[588] were analyzed for this series. The artifacts were mostly recovered during surveys and cannot be associated with a certain culture only a broad chronological setting between the Early Horizon and the Late Intermediate Period could be made.[589] The geochemical analysis reveals that four points derive from Jichja Parco and that specimen 556_4 does not fall within the characteristic trace element concentration of this source (Fig. 80 and Fig. 81).

This point found on the surface of PAP-556 where no diagnostic ceramic or other traces of chronological markers were found.[590] The Sr/Rb plot indicates an origin of specimen 556_4 from the Cerro Huenul source. In order to clarify this picture a third plot of Zr/Rb was added (Fig. 82). This plot proves the assumption that the projectile point derives from Cerro Huenul.

6.3.6.16 Late Horizon

Specimen 1027_1 (Fig. 83) was found on the surface of the Inca site PAP-1027 in the Altiplano region.[591]

Apart from the archaeological context, this artifact does not match with the geochemical trace element composition of the Jichja Parco obsidian source and does not correspond to the trace element composition of other sources in southern Peru.

The results for this specimen presented in the Sr/Rb and Fe/Rb plot highlight the deviation of this artifact from the Jichja Parco source (Fig. 84 and Fig. 85). Though the trace element concentration of this point does not match with sources in southern Peru, it was imperative to compare its trace element composition to other known sources. Therefore, in order to locate the possible origin of the raw material used to produce this Late Horizon projectile point the geochemical trace element composi-

582 Burger, et al., 1994.
583 Asaro, et al., 1994.
584 Bigazzi, et al., 1992.
585 Bellot-Gurlet, Dorighel and Poupeau, 2008, p.273.
586 Burger, et al., 1994, p.235.
587 Asaro, et al., 1994, p.261.
588 Gräfingholt, 2011, p.98.
589 Gräfingholt, 2011, p.99.
590 Gräfingholt, 2011, p.98.
591 Gräfingholt, 2011, p.87.

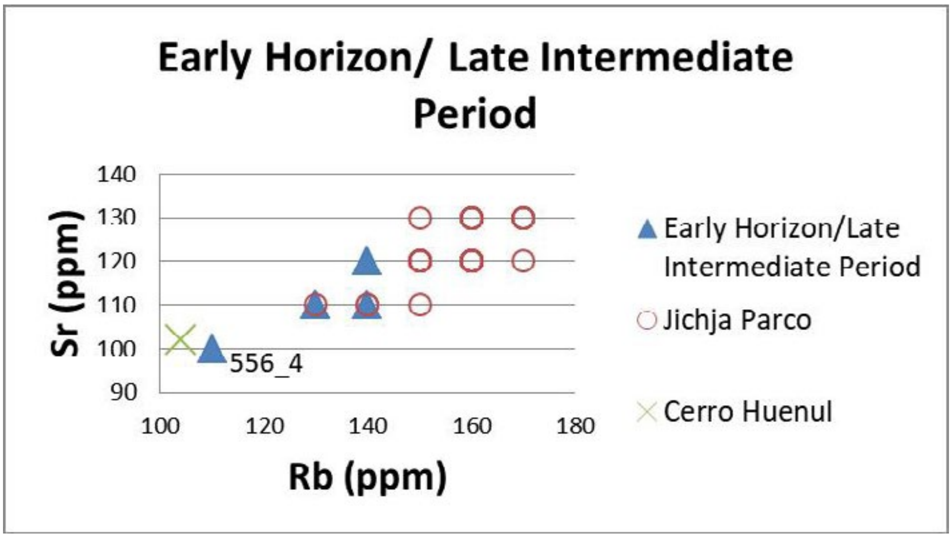


Fig. 80: Plot of Sr (ppm) versus Rb (ppm) for five obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Cerro Huenul source from XRF presented by Giesso et al. (2011) (Graphic: DBM, B. Gräfingholt).

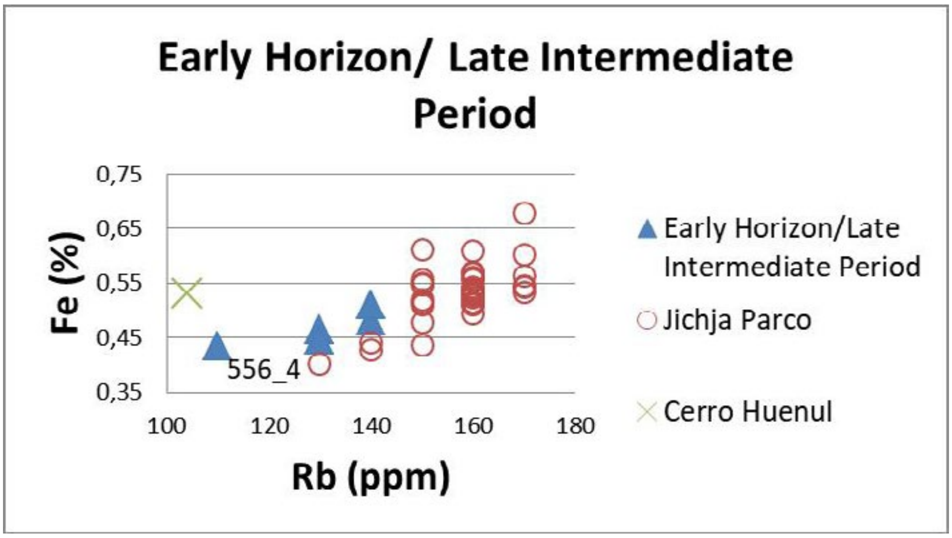


Fig. 81: Plot of Fe (%) versus Rb (ppm) for five obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

tion of three Ecuadorian obsidian sources Mullumica[592], Yanaurco-Quiscatola[593] and Callejones[594] were sampled. These deposits are located in the Sierra de Guamaní at an altitude of 3,900 to 4,200 m a.s.l. and can be found within a 15 km radius away from each other.[595] The trace element compositions presented for the Mullumica[596] and Yanaurco-Quiscatola[597] deposits clearly indicate that an origin from these sources can be excluded. According to the trace element concentration of Sr (ppm) and Fe (%) presented by Ogburn (2011, p.110) and Ogburn, Connell and Gifford (2009, p.749) the third source mentioned – Callejones – could be a possible origin of the raw material used to produce specimen 1027_1. Nonetheless, the Zr (ppm) element concentration of the artifact ranges slightly below the given data for the source. Therefore, further analysis of this artifact seems imperative to prove the assumed origin of the raw material from the Ecuadorian source.

592 Burger, et al., 1994.
593 Asaro, et al., 1994.
594 Bigazzi, et al., 1992.
595 Bellot-Gurlet, Dorighel and Poupeau, 2008, p.273.
596 Burger, et al., 1994, p.235.
597 Asaro, et al., 1994, p.261.

6.3.6.17 Undated obsidian artifacts

Objects that could not be assigned to a certain period were summarized under this group. Seventy-five belonging to

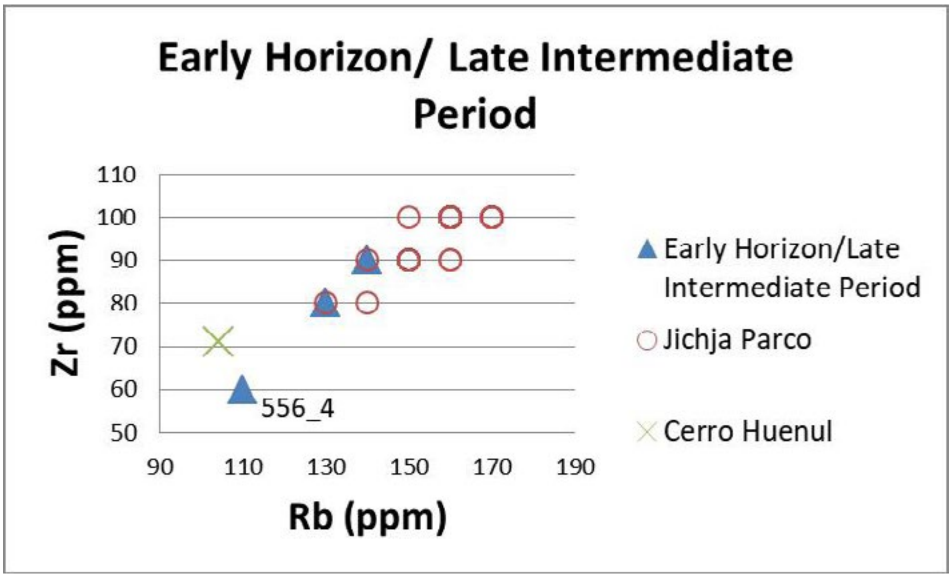


Fig. 82: Plot of Sr (ppm) versus Rb (ppm) for five obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

Fig. 83: PAP 1027. Late Horizon obsidian projectile point found on the surface of site PAP-1027 in the highlands (graphic: DBM, B. Gräfingholt).

the obsidian projectile point types 1 D, 1 D variant I, 1 I, 1 J variant I, 2 F variant II, 2 G, 2 I variant I, 3 C variant I, 3 C variant II, 3 D, 3 E variant I, 3 H, 3 I, 3 I variant I, 3 I variant II, 3 I variant III, 5 B variant I, 5 C variant I, 5 C variant III, 5 D, 5 D variant I, 5 E, and 8 A[598] were analyzed using the pXRF. To these the results of fifteen scrapers were added. These artifacts derive from coastal as well as from highland sites in the research area, represent an immense variety of artifacts and probably cover the whole period of human occupation in the area. The geochemical results for this group of artifacts indicate that at least six specimens may not derive from Jichja Parco (Fig. 86 and Fig. 87).

According to the Sr/Rb plot the origin of six obsidian artifacts from Jichja Parco is in question. Point 800_4 was found on the surface in Cabracancha (PAP-800) – a Middle Paracas dating was proposed for this site.[599] Specimen 785_2 was found on the surface of PAP-785 in the highlands.[600] Specimen 365 was found on the surface near a geoglyph in combination with Nasca 5 ceramic.[601] Specimen 398 derives from a survey on PAP-398 that was dated using Middle Nasca ceramic.[602] Specimens 4157_1 and 4157_2 were excavated in Huayuncalla in TP1 Capa C U.A1, a Wari setting may be possible but could not be confirmed though no diagnostic ceramic was excavated in that layer.[603] By comparing the results to the Fe/Rb plot

598 Gräfingholt, 2011, pp.26, 29, 37, 39, 53, 54, 60, 70, 71, 75, 79, 80, 81, 82, 83, 93, 96 97, 99, 100, 101, 103.

599 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.164.

600 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.212.

601 Reindel, Isla Cuadrado and Tomasto Cagigao, 2001, Appendix II, p.249-250.

602 Reindel, Isla Cuadrado and Tomasto Cagigao, 2001, Appendix II, p.267-268.

603 Tomasto Cagigao, Reindel and Isla Cuadrado., 2009, p.164.

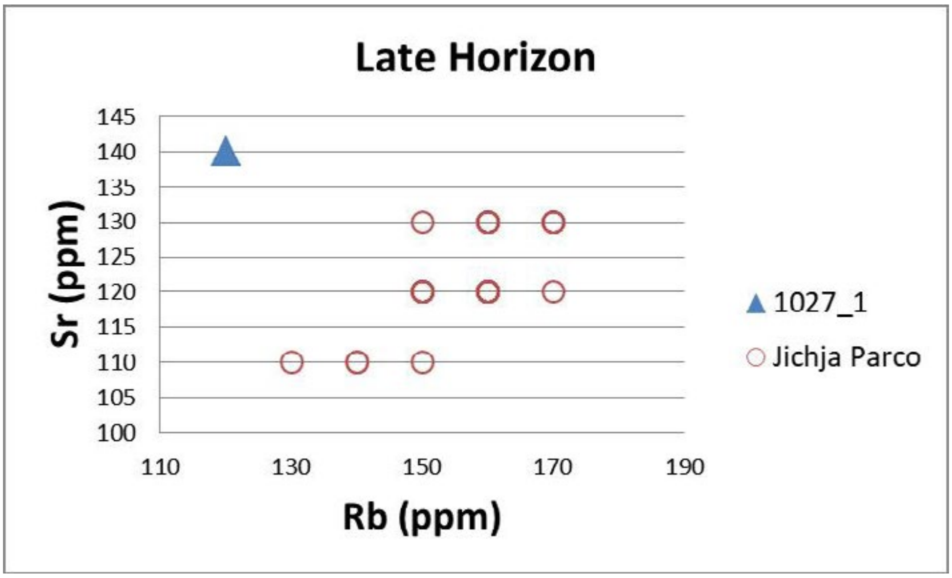


Fig. 84: Plot of Sr (ppm) versus Rb (ppm) for specimen 1027_1 and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

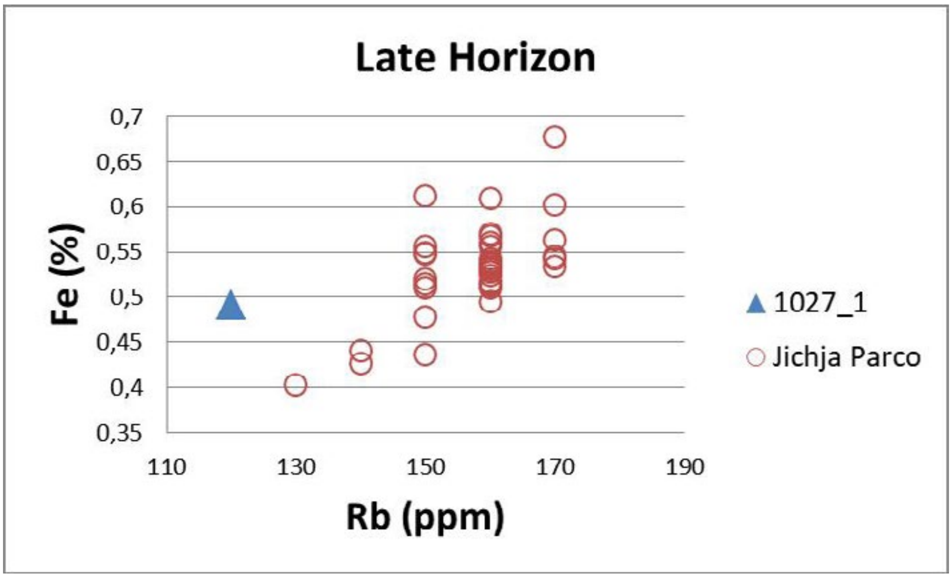


Fig. 85: Plot of Fe (%) versus Rb (ppm) for specimen 1027_1 and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis (graphic: DBM, B. Gräfingholt).

these six – before mentioned – artifacts again do not fall within the geochemical trace element composition of Jichja Parco, whereby all other objects that show a diverging composition in the Fe/Rb match with Jichja Parco in the Sr/Rb plot. In order to confirm this result a third plot of Zr/Rb is added (Fig. 88).

After reviewing all three plots, it can be stated that specimens 4157_2, 800_4 and 785_2 do not fully match the trace element composition of Jichja Parco, but neither can they be assigned to another known source. Though the deviation from Jichja Parco in the Sr/Rb and the Zr/Rb plot is within the calculated error, these three artifacts may derive from the Jichja Parco source. Specimens 4157_1, 365 and 398 match the trace element composition of the Cerro Huenul source presented by Giesso, et al. (2011, p.8) Therefore, it can be assumed that the raw material used to produce theses three artifacts derive from the Cerro Huenul source in the highland region of northern Argentina. The remaining 69 artifacts could securely be assigned to the Jichja Parco obsidian source in the Huanca Sancos region – demonstrating how strongly the inhabitants of the Nasca-Palpa region relied on that source to satisfy their need for obsidian.

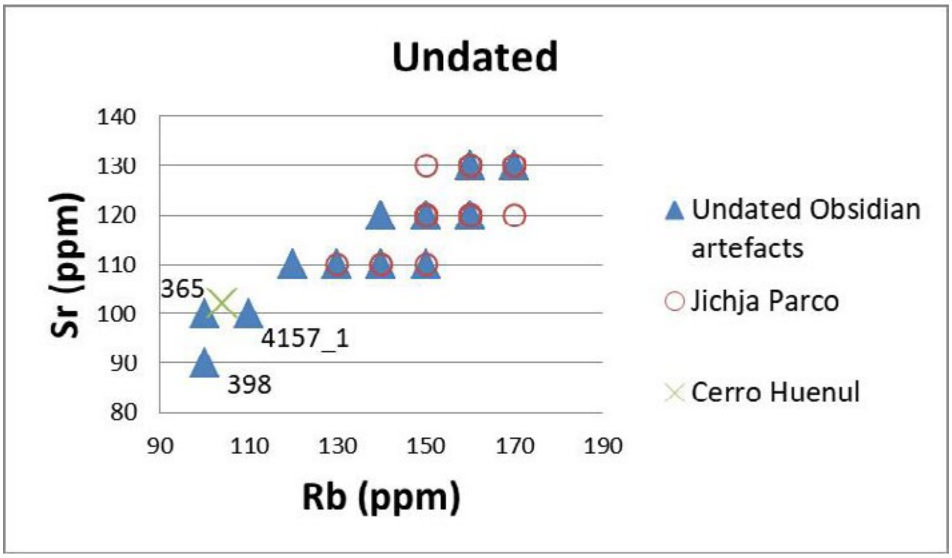


Fig. 86: Plot of Sr (ppm) versus Rb (ppm) for 75 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

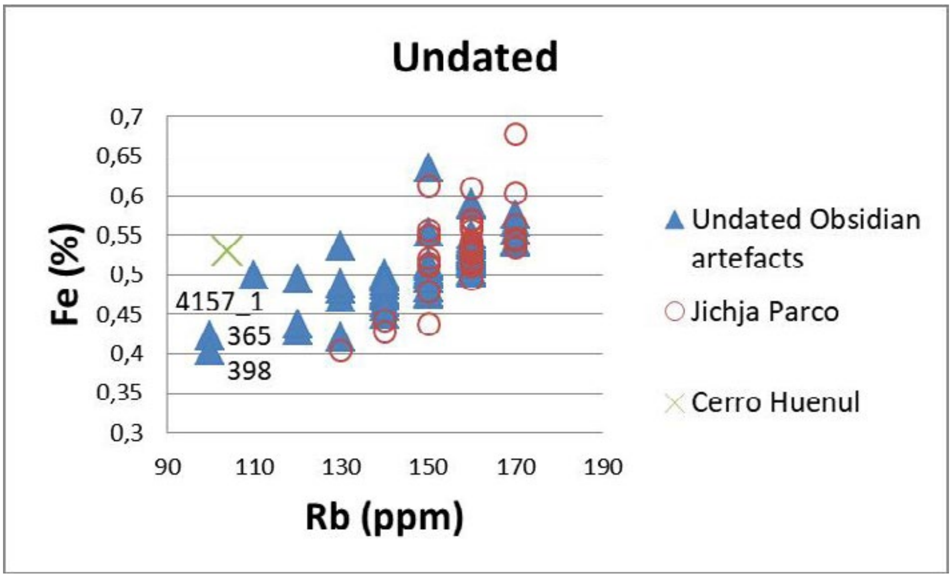


Fig. 87: Plot of Fe (%) versus Rb (ppm) for 75 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

6.4 Discussion

As demonstrated by the results of the geochemical trace element analysis from the pXRF and the chronological differentiation, 342 of the obsidian objects found in the Nasca-Palpa area derive from the obsidian source Jichja Parco in the Huanca Sancos region. The result presented for the 40 samples from the Jichja Parco obsidian source indicate that the so far postulated trace element concentration means and standard deviations for the Quispisisa/ Jichja Parco source that have been proposed by Glascock, speakman and Burger (2007, p.540 tab.II) and Tripcevich and Contreras (2011, p.127 fig.5) have to be supplemented by the data presented for the obsidian quarry Jichja Parco in the current study (Tab. 4). Additionally, the results of this study revealed that from the Early Horizon onward the inhabitants of the research area had access to other sources which has been demonstrated by the diverging trace element concentration of 23 obsidian artifacts found in the Nasca-Palpa area.

The first settlers in the research area during the Archaic and Initial Period exclusively used the obsidian source Jichja Parco in the Huanca Sancos region as a raw material exploitation site. But already in the Early Horizon the inhabitants of the research area were able to use obsidian that did not originate from Jichja Parco.

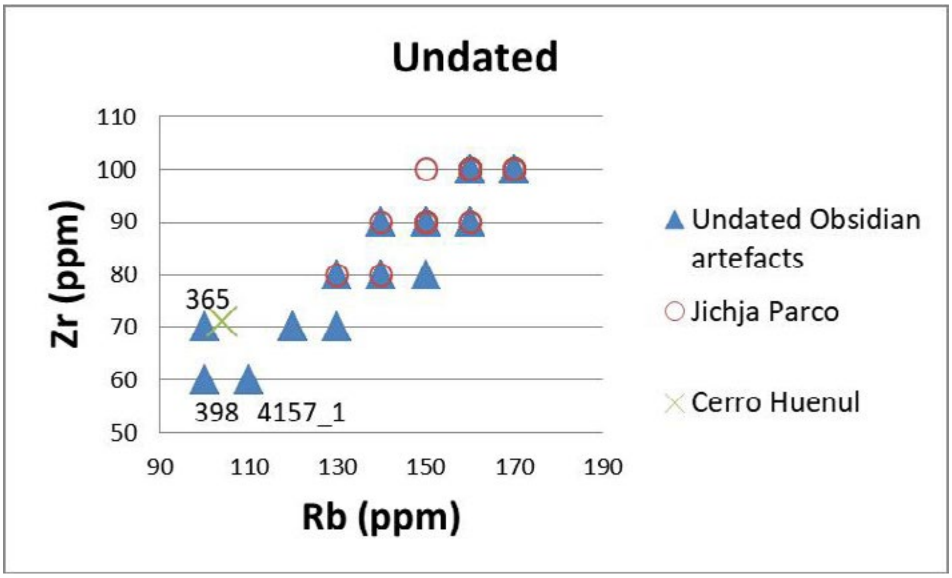


Fig. 88: Plot of Zr (ppm) versus Rb (ppm) for 75 obsidian objects and 40 samples from the Jichja Parco obsidian quarry from pXRF analysis combined with the results for the Cerro Huenul source from XRF presented by Giesso, et al. (2011) (graphic: DBM, B. Gräfingholt).

Due to the geochemical trace element concentration of specimen 4196_1 dating to Late Paracas[604] it is most likely that the raw material was exploited at the Puzolana source located in the highland region of Ayacucho. Though Glascock, Spakman and Burger (2007, p.536) stated that obsidian from this source is rarely found in archaeological excavations outside of Ayacucho, this artifact must be regarded as a very special item. Furthermore, the burial context has to be taken into account, which demonstrated that the ten obsidian projectile points offered to the decedent belonged to a unique assemblage of obsidian offerings.[605] The results presented for specimens 770_5 from Qechqalla (PAP-770) associated to a Middle or Late Paracas context in the highlands[606], specimen 828_4 from the surface of PAP-828 in the highlands associated with Early Horizon/ Late Intermediate Period ceramic[607], specimens 800_2 a surface find from Cabracancha (PAP-800) that was dated to Middle Paracas[608], specimen 586 from the surface of PAP-586[609] and specimen 3855 from Cutamalla dated to Ocucaje 6-7[610] indicates that an access to the Cerro Huenul source in Argentina existed during the Early Horizon. Specimen 770_5 has to be regarded as a direct import from the south, as this type of obsidian projectile point is unique in the research area and cannot be associated to the common tool-kit used by the hunters and warriors of the Nasca-Palpa area. Six obsidian artifacts do not fall within the trace element concentration of Jichja Parco and cannot be securely assigned to another source. Points 785_1 and 785_2 are surface finds from PAP-785[611], point 2280 derives from Jauranga where it was excavated in layer E U 2 R U.A. 3 that was dated using Ocucaje 8 ceramic[612], specimen 3823_2 excavated in Cutamalla (PAP-767) in layer A-1 U 1 R Hallazgo 1 dating to Middle Paracas[613], point 800_4 was found on the surface in Cabracancha (PAP-800) – a Middle Paracas dating was proposed for this site[614] and projectile point 1057_3 found during a survey on site PAP-1057 where overall Late Paracas and Early Nasca occupation was found.[615] Point 1108 found in the highlands on PAP-1108 points into another geographical region. This Late Paracas point may derive from the Callejones source in Ecuador and connects the research area with the origin of a highly valued exchange product of the pre-Columbian periods in South America: the Spondylus shell.[616] Combined these point further support the assumption that the inhabitants of the research area did not only rely on the known obsidian source Jichja Parco in the highlands which was relatively easy to reach from the Nasca-Palpa area but also obtained raw materials from outside their cultural hemisphere.

Summing up these fourteen artifacts proves that a long-distance exchange of raw material took place during the apogee of the Paracas culture in the Nasca-Palpa area and that the inhabitants of the research area had access to external obsidian sources that do not match with the trade routes and patterns so far postulated for obsidian consumption in southern Peru.[617]

604 Tomasto Cagigao, Reindel and Isla Cuadrado, 2009, p.141.
605 Tomasto Cagigao, Reindel and Isla Cuadrado, 2009, p.141.
606 Tomasto Cagigao, Reindel and Isla Cuadrado, 2007, p.280-283.
607 Reindel, Solis Quintero and Isla Cuadrado, 2008, pp.181-182.
608 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.16.4
609 Gräfingholt, 2011, p.91.
610 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.135.
611 Gräfingholt, 2011, p.77.
612 Reindel, Solis Quintero and Isla Cuadrado, 2004, p.21.
613 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.122.
614 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.164.
615 Gräfingholt, 2011, p.43.
616 Paulsen, 1974, pp.599-602; Hosler, 2009, pp.189-190.
617 Eerkens, et al., 2010.

A similar picture can be drawn for the Early Intermediate Period. It was possible to assign projectile point 2411 that was excavated in Jauranga (PAP-150)[618] to the Lisahuacho obsidian source in the Aymara's region.[619] This point proves that a connection between Jauranga and the Aymara's region existed during Early Nasca on at least one occasion and that the inhabitants of the research area did use other sources than Jichja Parco to satisfy their need for the desired raw material to produce tools and weapons.

The ties to the south, which existed during the Early Horizon, continued into the Early Intermediate Period. The trace element concentration of the raw material that was used to produce the following specimens:

- specimen 19, which was found during a survey on PAP-19, where apart from the projectile point mainly Nasca ceramic was found[620],
- specimen 365, which was found on the surface near a geoglyph in combination with Nasca 5 ceramic[621],
- projectile point 398, which derives from a survey on PAP-398 that was dated using Middle Nasca ceramic[622] and
- specimen 17, that was found on the surface near Geoglyph 468 PAP-17, which was probably constructed during the Early Intermediate Period[623]

matches the trace element composition of the Cerro Huenul source presented be Giesso, et al. (2011, p.8). Therefore, it can be assumed that the raw material used to produce these four artifacts during the Early Intermediate Period derives from the Cerro Huenul source in the highland region of northern Argentina. The same holds true for specimen 556_4, which could not be assigned to a certain time period due to the lack of diagnostic ceramic found on site PAP-556.[624]

In comparison to the Early Horizon the access to external obsidian sources declined and demonstrates a concentration on the local source Jichja Parco as well as a compartmentalization of the research area from external influences.

In the Middle Horizon the limited import of raw materials that existed from other sources than Jichja Parco such as Cerro Huenul, Puzolana and Lisahuacho ceased. Parallel to the decline of the Nasca culture and the shift of the settlement centers to the highlands – which ultimately led to the complete abandonment of the coastal area during the Middle Horizon[625] – a concentration on the Jichja Parco obsidian source manifested and probably the inhabitants of the research area exploited no other sources during the Middle Horizon. The only hint that may indicate a deviation from this assumption was given by the trace element composition of specimens 4157_1 and 4157_2, which were excavated in in Huayuncalla in TP1 Capa C U.A1.[626] For specimen 4157_1 an origin from the Cerro Huenul obsidian source in Argentina seems probable, and the trace element concentration of specimen 4157_2 does not match with any known source in the Andean region, but as no diagnostic ceramic was excavated in that layer, a Middle Horizon setting can only be assumed.

Due to the limited amount of obsidian projectile points from the Late Horizon a very special emphasis must be laid on specimen 1027_1 from site PAP-1027. Due to the Inca context postulated for site PAP-1027[627] and the diverging trace element concentration of this artifact, raw material sources from outside southern Peru were taken into consideration as possible exploitation sites. The data given indicate that this object may derive from the Callejones obsidian source[628] in Ecuador. This would imply that this artifact was transported into the research area during the Inca rule of the territory and after the submission of the Cayambe by the Inca, who controlled the Callejones source before the invasion of the Inca army.[629] The raw material or finished projectile points were probably given to the Inca army as a tribute by the local people who had access to the Callejones obsidian source[630] and were then carried into the research area as part of the army equipment.

These results impressively demonstrate that although the overwhelming majority of 342 obsidian artifacts found in the research area derives from the Jichja Parco obsidian source; a considerable number of obsidian artifacts were introduced into the Nasca-Palpa region from different and above all exceptional sources such as Cerro Huenul in Argentina and probably Callejones in Ecuador. The 12 Paracas and Nasca artifacts that were made of raw material that could derive from the Cerro Huenul source indicate that during the apogee of these cultures – especially during the Paracas rule of the region – external sources were accessible and contacts to the south existed. This could indirectly prove that a knowledge transfer for mining could have taken place and was handed down with these raw materials northward into the research area. Implying that the origins of the mining tradition encountered in the Palpa valley were passed on from the early mining centers in Chile – most likely during the Early Horizon as copper exploitation sites in Northern Chile can be dated to that time period.[631]

618 Reindel, Isla Cuadrado and De La Torre, 2004, Appendix IV, p.4.
619 Glascock, Speakman and Burger, 2007, p.537.
620 Reindel, 1998, Appendix III, p.31.
621 Reindel, Isla Cuadrado and Tomasto Cagigao, 2001, Appendix II, pp.249-250.
622 Reindel, Isla Cuadrado and Tomasto Cagigao, 2001, Appendix II, pp.267-268.
623 Reindel, 1998, Appendix III, p.31.
624 Gräfingholt, 2011, p.98.
625 Reindel, Stöllner and Gräfingholt, 2013, pp.301-302.

626 Tomasto Cagigao, Reindel and Isla Cuadrado, 2009, p.164.
627 Gräfingholt, 2011, p.87.
628 Ogburn, et al., 2009, p.749; Ogburn, 2011, p.110.
629 Ogburn, 2009, p.743.
630 Ogburn, 2009, p.750.
631 Salazar and Salinas, 2008, p.172; Salazar, et al., 2011a, p.124;

Therefore the results of this study not only highlight the immense importance of the raw material obsidian that was used and exploited over the whole time span of human occupation in the research area but also indicates that the trans-Andean mining tradition that was first encountered in Taltal (Northern Chile) and was undertaken by a hunter-fisher-mining Archaic society at the site San Ramon 15[632] could have been introduced into the Nasca-Palpa area during the Early Horizon by long distance exchange or via down the line trade of obsidian from the south.

6.5 pXRF for the sourcing of corroded metal artifacts

The effects of corroded metal artifact surfaces on XRF analysis were first discussed by Roberts[633] since then researchers have often viewed the enrichment in secondary metals such as tin, lead, or silver in the corrosion layer of copper alloy artifacts as problematic.[634] But often metal artifacts are inaccessible for researchers who want to conduct invasive analytical techniques such as Inductively Coupled Plasma Spectroscopy or Atomic Absorption Spectroscopy were it is indispensable to at least damage the object to a certain extent and in most of the cases export the objects to laboratories abroad.[635] As the pXRF analysis – which is always a surface composition analysis – is an analytical technique that penetrates into the sample between a few microns to a few mm depending on the composition of the sample and the energy emitted by the pXRF instrument[636], some researchers stated that without removing the corrosion layer it is impossible to measure the real composition of a metal.[637] Especially in the case of copper or copper-based artifacts where the corrosion layer of oxidized material often extends 30 microns.[638] Despite the concerns mentioned the use of pXRF in order to sample a great amount of copper-based artifacts non-destructively and to determine the element composition of these artifacts must be viewed as a great contribution to archaeological research in order to answer major archaeological questions.[639] Due to a preliminary test series with 28 corroded copper/copper alloys that compared the accuracy of a pXRF[640], ICP-MS and EDX-RF and outlined that the results of these three method matches to nearly 80%[641], the current study applied the methodology postulated by Prange, Modaressi-Tehrani and Demant (2016, p.248) to a greater number of artifacts. The current study had access to 199 pre-Columbian corroded metal objects from the research area in the Nasca-Palpa region that were analyzed using a pXRF of the Deutsches Bergbau-Museum Bochum. It was prohibited to remove the corrosion layer or extract samples for a detailed invasive analysis, in order to determine the lead isotope composition, which would have enabled the author to directly link the artifacts to the so far characterized copper mining districts in southern Peru[642]. Nonetheless, the chance to access these objects via a pXRF analysis prepared the ground to answer the question of the development of metallurgy in the Nasca-Palpa region.

6.5.1 Application of pXRF to archaeological metal studies in Peru

So far, the only documented application of pXRF analysis to pre-Columbian artifacts in Peru has been conducted by Speakman, et al. (2006) – regarding the date of this publication at the beginning of the 21st century –it is highly improbable that a pXRF was used. Therefore, the data that has been collected using the pXRF of the Deutsches Bergbau-Museum Bochumfor the study by the author represents the first true application of a pXRF analysis on copper-based artifacts in Peru.

6.5.2 Sampling strategy

During the fieldwork 2013 in Peru the author had the chance to access a body of 199 metal artifacts that were at that point being studied for an archaeometallurgical investigation by Castro de la Mata Guerra Garcia and Velarde Dellepiane (2013). This body represents all metal artifacts that were found to this date in the Nasca-Palpa region. It was a unique chance to study the metal artifacts non-destructively using the pXRF because an invasive analysis of the precious objects was forbidden. Therefore, no Pb isotope analysis could be conducted which would have enabled the author to compare the Pb isotope composition of the metal artifacts from the Nasca-Palpa area with the already existing Pb isotope results for the

Figueroa, et al., 2013, p.62.
632 Salazar et al., 2011b; Salazar, Borie and Oñate, 2013.
633 Roberts, 1960, pp.36-37.
634 Climent-Font, et al., 1998, pp.235-236; Delange, Meyohas and Aucounturier, 2005, p.109; Denker, et al., 2005, p.208; Dussubieux, et al., 2008, p.644; Hughes, 1993, p.6; Mantler and Schreiner, 2000, p.16; Nicholas and Manti, 2014, p.6; Swann, Fleming and Jaksic, 1992, pp.500- 501; Wadsak, et al., 2000 cited in Schulze, 2013.
635 Charalambous, Kassianidou and Papasavvas, 2014, p.207.
636 Dussubieux and Walder, 2015, p.170.
637 Geilmann, 1967, p.123; Lutz and Pernicka, 1996, p.316.
638 Dussubieux and Walder, 2015, p.170.
639 Charalambous, Kassianidou and Papasavvas, 2014, p.207; Prange, Modaressi-Tehrani and Demant, 2016, pp.247-248.
640 The Niton XL3t GOLDD pXRF device used by Prange, et al. (2016) has also been used by the author for the current study.
641 Prange, Modaressi-Tehrani and Demant, 2016, p.255.
642 Gunnesch, Bauman and Gunnesch, 1990; Kontak, et al., 1990; MacFarlane, 1990; MacFarlane and Peterson, 1990; Peterson, MacFarlane and Danielson, 1993; Lechtman, 1991; Lechtman and MacFarlane, 2005; Desaulty, et al., 2011; Stöllner, et al., 2013; Reindel, Stöllner and Gräfingholt, 2013.

pre-Columbian mining district of the Nasca-Palpa area[643], to the Andean ore lead isotope provinces defined by MacFarlane and Lechtman[644] and other existing lead isotope analysis of ores from Peru[645]. There is no doubt that a lead isotope analysis[646] in combination with the information from the trace elements of the objects would have been the most effective way to trace the origin and mining district for the ores that were used to produce the metal artifacts of the Nasca-Palpa area.[647] The before mentioned archaeometallurgical study[648] took samples from some metal artifacts of the assemblage of Nasca-Palpa metal objects. Numerous attempts were made by the author to gain access to these samples in order to reuse them for lead isotope analysis in Germany, but the Peruvian authorities granted no permission. It is imperative for the reconstruction of the exchange processes in the Nasca-Palpa area to analyze theses already taken samples and compare the lead isotope composition of the artifacts to the available data of the lead isotope composition of the Nasca-Palpa mining district.[649] Due to a diverging count of artifacts from the same archaeological context in the before mentioned study and the current study, only some results can be compared directly. Nonetheless, the undertaken study offers a unique change to cross-check some of the results gained by the pXRF.

6.5.3 Archaeological artifacts

The 199 metal objects (Tab. 4) that were accessible for this study all derive from the Palpa Archaeological Project that encircles the town of Palpa and the nearby slopes and plateaus as well as the upper and lower reaches of the river valley of the river Rio Grande, Rio Palpa and Rio Viscas,[650] as well as the Altiplano region around Laramate and Llauta.[651] All artifacts were excavated and found in the project area.[652] They represent the metal using cultures of Paracas, Nasca, Wari and LIP that flourish in the area from the Early Paracas (800–500 cal BC) up to the Late Intermediate Period (1180–1560 cal AD).[653] The metal object can be divided into the following groups of artifacts (Fig. 89): discs, tupus, tupus discoidal, tupus circular macizo, tupus triangular, rattles, textile applications, beats, weapons, tools and objects of other uses.[654]

6.5.4 Analytical instruments for the pXRF analysis

In the course of the fieldwork in Peru a Niton XL3t GOLDD was used to analyze the metal objects in Lima. The X-ray source of the analyzer was a 40-kV tube with Ag anode target, and the detector was a Peltier-cooled Si-PN diode covered by a 20-mm detector window. For the analysis the alloy mode with the Light Element Analysis Program (LEAP) and an aluminum filter for the determination of elements in light matrix samples was chosen. The voltage was 40 kV and the current 20 mA. This setting allows analysis down to phosphorus and the measurement of 33 elements (Sb, Sn, Cd, Pd, Ag, Mo, Nb, Zr, Bi, Pb, Au, As, Se, W, Zn, Cu, Ni, Co, Fe, Mn, Cr, V, Ti, Al, S, P, Si, Mg, Ba, In, Br, Pt, Ga).[655] Total measurement time was 30 s. Quantitative results are calculated, using fundamental parameters, by the software provided with the device. The aperture of the instrument is approximately 1 cm² and was totally covered by the sample. All metal artifacts were cleaned after excavation; no further preparation of the objects was conducted because even a small removal of the corrosion layer was forbidden.

6.5.5 Results

The given body of metal artifacts from the Nasca-Palpa area must be seen as a cross section of all metal and ceramic using and producing cultures in the research area. In the course of a previous study 29 artifacts out of the whole assemblage of documented metal objects were previously analyzed using Scanning Electron Microscopy (SEM)[656] – this offers a unique chance to cross-check some of the results gained by the current pXRF study. First of all, it is due to the few documented and excavated Late Intermediate Period sites e. g. Chillo (PAP-396), Pinchango Alto (PAP-114), Pinchango Bajo (PAP-115) and PAP 650[657] that only two metal artifacts date to this time period. It can be assumed that with an intensification of archaeological research that specially targets LIP sites more metal artifacts might be found, especially because of the very limited character of the conducted test excavations.[658] The two analyzed objects derive from Chillo (PAP-396).[659] The Middle Horizon is represented with 161 artifacts, 146 of which derive from the site Huayuncalla[660] in the highlands. Although the site has a relatively stable occupation from the Paracas until the Middle Horizon; metal artifacts were only documented in the Middle Horizon layers of

643 Stöllner, et al., 2013, p.126.
644 Lechtman and MacFarlane, 2005; MacFarlane and Lechtman, 2014.
645 MacFarlane, et al., 1990; Kontak, et al., 1990; Petersen, et al., 1993; Lechtman and MacFarlane, 2006.
646 Niederschlag, et al., 2003, p.67.
647 MacFarlane and Lechtman, 2014, p.2; Pernickab, 2014, p.250.
648 Castro de la Mata Guerra Garciá and Velarde Dellepiane, 2013.
649 Stöllner, et al., 2013, Fig. 22.
650 Unkel, et al., 2012, pp.2295-2296.
651 Tomasto Cagigao, Reindel and Isla Cuadrado, 2009; 2015.
652 Castro de la Mata Guerra Garciá and Velarde Dellepiane, 2013, p.2.
653 Unkel. et al., 2012, pp.2301-2302.
654 Castro de la Mata Guerra Garciá and Velarde Dellepiane, 2013, p.16-18.
655 Personal communication with Prof. Dr. Michael Prange, 2014.
656 Castro de la Mata Guerra Garcia and Vellarde Dellepiane, 2013, p.26.
657 Unkel, et al., 2012, p.2302.
658 Soßna, 2014, p.202.
659 Unkel, et al., 2012, p.2302.
660 Castro de la Mata Guerra García, Reindel and Isla Cuadrado, 2012, pp.205-206

Fig. 89: Metal object types analyzed with the pXRF (graphic: DBM, B. Gräfingholt). 1 – Disc 4799. 2 – Tupu discoidal 4840_1. 3 – Tupu circular macizo 4840_7. 4 – Tupu triangular 4920. 5 – Tattle 4840_2. 6 – Textile application 1190 C4. 7 – Weapon 4799_3. 8 – Tool 4706.

the excavation.[661] The remaining Middle Horizon objects were found on the highland sites Ocoro (PAP-751)[662] and Botigiriayoq (PAP-784)[663] as well as on sites near the town of Palpa Lucriche (PAP-150)[664] Los Molinos (PAP-93)[665], Parasmarca (PAP-196)[666], PAP-467[667] and Huaraco[668]. Still there is a considerable number of artifacts that have been manufactured during the Nasca (25) and even the Paracas (3) period. The Nasca metal objects derive from

661 Castro de la Mata Guerra Garcia and Vellarde Dellepiane, 2013, p.13.
662 Tomasto Cagigao, Reindel and Isla Cuadrado, 2009, pp.142-143.
663 Reindel, Solis Quintero and Isla Cuadrado, 2008, pp.135-136.
664 Reindel, Solis Quintero and Isla Cuadrado, 2008, pp.73-74.
665 Reindel and Isla Cuadrado, 2001.
666 Unkel, et al., 2012, p.2302.
667 Assigned to the Middle Horizon by Johny Isla, personal communication 2014.
668 Assigned to the Middle Horizon by Johny Isla, personal communication 2014.

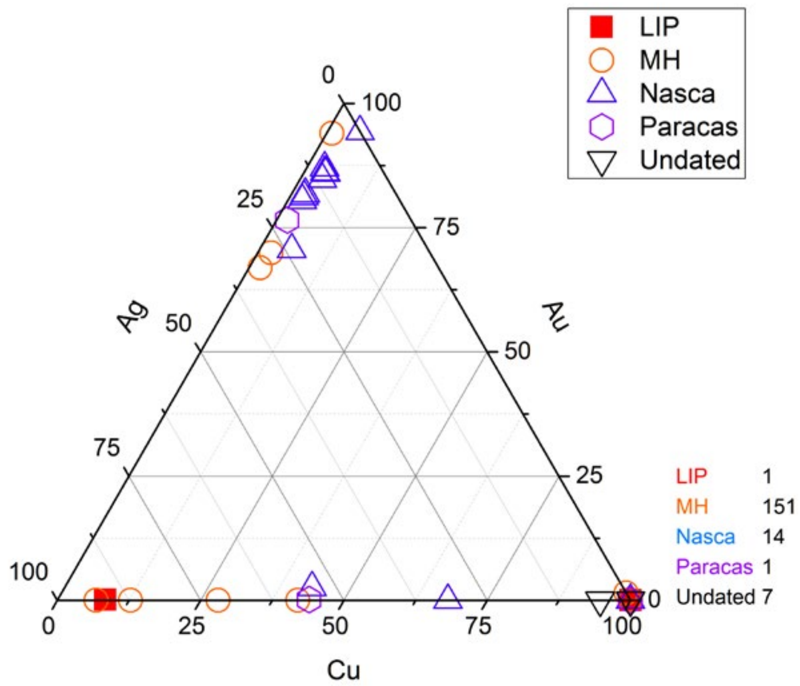


Fig. 90: Compositional results of pXRF analysis on Au, Ag and Cu of 199 archaeological metal artifacts recovered in the research area (graphic: DBM, B. Gräfingholt).

the sites Hanaq Pacha[669], Mollake Chico[670], Los Molinos (PAP-93), La Muña (PAP-79)[671], PAP-468 and Chillo (PAP-396)[672] in the surroundings of Palpa. In the course of the Paracas culture the use of metal was introduced into the Nasca-Palpa area as has been demonstrated very early in the archaeological research of the Paracas culture by metal artifacts in burial contexts.[673] The documented metal artifacts from Pariaccacca (PAP-806)[674] and Piedras Gordas Bajo (PAP-1056)[675] have been assigned to the Paracas culture as well as an outstanding golden ring from Mollake Chico dating to Ocucaje 3[676]. This ring was earlier identified as stylistically and technically comparable to three rings from the Ebnöther Collection in Switzerland.[677] A number of artifacts could not be assigned to a certain culture mostly because the objects derive from surveys and were found on the surface such as the artifacts from Maucallaqta (PAP-780)[678], Quyu (PAP-794)[679], PAP-128, Jauranga (PAP-150)[680], Lindero (PAP-808)[681], Cerro Ayapata (PAP-828)[682] and Piruruyocc (PAP-809)[683]. The analysis conducted with the pXRF revealed the geochemical composition of the artifacts´ surface and allows distinguishing the different types of ores and metals used to produce the artifacts (Fig. 90). As outlined before, due to the structure of the metal artifacts, which were mostly made of thin metal plates the results presented in the current study are not as precise as those that can be achieved with destructive samples. Nonetheless the results gained impressively demonstrate that the pXRF can be used in the field to rapidly characterize the geochemical composition of corroded metal artifacts and gain detailed information on the metallurgical know-how of the pre-Columbian cultures in the research area.

The metallurgical development in the research area can be reconstructed using the results of the pXRF analysis of the recovered metal artifacts. As outlined before, the use of metal artifacts in the Nasca-Palpa area already commenced during Early Paracas as the golden ring (1802) recovered from Mollake Chico (PAP-435)[684] impressively demonstrates as well as two other objects: a Cu needle (806) from PAP-806[685] and a Cu plate (1056) from PAP-1056[686]. An extractive copper metallurgy has so far been neglected for the Early Horizon[687] therefore it

669 Reindel, Isla Cuadrado and De La Torre, 2005, pp.23-24.
670 Reindel, Isla Cuadrado and De La Torre, 2004, Appendix 5, pp.2-3.
671 Reindel and Isla Cuadrado, 2001.
672 Reindel, Isla Cuadrado and De La Torre, 2004, Appendix 6, pp.2-3.
673 Root, 1949, p.12; Tello, 1959.
674 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.167.
675 Reindel, Solis Quintero and Isla Cuadrado, 2010, p.296.
676 Reindel, Isla Cuadrado and De La Torre, 2004, Appendix 5, p.3.
677 Schlosser, et al., 2009, p.436.
678 Tomaste Cagigao, Reindel and Isla Cuadrado, 2007, pp.294-295.
679 Tomaste Cagigao, Reindel and Isla Cuadrado, 2007, pp.310-311.
680 Reindel, Isla Cuadrado and De La Torre, 2004, Appendix 11.
681 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.169.
682 Reindel, Solis Quintero and Isla Cuadrado, 2008, pp.181-182.
683 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.170.
684 Reindel, Isla Cuadrado and De La Torre, 2004, Appendix 5, p.3.
685 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.167.
686 Reindel, Solis Quintero and Isla Cuadrado, 2010, p.296.
687 Lechtman, 2014, p.374.

is imperative that these artifacts should be re-examined concerning their material properties in order to clarify, if they were produced using a "true metallurgy"[688] or if a simple hammering out of native copper was applied. Due to the archaeological context of both artifacts, which were found on the surface, an uncertainty concerning the chronological setting remains.

The analyzed Nasca objects can be divided into two groups – a native copper group consisting out of 14 artifacts and a group of 10 artifacts that have been manufactured using noble metals. Two plates (1180, 1190) found at La Muña are exceptional in this noble metal group as they contain high amounts of silver and seem to be made out of a Cu-Ag alloy. Because there are no silver deposits in the research area, the raw material for these artifacts was probably imported from Northern Peru or the Lake Titicaca region, where rich silver deposits are located. These deposits have been identified as the suppliers of the silver that was used by the predecessor of the Paracas during the Nasca culture.[689] For the Paracas culture the use of silver has not been documented[690] but comparable alloys that typically contain more copper than silver have been documented from Virú and Chincha[691] and have also been found in the research area.[692] Copper-silver alloys are often found, as in the given context, as sheet metal with enriched silver surfaces through hammering in Ecuador, Peru and Mexico.[693] Another effect of the hammering is that the alloy becomes hard but retains its flexibility.[694] The remaining low-level concentration of silver in the artifacts of the Nasca noble metal group derive from the silver content in the gold ores used to manufacture the artifacts[695] in combination with the surface enrichment that is measured by the pXRF. These results require an additional investigation of the assumed copper-silver artifacts in order to verify the gained results. A detailed provenance study of all gold artifacts from the research area should be initiated in order to clarify the picture – to ensure a successful procedure a joint Peruvian-German research team should be concentrating on this task in order to avoid the lack of institutional support an independent study will probably face. Recently the possibilities and limitations of gold and silver provenance studies have been highlighted[696] and should be taken as a blueprint for an additional study. A first step in this direction has been taken by a previous study but the complete picture is still unclear. So far it can be stated that the gold that has been used to produce the Nasca artifacts has probably been mined to a great extend in the research are.[697] This is supported by the current study and the archaeological excavations of the pre-Columbian mining districts of Mollaque Grande and Saramarca (chapter 7). During the Middle Horizon the metallurgy reached a new level, as has been outlined before. This clearly manifest in the results gained by the pXRF analysis. Apart from the copper alloys dating to the Middle Horizon, especially the artifacts 3910, 3942 and 3933 from Lucriche (PAP-150) with very high Ag contents prove that the metallurgy at this point in time was diversified and that the inhabitants of the research area had access to distant silver rich ore deposits in the Altiplano region. A future provenance study should definitely sample artifact 4196 from PAP-454, in order to locate the origin of the Au used to produce this artifact, as the current study has not revealed clear traces of Middle Horizon mining activities in the research area. The same holds true for the Ag bracelet from Chillo dating to LIP.

Apart from the noble metal artifacts identified by the current study an overwhelming number of artifacts (178) were produced on the basis of copper – either in native form or in form of alloys such as Cu-As, Cu-Sn and Cu-As-Ni (Fig. 91).

Two assumed Paracas object and 14 Nasca objects have been produced using native copper. This demonstrates how important the copper deposits in the research area might have been as suppliers of the raw materials needed to manufacture these artifacts during the early stages of metallurgy. An earlier lead isotope analysis of metals from the research area has revealed that it is most likely that the local deposits were used by the pre-Columbian inhabitants.[698] The Middle Horizon artifacts are characterized by the introduction of copper arsenic alloys – a result that was anticipated due to the wide distribution and use of Cu-As alloys during that time period in the Andes.[699] Due to the deposit concentration of arsenic-bearing copper sulfide and iron sulfide ores in the Central Andes the production of copper-arsenic alloys was facilitated and it has been proposed that "depending upon the concentration of arsenic in the smelted metal that these alloys may be considered arsenical copper or arsenic bronze."[700] The measured arsenic concentrations in the artifacts reaches up to 11%, but this is definitely due to the surface enrichment caused by the corrosion process. It has been proposed that copper-arsenic alloys with a range of 0.5-2% As have been intentionally manufactured by the Andean metalsmith as they were aware of the increase in hardness and tensile strength. An As concentration under 0.5% would have had no effects on the alloy and therefore can be regarded as unintentional or as has been stated by Lechtman (1996, pp.509-510) "producing arsenical copper, low arsenic copper-arsenic alloys, or arsenic bronzes was inescapable once people began exploiting appropriate ore bodies". The presented data supports the assumption and perfectly fits into the

688 Lechtman, 1991, p.17.
689 Stöllner, et al., 2013, p.124.
690 Schlosser, et al., 2009, p.416.
691 Peterson and Brooks, 2010, p.58
692 Reindel, Stöllner and Gräfingholt, 2013, p.317.
693 Lechtman, 1996, p.510.
694 Lechtman, 1984, p.23.
695 Schlosser, et al., 2009, p.410.
696 Pernicka, 2014a.
697 Schlosser, et al., 2009, p.432.

698 Reindel, Stöllner and Gräfingholt, 2013, p.313.
699 Lechtman, 1991, p.72; Lechtman and Klein, 1999, p.497.
700 Lechtman, 2014, p.365.

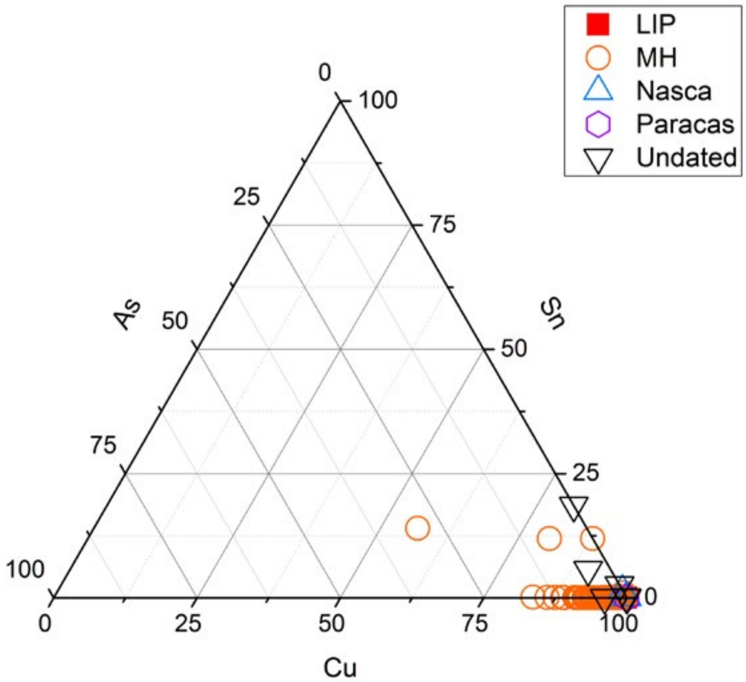


Fig. 91: Compositional results of pXRF analysis on Cu, Sn and As of 178 archaeological metal artifacts recovered in the research area (graphic: DBM, B. Gräfingholt).

pattern described so far of the metallurgical development in the Andes concerning the use of copper-arsenic alloys.

Thought-provoking results were gained for the metal objects 128, 808, 809 and 4709 – all four show a surface enrichment of tin (Sn) between 2 and 13%. Specimen 809 could be a ternary copper-arsenic-tin alloy; the remaining three objects show no traces of an arsenic surface enrichment therefore these must be labeled as copper-tin alloys. It has been stated by Lechtman and MacFarlane (2006, p.506) that "durante el Horizonte Medio y entre las esferas de interacción influenciadas por Tiwanaku y las influenciadas por Wari, existio una línea divisoria del bronce (a bronze divide) que puede ser documentada arqueológicamente y mediante análisis de laboratorio de artefactos de bronce." The documented results of the current study seem to question this statement as objects definitely made out of a Cu-Sn alloy have been found in a Wari controlled region. Furthermore, the given archaeological contexts of specimens 808 and 809 indicate that, although they have been found on the surface, a Nasca setting might be possible. The metal sheet 4709 derives from Huayuncalla and was excavated in Unidad 1 layer A-1 which is associated to the Wari culture. Specimen 128 is described as a "tumi de metal con madera" which means that the metal artifact is shafted with a wooden haft. It was found on the surface of Las Colcas (PAP-128) a site that at first sight seemed to be associate with the Middle and Late Horizon.[701] Recently the site was reinvestigated and a Middle-Late Ica and Inca context was proposed for this site.[702] Therefore the fact that a Cu-Sn alloy was found on this site is not surprising as the Inca tried to replace the frequently used Cu-As alloys in the territories they controlled by Cu-Sn alloys and transported cassiterite and tin metal to the north to produce tin bronze objects.[703] Only minimal traces of nickel were detected in some of the artifacts analyzed – but the rare ternary Cu-As-Ni bronze, which has so far been exclusively associated with Tiwanaku and San Pedro de Atacama[704] has probably been used in the research area during the Middle Horizon. A needle (4799_15) excavated in Huayuncalla in Unidad 2 layer C1 rasgo UA1 together with individuo 12[705] perfectly fits the defined element concentration of this rare southern alloy of round about 4% (As+Ni).[706] It has been proposed that this alloy was produced in the Altiplano or northwestern Argentina and that an interregional redistribution process was in place controlled by Tiwanaku.[707]

6.5.6 Discussion

In total, the given body of metal artifacts can be divided on the basis of the data presented into three groups of metals that were used by the cultures of the research area: native copper, copper alloys and noble metals.

Native copper and gold have been used from Early Paracas onward. During the Nasca culture the consumption

701 Reindel, 1998, Appendix III, p.172.
702 Soßna, 2014, p.203.
703 Lechtman, 1996, p.478.
704 Lechtman, 2006, pp.510-511.
705 Castro de la Mata Guerra Garcia, Reindel and Isla Cuadrado, 2012, p.349.
706 Lechtman, 2003, p.256.
707 Salazar, et al., 2011a, p.143.

PAP-Nr.	Instrument	Type	Cu (%)	Ag (%)	Au (%)	Ni (%)	As (%)
3933							
Castro de la Mata Guerra García/ Vellarde Dellepiane 2013	SEM	Lámina rectangular con orificio	5.18	79.78			
	pXRF		5.763	79.215			
4716							
Castro de la Mata Guerra García/ Vellarde Dellepiane 2013	SEM	Vástago de tupu (cabeza semitriangular)	97.95				
	pXRF		66.894				
4799							
Castro de la Mata Guerra García/ Vellarde Dellepiane 2013	SEM	Disco de oro		20.58	79.42		
	pXRF		1.127	18.304	39.37	0.107	
4920							
Castro de la Mata Guerra García/ Vellarde Dellepiane 2013	SEM	Vástago de tupu	95.8			0.72	
	pXRF		67.837				0.007
4840							
Castro de la Mata Guerra García/ Vellarde Dellepiane 2013	SEM	Disco de Oro		23.69	76.31		
	pXRF		1.865	22.235	56.115		
1802							
Castro de la Mata Guerra García/ Vellarde Dellepiane 2013	SEM	Anilo de Oro	0.66	6.05	91.17	0.43	
	pXRF		1.61	18.71	66.27		

Tab. 2: Comparison of selected geochemical trace elements gained by the pXRF from six metal objects found in the PAP with the results for the same objects gained by SEM published by Castro de la Mata Guerra Garcia and Vellarde Dellepiane (2013) (table: DBM, B. Gräfingholt).

of these metals continued and silver started to be used as well. From the Middle Horizon onward the use of copper alloys was established in the research area but native copper continued to be produced and consumed. Copper-arsenic alloys started to become the metal of choice for the Wari culture, as has been documented in other regions, but the postulated division between Wari and Tiwanaku concerning Cu-As and Cu-Sn bronzes[708] could not be demonstrated in the course of the current study, instead Cu-Sn bronzes have probably been used by the inhabitants of the research area during the Middle Horizon, which has been excluded so far by previous investigations.[709] Because a constant flow of high-valued Tiwanaku artifacts has been documented in the South Central Andes and Tiwanaku colonies have probably been established in the Arequipa Region, [710] recent investigations at the Wari center of Cerro Baul illustrate “that in the later phases (ca. 800-1000 AD) of the Middle Horizon there was significant interaction between Wari and Tiwanaku, including cohabitation of the upper sierra”[711], which implies that an exchange of Cu-Sn bronzes could have taken place at this location. A bronze briefly used in “Tiwanaku, the urban pilgrimage center on the Bolivian Altiplano at the southern limit of Lake Titicaca, and San Pedro de Atacama, the desert oasis on the western slopes of the north Chilean Andes”[712] – Cu-As-Ni has also been detected in the given body of metal artifacts.

This assumption is supported by the presented results of the SEM study. The authors stated that “esta aleación ternaria se encontró en la manufactura de un fragmento de tupu de cabeza semicircular con dos perforaciones en la parte superior, y en un pequeño ornamento vaciado con forma antropomorfa y pedúnculo.”[713] As described above one needle (4799_15) from Huayuncalla seems to be made out of a Cu-As-Ni alloy. In contrast to this result the previous study identified two objects “un fragmento de tupu de cabeza semicircular con dos perforaciones en la parte superior, y en un pequeño ornamento vaciado con forma antropomorfa y pedúnculo”[714] that have probably been manufactured using a ternary alloy of copper-arsenic-nickel. It would be interesting to directly compare the results, in order to cross-check the data of the artifacts that have trace of Ni in the pXRF measurement. Due to the different sub numbers, it was only possible to directly correlate the results of the SEM and the pXRF data for six

708 González, 2004, p.37; Lechtman and MacFarlane, 2006, p.506.
709 Lechtman, 2003, p.250.
710 Stanish, et al., 2010, pp.525-526.
711 Williams, 2001, p.81.
712 Lechtman, 2014, p.381.
713 Castro de la Mata Guerra Garcia and Vellarde Dellepiane, 2013, p.27.
714 Castro de la Mata Guerra Garcia and Vellarde Dellepiane, 2013, p.27.

artifacts in the current study. The highlight is obviously the above mentioned Paracas gold ring (1802), which was not only analyzed in the course of the current study, but also in the course of the previous investigation of metal artifacts from the research area. The semi-destructive analysis with the SEM estimated the following geochemical composition of the artifact: Au 91.17%, Ag 6.05%, Cu 0,66%.[715] In comparison the non-destructive analysis with the pXRF provided a slightly diverging result, due to the surface enrichment of the elements contained: Au 66.27%, Ag 18.71%, Cu 1.61%. Additionally it was possible to compare five other results of the previous study to the results gained from the pXRF.[716]

It is obvious that the results gained with the SEM are more precise and offer a more detailed insight into the compositional element concentration, but the advantages of the pXRF as a nondestructive method are striking (Tab. 1). First of all, the results presented for specimen 3933 (Fig. 92) are nearly identical, this is probably due to the material properties of this object.

Fig. 92: Lucriche PAP-150. Ag-Cu sheet with holes excavated in TP 3 layer B, associated to a Middle Horizon context (photo: DBM, B. Gräfingholt).

The thin silver sheet was not corroded and had a slight patina therefore the pXRF could be applied very effectively and must be regarded as the method of choice for artifacts of this type. For all other types the results gained by the SEM are more precise, mostly because of the surface enrichment and the corrosion that was measured by the pXRF. But regarding the final outcome both methods eventually produced comparable data. The given body of metal artifacts from the Nasca-Palpa region can be divided into three metal groups: native copper, copper alloys and noble metals. Due to the comprehensive analysis of all metal artifacts the current study offers a more detailed picture than the previous study and has given an insight into the early metal using history of the research area. As long, as no lead isotope analysis is conducted with the taken samples, it must be questioned whether a destructive analysis is necessary in this context, since both methods have produced comparable results.

715 Castro de la Mata Guerra Garcia and Vellarde Dellepiane, 2013, p.28.

716 The fact that most of the artifacts are stored in bags containing more than one object prevents the direct comparison of all analyzed artifact simply because it is not possible to correlate the results as soon as more than one object derives from one bag. All artifacts from one bag automatically are assigned to the same number. The sub numbers awarded vary between the previous study and the current one.

7 Results and Analysis of test excavation and geochemical analysis

7.1 Locations of the Test pits in the mining districts

7.1.1 Mollaque Grande

Mollaque Grande (Fig. 93) was identified in 2009 as one of the oldest pre-Columbian mining districts in the Palpa area by a team lead by Prof. Dr. Thomas Stöllner and Dr. Guntram Gassman.[717] The results gained during the 2009 campaign were indicating a Paracas occupation of the site and led to the assumption of a pre-Columbian mining context because of ceramic and stone mining tools found on the surface of the site.[718] To clarify this picture and to prove pre-Columbian mining by the Paracas culture on the site of Mollaque Grande three test pits were excavated on different spots on the hill slop. Since 2009, the site was worked intensively by modern mineros informales. Some new mines were opened and existing ones were further drifted. The main characteristic of Mollaque Grande is a mineralization zone that runs down the hill in a curved line from south-west to north-east.

Fig. 93: Mollaque Grande. Overview of the research area with adits following the curved mineralization running down the hill from south-west to north-east (photo: DBM, B. Gräfingholt).

Along the mineralization zone small mines are lined up like pearls on a string targeting the gold enriched vein (Fig. 94). An interesting fact is that this method of mining was described earlier by Petersen (2010, p.36) and can be found on the slopes of Descuelga, Nevado Illimani, and Micuipampa. A direct connection to pre-Columbian mining can be drawn when this typical method of ancient mining is encountered. Small adits in the softer rocks are opened and follow the mineralization up to the igneous and metamorphic rocks then another adit is opened further down which again targets the mineralization.

Fig. 94: Mollaque Grande. Typical pre-Columbian mining assemblage. Adits following a mineralization at the site Mollaque Grande (photo: DBM, B. Gräfingholt).

All of these small adits have recently been reopened but their origin must be assumed in pre-Columbian times. During spring 2014 the whole site looked as if the miners had just stopped working, but an old newspaper revealed that the work probably dated back to December 2012. A waste dump (PJ007/2009) documented in 2009[719] was chosen to be test pit 1 and was assigned: PE_14_MoGr_02_TP1. The mineros informales were stooping ores and added new material to the waste dump, but the status of preservation was still in the same condition as in 2009. Test pit 2 (PE_14_MoGr_13_TP2) was opened further down the hill in a waste dump in front of the portal of the biggest mine in the assemblage, which was documented in 2009 (PJ005/2009). At last test pit 3 (PE_14_MoGr_14_TP3) was opened. The site for this test pit was carefully chosen,

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717 Stöllner, 2011; Reindel, Stöllner and Gräfingholt 2013; Stöllner, et al., 2013.

718 Stöllner, et al., 2013, p.118.

719 Reindel, Stöllner and Gräfingholt, 2013, p.313 fig.14.14.

in order to prevent the excavation of modern mining waste and instead penetrated layers that are directly related with the pre-Columbian occupation of the site.

During the survey campaign 2018, the Mollaque Grande site was extensively documented using the Structure for Motion (SfM) method. The test excavations of the 2014 field campaign as well as the pit workings of recent small-scale mining were recorded. A total of 2,400 photos were taken from a wide variety of perspectives, which were then assembled into a 3D terrain model at the Deutsches Bergbau-Museum Bochum (Fig. 95). Mollaque Grande is the oldest known gold and copper mining zone in Peru to date and, due to the natural conditions, was an obvious choice for the SfM method. The mines and the test excavations are easily visible from the surrounding mountain tops and the terrain is relatively accessible. It was therefore possible to document the entire extraction zone of pre-hispanic and modern ore mining. Also, a pre-Hispanic, probably Paracas period processing terrace could be included in the documentation.


Fig. 97: Mollaque Grande. Recent test pit (photo: DBM, B. Gräfingholt).

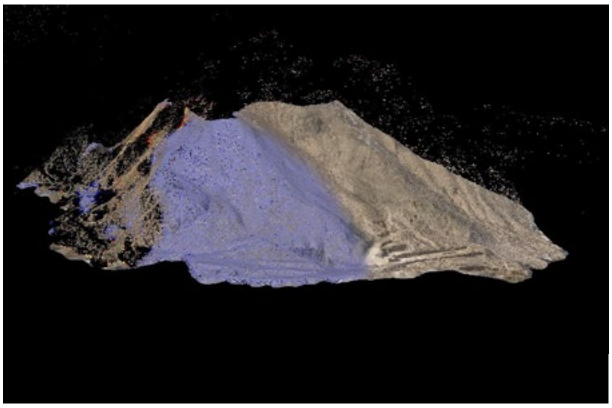
Fig. 95: Mollaque Grande. Hybrid view 3D terrain model Mollaque Grande (graphic: DBM, N. Schimerl).


Fig. 98: Mollaque Grande. Late Paracas/Initial Nasca settlement (photo: DBM, B. Gräfingholt).

A LIP site dominates the hilltop above the mining assemblage and a large settlement area (PE_14_MoGr_03) dating to Late Paracas (Ocucaje 8) is located right above the mines and the waste dump (Fig. 96).


Fig. 96: Mollaque Grande. Late Paracas settlement at the top of the hill, which contains the curved mineralization zone that was targeted by the ancient miners (photo: Deutsches Bergbau-Museum Bochum, B. Gräfingholt).

The whole hilltop is covered with terraces, storage pits, ceramic and stone walls indicating an intensive population density during a longer period of time. An interesting aspect that makes the site Mollaque Grande special is that settlements belonging to Late Paracas are normally found nearer to the valley floor.[720] Climbing up further a small modern test pit (PE_14_MoGr_04) was found that was recently opened (Fig. 97).

The next hilltop revealed another settlement (PE_14_MoGr_05) even larger than PE_14_MoGr_03. This settlement was dated to Paracas/Nasca and has also been described by Soßna as followed (2014, p.157): “The settlement S-26 at PAP-460 (Mollake Grande) differed from all other contemporaneous foothills villages by its location high in the mountains at 220 m above the valley floor. It is only accessible by a small and easy-to-control path departing from the large settlement S-859 (Buena Vista) located in the left margin of the middle Palpa valley. Given their close proximity, it seems likely that S-26 and S-859 formed a functional unit with most of the high-status buildings located at S-26 and the major common dwelling sectors at S-859.” (Fig. 98). Again, the location of the site Mollaque Grande in a considerable distance from the

720 Personal communication with John Isla Cuadrado on the site, 2014.

Fig. 99: Mollaque Grande. Muros de protección safeguarding the Late Paracas/Initial Nasca settlement from annual floods (photo: DBM, B. Gräfingholt).

The waste dump of PE_14_MoGr_02 can be regarded in the context of the settlement as a trash pit or leftovers that were washed down from the settlement, but on the other hand the mines and the mining tools found in 2009 strongly support a mining context of this waste dump. To prove these assumptions, three test pits were excavated on the site of Mollaque Grande (Fig. 100).

7.1.2 Saramarca

As documented in 2006[721] and 2009[722], the site Saramarca in the Viscas valley is still a gold mining center and basically all mines are operated by the locals living in the modern

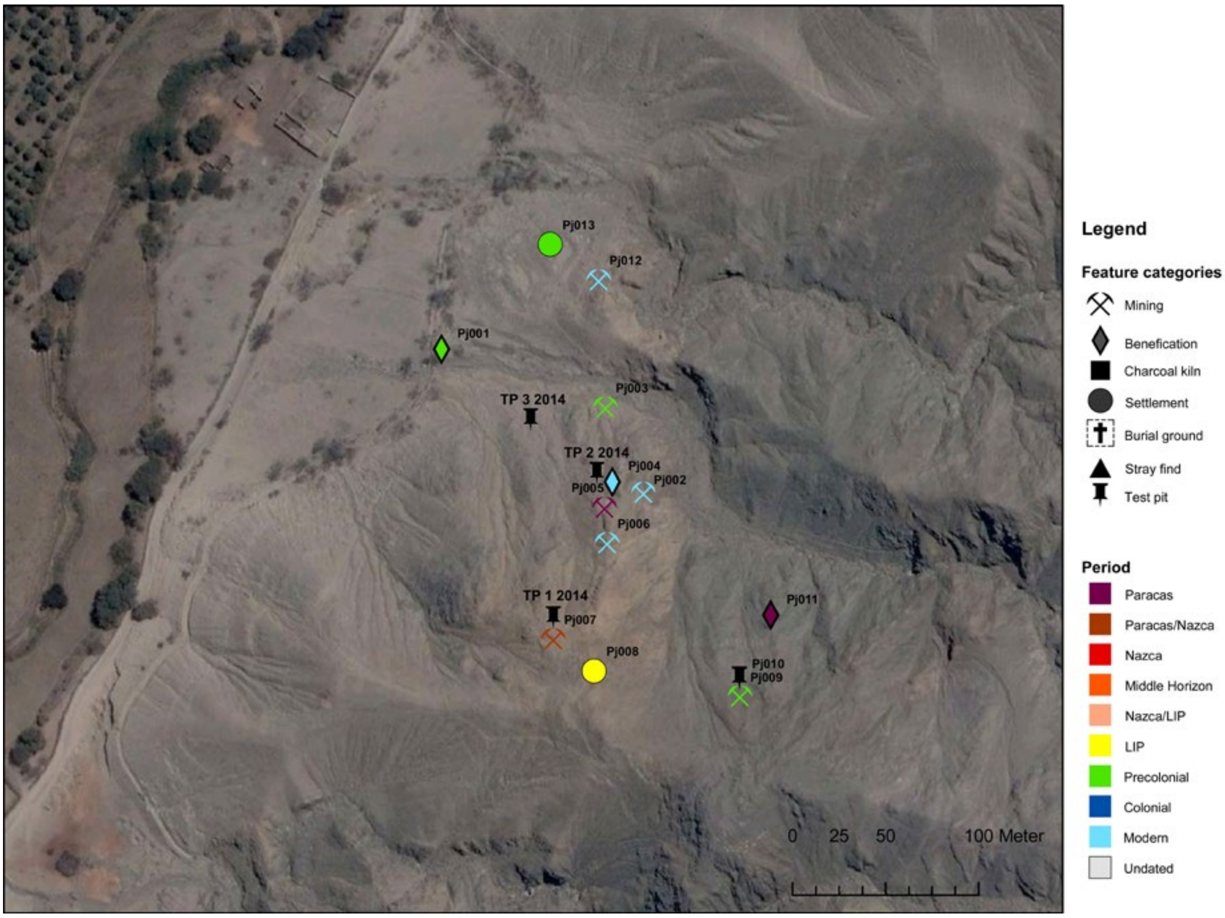

Fig. 100: Mollaque Grande. Pre-Columbian mining sites discovered during a previous survey by Stöllner, et al. (2013) and the locations of the test pits of the current study (graphic: DBM, A. Hornschuch for Stöllner, et al. (2013, 121 fig.17), modified by B. Gräfingholt).

valley floor and the settlements documented here must be emphasized. There had to be a reason, why such high-status buildings were constructed outside the “normal” construction patterns of the Paracas and Nasca culture in the region. The direct access to the mineralization zones might be an explanation.

The former inhabitants put an emphasis on securing the site from the annual floods that come running down the hill by constructing muros de protección on crucial points on the hill slop (Fig. 99).

mining village Saramarca and in the surrounding area. The tremendous risks for health and environment[723] caused by the use of mercury in the course of the amalgamation process[724] are completely ignored by the modern mineros artesanales. Maybe the recent shut-down of the Madre de

721 Stöllner and Reindel, 2007; Stöllner, 2009.
722 Stöllner, 2011; Stöllner, et al., 2013; Reindel, Stöllner and Gräfingholt, 2013.
723 Soßna, 2014, p.11.
724 Stöllner, 2009, p.405

Dios gold mining region because of the Hg-contamination detected[725] will promote a more sustainable mining in Peru. Nonetheless, in the modern small-scale mining district of Saramarca gold mining traces of pre-Columbian mining exploitation and ore-beneficiation were documented and pre-Columbian, mines which were overprinted by modern exploitation, were also found near the ancient settlements.[726]

In one case, a processing and mining site (Pe029-031) was documented next to the settlements Pe028 and Pe031, which have direct accesses to the mine (Fig. 101). Further into the valley more sites were found but failed to reveal traces of ancient mining. Assuming that similar patterns for mining operation were also in place, mining should have been conducted near the settlements not far away from the habitable zones. Judging from the ceramic sherds, this site was first used during Late Paracas (Ocucaje 7/8) and later flourished during Late Nasca. A looted Nasca cemetery (Sa_07) was documented near the valley floor (Fig. 102).

Fig. 101: Saramarca. Sa 01: Ore-beneficiation site with Nasca ceramic (photo: DBM, B. Gräfingholt).

Fig. 102: Saramarca. Looted Nasca cemetery near the valley floor (photo: DBM, B. Gräfingholt).

These sites are therefore very good indicators of ancient mining activities in the region. It may not be possible to always locate the actual mine, as seen on site Pe029, where overprinting in sub-recent times occurred and made it difficult to date the site. In order to obtain a spotlight into the past, the previous 2009 site PE29 (2009) was re-investigated. Due to the extensive surveys conducted around that site[727] PE29was chosen as a spot for an ultimate test pit (Fig. 103).

The terrain is very steep and it takes a while to reach the site. After surveying the whole area five spots for further research were identified: PE_14_Saramarca_Sa_02 (Fig. 104), PE_14_Saramarca_Sa_03, PE_14_Saramarca_Sa_04, PE_14_Saramarca_Sa_05, PE_14_Saramarca_Sa_06. All of these sites are modern mines with pre-Columbian hammering traces near the surface and underground galleries that were clearly worked using iron mining tools and dynamite. The mines all follow an Au vein and all seem to have been reworked recently. Interesting though was PE_14_Saramarca_Sa_06. Here two Au veins met and under this junction a Cu vein was opened (Fig. 105).

Nasca ceramic and a stone tool were found nearby the entrance to this mine. Therefore, a test pit was excavated in front of the mining portal of PE_14_Saramarca_Sa_06, in order to clarify the pre-Columbian mining history of this site (Fig. 106).

7.2 TP 1 Mollaque Grande Excavation

7.2.1 Site description PE_14_MoGr_02_TP1

TP 1 PE-14-MOG-02-Tp1-PU-0 seemed to be an ancient waste dump and is located at UTM 18L E 484079 N 8397368 573 m a.s.l. in front of a portal of a mine, which is equivalent to PJ009 from the 2009 campaign[728] (Fig. 107). The adit seemed to have been reworked in recent times but could have been exploited by pre-Columbian miners.

The site overlooks the mining assemblage that characterizes Mollaque Grande and is located at the southern end of the hill slop. A diagonal shaft in the deposit was drifted to reach the Au vein. Modern test excavations were documented next to the portal (Fig. 108).

In front of this mine, the test pit was excavated on the hill slope (Fig. 109). Already in 2009 Paracas ceramics, stone mining tools and the remains of the ultimate exploitation were documented on the surface.[729]

725 Deutsche Welle, 2016.
726 Stöllner, et al., 2013, p.118.
727 Stöllner, et al., 2013, p.118.

728 Reindel, Stöllner and Gräfingholt, 2013, p.313 fig.14.14.
729 Stöllner, et al., 2013, p.122 fig.18.

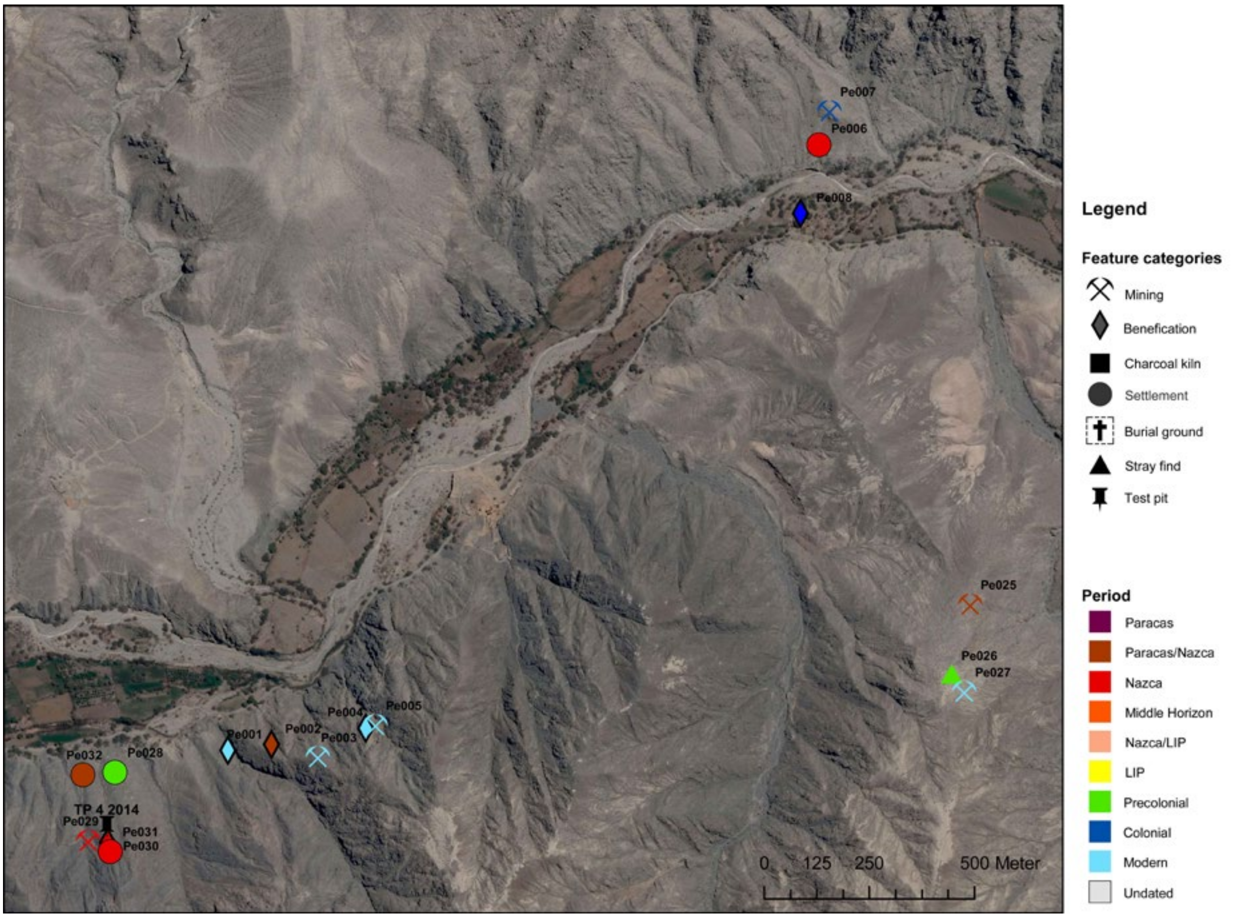

Fig. 103: Saramarca. Pre-Columbian mining sites discovered during a previous survey by Stöllner, et al. (2013) and the locations of the test pits of the current study (graphic: DBM, A. Hornschuch for Stöllner, et al. (2013, 119 fig.15), modified by B. Gräfingholt).

Fig. 104: Saramarca. Sa 02: Ancient mine that has been reopened by mineros artesanales in the past decade (photo: DBM, B. Gräfingholt).

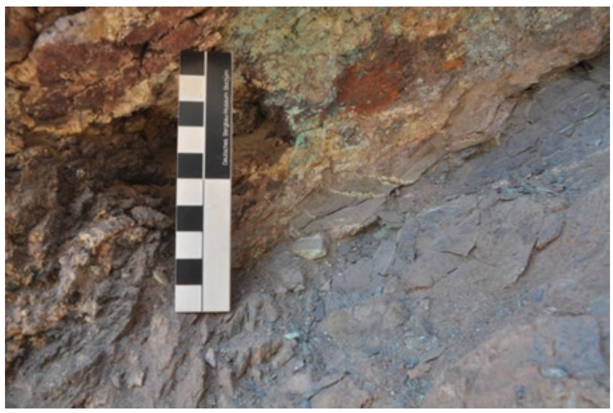

Fig. 105: Saramarca. Cu mineralization inside the mine Sa 06 (photo: DBM, B. Gräfingholt).

Therefore, this site was chosen for test pit 1 and a 2 × 4m grid was excavated with an angel of 30° because of the natural gradient (Fig. 110).

7.2.2 Layer S Rasgo 5484

The layer can be addressed as modern mining waste. This waste consists of angular stones, angular blocks and angular big blocks and is blended with fine sand. The material does not show any unwinding and must be viewed as dead rock with no traces of ores. Alongside with the mining waste Paracas ceramic (Ocucaje 8) and LIP ceramic was documented (3454g) (Fig. 111).

The LIP ceramic was probably brought in from the LIP settlement overlooking the whole site. A very typical location for a LIP settlement as has been documented throughout the central highlands.[730] Additionally the stone

[730] Covey, 2008a, p.293.

Fig. 106: Saramarca. Sa 06: Ancient mine portal that has been opened up by mineros artesanales in the last decade (photo: DBM, B. Gräfingholt).

Fig. 107: Mollaque Grande. Portal of the pre-Columbian mine above TP 1 (photo: DBM, B. Gräfingholt).

Fig. 108: Mollaque Grande. Recent test excavations (photo: DBM, B. Gräfingholt).

tools found in 2009 were identified as mining tools.[731] The color of the soil was defined as 10Y 6/8 brownish yellow following Munsell[732]. Layer S Rasgo 5484 was above layer A Rasgo 5485 (Fig. 112).

Fig. 109: Mollaque Grande. Superposition of a sub-modern mining dump over ancient mining tailing characterized by Prehispanic stone tools and ceramic sherds dating to Late Paracas (photo: DBM, B. Gräfingholt).

Fig. 110: Mollaque Grande. TP 1 before the excavation. Waste dump of a mining operation mixed with pre-Columbian artifacts (photo: DBM, B. Gräfingholt).

7.2.3 Layer A Rasgo 5485

The layer consists of very well sorted rough sand mixed with fine gravel and angular detritus. Ceramic was documented alongside other artifacts. The color of the soil was defined as 10Y 4/3 brown following Munsell. Apart from the ceramic (Ocucaje 8 and Nasca 1, 816g) one obsidian projectile point (5485_PO_1) and a stone tool (5485_1, 903g) were found (Fig. 113).

Layer A Rasgo 5485 was under layer S Rasgo 5484 and above layer B Rasgo 5486 (Fig. 114).

7.2.4 Layer B Rasgo 5486

The layer is characterized by rubble of angular big blocks, which are distributed along a diagonal line, which runs from north-east to south-west. The angular big blocks are framed by a layer of well sorted middle fine sand and rough sand which is mixed with angular stones. The layer could be dated using the excavated ceramic (Ocucaje 8 and Nasca Initial, 1275g) to Late Paracas-Early Nasca. A mortar stone tool (5486_26, 903g) and a sea snail

731 Reindel, Stöllner and Gräfingholt, 2013, p.313 fig.14.15.
732 All color definitions in the following chapters are taken from Munsell Color Company, 2010.

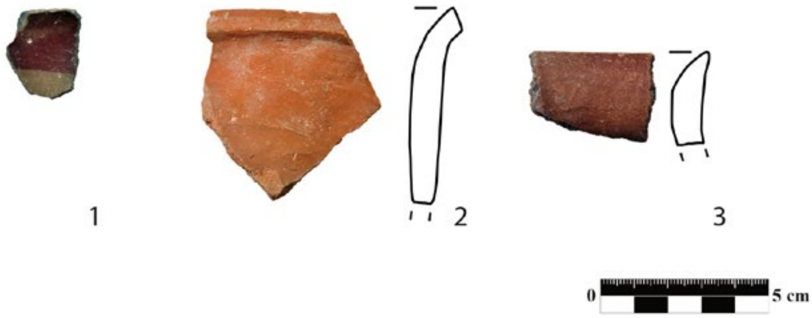

Fig. 111: PAP 461. TP1, layer S Rasgo 5484 (graphic: DBM, B Gräfingholt). 1 – Ocucaje 8. 2 – LIP. 3 – Ocucaje 8.

Fig. 112: Mollaque Grande. TP 1, layer S Rasgo 5484 (photo: DBM, B. Gräfingholt).

identified as Olivia peruviana (5486_23) (Fig. 115) could be excavated as well.

Furthermore, a massive angular stone mining tool (5486_25, 2971g) (Fig. 116 and Fig. 125) was found in this layer.

The color of the soil was defined as Munsell 10Y 4/4 dark yellowish brown. Layer B Rasgo 5486 was under layer A Rasgo 5485 and above layer C Rasgo 5488 and equal to layer B Rasgo 5487 Entierro I (Fig. 117).

7.2.5 Layer B Rasgo 5487 Entierro I

In this layer a single crouched inhumation orientated south with one ceramic bowl dating to Ocucaje 8 encircled by a stone setting was excavated. The color of the soil was defined as Munsell 10Y 4/4 dark yellowish brown. Layer B Rasgo 5487 Entierro I was under layer A Rasgo 5485 and above layer D Rasgo 5492 and equal to layer B Rasgo 5486 (Fig. 118).

7.2.6 Layer C Rasgo 5488

The layer is characterized by rough sand with a badly sorted mixture of rough detritus, angular stones, angular blocks and ores. The color of the soil was defined as Munsell 10Y 3/3 dark brown. Ceramic sherds (Oucaje 7/ Ocucaje 8, 2765g) (Fig. 119) were excavated which document that this layer represents the transition from Middle to Late Paracas.

Embedded in layer C Rasgo 5488 two features were documented: Rasgo 5489 and 5490. Layer C Rasgo 5488 was found under layer B Rasgo 5486 and above layer D Rasgo 5492 and is equal to layer C Rasgo 5489, layer C Rasgo 5490 and layer C Rasgo 5491 (Fig. 120).

7.2.7 Layer C Rasgo 5489

A well sorted assemblage of fine sand with a concentration of big blocks was documented in this layer. The color of the soil was defined as Munsell 10Y 6/8 brownish yellow. Layer C Rasgo 5489 was found under layer B Rasgo 5486 and above layer D Rasgo 5492 and is equal to layer C Rasgo 5488, layer C Rasgo 5490 and layer C Rasgo 5491.

7.2.8 Layer C Rasgo 5490

The layer is characterized by fine sand blended with rough detritus. The color of the soil was defined as Munsell 10Y 5/8 brownish yellow. Embedded in the layer a stone tool (5491_01, 4344g) (Fig. 121) was documented.

Layer C Rasgo 5490 was found under layer B Rasgo 5486 and above layer D Rasgo 5492 and is equal to layer C Rasgo 5488, layer C Rasgo 5489 and layer C Rasgo 5491.

Fig. 113: PAP 461 TP1 A 5485 (photo: DBM, B. Gräfingholt). 1 – 5485_1. 2 – 5485_PO_1. 3–5 – Ocucaje 8. 6 – Nasca 1. 7 – LIP.

Fig. 114: Mollaque Grande. TP 1, layer A Rasgo 5485 (photo: DBM, B. Gräfingholt).

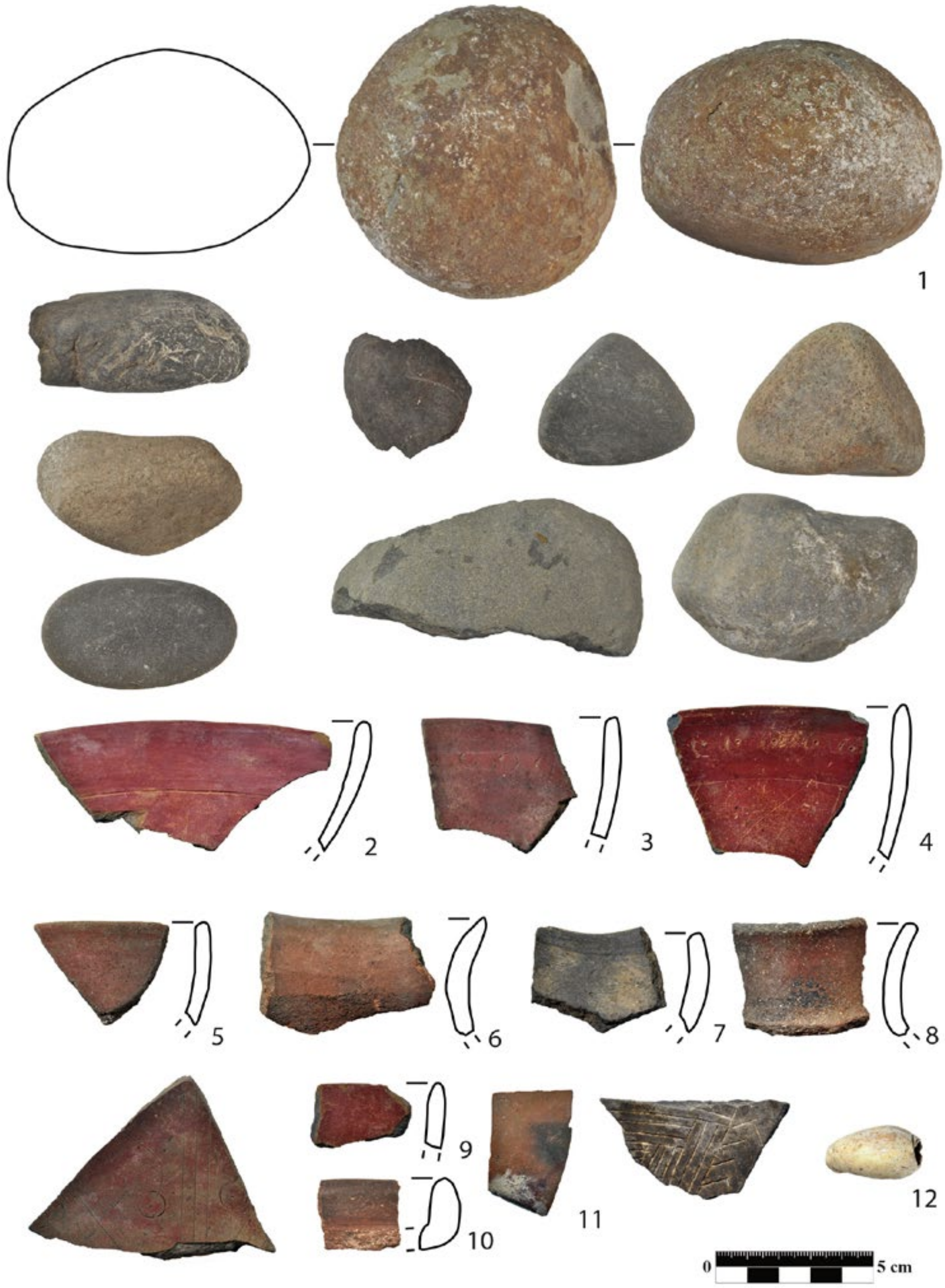

Fig. 115: PAP 461 TP1 B 5486 (graphic: DBM, B. Gräfingholt). 1 – 5486_26. 2–10 – Ocucaje 8. 11 – Nasca 1. 12 – 5486_23 Olivia peruviana.

Fig. 116: PAP 461. TP 1, layer B Rasgo 5486. Angular stone mining tool (5486_25) dating to Late Paracas (Ocucaje 8) (photo: DBM, B. Gräfingholt).

Fig. 117: Mollaque Grande. TP 1, layer B Rasgo 5486 (photo: DBM, B. Gräfingholt).

Fig. 118: Mollaque Grande. TP 1, layer B Rasgo 5487 Entierro I. Single crouched Late Paracas (Ocucaje 8) inhumation encircled by a stone setting (photo: DBM, B. Gräfingholt).

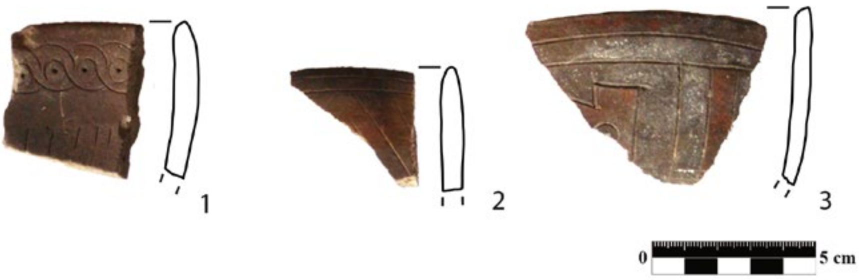

Fig. 119: PAP 461. TP 1, layer C Rasgo 5488 (graphic: DBM, B. Gräfingholt). 1 – Ocucaje 7. 2–3 – Ocucaje 8.

Fig. 120: Mollaque Grande. TP 1, layer C Rasgo 5488 (photo: DBM, B. Gräfingholt).

7.2.9 Layer C Rasgo 5491

The feature can be addressed as a porous stone tool (5491_1, 4344g) (Fig. 120), probably used to grain pre-crushed minerals. It was found under layer B Rasgo 5486 and above layer D Rasgo 5492 and is equal to layer C Rasgo 5488, layer C Rasgo 5489 and layer C Rasgo 5490 (Fig. 122).

7.2.10 Layer D Rasgo 5492

Layer D Rasgo 5492 represents the solid rock and features two pits cut into the soil. Layer D Rasgo 5492 was found under layer C Rasgo 5488, layer C Rasgo 5489, layer C Rasgo 5490 and layer C Rasgo 5491 (Fig. 123).

7.2.11 Discussion of the TP 1 Excavation

The excavation of this test pit revealed the long mining tradition of the site Mollaque Grande but has also highlighted the mortuary practice of the Paracas culture that deposited a grave next to a mine portal in a mining waste dump (Fig. 124).

It can be assumed that the origins of the mine date to Middle Paracas as documented by the Ocucaje 7 ceramic in layer C Rasgo 5488. It is most likely that the inhabitants of the site used the raw materials they had direct access to on the slope of the hill on the site. With the complete angular stone mining tool (5486_25) excavated in layer B Rasgo 5486 the first in situ mining tool dating to Late Paracas (Ocucaje 8) could be excavated – representing the oldest complete mining tool so far excavated in Peru (Fig. 125).

In combination with the documented surface finds of stone tools from the 2009er campaign[733] and the mining tools documented on the surface of the site Mollaque Grande (MoGr 01, MoGr 09, MoGr 10 and MoGr 12) (Fig. 126 and Fig. 127) during this campaign, it can be stated that active mining took place on the site at least during Late Paracas.

An interesting fact is that all documented mining tools revealed wear marks but none was hafted, which implies that the favored mining technique used on the site Mollaque Grande relied on handheld stone tools. Future test with river stones could clarify the picture if the given geological setting favors handheld stone tools over hafted ones. A special emphasis must be laid on the multi-functional mining tool MoGr 12 (Fig. 127) which had a dual use. It was used as a hammerstone; but it was also used for grinding and crushing ores. This gives an indirect proof that ores were processed on the site of Mollaque Grande and further supports the assumption that Mollaque must been seen as the oldest metal ore mining district documented in Peru so far. Due to the documented Nasca 1 ceramic in layer A Rasgo 5485 it appears that the site of Mollaque Grande and the mines on the site may have been used during Early Nasca as well.

733 Stöllner, et al., 2013, p.122 fig.19.

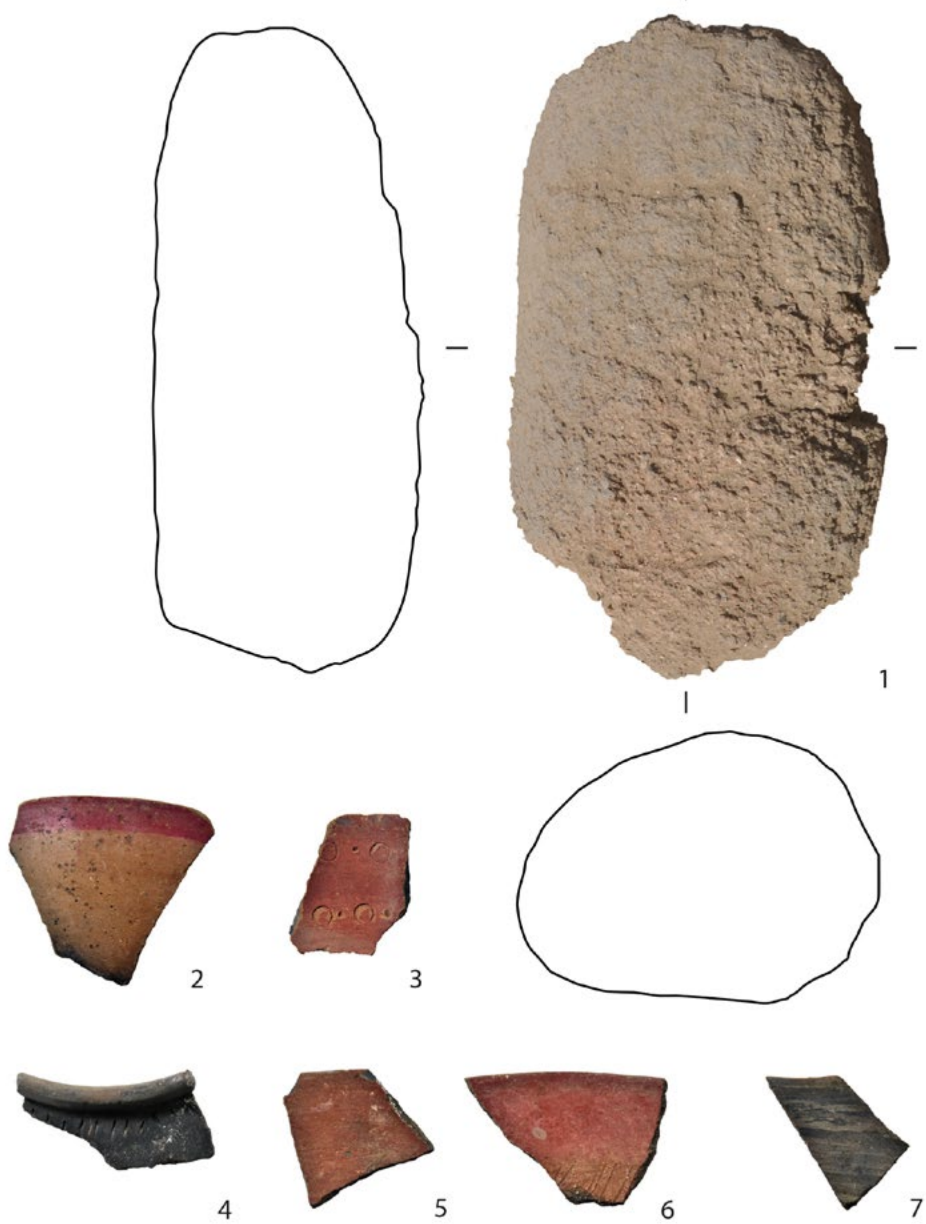

Fig. 121: PAP 461. TP 1, layer C Rasgo 5488 to 5491 (graphic: DBM, B. Gräfingholt). 1 – 5491_01. 2–7 – Ocucaje 8.

Fig. 122: Mollaque Grande. TP 1, layer C Rasgo 5491. Porous stone tool (photo: DBM, B. Gräfingholt).

Fig. 123: Mollaque Grande. TP 1, layer D Rasgo 5492. Two pits that have been cut into the natural soil are clearly visible (photo: DBM, B. Gräfingholt).

Fig. 124: Mollaque Grande. TP 1, layer B Entierro I (photo: DBM, B. Gräfingholt).

Fig. 125: Angular stone mining tool (5486_25) from layer B Rasgo 5486 dating to Late Paracas (Ocucaje 8) (photo: DBM, B. Gräfingholt).

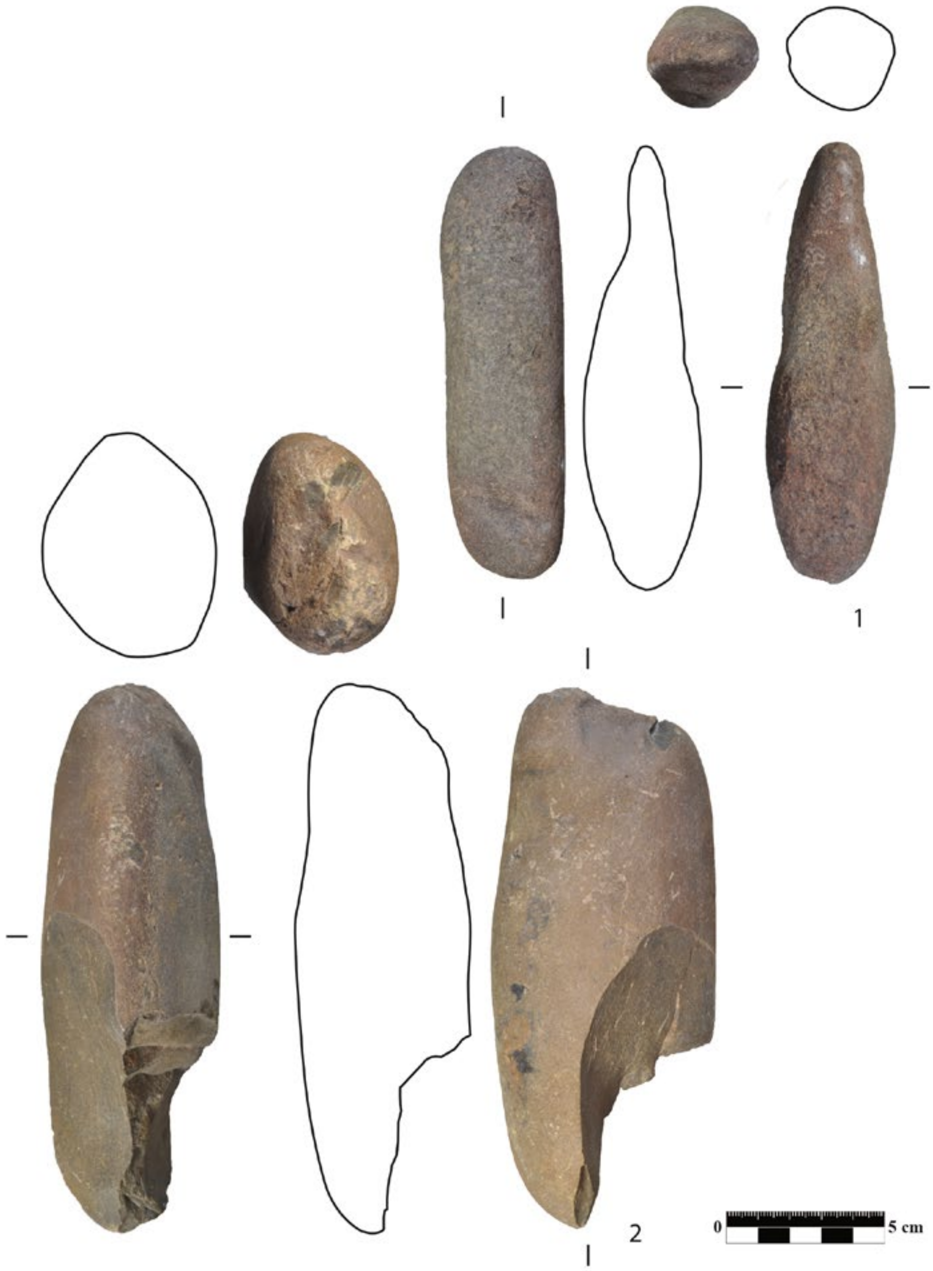

Fig. 126: PAP 461. Mining tools documented on the surface of the site Mollaque Grande (graphic: DBM, B. Gräfingholt). 1 – MoGr 01. 2 – 2 MoGr 09.

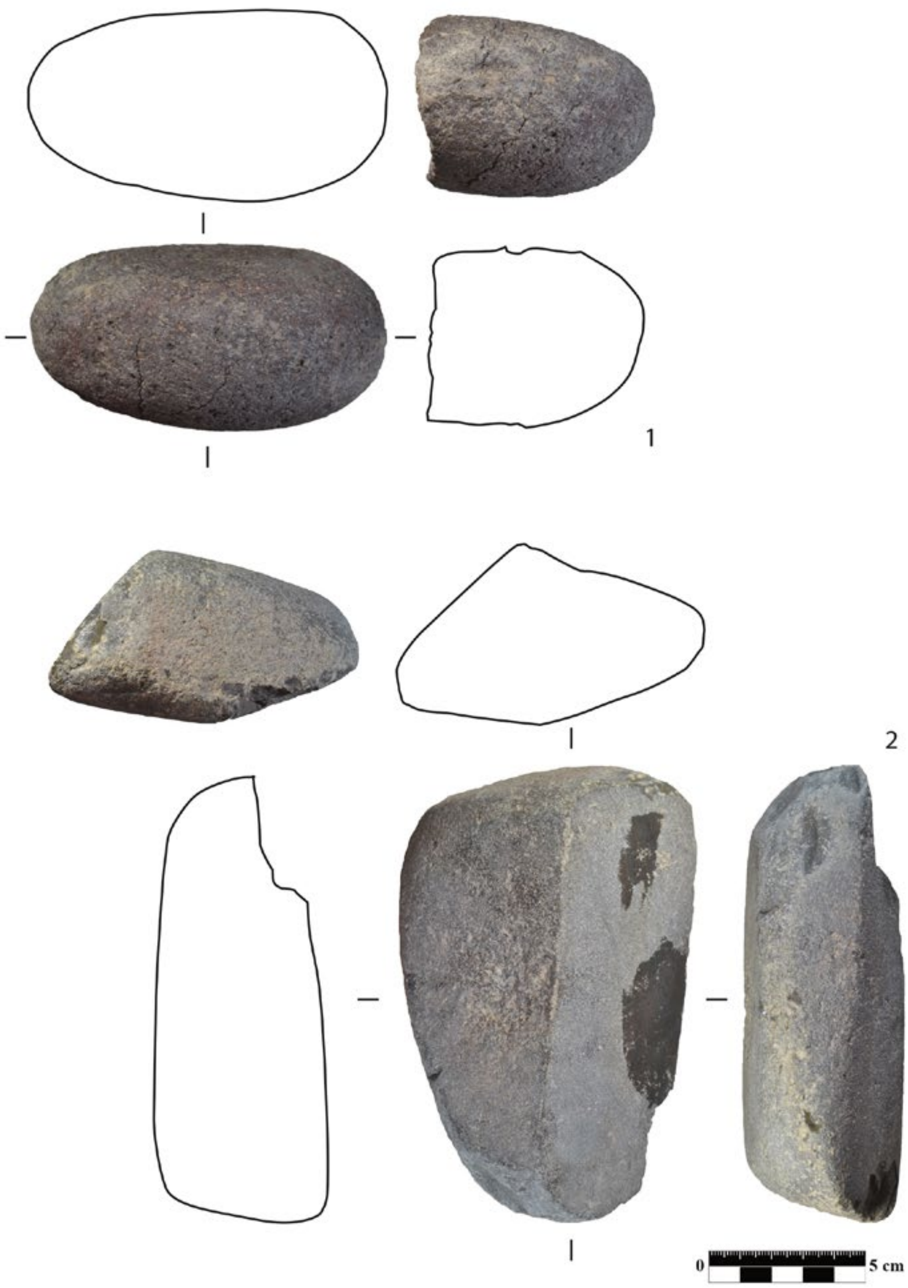

Fig. 127: PAP 461. Mining tools documented on the surface of the site Mollaque Grande (graphic: DBM, B. Gräfingholt). 1 – MoGr 10. 2 – MoGr12.

7.3 TP 2 Mollaque Grande Excavation

7.3.1 Site description

The second test pit PE-14-MOGR-13-TP2-PU-0 was excavated further north down the hill and is located at UTM 18L E 484094 N 8397460 535 m a.s.l. (Fig. 128).

During the 2009er campaign the biggest adit that followed the mineralization down the hill was documented as PJ005 and was renamed for the current excavation PE_14_MoGr_13 (Fig. 129).

A waste dump in front of PE_14_MoGr_13 contained a lot of Paracas ceramic as well as 3 stone tools (PE_MoGr_09 1022g, PE_MoGr_10 918g, PE_MoGr_12 2070g) and an obsidian projectile point (PE_MoGr_11). PE_MoGr_09 was identified as a handheld stone mining tool that revealed intensive wear marks on the front. PE_MoGr_12 has obviously been used as a mortar to crush the exploited ores on site (Fig. 130). Since modern mineros artesanales tend to reuse old mining mortars to test the ore quality, this mortar was probably placed here in recent times. Still, it can be assumed that this heavy stone was not brought here by modern miners, the comparison with the crushing sites in the Mina Primavera[734] highlights that this stone tool definitely is of a pre-Columbian origin.

734 Vaughn, et al., 2013a, pp.164-165.

Fig. 128: Mollaque Grande. View from TP 1 north onto TP 2 (photo: DBM, B. Gräfingholt).

Fig. 131: Mollaque Grande. Leftovers from the recent mining operation in PE_14_MoGr_13 (photo: DBM, B. Gräfingholt).

Fig. 129: Mollaque Grande. TP 2 Overview before the excavation. Left the portal to the recently reworked adit can be seen. The waste dump to the right was excavated in the course of the test excavation as TP 2 (photo: DBM, B. Gräfingholt).

Fig. 132: Mollaque Grande. TP 2 overview before the excavation (photo: DBM, B. Gräfingholt).

Fig. 130: Mollaque Grande. PE_MoGr_12: crushing anvil (photo: DBM, B. Gräfingholt).

Fig. 133: Mollaque Grande. TP 2, layer S Rasgo 5493 (photo: DBM, B. Gräfingholt).

This assemblage and the whole composition of the site indicate that mining operations were most likely carried out at this mine during Paracas times as has been suggested by Stöllner (2011, p.203) and Stöllner, et al. (2013, p.118) previously. In comparison to 2009 the adit was slightly modified by recent mining operations (Fig. 131).

This mine seems to have attracted miners over a certain period of time, therefore test pit 2 PE_14_MoGr_13_TP2 was excavated in front of the portal of this mine – again a 2 × 4 m grid was used. The terrain was even more demanding than at TP 1, because the waste dump fell away sharply with an angel of 30°. Still, it was possible to establish a secure grid (Fig. 132).

7.3.2 Layer S Rasgo 5493

This layer is characterized by angular stones and angular big blocks and represents the modern mining waste. Layer S Rasgo 5493 was documented above layer A Rasgo 5494 (Fig. 133).

Fig. 134: Mollaque Grande. TP 2, layer A 5495. Newspaper article and cigarette pack from the 1990s (photo: DBM, B. Gräfingholt).

Fig. 137: Mollaque Grande. Working platform in the east of TP 2. Probably used by modern and pre-Columbian miners (photo: DBM, B. Gräfingholt).

Fig. 135: Mollaque Grande. TP 2, layer A 5494 (photo: DBM, B. Gräfingholt).

Fig. 138: Mollaque Grande. Layer D Rasgo 5497 (photo: DBM, B. Gräfingholt).

Fig. 136: Mollaque Grande. TP 2, layer B Rasgo 5495. This layer was absolutely dated to the 9th of February 1993 because of a newspaper article found within the layer (photo: DBM, B. Gräfingholt).

7.3.3 Layer A Rasgo 5494

In this layer, angular blocks and angular stones are embedded in middle fine sand and rough detritus. This layer is the modern mining waste. It basically represents the fine material that was produced during the recent exploitation of the mine in the course of the beneficiation process that took place in front of the mine. The recent miners hand-sorted some ores from the mine, crushed them on site and grinded this material in order to estimate the Au content of the ores and see if it was worth mining. A newspaper article that could be date back to around 1993 and a cigarette pack of the brand “ritmo” were excavated. The cigarette brand “ritmo” was smoked by miners during the 90s[735] (Fig. 134).

This leaves no doubt that a second exploitation of the mine was undertaken during the 1990s. Layer A Rasgo 5494 was found under layer S Rasgo 5493 and above layer B Rasgo 5495 (Fig. 135).

7.3.4 Layer B Rasgo 5495

This layer represents the penultimate layer of modern mining waste. It consists of angular blocks, middle fine sand and rough detritus. A page from a newspaper dating to 9th of February 1993 was found beside cigarettes, textiles and a fuse. The layer was documented under layer A Rasgo 5494 and above layer C Rasgo 5495 (Fig. 136).

735 Personal communication with former miners.

Fig. 139: Mollaque Grande. TP 2, layer E Rasgo 5498 (photo: DBM, B. Gräfingholt).

7.3.5 Layer C Rasgo 5496

Layer C Rasgo 5496 represents the solid rock in the east of TP 2 that was leveled to construct a working platform. On this working platform ores seemed to have been crushed during the recent excavation, therefore no pre-Hispanic remains have been documented so far in the TP2. Nonetheless, it may be possible that the modern mineros artesanales only reused the already existing platform that was constructed by their predecessors in pre-Columbian times. The layer was documented under layer B Rasgo 5495 (Fig. 137).

7.3.6 Layer D Rasgo 5497

This layer was located in the west of the leveled working platform and is characterized by angular stones, rough sand, rough detritus and angular blocks. The layer was found under layer B Rasgo 5495 and above layer E Rasgo 5498. A cigarette from the 1990er exploitation operation was found in the ultimate layer (Fig. 138).

Fig. 140: Mollaque Grande. Profile of TP 2 taken from the assumed pre-Columbian working platform (photo: DBM, B. Gräfingholt).

Fig. 141: Mollaque Grande. TP 3 before the excavation. In the upper left the line of adits run down the hill (photo: DBM, G. Puzicha).

7.3.7 Layer E Rasgo 5498

The layer represents the unmodified solid rock and was documented under layer D Rasgo 5497 (Fig. 139).

7.3.8 Discussion of the TP2 Excavation

A pre-modern context cannot fully be excluded, although no pre-Hispanic, not even pre-modern artifacts were documented. The excavated ensemble represents the 1990ies exploitation of the mine, as was proven by the newspaper article and cigarettes from that time documented

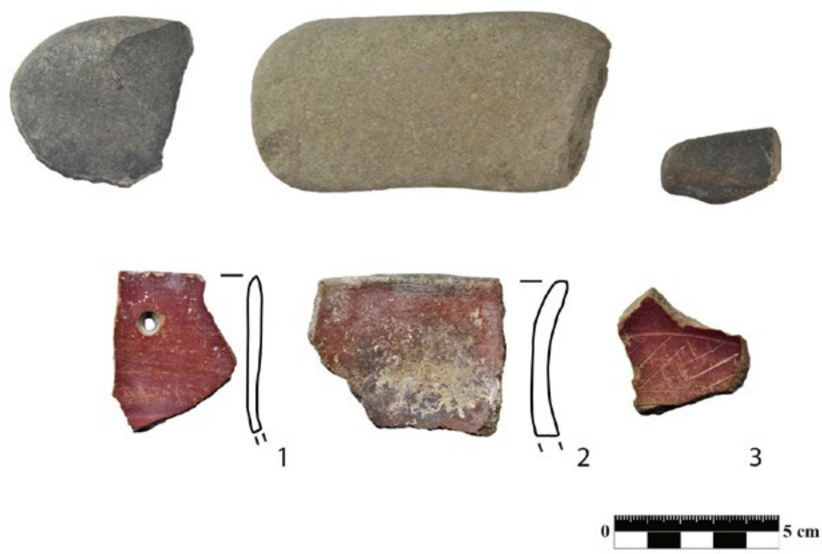

Fig. 142: PAP 1141. TP 3, layer S Rasgo 5499 (graphic: DBM, B. Gräfingholt). 1–3 – Ocuaje 8.

Fig. 143: Mollaque Grande. TP 3, layer S Rasgo 5499 (photo: DBM, B. Gräfingholt).

in layer B Rasgo 5495. The mine is today nearly half filled with waste of recent exploitation and would have been an impressive informal mine while in full operation during the 1990ies.

Nonetheless, the documented Paracas sherds and the mining tools found on the surface in the surroundings leave room for the assumption that this mine – which still attracted mineros artesanales in the 1990ies and up to now – was known to the pre-Columbian Paracas miners. A further hint at this is the irregular working platform, which would have enabled pre-Columbian miners to start an exploitation of the polymetallic ore vein. For these reasons an origin of this mine in pre-Columbian times must be assumed (Fig. 140).

7.4 TP 3 Mollaque Grande Excavation

7.4.1 Site description

Test pit 3 (Pe_14_MOGR_14_TP3_PU_0) was excavated even further down the hill on the slope of the hill just below the line of adits following the mineralization zone at UTM 18L E 484074 N 8397470 516 m a.s.l.

The spot for TP 3 was carefully chosen, so that disturbance of artifacts and waste from the Late Paracas settlement PE_14_Mollaque_Grande_MoGr_03 can be ruled out in this TP, instead only artifacts that were used on the slope of the hill, probably during the pre-Columbian mining operation, would be documented in the course of the excavation (Fig. 141).

Fig. 144: PAP 1141. TP 3, layer A Rasgo 5500 (graphic: DBM, B. Gräfingholt). 1 – 5500_14 Choromytilus chorus. 2–4 – Ocucaje 8. 5 – Ocucaje 9.

Fig. 145: Mollaque Grande. TP 3, layer A Rasgo 5500 (photo: DBM, B. Gräfingholt).

7.4.2 Layer S Rasgo 5499

The layer is characterized by angular stones, rough detritus, rough sand and angular blocks. Because of the location of this test pit it is extremely unlikely that this assemblage was composed by modern mining waste. The color of the soil was defined as Munsell 10Y 8/8 yellow. Alongside lithic material ceramic dating to Late Paracas (Ocucaje 8, 418g) was documented (Fig. 142).

The layer was located above layer A Rasgo 5500 (Fig. 143).

7.4.3 Layer A Rasgo 5500

The layer is composed of well sorted angular stones, rough detritus, rough sand and angular blocks. In the east, a rubble of angular blocks was documented. The color of the soil was defined as Munsell 10Y 4/6 dark yellowish brown. Ceramic dating to Late Paracas (Ocucaje 8/9, 979g) and a seashell from the species Choromytilus chorus (5500_14) were documented alongside lithic material (Fig. 144).

The layer was found under layer S Rasgo 5499 and above layer B Rasgo 5501 (Fig. 145).

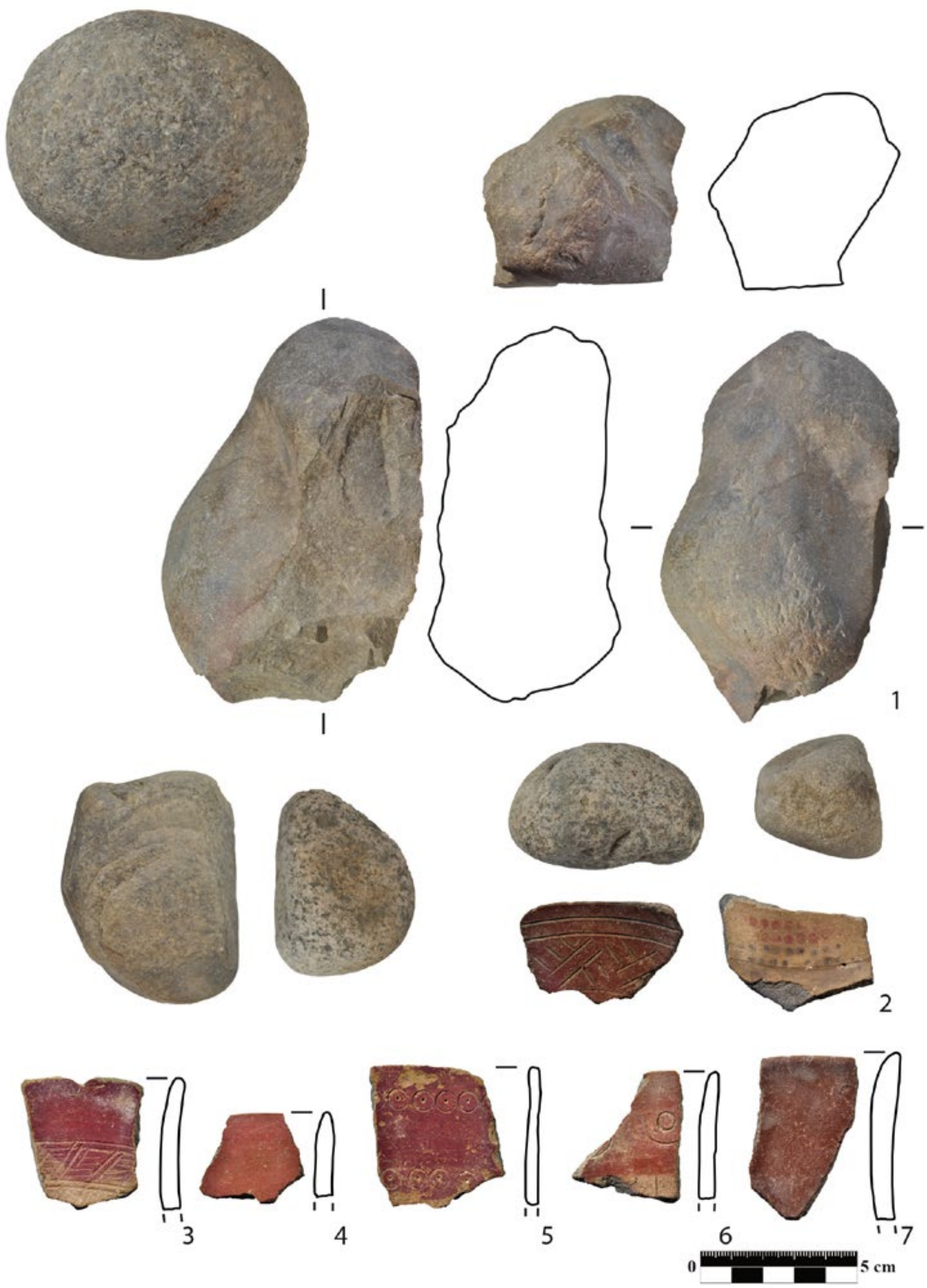

Fig. 146: PAP 1141. TP 3, layer B Rasgo 5501 (graphic: DBM, B. Gräfingholt). 1 – 5501_23. 2 – Ocucaje 9. 3–7 – Ocucaje 8.

7.4.4 Layer B Rasgo 5501

This layer is characterized by badly sorted angular stones, rough detritus, rough sand and angular blocks that were mixed with ores. In the east, as well as in the layer above, a rubble of angular blocks was documented. The color of the soil was defined as Munsell 10Y 4/3 brown. Ceramic (Ocucaje 8/9, 1474g) (Fig. 146) was documented.

Beside of the lithic material, e.g. a massive stone (5501_24, approx. 9000g) was also found (Fig. 147).

A notable difference to the layer above was that a great amount of ores was found here. The layer was found under layer A Rasgo 5500 and above layer C Rasgo 5502 (Fig. 148).

7.4.5 Layer C Rasgo 5502

This layer is characterized by badly sorted angular stones, rough detritus, rough sand and angular blocks that are mixed with ores. In the east, as well as in the two layers above, rubble of angular blocks was documented. The color of the soil was defined as Munsell 10Y 4/3 brown. Ceramic (Ocucaje 7/8, 603g) was documented alongside lithic material, 17 shellfish fragments belonging to the species Perumytilus purpuratus (5502_13) and one incomplete stone mining tool (5502_15, 865g). An obsidian projectile point (5502_05) that can be classified as type 1 F variant I[736]

[736] Gräfingholt, 2011, p.32.

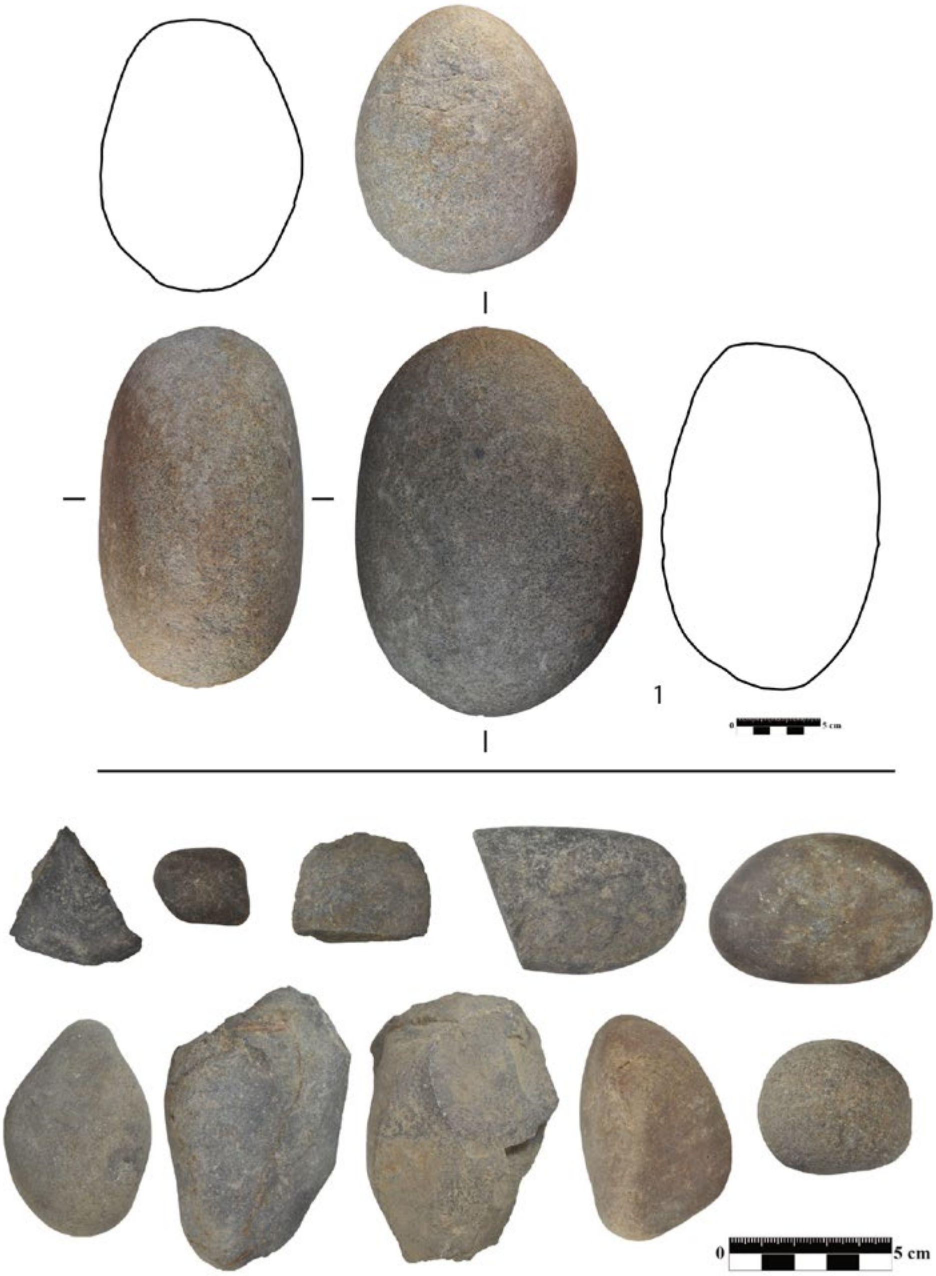

Fig. 147: PAP 1141. TP 3, layer B Rasgo 5501 (graphic: DBM, B. Gräfingholt). 1 – 5501_26.

was found and matches the chronological setting of this type into Ocucaje 7 (Fig. 149).

The layer was found under layer B Rasgo 5501 and above layer D Rasgo 5503 (Fig. 150).

7.4.6 Layer D Rasgo 5503

The layer is composed of very well sorted rough detritus mixed with angular stones and rough sand. The color of the soil was defined as Munsell 10Y 4/4 dark yellowish brown. Ceramic (Ocucaje 3/4, 579g) (Fig. 150) was documented alongside lithic material and shells (5502_13) as well as part of a crab pincer (5502_14) (Fig. 151).

An obsidian projectile point (5503_06) that can be classified as type 2 A[737] was found and widens the chronological setting of this type into Ocucaje 3/4. The layer was found under layer C Rasgo 5502 and above layer E Rasgo 5504 (Fig. 152).

737 Gräfingholt, 2011, p.42.

Fig. 148: Mollaque Grande. TP 3, layer B Rasgo 5501 (photo: DBM, B. Gräfingholt).

Fig. 149: PAP 1141. TP 3, layer C Rasgo 5502 (graphic: DBM, B. Gräfingholt). 1 – Ocucaje 8. 2 – 5502_13 Perumytilus purpuratus. 3 – 5502_15. 4 – 5502_14. 5 – 5502_05.

Fig. 150: Mollaque Grande. TP 3, layer C Rasgo 5502 (photo: DBM, B. Gräfingholt).

Fig. 151: PAP 1141. TP 3, layer D Rasgo 5503 (graphic: DBM, B. Gräfingholt). 1–4 Ocucaje 3/4. 5 – 5503_06.

Fig. 152: Mollaque Grande. TP 3, layer D Rasgo 5503 (photo: DBM, B. Gräfingholt).

Fig. 154: Mollaque Grande. TP 3, final profile – documenting Early Paracas to Late Paracas occupation of the site (photo: DBM, B. Gräfingholt).

Fig. 153: Mollaque Grande. TP 3, layer E Rasgo 5504 (photo: DBM, B. Gräfingholt).

Fig. 155: Saramarca. Overview of TP 4 facing east towards the slopes of the mountain. In the middle, the modern waste dump can be seen which has recently been reopened (photo: DBM, B. Gräfingholt).

7.4.7 Layer E Rasgo 5504

This layer represents the sterile soil and revealed no further finds (Fig. 153).

7.4.8 Discussion of the TP 3 Excavation

TP 3 reviled that the site Mollaque Grande was continuously occupied from Early Paracas (840–500 cal BC) to Late Paracas (380–260 cal BC). Apart from Mollaque Grande only the sites Mollaque Chico and Pernil Alto[738] have had an occupation history that reached thus far back in time (Fig. 154).

As mentioned before the location of this site as a working and processing place in combination with a settlement at the slopes of the hill was rather exceptional for the Paracas culture[739] – there had to be a reason why people settled so far away from the river. The documented shells and obsidian projectile points also indicate that the people who dwelled at this site were being supplied in the best possible way. Furthermore, the lithic material that was found in this TP supports the assumption that ores were processed on this site and that the people exploited the rich mineral resources of the mineralization zone they were living next to already during Early Paracas. This proves the statement formulated by Stöllner, et al. (2013, p.118) that: “in all cases permanent ancient settlements were situated nearby or even in short, easy reachable distances from the mines!” The incomplete mining tool (5502_15) documented in layer C Rasgo 5502 demonstrates that mining was conducted on the site and that in the course of the mining operations tools broke and had to be replaced. Though only a small proportion of the site was investigated, the excavated seashells from layer A Rasgo 5000 and layer C Rasgo 5502 as well as the crab pincer from the same layer prove that the inhabitants of this site had access to maritime seafood and were supplied on a regular basis. The Choromytilus chorus fragment (5500_14, Fig. 144) for example can be interpreted in two ways; first of all as an addition to the locally available food and secondly in the course of rituals as has been documented for example

738 Unkel, et al., 2012, p.2301.
739 Soßna, 2014, p.157; personal communication with Johny Isla Cuadrado at the site, 2014.

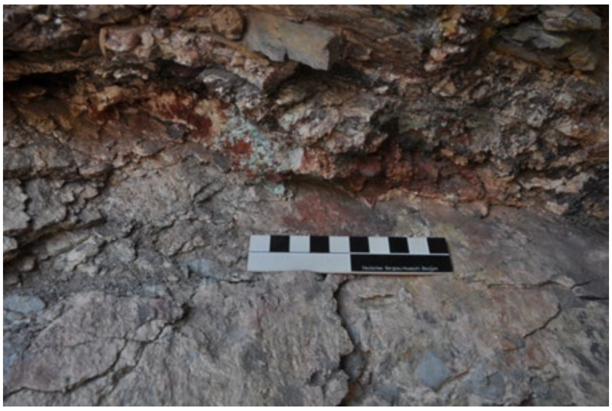

Fig. 156: Saramarca. TP 4: Copper mineralization documented at the portal of the mine (photo: DBM, B. Gräfingholt).

Fig. 158: Saramarca. TP 4: Modern beneficiation site with copper and gold bearing ores being tested on a pre-Columbian crushing plate. Sacks containing crushed ores were found in situ next to the grinding stone (photo: DBM, B. Gräfingholt).

Fig. 157: Saramarca. TP 4: Nasca 4 ceramic before excavation on the surface of test pit 4 (photo: DBM, B. Gräfingholt).

in Cahuachi.[740] The shellfish fragments of Perumytilus purpuratus (5502_13, Fig. 149) can be interpreted in a similar way as the before mentioned and additionally adding a third possible purpose of this species on the site: the making of purple color.[741] Combined with the permanent occupation of Mollaque Grande from Early to Late Paracas this indicates the importance of the site as a supplier for raw material that was probably extracted from the polymetallic vein.

7.5 TP 4 Saramarca Excavation

7.5.1 Site description

As mentioned above five recently reopened ancient mines (PE_14_Saramarca_Sa_02, PE_14_Saramarca_Sa_03, PE_14_Saramarca_Sa_04, PE_14_Saramarca_Sa_05, PE_14_Saramarca_Sa_06.) revealed promising spots for a test excavation. Due to the limited time during this campaign only one of these had to be chosen. PE_14_Saramaraca_Sa_06 seemed to be the most promising location for the ultimate test pit though here an Au mineralization and a Cu vein were documented (Fig. 156).

The test pit is located at UTM 18L E 488105 N 8396822 680 m a.s.l. overlooking the valley of the Rio Viscas (Fig. 155).

Nasca ceramic and a stone tool were found nearby the entrance to this mine. As in the surrounding at the valley floor a looted Nasca cemetery was documented which implied that in combination with the settlement localized during the 2009er campaign the mineralization zones of this area were known to the pre-Columbian inhabitants of the area (Fig. 156 and Fig. 157).

7.5.2 Layer S Rasgo 5505

The layer was clearly identified as a beneficiation site from the recent mining activities in the mine nearby. A pre-Columbian crushing plate was recycled and used by the modern mineros artesanales to process the ores extracted during the recent mining operation on that site (Fig. 158).

In total, the layer consists of ores in the form of angular Stones, angular blocks and rough sand. Apart from the quartz gold ores some copper ores were found. A pre-Columbian stone mining tool and ceramic dating to Nasca 4 (Fig. 159) were documented on the surface.

The color of the soil was defined as Munsell 10Y 5/8 yellowish brown. The layer was found above layer A Rasgo 5506 (Fig. 160).

7.5.3 Layer A Rasgo 5506

The layer is characterized by middle fine sand, angular stones, angular blocks and rough detritus from the beneficiation process. In contrast to the layer above no copper ores were found and it was possible to date the layer by

740 Silverman, 1993, p.295.
741 Silverman, 2002, p.157.

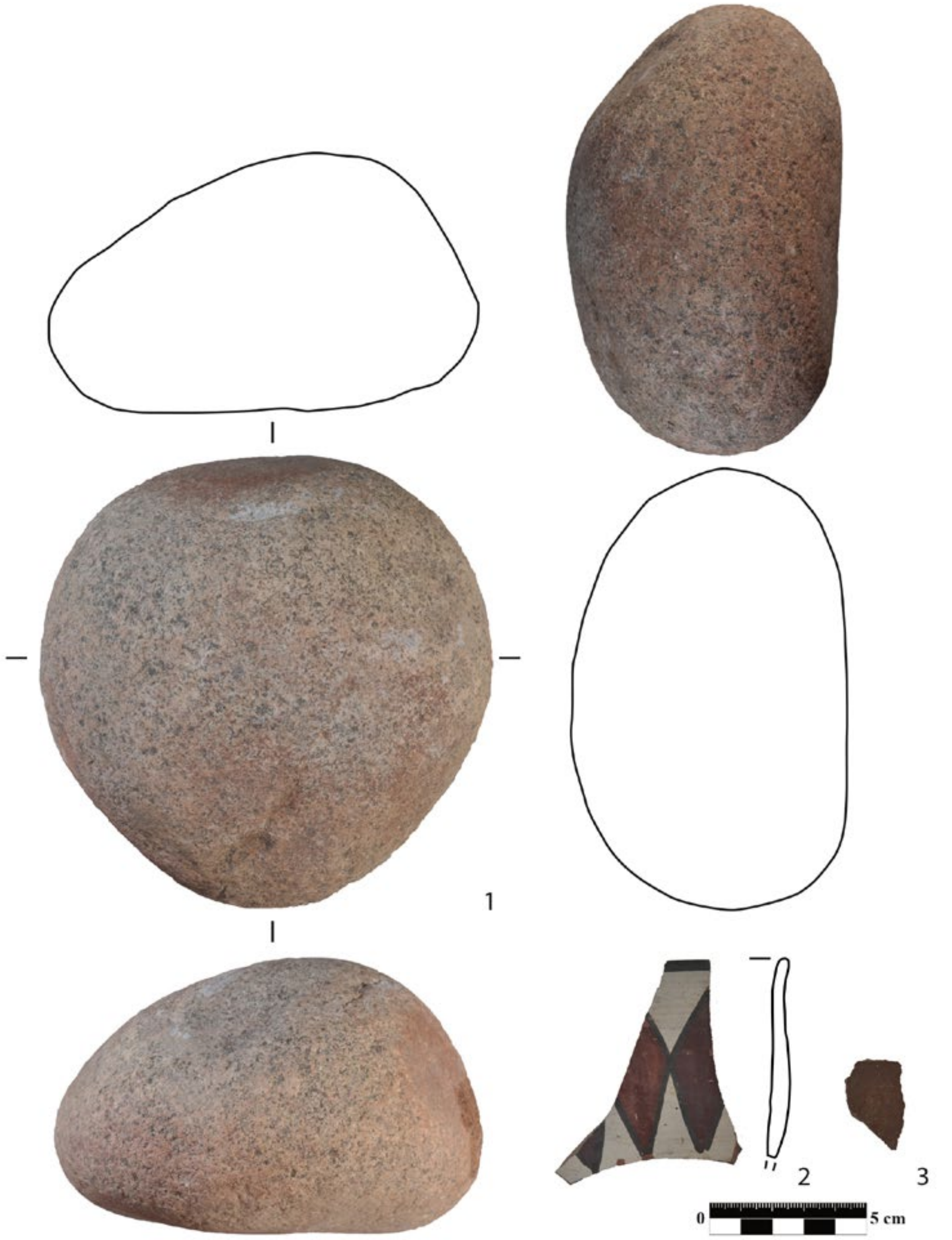

Fig. 159: PAP, Saramarca. TP 4, layer S Rasgo 5505 (graphic: DBM, B. Gräfingholt). 1 – 5505_03. 2–3 – Nasca 4.

Fig. 160: Saramarca. TP 4, layer S Rasgo 5505 (photo: DBM, B. Gräfingholt).

Fig. 161: Saramarca. TP 4, layer A Rasgo 5506 (photo: DBM, B. Gräfingholt).

Fig. 162: Saramarca. TP 4, layer B Rasgo 5507 (photo: DBM, B. Gräfingholt).

Fig. 163: Saramarca. TP 4, layer C Rasgo 5508 (photo: DBM, B. Gräfingholt).

Fig. 164: Saramarca. TP 4, layer D Rasgo 5509 (photo: DBM, B. Gräfingholt).

an old cigarette pack dated to the early 1990s. The color of the soil was defined as Munsell 10Y 5/8 yellowish brown. The layer was found under layer S Rasgo 5505 and above layer B Rasgo 5507 (Fig. 161).

7.5.4 Layer B Rasgo 5507

This layer consists of middle fine sand, rough detritus and angular stones. In the east, it was possible to document angular block showing traces of copper. The color of the soil was defined as Munsell 10Y 6/8 brownish yellow. The layer was found under layer A Rasgo 5506 and above layer C Rasgo 5508 (Fig. 162).

7.5.5 Layer C Rasgo 5508

The layer is characterized by well sorted middle fine sand mixed with angular stones and angular blocks. In the north the solid rock was reached. Here the Au vein was recorded and copper ores were found. The color of the soil was defined as Munsell 10Y 7/3 very pale brown. The layer was found under layer B Rasgo 5507 and above layer D Rasgo 5509 (Fig. 163).

7.5.6 Layer D Rasgo 5509

Layer D Rasgo 5509 represents the unmodified solid rock (Fig. 164).

7.5.7 Discussion of the TP4 Excavation

Although artifacts were only documented on the surface of this TP it seems nonetheless imperative to postulate that this region had to be a hotspot for pre-Columbian gold mining (Fig. 165).

The modern mining waste – characterized by rough detritus and angular stones – which was produced by iron tools, overflows well sorted middle fine sand which is an indicator of mining with stone tools. By crushing the rocks these stone tools produce middle fine sand which was clearly documented in layer C Rasgo 5508. Furthermore, the whole ensemble of ancient mines, processing sites, cemeteries and settlements documented in the Saramarca region leave no doubt that not only modern miners were attracted to this site. Judging from the ceramic material that was found on the surface it can be assumed that in contrast to the Paracas site Mollaque Grande Saramarca flourished in the Early Nasca period. Stone tools that

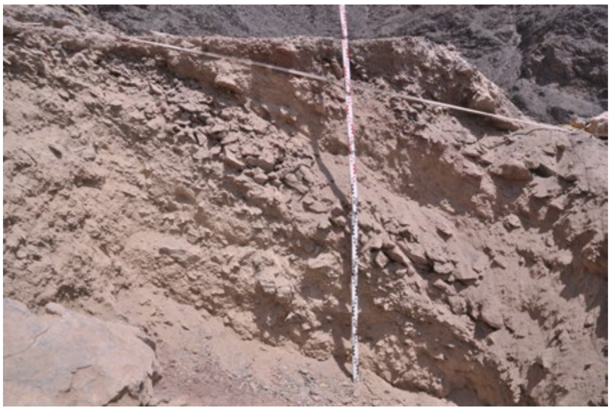

Fig. 165: Saramarca. Southern Profile of TP 4. The waste of mine SA_06 can clearly be identified in this profile (photo: DBM, B. Gräfingholt).

Fig. 166: Saramarca. Stone tool (Sa_07) documented on the surface of the Nasca cemetery near the valley floor (photo: DBM, B. Gräfingholt).

were documented on the surface of TP 4 next to the mine SA_06 and on the looted cemetery indicate that mining equipment was present, but because of the complete destruction of the cemetery by huaqueros (grave robbers), no secure context of these finds could be established. One example of this mining equipment that probably dates to Early Nasca is a stone tool documented on the surface (Sa_07, 3576g) (Fig. 166).

7.6 Geochemical analysis of ores from the test pits

7.6.1 Sampling strategy

In total ten ore samples were taken during the excavations of the TP´s in Mollaque Grande and Saramarca. The objective was to take samples from securely dated contexts from the archaeological excavations, due to the given circumstances the samples from TP 2 and TP 4 cannot be assigned to a certain cultural horizon. All samples were analyzed with XRD in the Deutsches Bergbau-Museum Bochum (DBM) to gain information on the composition of the samples.

7.6.2 Sample preparation

In order to get a homogenous material for the XRD analyses, all samples were pulverized to a grain size of less than 100 µm. The powder created was then transferred to a sample holder and placed in the diffractometer.

7.6.3 Analytical instrument for the XRD analyses

XRD-analyses were performed with a PANalytical X'Pert instrument (PRO MPD) and X'Celerator detector, interpretation with High Score Plus-software. A small amount of powdered sample (< 0.063 mm fraction size) was analyzed with ADS (automatic divergence slit) and Cu-Kα-radiation of 1.54178 Å at 45 kV and 40 mA. Angle array was 5–70° 2-theta with a rate of 0.017°/10 sec.[742]

7.6.4 Results

7.6.4.1 TP 1, layer B Rasgo 5487 Entierro I

Sample 4959-14 was taken from TP 1, layer B Rasgo 5487 Entierro I near the crouched inhumation, which was dated to Late Paracas (Ocucaje 8). The XRD analysis did not detect any traces of copper or gold in the sample.

7.6.4.2 TP 1, layer C Rasgo 5488

Sample 4661-14 was taken from TP 1, layer C Rasgo 5488 which was dated using Late Paracas (Ocucaje 8) ceramic. (Plate 8) The XRD analysis did not detect any traces of copper or gold in the sample.

7.6.4.3 TP 2, layer D Rasgo 5497

Sample 4664-14 was taken from TP 2, layer D Rasgo 5497, which was probably associated to the recent exploitation of the pre-Columbian mine in the 1990ies. The XRD analysis did not detect any traces of copper or gold in the sample.

7.6.4.4 TP 3, layer B Rasgo 5501

Sample 4659-14 was taken from TP 3, layer B Rasgo 5501, which was dated using Late Paracas (Ocucaje 8/9)

742 Personal communication with Dr. Michael Bode (Material Science, Deutsches Bergbau-Museum Bochum [DBM]) 2016.

ceramic (Fig 148). The XRD analysis did not detect any traces of copper or gold in the sample.

7.6.4.5 TP 3, layer D Rasgo 5503

Sample 4663-14 was taken from TP 3, layer D Rasgo 5503 which was dated using Early Paracas (Ocucaje 3/4) ceramic (Fig. 152). The XRD analysis did not detect any traces of copper or gold in the sample.

7.6.4.6 TP 4, layer S Rasgo 5505

Sample 4660-14 was taken from TP 4, layer S Rasgo 5505 which is associated to the recent artisanal gold extraction at this site. The XRD analysis did not detect any traces of copper or gold in the sample; only traces of Hematite (Fe_2O_3) were present.

7.6.4.7 TP 4, layer B Rasgo 5507

Samples 4658-14a and 4658-14b were taken from TP 4, layer B Rasgo 5507 which is associated with the recent artisanal gold extraction at this site. The XRD analysis did not detect any traces of copper or gold in the sample; only traces of hematite (Fe_2O_3) were present in sample 4558-14b. This may indicate that the modern miners either carefully selected the gold bearing ores, or that this mine did not produce any valuable raw material and was therefore abandoned. The fact that two more layers of extracted material were excavated, indicates that gold bearing ores were exploited at this site and that the mine was worth a considerable amount of work. Therefore, it can be assumed, that gold mining took place at this site recently, leading to the assumption that also the pre-Columbian inhabitants of this region during the Nasca period had knowledge of the gold bearing vein of these hills.

7.6.4.8 TP 4, layer C Rasgo 5508

The samples 4657-14a and 4657-14b were taken from layer C Rasgo 5508, which is probably associated to a pre-Columbian gold extraction at this site. Still, the XRD analysis did not detect any traces of copper or gold in the samples; only traces of Hematite (Fe_2O_3) were present in sample 4557-14b. This may indicate that the pre-Columbian miners either carefully selected the gold bearing ores, or that this mine produced other valuable raw materials such as Hematite (Fe_2O_3), which was used as pre-fire slip-pigment paint for the polychrome ceramic manufactured during the Nasca period.[743]

[743] Vaughn, et al., 2005, p.142.

7.7 Geochemical analysis of ore samples from the research area

7.7.1 Introduction and question

The central Andes region is considered a zone of wide-spread gold and polymetallic ore deposits that have been exploited since the Formative Period, especially in northern Peru.

In the course of three survey campaigns, ore samples were taken in order to characterize the geochemical composition of the research area. The Nasca-Ocoña belt extends from the arid coastal region of Peru to the Atacama Desert in northern Chile. The area studied was limited to the Palpa/Nazca region. As a result of these surveys extensive pre-columbian gold mining was located. Samples were analyzed in the laboratories in Bochum and Frankfurt. The samples derive from the river systems in the area around Palpa. The samples originate from overburden dumps and are therefore only suitable for providing an overall impression of the ore district. Preference was given to locations with old mining sites, or areas from the context of the numerous pre-Columbian settlements.

7.7.2 Natural environment conditions

The origin of the deposits in the Andes region is roughly generalized and attributed to major plate tectonic events, which are connected to a collision of terrestrial and oceanic crust of continental dimensions that has been continuous since the Tertiary. In central South America, major plate tectonic events push (subducted) a relatively heavier oceanic lithosphere plate (Nazca Plate) several kilometers below the relatively lighter continental plate of the mainland. This leads to the formation of the Andean mountain range with a deep-sea trench in front of it, with a thickening of the crust and the formation of huge intrusive bodies, which develop their effect in the deeper subsoil in the form of piles of storeys, for example to supply fluids with metal contents, which can be excreted in large quantities elsewhere. Due to the movements of the plate collision, a so-called active continental margin is formed, which is characterized by high earthquake activity and particularly explosive volcanism, but also has a considerable potential for the formation of deposits of various (polymetallic) ores, especially in the Palpa-Nazca district, an ore belt running parallel to the mountains is found, whose mineralization is related to a huge intrusive body (coastal batholiths) and its movements underground. In the area from Ica to Nazca rift structures (Ica-Nazca-Depression) have developed, which show hydrothermally formed vangue systems mineralized in Mesozoic layers at several partly crossing fault lines. In near-surface areas of the batholite, scarring is also possible. The vein fillings consist mainly of iron-copper-gold ores in quartz-dominated veins or quartz veins with partly extremely high precious metal contents.

7.7.3 Laboratory work

The ore samples taken were processed and properly examined in the laboratories of the Deutsches Bergbau-Museum Bochum (DBM) with the resources available there, Dr. Guntram Gassmann has supervised this part of the project and was in charge of the laboratory work. The processing and washing of gold samples was carried out in Dortmund by Dr. Wolgang Homann (†), in-situ chemical analyses were performed using a field-emission electron microprobe "SXFiveFE" at the Ruhr-Universität Bochum by Dr. Nils Jöns.

Under the supervision of Dr. Guntram Gassmann, the investigations followed a proven analysis program; the focus was laid on the characterization of the sample material including the determination of the ore content and the main, minor and trace element contents for possible provenance analysis. The samples derive from different survey campaigns in the research area conducted in 2009 and 2018 (Tab. 3). In total, these samples represent a meridian of the mineralization zone of the Nasca-Palpa area.

DBM Lab.-Nr.	Survey Ref.-Nr.	UTM Zone	UTM N	UTM E	Altitude	Date	Location
3980_18	P18017	18L	8401805	476330	650	19.2.2018	Locari
3981_18	P18018	18L	8404921	478163	737	19.2.2018	Locari
3982_18	P18020	18L	8404799	478155	764	19.2.2018	Locari
3983_18	P18022	18L	8404517	478008		19.2.2018	Locari
3984_18	P18023	18L	8400364	473334	562	20.2.2018	El Carmen
3985_18	P18024	18L	8401472	473320	579	20.2.2018	El Carmen
3986_18	P18025	18L	8401897	476566	666	20.2.2018	?
3987_18	P18026	18L	8401940	476464	644	20.2.2018	?
3988_18	P18027	18L	8404446	478109	687	20.2.2018	Locari/ San Miguel
3989_18	P18028	18L	8404442	478295		20.2.2018	San Miguel
3990_18	P18030	18L	8404234	477703	701	20.2.2018	Locorai
3991_18	P18032	18L	8398473	489881	613	21.2.2018	Saramarca
3992_18	P18033	18L	8398527	489740	707	21.2.2018	Saramarca
3993_18	P18034	18L	8398139	489602	671	21.2.2018	Saramarca
3994_18	P18035	18L	8396707	488189		21.2.2018	Saramarca
3995_18	P18036_1	18L	8396915	488092		21.2.2018	Saramarca
3996_18	P18036_2	18L	8396915	488092		21.2.2018	Saramarca
3997_18	P18037	18L	8396827	488110	679	21.2.2018	Saramarca
3998_18	P18038	18L	8397527	484090	467	22.2.2018	Mollaque Grande
3999_18	P18048	18L	8397371	484082	570	22.2.2018	Mollaque Grande
4000_18	P18056	18L	8397459	484093	530	22.2.2018	Mollaque Grande
4001_18	P18060	18L	8397594	482371		22.2.2018	Pinchango
4002_18	P18061	18L	8398075	482497	541	23.2.2018	Pinchango
4003_18	P18069	18L	8390568	475716	319	24.2.2018	La Muna
4004_18	P18070	18L	8390306	475797	320	24.2.2018	La Muna
4005_18	P18071	18L	8390437	475718		24.2.2018	La Muna
4006_18	P18072	18L	8390749	475353	383	24.2.2018	La Muna
4338-09	PA12-1	18L	8386740.45	495875.21	773.74	02.04.2009	Ayapana-Valley
4345-09	PD17-1	18L	8404521.26	478018.71	720.15	05.04.2009	Santa Cruz, Locari, mine site
4339-09	PC01-1	18L	8356641.93	522975.02	1512	04.04.2009	Cerro-Chucchurumi
4346-09	PE 01-1	18L	8397039.65	488436.754	599.02	06.04.2009	Vizcas, Saramarca

Tab. 3: Sample list (table: DBM, B. Gräfingholt).

7.7.3.1 Sampling strategy

The sampling strategy initially envisaged a macroscopic approach and documentation. Then the handpieces were separated so that only one part was used for elemental analysis. In the case of copper-rich samples, sections were produced from the counterpart, in order to document them using microscopic methods. If necessary, investigations were carried out on the SEM with coupled semiquantitative EDX element analysis with rich photo documentation. These samples were further analyzed and the element content was determined by ICP MS. (Tab. 6) Furthermore, the gold content of the samples was measured in the laboratory of the German Mining Museum. (Tab. 7 and Tab. 8) For the samples with the most promising gold contents, an excellent gold panning expert was found, who was able to prepare the material mechanically in such a way that he could extract individual flakes by hand and transfer them to sample carriers. The recovered flakes could then be analyzed again under the SEM and at the Ruhr-Universität Bochum with the microprobe there, also with extensive analysis and image documentation.

7.7.4 Description of ore samples under the light microscope

Preparation of the cross sections was done by Dr. Guntram Gassmann. Description of the ore sections under the light microscope were prepared by Dr. Guntram Gassmann and Dr. Katrin Westner.

3995 P18036_1 (Fig. 167 and Fig. 168)

Sulfide droplets in quartz
Quartz (qz)
Iron hydroxide (gt)
Atacamite
Copper sulfide
Iron oxides and hydroxides
Chalcopyrite (ccp)

Brief description:
Massive portions of quartz interspersed with iron hydroxides and secondary copper mineralization (atacamite) in the quartz grains are sulphide droplets, including chalcopyrite.

3981 P18018 (Fig. 169 and Fig. 170)

Chalcopyrite (ccp)
Magnetite (mt)
Digenite (dg)
Chalcotin/Covellin (cct)
Iron hydroxide (gt)
Stem phase: clarify on grid

Brief description:
Secondary copper and iron mineralization with some magnetite and chalcopyrite, the latter occasionally lined with secondary formation (chalcotite and digenite?).

3990 P18030 (Fig. 171 and Fig. 172)

Iron hydroxide (gt)
Magnetite (mt)
Atacamite in stem form
Pyrite?

Brief description:
Secondary copper mineralization (atacamite in characteristically stem-like form) and iron mineralization with some magnetite, perhaps also pyrite (clarify on grid).

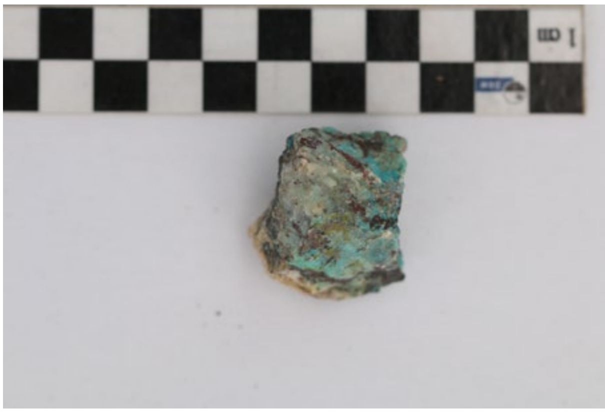

Fig. 167: Ore smaple P18036_1 (photo: DBM, G. Gassmann).

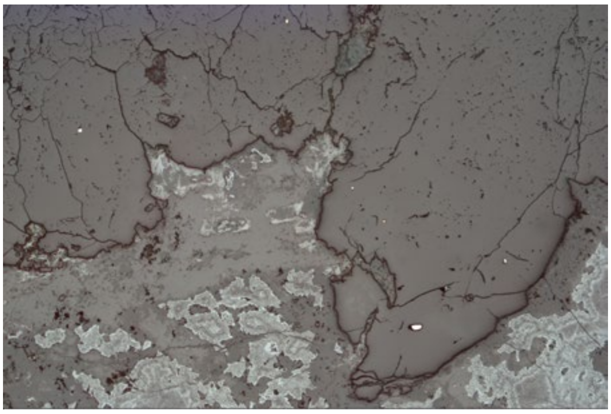

Fig. 168: SEM picture of the cross-section of ore sample P18036_01 (graphic: DBM, D. Demant).

Fig. 169: Ore sample P18018 (photo: DBM, G. Gassmann).

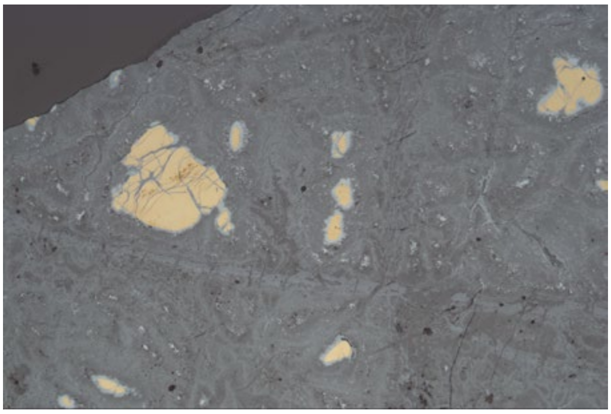

Fig. 170: SEM picture of the cross section of ore sample P18018 (graphic: DBM, B. Gräfingholt).

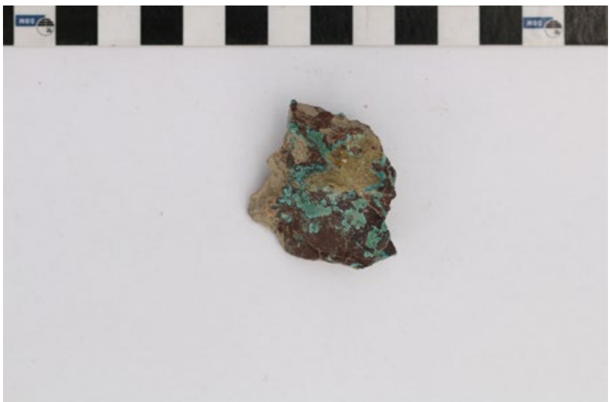

Fig. 171: Ore sample P18030 (photo: DBM, G. Gassmann).

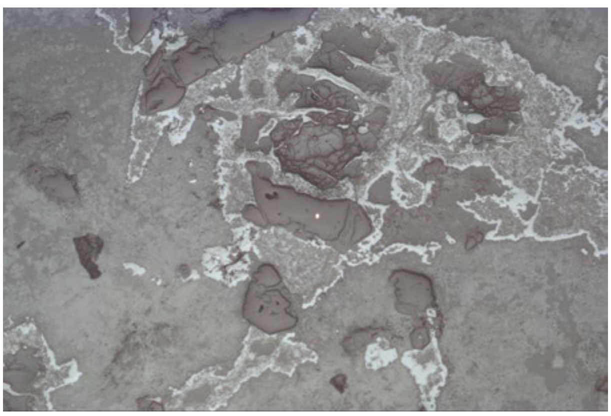

Fig. 172: SEM picture of the cross section of ore sample P18030 (graphic: DBM, B. Gräfingholt).

Fig. 173: Ore sample P18034 (photo: DBM, G. Gassmann).

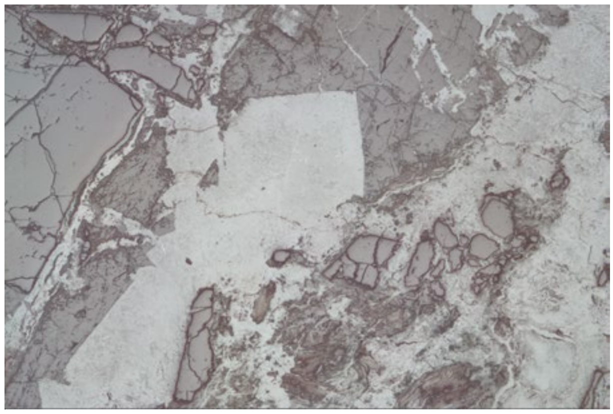

Fig. 174: SEM picture of the cross section of ore sample P18034 (graphic: DBM, B. Gräfingholt).

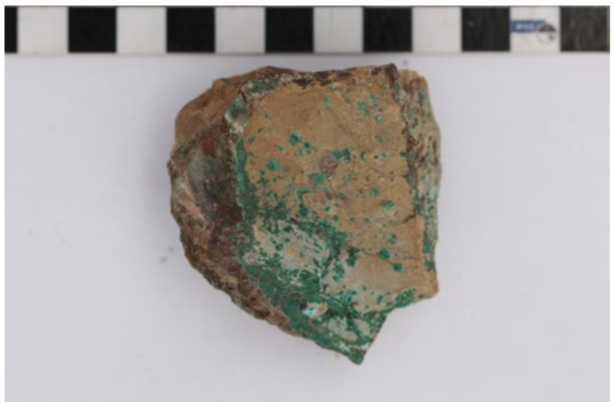

Fig. 175: Ore sample P18060 (photo: DBM, G. Gassmann).

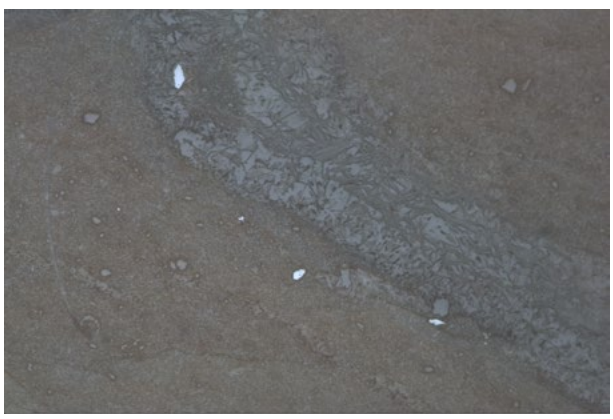

Fig. 176: SEM picture of the cross section of ore sample P18060 (graphic: DBM, B. Gräfingholt).

3993 P18034 (Fig. 173 and Fig. 174)

Quartz (qz)
Iron oxide
Atacamite
Magnetite?
Sulfide droplets

Brief description:
Quartz bands alternating with layers of iron hydroxides with magnetite and secondary copper mineralizations (atacamite). Isolated sulphide droplets in the secondary precipitations.

4001 P18060 (Fig. 175 and Fig. 176)

Chalcedony
Quartz?
Pyrite?
Atacamite (atc)

Brief description:
Ground mass of chalcedony (?) interspersed with granular quartz. With veins of iron oxide and atacamite. Some pyrite (?) in the matrix.

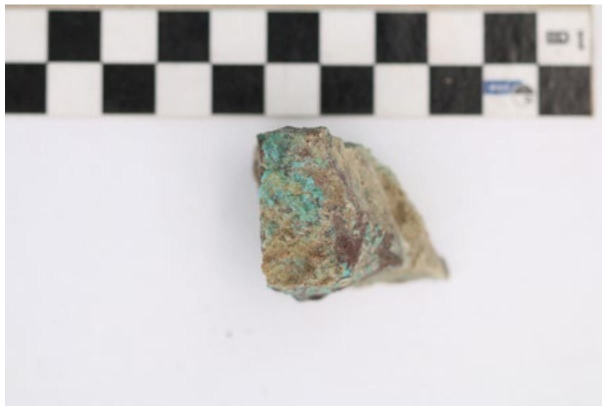

Fig. 177: Ore sample P18027 (photo: DBM, G. Gassmann).

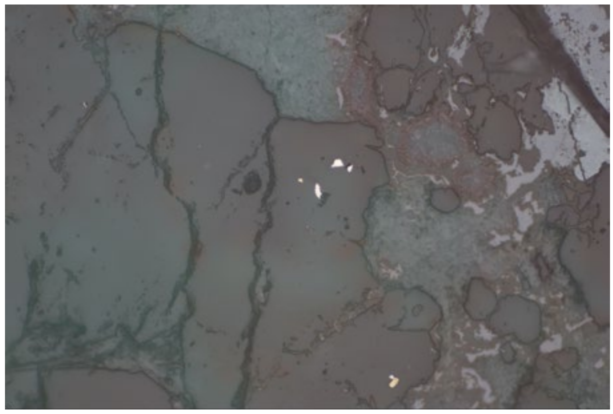

Fig. 178: SEM picture of the cross section of ore sample P18027 (graphic: DBM, B. Gräfingholt).

3988 P18027 (Fig. 177 and Fig. 178)

Pyrite
Quartz
Atacamite
Iron Hydroxide
Hematite
Chalcopyrite
Magnetite

Brief description:
Quartz vein with layers of iron oxides and hydroxides including magnetite and hematite and secondary copper mineralization (atacamite). There is some pyrite or chalcopyrite in the quartz.

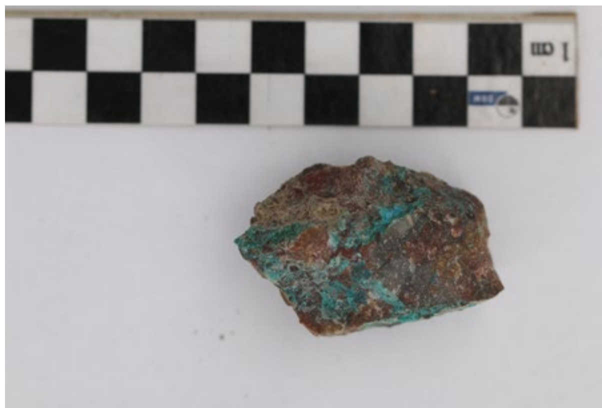

Fig. 179: Ore sample P18020 (photo: DBM, G. Gassmann).

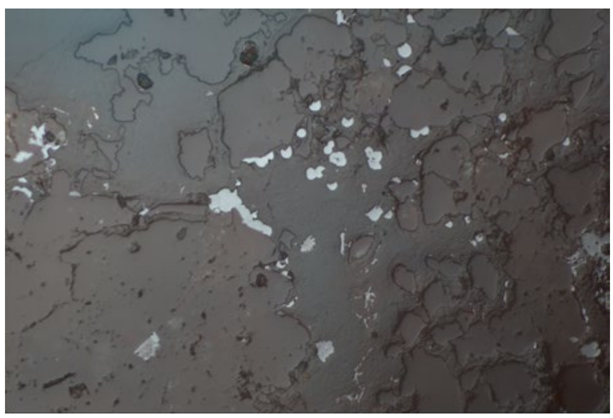

Fig. 180: SEM picture of the cross section of ore sample P18020 (graphic: DBM, B. Gräfingholt).

3982 P18020 (Fig. 179 and Fig. 180)

Fe oxide phases
Cu Sulfide
Ouartz
Pyrite
Magnetite

Brief description:
Quartz vein with banding, containing secondary iron and copper mineralization. Cu sulfide inclusions often occur in the quartz grains. At the grain boundaries there is also magnetite (?).

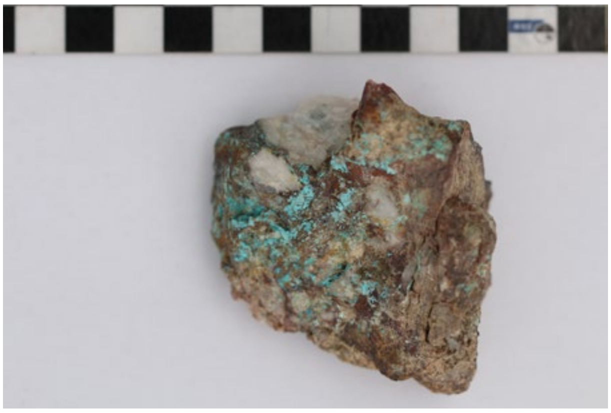

Fig. 181: Ore sample P18022 (photo: DBM, G. Gassmann).

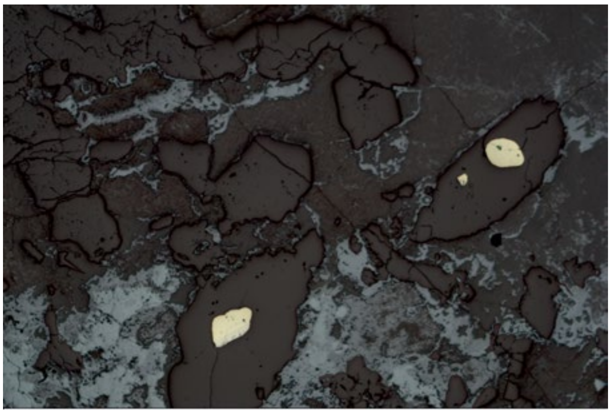

Fig. 182: SEM picture of the cross section of ore sample P18022 (graphic: DBM, B. Gräfingholt).

3983 P18022 (Fig. 181 and Fig. 182)

Fe oxide phases
Cu Sulfide
Quartz
Pyrite
Fe Sulfide

Brief description:
Quartz vein interspersed with secondary iron and copper mineralization. The quartz contains partly larger Cu sulfides, occasionally intergrown with pyrite. Isolated sulfide droplets contain some covellite.

3985 P18024 (Fig. 183 and Fig. 184)

Mt with sulfide inclusions
Quartz
Chalcopyrite (ccp)
Atacamite
Pyrite inclusions in quartz

Brief description:
Much magnetite with further iron oxides at the grain boundaries, in between some quartz with chalcopyrite inclusions and pyrite. In the magnetite, there are further sulfide inclusions. Mainly peripheral veins of secondary copper and iron mineralization.

Fig. 183: Ore sample P18024 (photo: DBM, G. Gassmann).

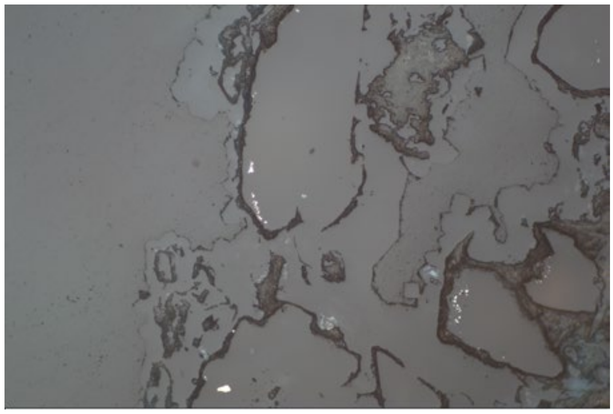

Fig. 184: SEM picture of the cross section of ore sample P18024 (graphic: DBM, B. Gräfingholt).

7.7.5 Gold

Until now, only one study has analyzed gold from the Nasca-Palpa area. In total, ore samples from four mines were used to characterize the gold composition of the research area.[744] Here, a wider sampling strategy was applied. Twenty-seven samples from recent and ancient mining sites were analyzed with a variety of methods. Accoording to the data provided by Schlosser, et al. (2009, p.432) scatterplots of the Pd-Rh (Fig. 185) and Ni-Ag/Au (Fig. 186) graph demonstrate a much more differentiated deposit composition than earlier assumed.

The samples (Tab. 4) with the most promising gold content were selected to be processed mechanically by an expert on gold panning. Dr. Wolfgang Homann (†) was able to prepare the material mechanically in such a way that he could extract individual flakes by hand and transfer them to sample carriers provided by the Deutsches Bergbau-Museum Bochum (DBM), which fit into the SEM.

7.7.5.1 Scanning Electron Microscope (SEM)

The Zeiss GEMINI Supra 40 VP scanning electron microscope (SEM) is a type of electron-microscope, which uses a focused electron beam to raster scan a specimen

[744] Schlosser, et al., 2009.

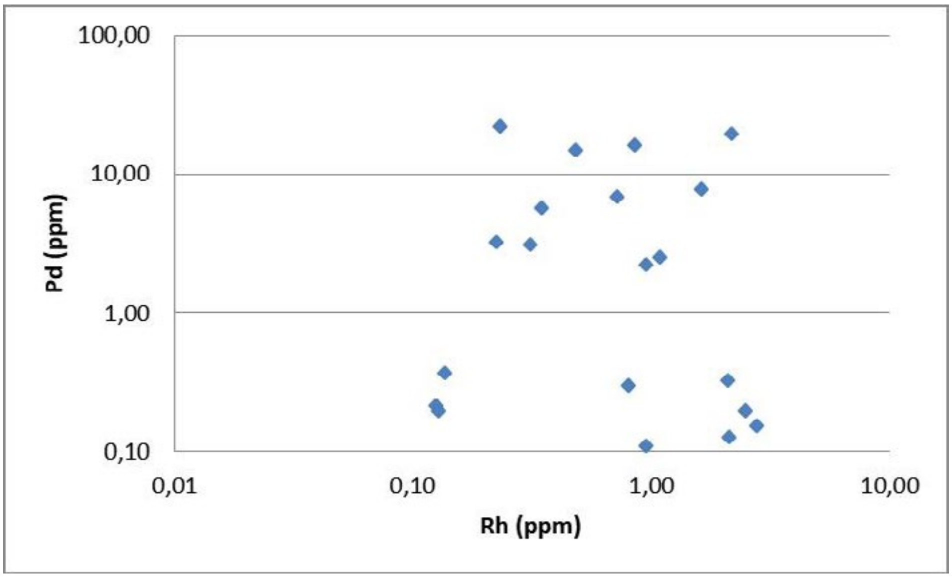

Fig. 185: Pd-Rh scatterplot for 27 samples from the research area (graphic: DBM, B. Gräfingholt).

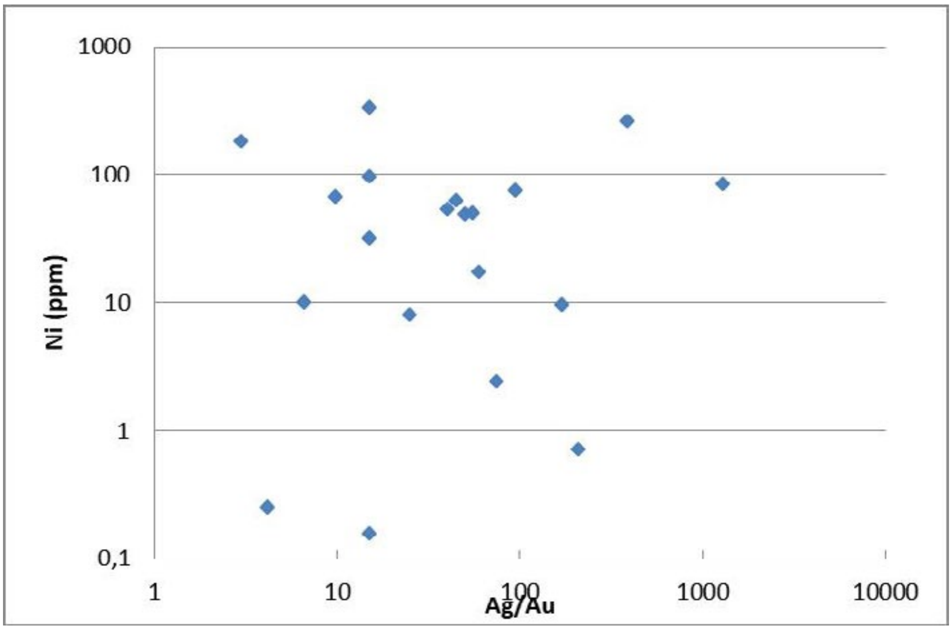

Fig. 186: Ni-Ag/Au scatterplot for 27 samples from the research area (graphic: DBM, B. Gräfingholt).

surface and thereby generates different signals that contain information about the topography and chemical composition of the sample.

In a very simplistic way, the general buildup of an SEM can be described as the following:

At the top there is an electron gun generating the electron beam, which afterwards is accelerated towards the specimen and focused by different condenser and objective lenses as well as an aperture. In order to achieve best results, the system needs to be under high vacuum levels.

On the bottom there is the specimen holder, which can be controlled in x,y and z axis and thereby moves, tilt and rotate the specimen.

On top of the Specimen surface where the electron beam hits the atoms of the specimen surface, is an area of beam/specimen interaction at which different kind of signals are produced. The most common being the secondary electrons and back-scattered electrons.

Secondary electrons are generated when primary electrons from the beam hit electrons inside the specimen atoms and kick them out of valence bands. The process is called inelastic shattering and only occurs within a few nanometers below the specimen surface. Therefore, secondary electrons can be used for displaying the topography of a sample and yield a very high resolution.

Back scattered electrons are generated, when electrons of the primary Beam pass near an atomic core of the specimen and are elastic scattered. The heavier the atom the more backscattering occurs. This principle is used to display material contrasts inside the sample. In a back scattered picture heavy elements appear brighter then light ones.

DBM Lab.-Nr.	Survey Ref.-Nr.	UTM Zone	UTM N	UTM E	Altitude	Date	Location
3987_18	P18026	18L	8401940	476464	644	20.2.2018	?
4338-09	PA12-1	18L	8386740.45	495875.21	773.74	02.04.2009	Ayapana-Valley
4345-09	PD17-1	18L	8404521.26	478018.71	720.15	05.04.2009	Santa Cruz, Locari, mine site
4339-09	PC01-1	18L	8356641.93	522975.02	1512	04.04.2009	Cerro-Chucchurumi
4346-09	PE 01-1	18L	8397039.65	488436.754	599.02	06.04.2009	Vizcas, Saramarca

Tab. 4: List of gold flakes extracted from the ore samples by mechanical procession (table: DBM, B. Gräfingholt).

Besides these two signals, there is a variety of other interaction signals that can be detected. Examples are EBSD, fluorescence, Auger electrons, wavelength dispersive X-ray analysis and energy dispersive analysis.

The Zeiss Supra 40 VP has an EDX (Energy dispersive X-ray analysis) Detector to analyze the chemical composition of a given specimen surface. The primary beam may eject an electron in an inner shell, while creating an electron hole. An electron from an outer, higher-energy shell then fills the hole and the difference in energy between the higher-energy shell and the lower energy shell is released in form of a X-ray. These X-rays can be measured and are characteristic for every given element in the periodic table of elements. This allows quickly measuring the chemical composition of a sample.[745] Dirk Kirchner performed the SEM measurements of the flakes in the laboratories of the Deutsches Bergbau-Museum Bochum (DBM) accompanied by Dr. Guntram Gassmann and the author. Results are given in Tab. 12, and Figs. 187–201 show the samples in high resolution.

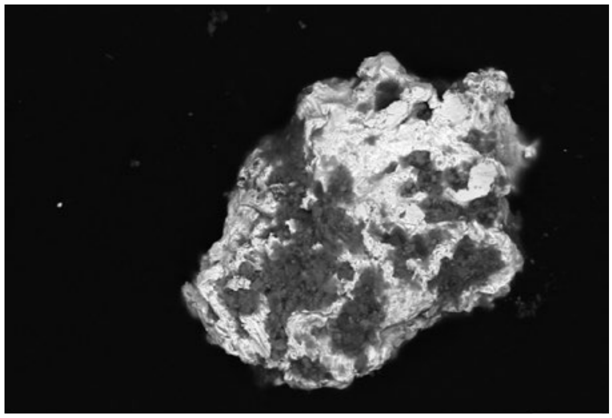

Fig. 187: SEM high-resolution topography scan of sample PE01 (4346-09) (graphic: DBM, D. Kirchner).

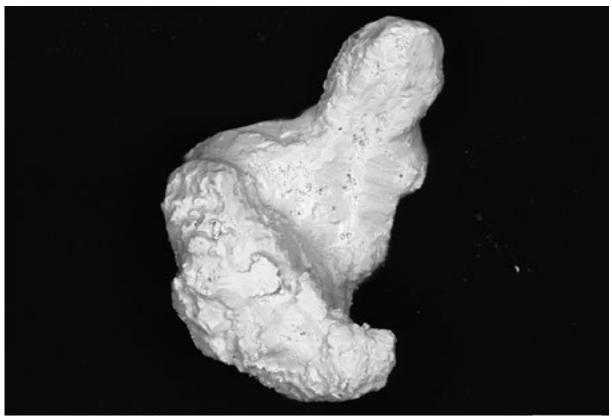

Fig. 188: SEM high-resolution topography scan of sample PD17 (4345-09) (graphic: DBM, D. Kirchner).

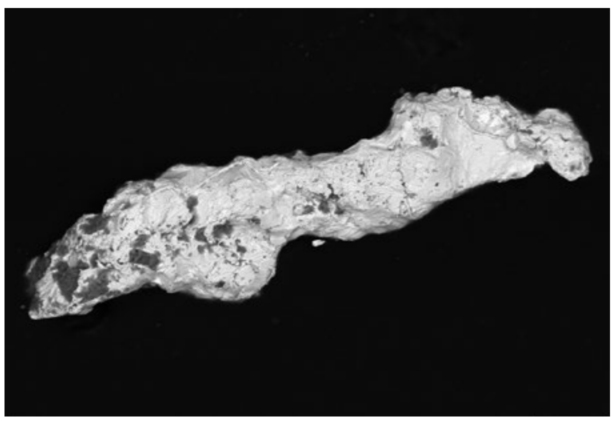

Fig. 189: SEM high-resolution topography scan of sample PD17 (4345-09) (graphic: DBM, D. Kirchner).

745 Goldstein, et al., 2018.

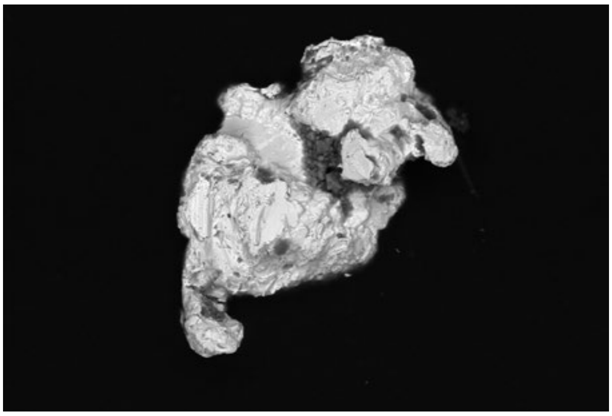

Fig. 190: SEM high-resolution topography scan of sample PD17 (4345-09) (graphic: DBM, D. Kirchner).

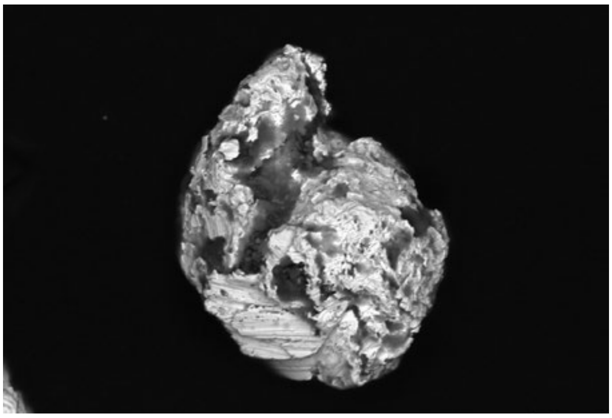

Fig. 191: SEM high-resolution topography scan of sample PA12 (4338-09) (graphic: DBM, D. Kirchner).

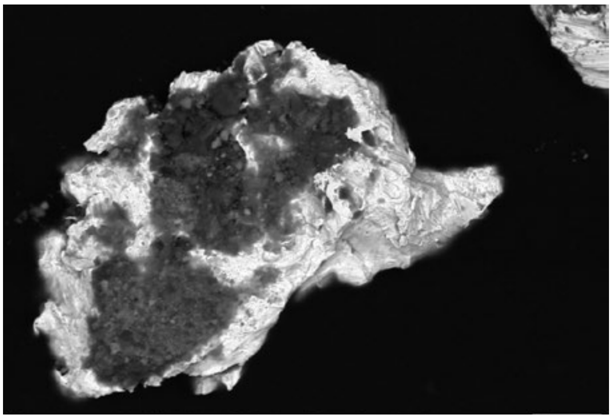

Fig. 192: SEM high-resolution topography scan of sample PA12 (4338-09) (graphic: DBM, D. Kirchner).

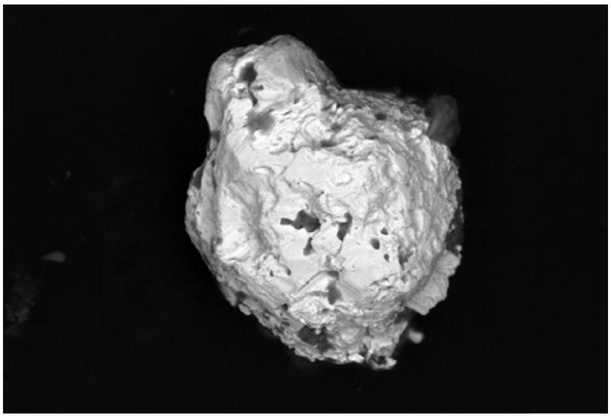

Fig. 193: SEM high resolution topography scan of sample PD01 (graphic: DBM, D. Kirchner).

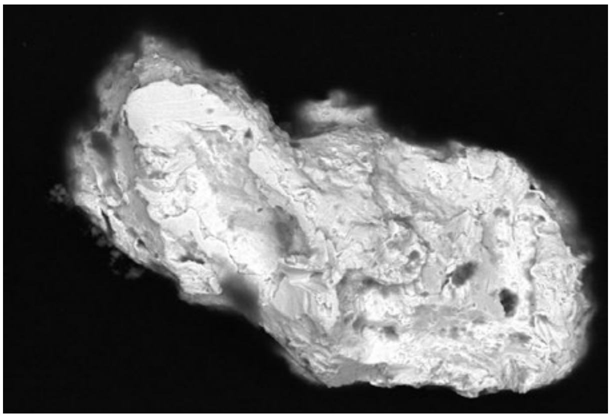

Fig. 194: SEM high resolution topography scan of sample PD01 (graphic: DBM, D. Kirchner).

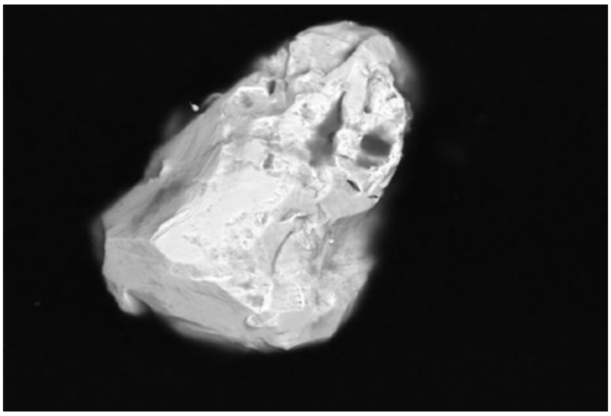

Fig. 195: SEM high resolution topography scan of sample PD01 (graphic: DBM, D. Kirchner).

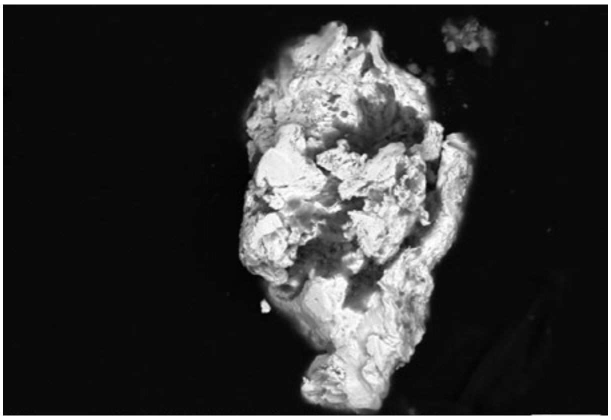

Fig. 196: SEM high resolution topography scan of sample PD01 (graphic: DBM, D. Kirchner).

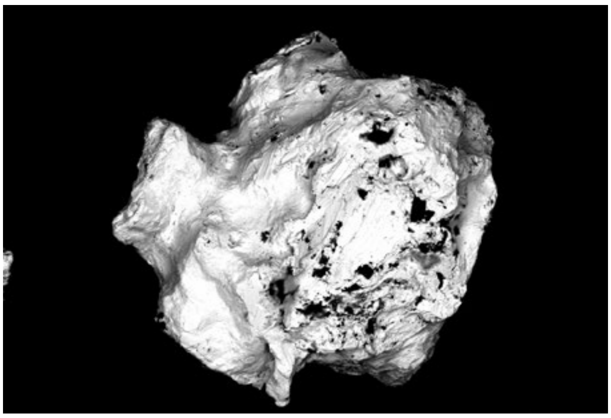

Fig. 197: SEM high resolution topography scan of sample P18026 (3987-09) (graphic: DBM, D. Kirchner).

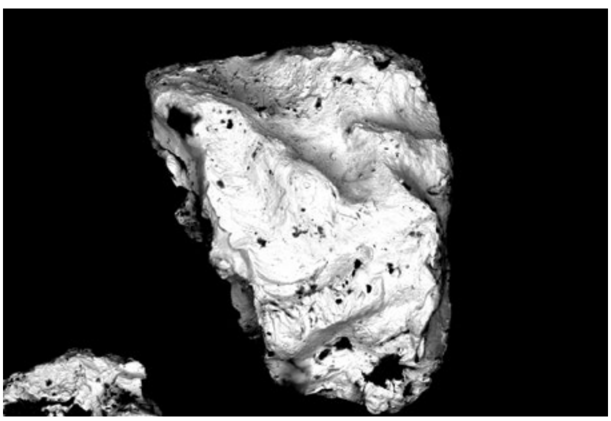

Fig. 198: SEM high-resolution topography scan of sample P18026 (3987-09) (graphic: DBM, D. Kirchner).

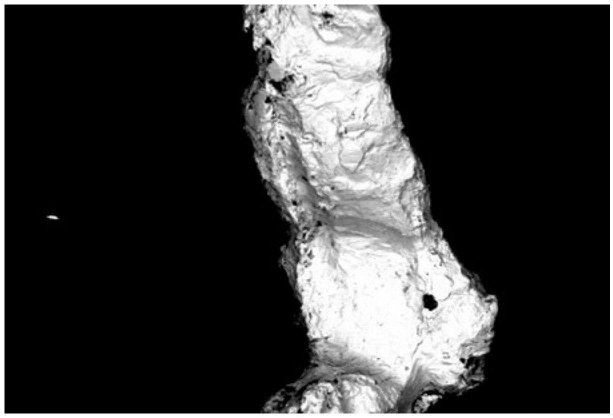

Fig. 199: SEM high-resolution topography scan of sample P18026 (3987-09) (graphic: DBM, D. Kirchner).

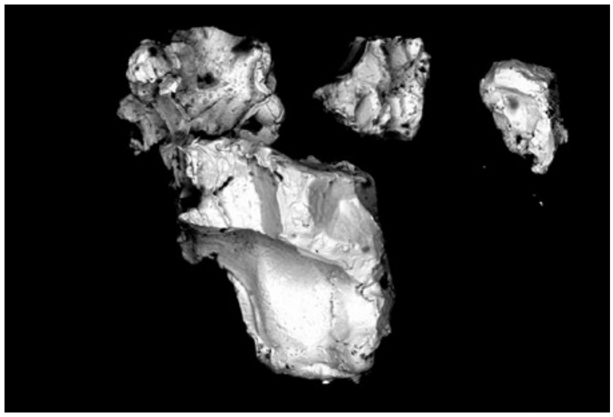

Fig. 200: SEM high resolution topography scan of sample PC01 (4339-09) (graphic: DBM, D. Kirchner).

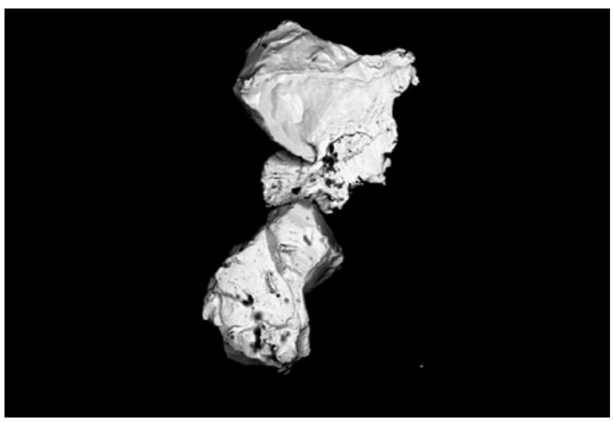

Fig. 201: SEM high-resolution topography scan of sample PC01 (4339-09) (graphic: DBM, D. Kirchner).

High-resolution pictures were taken after the SEM analysis, the raster of the SEM is still visible in the pictures as a light imprint on the sample carriers. (Fig. 202 – Fig. 206)

Afterwards these gold flakes were analyzed at the Ruhr-Universität Bochum. In-situ chemical analyses of the gold flakes from the research area were performed using a field-emission electron microprobe “SXFiveFE” by Cameca, equipped with five wavelength-dispersive spectrometers. An acceleration voltage of 20 kV and a probe current of 80 nA were used. Reference materials were natural $CuFeS_2$ for Cu, Fe and S, synthetic Ag_2Te for

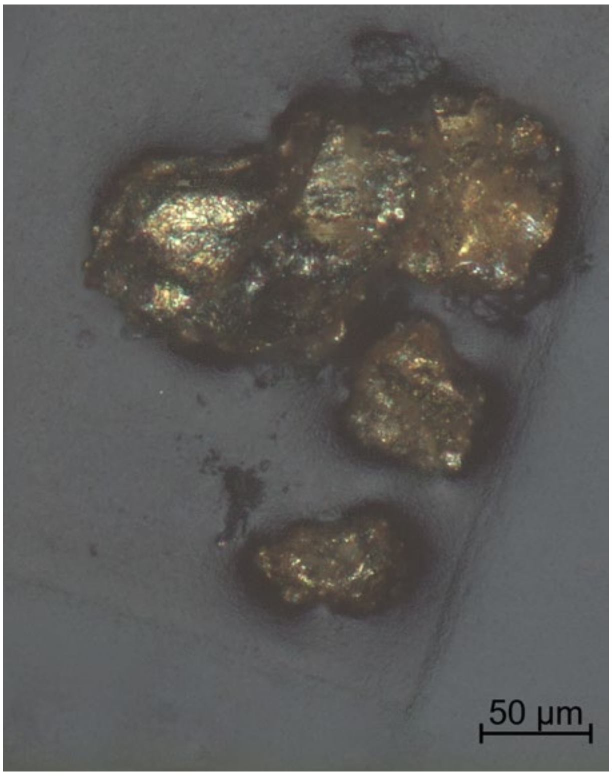

Fig. 202: High-resolution picture of PC 01 (photo: DBM, B. Gräfingholt).

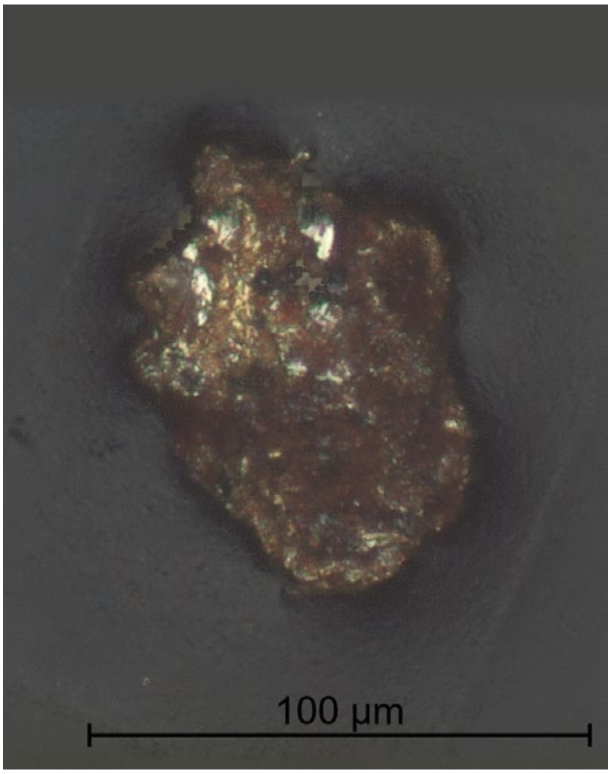

Fig. 204: High-resolution picture of PE 01 (photo: DBM, B. Gräfingholt).

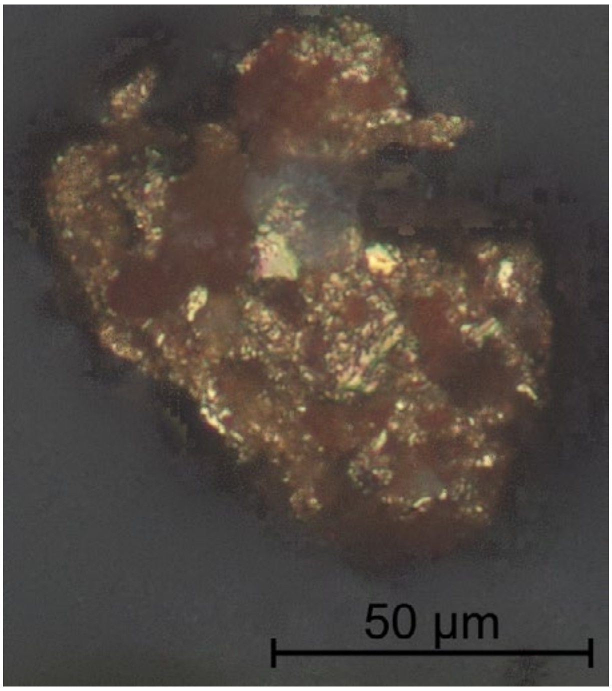

Fig. 203: High-resolution picture of PD 01 (photo: DBM, B. Gräfingholt).

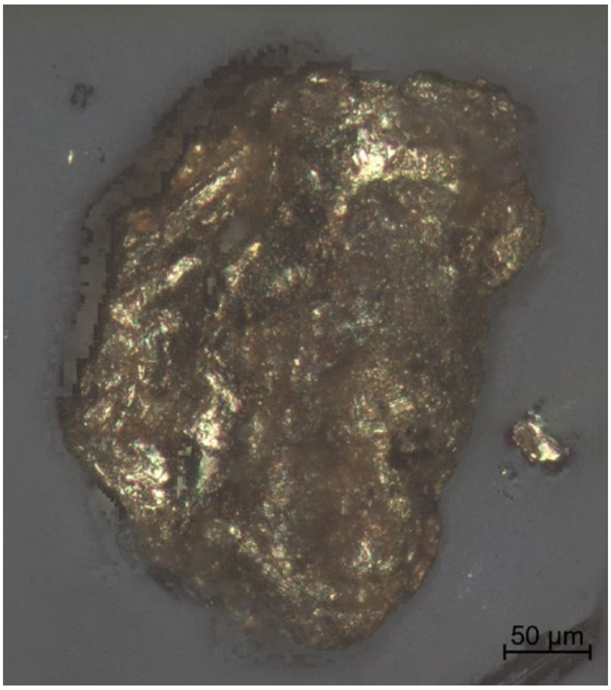

Fig. 205: High-resolution picture of P18026 (photo: DBM, B. Gräfingholt).

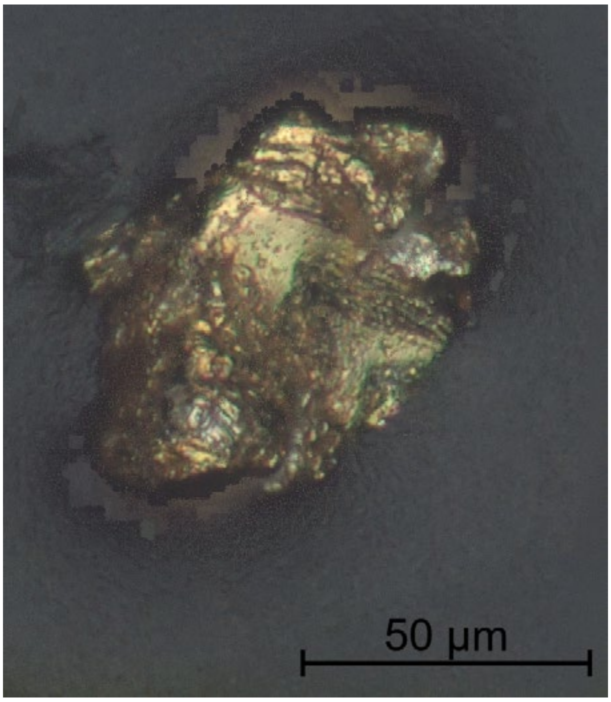

Fig. 206: High-resolution picture of PA 12 (photo: DBM, B. Gräfingholt).

Ag and Te and pure elements for all others. Raw data were quantified using the X-Phi procedure of Merlet[746] (Tab. 9).

Special emphasis was placed on the accompanying elements, in hope that this will enable the detection and characterization of deposit districts. The role of the PGE (Platin Group Elements) was erroneously over-focused in this context, because in mountain gold they are not meaningful and cannot be regarded as characterizing. Many PGEs in gold tinsel are only acquired by flux transport of the gold.[747]

7.8 Discussion

The archaeological investigation and excavations conducted in the pre-Columbian mining districts of Mollaque Grande and Saramarca have demonstrated that the inhabitants of the Nasca-Palpa area who settled in the region from the Archaic onward[748] were aware of the rich polymetallic ores embedded on the flanks of the quebradas. The site Mollaque Grande is extremely important for the pre-Columbian mining archaeological research as it offers an insight into an early stage of mining and the organization of labor in a mining settlement during the whole span of the Paracas culture. This site was continuously occupied from Early to Late Paracas with a short transition into the Nasca Period as demonstrated by the Initial Nasca ceramic found in TP 1, layer A Rasgo 5485. Due to the excavated stone mining tools (5486_25; 5502_15) and ore fragments as well as the documented surface finds of mining equipment (e.g. crushing anvil MoGr 12) it can be stated that mining was conducted on this site. Nonetheless the conducted XRD analysis of the excavated ores failed to produce such impressive results of copper and gold content, which were received for the samples from Mollaque Grande and Saramarca during the 2009 campaign.[749] One reason that no traces of copper or gold were documented in the excavated ores might be a very careful processing of the exploited ores by the pre-Columbian miners, who did not waste the precious raw materials. Such a very careful processing technique has been documented for the modern artisanal silver processing in the Andes, were the slag is recycled and added together with the litharge into the furnaces again to maximize the amount of silver.[750] This technique has probably been handed down unchanged from the pre-Columbian times according to litharge that was documented in the archaeological context in Ancón dating to the Middle to Later Horizon.[751] Another reason might also be that the ores samples chosen did not represent the whole variety of excavated material and a wider cross section of samples that are still stored in Peru may specify the results. Therefore, it seems imperative to clarify this open question by running a second round of analysis with more of the excavated samples. But due to the results received from Stöllner, et al. (2013, p.125 tab.1) , which verified gold and copper deposits at the sites of Mollaque Grande and Saramarca and taking into account the gold mining operations still existing on both sites – it is most likely that the pre-Columbian miners targeted the polymetallic ores in order to extract copper and gold. Because of the very early stage of ore mining documented on this site, one cannot expect to find an as extensive and diversified mining district as in Batan Grande in northern Peru[752]. Still the patterns of pre-Columbian mining in the Nasca-Palpa area can be outlined very precisely because of the results of this study. The unusual settlement location in a considerable distance from the river valley, which already existed during Early Paracas, makes Mollaque Grande special. So far it has not been possible to document in situ Early Paracas mining equipment and tools or directly link the mining ensemble documented on the hill slope of Mollaque Grande to the earliest occupation horizon. A reason for this may certainly be the limited scope of the excavations conducted during this study – a wide-range excavation of the whole site is definitely needed to clarify the results. Still the complete angular stone mining tool (5486_25) found in situ in TP 1, layer B Rasgo 5486 (Fig. 116) dating to Late Paracas and the incomplete stone mining tool (5502_15) found in TP 3,

746 Merlet, 1994.
747 Personal communication with G. Gassmann, 2020.
748 Unkel, et al., 2012, p.2301.

749 Stöllner, et al., 2013; Reindel, Stöllner and Gräfingholt, 2013.
750 Rehren, 2011, p.261.
751 Lechtman, 1976, p.36-37.
752 Goldstein and Shimada, 2007; Merkel, Shimada and Doonan, 1994; Shimada, 1981; Shimada, Epstein and Craig, 1982; Shimada and Craig, 2013.

layer C Rasgo 5502 (Fig. 149) represent the oldest mining tools excavated in Peru so far and outdate all mining tools documented in Chile[753], apart from the stone tools that were found in San Ramon 15[754]. The sea snail and shells documented in TP 1 (layer B) and TP 3 (layer A and layer C) excavated in Mollaque Grande underline the integration of this site in a network of long-distance exchange and constant inflow of goods from the coast as well as from the highlands demonstrated by the obsidian projectile points found in the TP 1 (layer A) and TP 3 (layer C and layer D). The results received from TP 2 can superficially be seen as a first step to modern mining archaeology as this TP brought to light the remaining of the 1993 mining operation conducted by mineros artesanales, in order to extract the remaining gold from the hill slope. But to the excavated traces of a pre-modern working platform and huge dimensions this mine had, it can be assumed that the mineros artesanales only reopened an existing pre-Columbian adit and further extended it, because even today the gold content in the veins documented in the mine is worth extracting as demonstrated by the previous study.[755] The same holds true for Saramarca, but at this site mining operations started slightly later than in Mollaque Grande. Probably during Early Nasca mining operations were initiated here, which overlapped with an intensified demand for raw materials as shown by the excavated metal objects dating to that time period from the research area.[756] Summed up, the picture of the pre-Columbian mining operation can be described as a near surface small-scale mining, which definitely lasted from Late Paracas to the end of the Nasca culture.

753 Figueroa, et al., 2013, p.69.
754 Salazaar, et al., 2013, pp.148-149.
755 Reindel, Stöllner and Gräfingholt, 2013, p.316 fig.14.17.
756 Schlosser, et al., 2009; Castro de la Mata Guerra Garciá and Vellarde Dellepiane, 2013.

Valle Las Trancas, south of Nazca, San Nicolas, an indigenous "mining padron", as called "Pedro" by us, at the pre-Columbian mining site, that had been reused in modern times (photo: DBM/RUB, T. Stöllner).

8 Discussion: Exchange processes in the Nasca-Palpa region and beyond

Apart from the results gained in the course of this study that mining was conducted in the Nasca-Palpa region from Early Paracas onward the question remains: How did the exchange processes in the research area work and which resources where imported and exported? Based on the results of the pXRF it is possible to reconstruct exchange routes and possible suppliers of raw material for the different cultures that flourished in the research area concerning the obsidian. Due to the proven mining operations in Mollaque Grande and Saramarca, which have been in operation at least since Late Paracas, it can be assumed that the knowledge for mining has been present in the research area since the inhabitants of the Nasca-Palpa area started to settle near the resource-rich flanks of the *quebradas*.

8.1 The case of obsidian

The results presented in the course of this study have proven that the obsidian quarry Jichja Parco has to be seen as the main supplier of raw material for the Nasca-Palpa area. As has also been demonstrated by another study[757] this obsidian quarry was used by the inhabitants of Southern Peru to satisfy their need for the desired and valued raw material since the Archaic up to the Late Horizon. The results presented in this study prove that during the Archaic and the Initial Period the inhabitants of the research area exclusively used the raw material from the Jichja Parco obsidian source near Huanca Sancos and traveled a considerable distance from the occupied area around Palpa to the source in the highlands. In fact, the obsidian from this quarry was a valued raw material for long distance exchange. So far, it has been documented that obsidian from the Jichja Parco/Quispisisa source was used to produce tools at the site of Pacopampa (2,140 m a.s.l.) during the Early Horizon. This implies that the raw material has been exchanged for more than 1,000 km to the north to reach its destination near the modern Ecuadorian border at the time of the Chavín. The fact that the Ecuadorian main obsidian sources Mullumica y Yanaurco-Quistacola are only 700 km away to the north of Pacopampa highlights how extremely valued the raw material from Jichja Parco/Quispisisa was during the Early Horizon.[758] It has been stated that an exchange on the basis of camelid caravans for a distance of 400 km takes approximately 2–3 months depending on the topography.[759] The driving factor for the interconnection of the cultures in the Central Andean was clearly the dominance of the Chavín culture in the first millennium BC,[760] which later on also influenced the religious ceremonies centers and iconography of the Middle Horizon Wari and Tiahuanaco Empires.[761] The fact that during Middle or Late Paracas specimen 770_5 from Qechqalla (PAP-770)[762] was probably introduced – as well as four other points – into the research area from the Cerro Huenul obsidian source in Argentina[763] widens the scope of this transcultural exchange network that incorporated not only the Central Andean but also reached more than 2,500 km into the south. Recently a mitochondrial dataset of the prehistoric Palpa population belonging to the Paracas and Nasca cultures has been compared to the contemporary indigenous population of the Southern Andes and Tierra del Fuego (Mapuche, Pehuenche and Yaghan) with the result that "*the three populations show high frequencies of haplogroups C (41%–48%) and D (46%–52%) comparable with the prehistoric Palpa and Paracas Peninsula populations.*"[764] The authors concluded that the close relationship between the two distant groups had to "*be founded in earlier population dynamic processes, e.g. the initial peopling of the continent.*"[765] Due to the results presented in the current study these population dynamic processes might be dated more precisely. The geo-chemical trace element composition of five obsidian projectile points (770_5, 828_4, 800_2, 586, 3855) dating mostly to Middle Paracas could be assigned to the Cerro Huenul source. This implies that currently two independent research projects have somehow related the Nasca-Palpa area during the apogee of the Paracas and Nasca culture to the Southern Andes

757 Burger and Glascock, 2000, p.265-266; Eerkens, et al., 2010, pp.829-830; Tripcevich and Contreras, 2013, p.28.

758 Burger and Glascock, 2009, p.25.
759 Tripcevich, 2007, p.166.
760 Stanish, 2001, p.51-52; Reindel, 2011, p.170.
761 Isbell, 2008, pp.731-732.
762 Tomasto Cagigao, Reindel and Isla Cuadrado, 2007, p.282.
763 Giesso, et al., 2011, p.8.
764 Fehren-Schmitz, et al., 2010, p.219.
765 Fehren-Schmitz, et al., 2010, p.219.

and Tiera del Fuego. Obviously, the intercultural exchange did not only date back to the initial migration phase into the continent, but occurred at the apogee of the Paracas culture. This is not only manifest in the mtDNA but in the archaeological record in the form of five projectile points whereby specimen 770_5 has such a unique form that it seems most likely that the complete tool was brought all the way from the Southern Andes into the research area. The contacts assumed did not end after the decline of the Paracas culture; instead during the Nasca culture an access to the raw material from Cerro Huenul continued. Four obsidian projectile points (17, 19, 365 and 398) dating to the Nasca period were assigned to the Cerro Huenul source in the course of the present study. The raw material from the Cerro Huenul source obviously represents the most special items used in the research area, but other sources were exploited as well. The geochemical composition of specimen 1108 dating to Late Paracas does not match with the Jichja Parco obsidian source or any other source in Southern Peru – in fact not even with a single quarry in Peru. According to the results obtained, the Callejones source in Ecuador might be a possible origin of this point. That would imply that during Late Paracas a connection between Ecuador and the research area existed. A possible explanation for this might be a long-distance exchange of the *Spondylus* oyster, which was well established during Late Paracas.[766] This type of oyster lives in dispersed deep water pockets from coastal Ecuador to southern Sinaloa, Mexico and needs a warm water climate to survive. The conditions in the waters of Peru and Chile do not support this kind of oyster. Probably because of this rarity *Spondylus* was highly valued by the pre-Columbian cultures of Peru and the oyster was traded southward on a regular basis by maritime trade at the time of the *Conquista*.[767] This implies that all fragments and complete oysters found in the research area had to be imported from Ecuador and beyond. Some fragments of this species have been found so far in the research area dating to Late Paracas[768], but during the Nasca period the oyster was definitely present in the research area[769] and from the Middle Horizon numerous artifacts excavated have been documented in the research area[770] and further south in the Mina Primavera.[771] The probable presence of Callejones obsidian from Ecuador in the research area – manifesting in specimen 1108 – during Late Paracas might therefore be explained by a long-distance exchange network for *Spondylus,* which as a by-product transported obsidian from Ecuador via the highlands into the research area. Some regional sources other than Jichja Parco supplied obsidian to the inhabitants of the research area from the Early Horizon onward as well. The Puzolana source,[772] which is located in the highland region of Ayacucho, has not been identified as a supplier for raw material outside the Ayacucho region as obsidian from this source is rarely found in archaeological excavations outside Ayacucho. Glascock, Speakman and Burger (2007, p.536) even postulate that "*it is unlikely that Puzolana was ever involved in a long-distance exchange network, perhaps due to the small nodule size*." Nonetheless, the data presented in the present study has demonstrated that specimen 4196_1 dating to Late Paracas derives from the Puzolana source. Due to the exclusive burial context it can be assumed that the origin of this projectile point from afar was known. During the Early Intermediate Period the raw material for projectile point 2411 excavated in Jauranga (PAP-150)[773] was introduced into the research area from the Lisahuacho obsidian source in the Aymaraes region.[774] Although just this projectile point derives from the source in the Aymaraes region, it still highlights a link that existed during Early Nasca between the research area and the Aymaraes region. During the Middle Horizon long-distance exchange processes concerning obsidian came to an end. The inhabitants of the Nasca-Palpa area satisfied their need for obsidian solitarily from the Jichja Parco source. Somehow the incorporation of the research area under Wari influence[775] and the shift of the population centers from the coast to the highland region because of the climatic change that occurred during that time[776] triggered the local population to rely solely on the locally available obsidian source Jichja Parco. This actually contradicts the presumed vital exchange processes, which are postulated to have taken place in the sphere of the Wari Empire mostly with camelid caravans.[777] This consumption pattern of obsidian in the research area was not altered during the Late Horizon with the exception of one obsidian projectile point that presumably derives from the Callejones obsidian source in Ecuador. Specimen 1027_1 found in the highlands should be considered as an example of the widespread exchange of resources and populations that took place during the rule of *Tawantinsuyu*. If the projectile derives from Ecuador, then it can be assumed that it was after the incorporation of the Callejones source into the Inca Empire that this specimen started it decent from the north. Therefore, a *terminus post quem* for this artifact is given by the conquering of the Cayambe by the Inca which controlled the Callejones source before. After the conquest the local inhabitants supplied obsidian to the Inca army on a regional level[778] – up to now raw material from the Callejones source has not been documented in Southern Peru. A possible explanation for the assumed presence of the projectile point in the research area might be the

766 Paulsen, 1974, p.599.
767 Hosler, 2009, p.189-190.
768 Castro de La Mata Guerra García et al., 2012, p.515.
769 Reindel, Isla cuadrado and De La Torre, 2005, p.166.
770 Tomasto Cagigao, Reindel and Isla Cuadrado, 2007, p.152; Reindel, Solis Quintero and Isla Cuadrado, 2008, p.96.
771 Vaughn, et al., 2013a, p.166.
772 Burger and Glascock, 2000.
773 Reindel, Isla Cuadrado and De La Torre, 2004, Appendix IV, p.4.
774 Glascock, Speakman and Burger, 2007, p.537.
775 Reindel, 2011, p.175.
776 Eitel and Mächtel, 2009, p.27.
777 Reindel, 2011, p.174.
778 Ogburn, 2009, p.743.

military movements in the highland region from the fortified sites in the north to newly established forts in the south or in the course of ongoing military expansions and stabilization of the Inca territory in the south.[779] A possible bearer of such a projectile point might have been an Aymara who after a successful campaign on the northern frontiers of *Tawantinsuyu* returned to their homeland in the Altiplano region.[780]

The case of obsidian in the research area should not be closed, instead this study presents multiple evidence of a vital raw material consumption of the local population through time, which should be further investigated. It is imperative to widen the scope of the geochemical analysis from the artifact group of obsidian projectile points to all obsidian artifacts documented in the research area, in order to clarify the given picture of raw material consumption in the research area. The pXRF has proven to be very effective and should be implemented in the research area on a regular basis to analyze the given assemblage of obsidian objects. Furthermore, a separated research approach concerning the obsidian quarries identified in the course of the current study that probably supplied raw material into the research area should be conducted in Ecuador, Peru and Chile. A test sequence with the pXRF device should be initiated on each of the obsidian quarry sites that are known to date, in order to accumulate a consistent set of data. The advantages of pXRF have been described in detail (chapter 6.3.) and it can be assumed that additional data concerning the origin of raw materials used in the research area will further clarify the results already received about the patterns of obsidian consumption in the Nasca-Palpa area.

8.2 The case of copper and gold

In the course of the present study it has not been possible to document direct evidence of metallurgical smelting operations in the research area. It can therefore be questioned, if the region can be labeled as a mining district, due to the lack of the defined parameter of a permanent center of production, which is characteristic of a mining district.[781] As Graffam, Rivera and Carevic (1996, p.198) have correctly stated "*without slag or furnace ruins, a reasonable claim cannot be made for metal smelting.*" Still the documented mining operations and analyzed metal objects lead to the conclusion that the knowledge for the rich resource deposits in the Nasca-Palpa area was present from Paracas onward and that due to the documented and assumed production processes in the region – which concentrated on native gold – the term mining district is justified. Different parts of a copper and gold metallurgical *chaîne opératoire* have been detected by previous studies in the research area[782] and in the course of this study. Since it was not possible to locate smelting sites and furnaces, it is imperative to concentrate on the given parts of the particular process as has been postulated by Stöllner (2014, p.134) because so far, the copper and gold metallurgical *chaîne opératoire* is incomplete. Secure evidence has been documented for the following parts of the productive and consumption process. At least from Late Paracas onward a secure archaeological proof exists that mining has been conducted on a small scale in the research area (chapter 7.2.9.), gold was used from Early Paracas (chapter 6.5.5.) onward and the access to the rich copper and gold mineralization zones opened up by the *quebradas* was given at the site Mollaque Grande from Early Paracas onward (chapter 7.4.8.). So far two explanations have been discussed in the course of this study why the documented evidence for a *chaîne opératoire* is incomplete in the given mining district: the metallurgical processes applied in the research area left no traces as they concentrated on the native gold which was probably cold-hammered without the need to operate furnaces[783] and that the annual floods of the rivers in the research area simply destroyed the archaeological evidence which may have been present in the region. A third theory about the reasons for the mineral extraction on the site Mollaque Grande has been presented lately by Soßna (2014, p.157) who speculated that *"the Nasca people might have been more interested in mineral pigments for ceramic painting than they were in metal production, as the scale of the pits is tiny and no slag deposits were found so far."* This theory should be taken into account as evidence for the use of pigments by the Nasca as pre-fire slip-pigment paint for the polychrome ceramic exists[784] and hematite (Fe_2O_3) has been documented in ores samples from layers S (chapter 7.6.4.6), B (chapter 7.6.4.7), and C (chapter 7.6.4.8) taken in TP 4 in Saramarca. Early examples of the use of extracted ores in a pre-metallurgical context have been presented for the temple complex of Pachacámac.[785] More important, a comparable bag with red pigments was also excavated in the southern sector of Los Molinos in grave 2 dating to Nasca 5 proving a long lasting tradition of at least offering those bags as grave goods.[786] Judging from the red color of the minerals inside – which have not been analyzed so far – it is probable that it contains some sort of Irion oxides such as hematite (Fe_2O_3), limonite (FeO) or magnetite (Fe_3O_4), as these minerals were used to produce red colors.[787] That again would reflect on the given results from TP 4 in Saramarca (chapter 7.5). But due to the results presented in the course of the present

779 Covey, 2000, pp.126-128; 2008, pp.819-821.
780 Murra, 1986, p.54.
781 Stöllner, 2008, p.169.
782 Stöllner and Reindel, 2007; Stöllner, 2009; 2011; Stöllner, et al., 2013; Reindel, Stöllner and Gräfingholt, 2013.
783 Stöllner, 2011, p.204.
784 Vaughn, et al., 2005, p.142.
785 Muelle and Wells, 1939, pp.268-270 fig.3.
786 Reindel and Isla Cuadrado, 2001, p.262.
787 Brooks, et al., 2008, p.442; Carmichael, 1998, p.217.

study concerning the richness of copper, gold and even silver alloys used in combination with the previously gained results of the mineralization zones in the research area which revealed rich copper and gold deposits[788] it seems quite improbable that the documented mining operations in Mollaque Grande and Saramarca exclusively concentrated on the extraction of pigments for the pottery production. This is highlighted by the fact that although a black pigment can be produced from copper oxide (CuO)[789] no traces of copper have been found in black painted ceramic samples from the research area.[790] It does not rule out the possibility that ores were used as pigments, but also leaves room to speculate that the copper and gold ores mined in the research area were actually transformed into metals highly valued by the inhabitants of the research area. In order to take a look at comparable mining districts, it is imperative to incorporate a transnational perspective and focus on the metallurgical development in Northern Chile where copper may have been exploited since 1500 BC.[791] In the pastoralist communities of the Tilocalar dating to the Early Formative (1200–500 BC) gold and copper sheets have been documented that indicate an independent development of a mining metallurgical tradition in the South Central Andean in a pastoralist context.[792] The results presented by Graffam, Rivera and Carevic (1996) for the Ramaditas site in Northern Chile highlight that metallurgy and mining were conducted on the site and in the surrounding *quebradas* during the first century BC. Therefore, a comparable chronological setting of initial mining activities is given for this area and the research area of the present study in the Nasca-Palpa area. It is most likely that the inhabitants of the Ramaditas site used sulfate ores in the course of the smelting process, probably brochantite and antlerite, which are typical ores in the region.[793] In comparison the ores analyzed in the Nasca-Palpa area consist of highly enriched "*bonanzas"*, which are mainly near surface oxides and carbonites that reveal high enrichments in copper and gold.[794] The clustering of the ore deposits in Northern Chile is comparable to the Nasca-Palpa region. Near the Ramaditas site in the Guatacondo valley copper veins have been exploited by small mines that can be found along the flanks of the *quebrada*. On the site itself, 12 furnace ruins have been documented in combination with slag, which supports the assumption that metallurgy was conducted at this location in the Early Formative.[795] In contrast to the results gained in the research area of the current study, where it seems probable that most of the mines documented are directly linked to nearby settlements and have been exploited in pre-Columbian times,[796] the situation in Northern Chile was described differently, as the nearest mine was approximately 8 km away and no clear traces of prehistoric mining were documented.[797] Due to the results presented the smelting process in Ramaditas was obviously much more effective than the one used at Batan Grande,[798] because the furnaces were operated with temperature near 1,250°, which enabled an effective separation of the metal from the slag.[799] But *"the site was not a trade center, certainly not an industrial hub, nor a prominent node of settlement marked by monumental architecture. If anything, this point adds strength to the argument that Early Ceramic period metal smelting was a pervasive and widespread activity, similar to craft production."*[800] Although the data presented have been questioned, because only one fragment of slag was documented in an Early Formative context,[801] the description of the metallurgical site in Northern Chile impressively demonstrates that metallurgy has to be seen as a "*normal*" craft that was already exercised on a local basis in the first century BC in Northern Chile. A renewed investigation of the site and material obtained during the excavation using the methods described by Hauptmann[802] would certainly reveal new insights in the early stages of metallurgy in Northern Chile. An overwhelming number of metal artifacts only start to appear in the archaeological context in Northern Chile in the following periods[803] indirect evidence of an active copper metallurgy in the Formative has been documented in form of some copper artifacts.[804] Therefore it can be concluded that copper metallurgy started in Chile sometime after 1000 BC as evidences of slag and metallurgical waste have been documented in the Salar de Atacama and the Loa River Basin dating to that time period as well.[805] The exchange processes of minerals and metals in Northern Chile have been intensively debated[806] and the predominant scientific view indicates that llama caravans were probably the most efficient way to transport goods, raw materials and finished artifacts from one point in the Andes to another.[807] A first comprehensive model for llama caravans has been proposed by Nuñez/Dillehay[808] who postulated that defined routes existed that connected the different ecological

788 Stöllner, et al., 2013, p.125; Reindel, Stöllner and Gräfingholt, 2013, p.316.
789 Vaughn, et al., 2005, p.142.
790 Personal communication with Daniela Oestreich.
791 Núñez, 2011, p.214.
792 Núñez, 1999, p.179.
793 Graffam, Carevic and Rivera, 1997, p.56.
794 Stöllner, et al., 2013, p.124.
795 Graffam, Rivera and Carevic, 1996, pp.104-105.
796 Stöllner, et al., 2013, p.118; Reindel, Stöllner and Gräfingholt, 2013, p.312.
797 Graffam, Rivera and Carevic, 1996, p.104.
798 Shimada and Craig, 2013, p.4; Shimada, Epstein and Craig, 1982; Shimada and Merkel, 1991; Shimada, 1994; Goldstein and Shimada, 2007.
799 Graffam, Carevic and Rivera, 1997, p.57.
800 Graffam, Rivera and Carevic, 1996, p.111.
801 Salazar, et al., 2011a, p.124.
802 Hauptmann, 2014.
803 Salazar, et al., 2011a, p.138-139.
804 Salazar, et al., 2011a, p.124.
805 Salazar, Borie and Oñote, 2013, p.253.
806 e.g. Núñez, 1999; 2006; 2011; Salazar and Salinas, 2008; Salazar, et al., 2011a; 2014.
807 Núñez and Dillehay, 1995; Berenguer, 2004; Tripcevich, 2007; Shimada and Shimada, 1985, p.22; Tripcevich and Capriles, 2016.
808 Núñez and Dillehay, 1995.

zones of the costa, puna and selva. A long-distance exchange that connected such different ecological zones probably relied on a complex logistic for each llama caravan implying that only regional centers participated in this form of trade. Furthermore, a system of regional redistribution must have been in place.[809] Tripcevich (2007, p.178) has described the Andean means of trade precisely as he states that "f*eatures of the Andean barter economy such as enduring trade relationships between households in complementary zones cemented by institutions like over-reciprocation and fictive kinship, are well demonstrated ethnographically in the region. However, seasonal market-like gatherings are also reported in the region and exchange of goods in those contexts may have been more alienable, and transactions may have been more synchronic in nature. Such gatherings may also have had evolutionary significance because they potentially relate to the development of early leadership in regional centers including ceremony, feasting, the use of monumental architecture, and centralized control of trade in certain goods."* In Northern Chile San Pedro de Atacama, an oasis located in the salt puna region with extensive trade connections to Tiwanaku,[810] was a hub for the exchange networks that were maintained by large llama caravans that connected Tiwanaku with the whole South Central Andean region.[811] The situation presented in the course of the present study for the mining district in the research area differs from this extensive trade network system during the Early Horizon and Early Intermediate Period, as the ore deposits were located mostly next to the settlements of the Paracas and Nasca culture, which ensured a direct access to the raw materials needed for the daily use. This proves the assumption formulated after an intensive survey campaign in the research area where first indications of a raw material consumption pattern were identified that was triggered by the access to the rich mineralization zones that were located next to permanent settlements.[812] It has to be emphasized that the small-scale mining that has been documented in the mining districts of Mollaque Grande and Saramarca was only operated on a minimum level, in order to satisfy the local need for the available raw materials such as copper and gold. No fully developed mining region, as has been presented for Batan Grande in Northern Peru[813] was in place in the research area during the Early Horizon and Early Intermediate Period. A comparable system on a local level was described for the Ramaditas site in Northern Chile[814], however the research area in the Nasca-Palpa region has to be regarded as an early mining district with a long-lasting and continuously developed mining tradition for pre-Columbian extraction of raw materials, as at least from Late Paracas onward the inhabitants of the area actively extracted the ores from the mineralization zones that were opened up by the *quebradas* (chapter 7) and consumed the raw materials on a local level. From the Middle Horizon, as the settlement centers shifted from the coast up into the highland area because of the climate change that dramatically altered the living condition in the lower margins of the river valleys,[815] the trade networks of the Wari empire introduced new alloys such as Cu-As into the research area and probably enabled the inhabitants of the highland region to access even exotic metal objects made out of Cu-Sn alloys from the Tiwanaku dominated zones (chapter 6.5). This indicates that the research area was actively incorporated into a transregional trade network that operated in the highland region of the altiplano, which must be regarded as the pre-Columbian "*Pan Americana*" that not only enabled permanent trade connections but also favored the exchange of mining and metallurgical knowledge throughout the Andean region. As the raw material consumption in the research area shifted from gold during Paracas and Nasca to a copper-based metallurgical technology,[816] which has been confirmed by the geochemical analysis of over 150 Cu, Cu-As and Cu-Sn excavated in Huayuncalla (chapter 6.5.5.), it is still an open research question, whether these copper-based objects were manufactured using the rich copper deposits of the Nasca-Ocoña belt. A first small lead-isotope sample-series conducted on metal fragments and ores from the research area indicates *"a characteristic isotopic pattern of the southern Peruvian coastal area that even overlaps also with some of the silver–copper artifacts found during the excavations and surveys in the highlands."*[817] This result combined with the data obtained in the course of the current study requires a further expansion of lead isotope analysis[818] of the metal artifacts associated with the cultures that flourished in the Nasca-Palpa area – especially the supposed Cu-Sn objects from Huayuncalla –, in order to clarify, whether the ore deposits of the research area have been used to produce the copper-based artifacts found in the course of the interdisciplinary projects conducted around Palpa.

809 Núñez and Dillehay, 1995, p.27 in Sepúlveda, Romero Guevara and Briones, 2005, p.227.
810 Rivera, 2008, p.968.
811 Lechtman, 2014, p.394
812 Stöllner, et al., 2013, p.118.
813 Shimada and Craig, 2013, p.4; Shimada, Epstein and Craig, 1982; Shimada and Merkel, 1991; Shimada, 1994; Goldstein and Shimada, 2007.
814 Graffam, Rivera and Carevic, 1996; Graffam, Carevic and Rivera, 1997.
815 Eitel and Mächtle, 2009, pp.27-29.
816 Reindel, Stöllner and Gräfingholt, 2013, p.319.
817 Stöllner, et al., 2013, p.125.
818 Niederschlag, 2003; Pernicka, 2014.

Vale de Vizcas. Pre-Columbian processing site overviewing the valley (photo: DBM, T. Stöllner).

9 Conclusion: Raw material consumption in Southern Peru

The independent introduction of mining[819] and metallurgy on the American continent[820] triggered mining operation throughout the Americas in the course of pre-Columbian history.[821] Still, mining did not start because of the need to extract raw materials for metallurgical processes. At the beginning of human dwelling in the Andean region hunter-gatherer-miners exploited the rich resources of Northern Chile in order to extract hematite (Fe_2O_3) to be used as pigments.[822] In the research area of the current study human occupation has been documented from the Archaic onward[823] (Fig. 192).

The aim of this thesis was to reconstruct the raw material consumption and mining patterns in the region throughout time and to use the examples of obsidian, copper and gold exploitations as a role model for the development of a small-scale mining district in the Nasca-Palpa region over the course of the whole span of human occupation in that area – starting in the Archaic up to the beginning of the Spanish conquest, when the Inca rule of the Andean region came to a sudden end. To achieve this goal a combined approach of non-destructively geochemical trace element analysis (chapter 6) and mining archaeological excavations in Mollaque Grande and Saramarca (chapter 7) was used to incorporate the data from the pXRF analysis of 365 obsidian artifacts and 199 metal artifacts which have been found in the research area since 1997 and combine this data with a secured archaeological proof of the beginning of raw material exploitation in the research area. The whole project was based on the previous work that has been conducted in the Nasca-Palpa area by the interdisciplinary research project[824] of the German Archaeological Institute which was implemented by Dr. Markus Reindel on the one hand and on the other hand by the mining archaeological research that has been initiated in the course of this interdisciplinary project by Prof. Dr. Thomas Stöllner[825] from the Deutsches Bergbau-Museum Bochum (DBM) and the Ruhr University Bochum. The results presented by these research groups have been used to further expand the range of the mining archaeological investigations in the Nasca-Palpa area and define the area as a small-scale mining district that provided direct access to the rich copper and gold mineralization zones opened up by the quebradas as well as to the high-quality obsidian quarries in the Altiplano to the pre-Columbian inhabitants of the research area. By bringing an pXRF device directly to the field to analyze a given assemblage of 365 obsidian artifacts and 199 metal artifacts it was possible to document the effectiveness of this method, which can be applied non-destructively and without further preparation of the samples. So far, only a small proportion of archaeological studies that applied geochemical investigations have been conducted during fieldwork with pXRF[826], therefore this study can be regarded as a successful contribution to the fundamental research efforts on the direct application of pXRF in the field, as for the first time pXRF was applied successfully on copper-based artifacts in Peru. First of all, the geochemical trace element composition of the obsidian quarry Jichja Parco was refined by the results of this study (chapter 6.3.4). As was anticipated by previously presented research concerning obsidian quarries in South Peru,[827] the results of the geochemical analysis conducted in the course of the present study has impressively demonstrated that the obsidian quarry Jichja Parco must be regarded as the main supplier for raw materials throughout the whole span of human occupation in the Nasca-Palpa region,

819 Salazar, et al., 2011b, pp.470-471.
820 Lechtman, 2014, p.370.
821 Brown and Craig, 1994; Burger, 2013; Eerkens, Vaughn and Linares Grados, 2009; Figueroa, et al., 2013; Mathien and Warren, 1985; Petersen, 2010; Reindel, Stöllner and Gräfingholt, 2013; Salazar et al., 2011b; Salazar, Borie and Oñote, 2013; Shimada, Epstein and Craig, 1982; Shimada, 1994; Stöllner, 2009; Tripcevich and Vaughn, 2013; van Gijseghem, et al., 2013; Vaughn and Tripcevich, 2013; Vaughn, et al., 2007; 2013a; 2013b; Weigand, 1994.
822 Salazar, Borie and Oñote, 2013, p.139.
823 Unkel, 2012, pp.2301-2302.
824 Castro de la Mata Guerra García, Reindel and Isla Cuadrado, 2012; Eitel and Mächtle, 2009; Eitel, et al., 2005; Fehren-Schmitz, Hummel and Herrmann, 2009; Fehren-Schmitz, et al., 2010; 2011; Hecht, 2009; Herrmann, Reindel and Wagner, 2009; Isla Cuadrado, 2009; Isla Cuadrado and Reindel, 2002-2006; Mächtle, et al., 2009; Reindel, 1997; 2007; 2008; 2009a; 2009b; 2011; Reindel and Isla Cuadrado, 1999; 2000; 2001; 2003; 2009; Reindel, Isla Cuadrado and De La Torre, 2004; 2005; Reindel, Isla cuadrado and Linares Grados, 2006; Reindel, Isla Cuadrado and Tomasto Cagigao, 20012002; Reindel, Solis Quintero and Isla Cuadrado, 2008; Reindel, Stöllner and Gräfingholt, 2013; Reindel and Wagner, 2009; Schlosser, et al., 2009; Stöllner, 2009; Stöllner and Reindel, 2007; Stöllner, et al., 2013; Tomasto Cagigao, Reindel and Isla Cuadrado, 2009; 2015; Unkel and Kromer, 2009; Unkel, et al., 2007; 2012.
825 Stöllner and Reindel, 2007; Stöllner, 2009; Stöllner, 2011; Stöllner, et al., 2013; Reindel, Stöllner and Gräfingholt, 2013.
826 Frahm and Doonan, 2013, p.1429.
827 Craig, et al., 2010, p.569; Eerkens, et al., 2010.

YEARS	PERIODS	CULTURES	PHASES	CERAMIC STYLE	SITES	RAW MATERIALS
1535 AD	LATE HORIZON	Inca/Ica		Inca/Ica		
1180 AD	LATE INTERMEDIATE PERIOD	Ica		Ica	Chillo, Montegrande	copper (Cu-Sn), gold, silver obsidian (Jichja Parco, Callejones)
1130 AD 850 AD						
790 AD 690 AD	MIDDLE HORIZON	Wari		Chakipampa	Huayuncalla, Primavera, Lucriche	copper (Cu-As; Cu-Sn; Cu-As-Ni), gold, silver,
660 AD				Loro	Montegrande	obsidian (Jichja Parco)
620 AD 470 AD	EARLY INTERMEDIATE PERIOD		Late	Nasca (6?), 7		gold, copper (Cu; Cu-Ag) obsidian (Jichja Parco, Cerro Huenul, Lisahuacho)
410 AD 340 BC		Nasca	Middle	Nasca 4, 5	La Muña	
270 AD 110 AD			Early	Nasca 2, 3	Saramarca, Mollaque Grande, Primavera, Montegrande	gold, copper (Cu), obsidian (Jichja Parco)
40 BC 130 BC	TRANSITION	Initial Nasca		Nasca 1 Ocucaje 10		gold, copper (Cu) obsidian (Jichja Parco)
330 BC 360 BC	FORMATIVE PERIOD – EARLY HORIZON		Late	Ocucaje 8, 9	Saramarca, Mollaque Grande, Montegrande, Jauranga, Cuttamalla	gold, copper (Cu), obsidian (Jichja Parco, Puzolana, Cerro Huenul, Callejones)
400 BC 440 BC		Paracas	Middle	Ocucaje 5, 6, 7		gold, copper (Cu?), obsidian (Jichja Parco, Cerro Huenul)
560 BC 800 BC			Early	Ocucaje 3, 4		gold, obsidian (Jichja Parco)
900 BC	FORMATIVE PERIOD – INITIAL PERIOD			Puerto Nuevo Disco Verde Hacha	Pernil Alto, Ocoro, Cuttamalla	obsidian (Jichja Parco), silex
1500 BC						
2960 BC 3760 BC	ARCHAIC			no ceramics	Pernil Alto	obsidian (Jichja Parco), silex
8000 BC					Cerro Llamoca	obsidian (Jichja Parco), silex

Fig. 207: Pre-Columbian chronology and raw material consumption in the pre-Columbian periods of South Peru according to Stöllner, et al. (2013) supplemented by the results of the current investigation in the Nasca-Palpa area (graphic: M. Reindel for Unkel, et al. (2012, p.2299 fig.2) modified by B. Gräfingholt).

as 342 obsidian artifacts could be directly linked to this deposit. However, the diverging geochemical results for 23 obsidian artifacts have highlighted that not only this quarry was used by the inhabitants of the area, but instead a variety of near and far deposits contributed raw materials for the daily use of the pre-Columbian inhabitants of the research area from the Early Horizon onward. Extraordinary results that must be further investigated were achieved concerning Trans-Andean quarries in the north and south of the research area. Two artifacts could be linked to the obsidian sources Lisahuacho and Puzolana, which highlights that although these sources are located within easily reachable distances from the research area, no permanent access to these sources existed due to the high quality obsidian that was obtained from Jichja Parco throughout the pre-Columbian history of raw material consumption in the Nasca-Palpa area. Up to now the Callejones obsidian quarry in Ecuador has not been regarded as a source that contributed raw materials to long distance exchange processes,[828] instead it has been postulated that the source was only locally used by the Cayambe who inhabited the region.[829] Still it was possible to detect the presence of raw material from this source in the research area, as two projectile points dating to the Early Horizon and the Late Horizon have been assigned to the Callejones source because of comparable geochemical trace element concentrations. A possible explanation for this far-reaching presence of Ecuadorian obsidian might be the trade of the *Spondylus* shell during the Early Horizon[830] and the warfare conducted by the Inca Empire during the Late Horizon that relied heavily on troops from all over the occupied territories of

828 Ogburn, 2011, p.101.
829 Ogburn, 2009, p.743.
830 Paulsen, 1974, p.599.

the *Tawantinsuyu.*[831] The fact that the area around the Callejones source was incorporated into the Inca Empire with the support of Aymara warriors,[832] who may have been equipped with new tools and weapons made out of obsidian from the newly conquered obsidian source,[833] would explain the distribution of Callejones raw material into the research area during the Late Horizon.

A thought-provoking result has been presented concerning artifacts dating to the Early Horizon and Early Intermediate Period. So far, the geochemical trace element concentration of 12 artifacts has indicated that an exchange of raw materials and finished artifacts took place during the apogee of the Paracas and Nasca cultures with the far south of the American continent as an origin from the Cerro Huenul obsidian quarry in Argentina seems reasonable to postulate for these artifacts. This result is further supported by a mitochondrial dataset that supposed a connection between the pre-Columbian inhabitants of the Nasca-Palpa area and the contemporary indigenous population of the Southern Andes and Tierra del Fuego (Mapuche, Pehuenche and Yaghan) that probably reaches back to the beginning of the human occupation of South America.[834] The data received for the obsidian artifacts enables the author to postulate a further timespan for these contacts, which – if the data received are consistent – probably took place during Middle and Late Paracas. The obsidian objects analyzed differ to a great extent from the projectile point types mainly used in the research area[835] and do also not overlap with the given trace element concentrations of the obsidian quarries in southern Peru[836]. Therefore, the trace element concentrations for the Cerro Huenul source that have been presented by two independent research groups[837] were taken into consideration. Due to the comparable trace element concentration of the artifacts to this source an origin from Argentina may be possible, but the author is convinced that these results definitely need an additional proof. Therefore, a field trip with the pXRF – used for the analysis of the given assemblage of obsidian artifacts from the research area – to the Cerro Huenul source should be undertaken. The source belongs to the so called Tilhué Formation consisting of three obsidian outcrops which are scattered over a distance of approximately 45 km. The geochemical composition of these three outcrops is similar and therefore does not allow a further differentiation.[838] Therefore, a comprehensive dataset of these sources should be established and used to compare this data with the trace element concentration of the obsidian objects in question. This method would exclude the possible measurement deviations and inaccuracies that may have occurred because of the combination of pXRF and XRF results in the course of this study.[839]

However, by combining the results of the obsidian consumption patterns and the results of the geochemical surface analysis of 199 metal artifacts from the research area in combination with the results from the archaeological excavations it can be stated that at least from Late Paracas onward a secure archaeological proof exists that mining was conducted on a small scale in the research area (chapter 7.2.9), gold was used from Early Paracas (chapter 6.5.5.) onward and the access to the rich copper and gold mineralization zones opened up by the *quebradas* was given at the site Mollaque Grande from Early Paracas onward (chapter 7.4.8). Still the origin of the mining tradition that has been encountered in the research area is unknown. Due to the presented data concerning mining it seems probable that a connection to the early mining tradition of Northern Chile must be taken into account. The mining tools that have been documented in the research area by the previous study[840] and during the archaeological fieldwork and excavations in Mollaque Grande (chapter 7) are closely related to the tools used for the earliest mining operations in Northern Chile.[841] With the introduction of these tools a mining tool typology was invented that was used only slightly modified until the *conquista*, but was also supplemented in Peru and Chile with tools made out of wood[842] and copper[843]. The contacts postulated that may have existed to the south, as indicated by the presence of obsidian raw material from the Cerro Huenul source, overlaps with the proven introduction of mining operations in the research area during Middle Paracas. If raw material from the south was somehow introduced into the research area, this would indicate that with this introduction ideas and mining knowledge could have been handed down as well. The fact that copper was mined and used on a regular daily basis,[844] mostly in the form of beads, by the inhabitants of Northern Chile since the Formative[845] and chronologically comparable examples of the use of copper have not been securely documented so far in the research area, leads to the assumption that an introduction of the mining tradition and technique from the south must be regarded as possible. Furthermore, the extensive interdisciplinary research that has been conducted in the research area as well as the present study leave no doubt, that metal usage in the form of a golden ring (1802) recovered from Mollake Chico (PAP-435)[846] certainly started from Early Paracas onward and that two copper artifacts – a Cu needle (806)

831 Covey, 2000, pp.126-128; 2008, pp.819-823.
832 Murra, 1986, p.54.
833 Ogburn, 2009, p.743.
834 Fehren-Schmitz, et al., 2010, p.219.
835 Gräfingholt, 2011.
836 Glascock, Speakman and Burger, 2007, p.540 tabs.II-III; Tripcevich and Contreras, 2011, p.127 fig.5.
837 Barberena, Hajduk and Gil, 2011; Giesso, et al., 2011.
838 Barberena, Hajduk and Gil, 2011, p.30.
839 Personal communication with Prof. Dr. Kirnbauer.
840 Reindel, Stöllner and Gräfingholt, 2013, p.315 figs.14.15; Stöllner, et al., 2013, p.122 fig.19.
841 Salazar, Borie and Oñate., 2013, p.151 fig.7.9.
842 Figueroa, et al., 2013, p.73.
843 Stöllner, 2011, p.205; Lechtman, 2014, p.15 fig.15.12.
844 Graffam, 1996, p.110.
845 Núñez, 1999, p.179.
846 Reindel, Isla Cuadrado and De La Torre, 2004, Appendix 5, p.3.

from PAP-806[847] and a Cu plate (1056) from PAP-1056[848] – may have been used at such an early stage. But due to the documented disturbed contexts of these two artifacts a secure chronological setting for the introduction of copper mining in the Nasca-Palpa area can only be given for Late Paracas (chapter 7.4.), and copper artifacts only start to appear regularly in the archaeological context during the Early Intermediate Period (chapter 6.5.3.). Furthermore, due to the geochemical analysis conducted with the pXRF an extraordinary result was gained by confirming the presence of Cu-Sn alloys. A first hint in this direction was already given, when a previous study identified one artifact made of this typical Tiwanaku alloy.[849] The prevailing research opinion[850] has so far postulated that this type of alloy was exclusively used in the influential sphere of the Tiwanaku Empire which covered the South Central Andes during the Middle Horizon. A clear division – a bronze divided – between Cu-As alloys that were used by the Wari Empire and Cu-Sn alloys that were used by the Tiwanaku Empire has been drawn.[851] The fact that the surface analysis of the pXRF detected considerable traces of Sn between 2-13% in four copper objects (128, 808, 809 and 4709) lead to the assumption that this clear division into a northern Cu-As hemisphere and a southern Cu-Sn hemisphere during the Middle Horizon cannot be postulated anymore as the Cu-Sn metal sheet 4709 derives from Huayuncalla and was excavated in Unidad 1 layer A-1, which is associated to the Wari culture.[852]

The results of this comprehensive mining archaeological investigation contribute to the ongoing intensification of mining archaeological research in South America and successfully implemented geochemical analysis and mining archaeological methods to define a small-scale mining district in Southern Peru. The research conducted raised new research questions concerning the long-distance exchange routes of obsidian and the consumption of exotic metal objects in the research area that definitely need to be further investigated in the near future, in order to clarify the results of raw material consumption patterns in the research area.

847 Reindel, Solis Quintero and Isla Cuadrado, 2008, p.167.
848 Reindel, Solis Quintero and Isla Cuadrado, 2010, p.296.
849 Stöllner, et al., 2013, p.124.
850 Lechtman, 1991; 2003; 2014; Lechtman and Klein, 1999; Lechtman and MacFarlane, 2005; 2006; MacFarlane and Lechtman, 2014.
851 Lechtman and MacFarlane, 2006, p.506.
852 Castro de la Mata Guerra Garcia, Reindel and Isla Cuadrado, 2012, p.517.

Abstract

Mining archaeological research is only starting to become recognized as an important contribution to the reconstruction of social, economic and cultural aspects of pre-Columbian societies in South America. Due to the fundamental research efforts that have been conducted in the Nasca-Palpa area since 1997 by interdisciplinary research projects of the German Archaeological Institute which were implemented by Dr. Markus Reindel and Johny Isla Cuadrado on the one hand and on the other hand encouraged by the mining archaeological research that has been initiated in the course of these interdisciplinary projects by Prof. Dr. Thomas Stöllner from the Deutsches Bergbau-Museum Bochum (DBM) and the Ruhr University Bochum, this study accessed a comprehensive set of data that already defined the given parameters for the cultural development in the research area. In order to incorporate a wider perspective the given situation in the research area shall be compared to another identified core region of pre-Columbian mining in Northern Chile to elaborate a role model for the development of a small scale mining district in the Nasca-Palpa region over the course of the whole span of human occupation by using the examples of obsidian, copper and gold mining operation. The pre-Columbian societies that flourished in Southern Peru in pre-Columbian times have never been regarded as the avant-garde in metallurgical inventions and innovations, still it can be assumed that the knowledge for mining was present in the research area since the inhabitants of the Nasca-Palpa area started to settle near the resource-rich flanks of the quebradas that were opened-up by the rivers in the course of millennia.

The current study uses mining archaeological excavations to target the pre-Columbian extraction sites in the mineralization zones of the Nasca-Ocoña at the pre-Columbian sites of Mollaque Grande in the Palpa valley and Saramarca in the Viscas valley to identify the chronological frame of the initial mining operation in the Nasca-Palpa area. In addition to that, handheld portable XRF analysis (pXRF) were conducted on 365 obsidian objects and 199 metal artifacts that have been excavated and found in the research area since 1997. The non-destructive pXRF was applied in a non-laboratory environment to highlight the huge potential of this method for future international archaeological investigation. pXRF has been used previously to analyze obsidian artifacts in Peru but so far the data that has been collected using the pXRF in the course of the current study represents the first true application of a pXRF analysis on copper-based artifacts in the research area.

The results of this comprehensive mining archaeological investigation contribute to the ongoing intensification of mining archaeological research in South America and successfully implemented geochemical analysis and mining archaeological methods to define a small-scale mining district in Southern Peru. Jichja Parco was identified as the main supplier of obsidian for the research area throughout the whole span of human occupation in the research area, but other Trans-Andean sources from north and south have contributed raw material for the daily use of the people living in the Nasca-Palpa area. Concerning the consumption patterns of metal the research conducted confirmed the general metallurgical development model for the Andean region as the inhabitants of the research area started to incorporate gold during Early Paracas and probably introduced copper consumption at the beginning of the Nasca culture. However, the results received for the Middle Horizon indicate that an access to exotic Co-Sn and Co-As-Ni alloys from the influence sphere of the Tiwanaku Empire was given.

The research of the current study opened up new research questions concerning the long-distance exchange routes of obsidian and the consumption of exotic metal objects in the research area that definitely need to be further investigated in the near future in order to clarify the already received results of raw material consumption patterns in the research area.

Palpa. PXRF analysis of obsidian projectile points in the in the “Casa Blanca”, field house of the PAP (photo: DBM, B. Gräfingholt).

Zusammenfassung

Der Beitrag von montanarchäologischen Forschungen zur Rekonstruktion von sozialen, ökonomischen und kulturellen Errungenschaften der vorspanischen Gesellschaften in Südamerika befindet sich noch in einem sehr frühen Stadium. Diese Arbeit wurde auf der einen Seite ermöglicht durch die grundlegenden Forschungen des Deutschen Archäologischen Institutes, die seit 1997 in der Nasca-Palpa Region von Dr. Markus Reindel und Johny Isla Cuadrado durchgeführt werden und die kulturelle Entwicklung der Region vom Archaikum bis zur conquista umfassend erforscht haben. Auf der anderen Seite haben die montanarchäologischen Forschungen und Surveys von Prof. Dr. Thomas Stöllner vom Deutschen Bergbau-Museum Bochum (DBM) und der Ruhr-Universität Bochum maßgeblich dazu beigetragen, diese Region als ein Untersuchungsgebiet für montanarchäologische Forschungen zu identifizieren. Ziel dieser Arbeit ist es, die Nasca-Palpa Region in einen überregionalen Zusammenhang mit Montanlandschaften im Norden Chiles zu setzen und anhand der Untersuchungsregion die Entwicklung des vorspanischen Gold-, Kupfer- und Obsidian-Bergbaus vom Archaikum bis zur conquista darzustellen. Die im Laufe der Jahrtausende in der Nasca-Palpa Region ansässigen Kulturen gehörten nie zur Avantgarde bezogen auf metallurgische Neuerungen und Innovationen, aber es kann als gesichert gelten, dass bergmännisches Fachwissen in der Region vorhanden war und zum Abbau der Erzlagerstätten an den Hängen der Flusstäler genutzt wurde.

Die vorliegende Arbeit betrachtet auf Grund von montanarchäologischen Untersuchungen in der Nasca-Palpa Region im Süden Perus die frühste Phase des vorspanischen Bergbaus an zwei ausgewählten Orten in den Flusstälern des Rio Palpa und Rio Viscas: Mollaque Grande und Saramarca. Außerdem konnten 365 Obsidianartefakte und 199 Metallartefakte, welche seit 1997 in der Untersuchungsregion gefunden wurden, mit einem tragbaren Röntgenfluoreszenzgerät (pXRF) analysiert werden. Die zerstörungsfreie Analysemethode wurde gezielt nicht unter Laborbedingungen eingesetzt, um anhand der gewonnen Erfahrungen das enorme Potential dieser Methode für zukünftige internationale archäologische Untersuchungen herauszuarbeiten. pXRF Analysen wurden bisher im archäologischen Kontext in Peru vorwiegend zur Untersuchung von Obsidian genutzt, die chemische Analyse von Metallartefakten mit Hilfe eines pXRF konnte im Zuge dieser Arbeit erstmalig in dieser Region angewendet werden.

Die Ergebnisse dieser umfassenden montanarchäologischen Untersuchung tragen zu der sich zunehmend entwickelnden Montanarchäologie in Südamerika bei, und es konnte gezeigt werden, wie wichtig ein interdisziplinärer Ansatz aus montanarchäologischen und geochemischen Methoden zur Untersuchung eines vorspanischen Bergbaudistrikts ist. Anhand der pXRF Ergebnisse konnte die Obsidianlagerstätte Jichja Parco als Hauptlieferant für den in der Untersuchungsregion genutzten Obsidian herausgearbeitet werden. Diese Lagerstätte spielte zu allen Zeiten der menschlichen Besiedlung der Region eine herausragende Rolle für die Rohstoffsicherung der Bewohner. Jedoch legen die Ergebnisse dieser Studie nahe, dass auch weit entfernte Lagerstätte im Norden und Süden der Untersuchungsregion einen Beitrag zur Rohstoffsicherung leisteten. Die geochemischen Analysen der Metallartefakte bestätigten die bisher postulierte Entwicklung der Metallurgie im Andenraum bis zum Mittleren Horizont. Mit Beginn der Paracas-Kultur wurde Gold als Rohstoff zur Herstellung von Schmuck genutzt, ab dem Übergang der Paracas- zur Nasca-Kultur lässt sich die Verarbeitung und Nutzung von Kupfer sicher belegen. Anhand der gewonnenen Daten lässt sich für den Mittleren Horizont eine signifikante Abweichung der bisher gängigen Forschungsmeinung belegen. Neben den Cu und Cu-As Legierungen konnten auch für das Untersuchungsgebiet exotische Legierungen wie Cu-Sn und Cu-As-Ni nachgewiesen werden, die bisher allgemeinhin exklusiv dem Tiwanaku Einflussbereich zugeordnet wurden.

Mollaque Grande. Pre-Columbian mining dumpsite overprinted by modern artisanal mining (photo: DBM, B. Gräfingholt).

Bibliography

Acuto, F.A., 2008. Experiencing Inca Domination in Northwestern Argentina and the Southern Andes. In: H. Silverman and W.H. Isbell, eds. 2008. *Handbook of South American archaeology.* New York: Springer, pp.845–861.

Aldenderfer, M.S., 1999. The Pleistocene/Holocene transition in Peru and its effects upon human use of the landscape. *Quaternary International,* 53/54, pp.11–19.

Aldenderfer, M.S., Craig, N., Speakman, R.J. and Popelka-Filcoff, R.S., 2008. Four-thousand-year-old gold artifacts from the Lake Titicaca basin, southern Peru. *Proceedings of the National Academy of Sciences of the United States of America,* 105(13), pp.5002–5005.

Aldunate del S., C., Castro, V. and Varela Guarda, V., 2008. San Bartolo y Cobija: Testimonios de un modo de vida minero en las tierras altas y la costa Atacama. *Estudios Atacameños,* 35, pp.97–118.

Andrefsky jr., W., 2009. The Analysis of Stone Tool Procurement, Production, and Maintenance. *Journal of Archaeological Research,* 17, pp.65–103.

Angiorama, C.I. and Becerra, M.F., 2010. Antiguas evidencias de minería y metalurgia en Pozuelos, Santo Domingo y Coyahuayma (Puna de Jujuy, Argentina). *Boletín del Museo Chileno de Arte Precolombino,* 15(1), pp.81–104.

Asaro, F., Salazar, E., Michel, H.V., Burger, R.L. and Stross, F.H., 1994. Ecuadorian Obsidian Sources Used for Artifact Production and Methods for Provenience Assignments. *Latin American Antiquity,* 5(3), pp.257–277.

Barberena, R., Hajduk, A. and Gil, A., 2011. Obsidian in the south-central Andes. Geological, geochemical, and archaeological assessment of north Patagonian sources (Argentina). *Quaternary International,* 245(1), pp.25–36.

Bellot-Gurlet, L., Dorighel, O. and Poupeau, G., 2008. Obsidian provenance studies in Colombia and Ecuador. Obsidian sources revisited. *Journal of Archaeological Science,* 35, pp.272–289.

Benic, C.M., 2000. Industrias Liticas de Huari y Tiwanaku. *Boletin de Arqueologia PUCP,* 4, pp.89–118.

Benson, E.P., ed., 1979. *Pre-Columbian Metallurgy of South America.* Washington, D.C.: Dumbarton Oaks Research Library and Collections, Trustees for Harvard University.

Bertrand, G., Guillou-Frottier, L. and Loiselet, C., 2014. Distribution of porphyry copper deposits along the western Tethyan and Andean subduction zones. Insights from a paleotectonic approach. *Ore Geology Reviews,* 60, pp.174–190.

Bigazzi, G., Coltelli, M., Hadler, N.J., Osorio Araya, A.M., Oddone, M. and Salazar, E., 1992. Obsidian-bearing lava flows and pre-Columbian artifacts from the Ecuadorian Andes. *Journal of South American Earth Sciences,* 6(1/2), pp.21–32.

Bird, J.B., 1979. The “Copper Man”. A Prehistoric Miner and his Tools from Northern Chile. In: E.P. Benson, ed. 1979. *Pre-Columbian Metallurgy of South America.* Washington, D.C.: Dumbarton Oaks Research Library and Collections, Trustees for Harvard University, pp.105–132.

Bissig, T., Clark, A.H., Rainbow, A. and Montgomery, A., 2015. Physiographic and tectonic settings of high-sulfidation epithermal gold–silver deposits of the Andes and their controls on mineralizing processes. *Ore Geology Reviews,* 65, pp.327–364.

Bogosavljevic, V., 1995. Mining Hammers of Prljusa. Mali Sturac site. In: P. Petrovic and S. Durdekanovic, eds. 1995. *Ancient Mining and Metallurgy in southeast Europe.* Belgrade: Baka Bor, pp.37–44.

Boivin, N. and Owoc, M.A., eds., 2004. *Soils, stones and symbols. Cultural perceptions of the mineral world.* London: UCL.

Boone, E.H., ed., 1996. *Andean art at Dumbarton Oaks.* Washington, D.C.: Dumbarton Oaks Research Library and Collection.

Borg, G., 2014. Gold is where you find it. Zeitgenössischer artisanaler Goldbergbau in Afrika als Analogie (prä-)historischer Goldgewinnung. In: H. Meller, R. Risch and E. Pernicka, eds. 2014. *Metalle der Macht – frühes Gold und Silber. 6. Mitteldeutscher Archäologentag vom 17. bis 19. Oktober 2013 in Halle (Saale) = Metals of power – early gold and silver.* Halle (Saale): Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt Landesmuseum für Vorgeschichte, pp.53–70.

Bradley, B. and Stanford, D., 2004. The North Atlantic ice-edge corridor. A possible Palaeolithic route to the New World. *World Archaeology,* 36(4), pp.459–478.

Bray, W., 1971. Ancient American Metal-Smiths. *Proceedings of the Royal Anthropological Institute of Great Britain and Ireland,* 1971, pp.25–43.

Bray, W., 1978. Gold-working in Ancient America. *Gold Bulletin,* 11, pp.136–143.

Briceno Rosario, J.G., 2010. *Las tradiciones liticas del Pleistoceno tardio en la quebrada santa Maria, costa norte del Peru. Una Contribucion al conocimiento de las puntas de proyectil paleoindias cola de pescado*. Doctoral thesis Freie Universität Berlin. [online] Available at: <https://refubium.fu-berlin.de/handle/fub188/13190> [Accessed 25 June 2021].

Bridgland, J., ed., 2014. *ICOM-CC 17th Triennial Conference Preprints, Melbourne, 15–19 September 2014.* Paris: International Council of Museums.

Brooks, S.O., Glascock, M.D. and Giesso, M., 1997. Source of volcanic glass for ancient Andean tools. *Nature,* 1997, pp.449–450.

Brooks, W.E., Piminchumo, V., Suárez, H., Jackson, J.C. and McGeehin, J.P., 2008. Mineral pigments at Huaca Tacaynamo (Chan Chan, Peru). *Bulletin de l´Institut Francais d`Études Andines,* 37(3), pp.441–450.

Browman, D.L., 1981. New Light on Andean Tiwanaku. A detailed reconstruction of Tiwanaku’s early commercial and religious empire illuminates the processes by which states evolve. *American Scientist,* 69(4), pp.408–419.

Brown, K.W. and Craig, A.K., 1994. Silver Mining at Huantajaya, Viceroyalty of Peru. In: A.K. Craig and R.C. West, eds.

1994. *In quest of mineral wealth. Aboriginal and colonial mining and metallurgy in Spanish America.* Baton Rouge, LA: Geoscience Publications, Dept. of Geography and Anthropology, Louisiana State University, pp.303–327.

Buchanan, B. and Collard, M., 2010. A geometric morphometrics-based assessment of blade shape differences among Paleoindian projectile point types from western North America. *Journal of Archaeological Science,* 37, pp.350–359.

Buchanan, B., Collard, M., Hamilton, M.J. and O'Brien, M.J., 2011. Points and prey. A quantitative test of the hypothesis that prey size influences early Paleoindian projectile point form. *Journal of Archaeological Science,* [e-journal] 38(4), pp.852–864. http://dx.doi.org/10.1016/j.jas.2010.11.007.

Burger, R.L., 1980. Trace-Element Analysis of Obsidian Artifacts from Pachamachay, Junin. In: J.W. Rick, ed. 1980. *Prehistoric hunters of the high Andes.* New York: Acad. Pr., pp.257–265.

Burger, R.L., 1989. An Overview of Peruvian Archaeology (1976-1986). *Annual Review of Anthropology,* 18, pp.37–69.

Burger, R.L., 2006. Interacción interregional entre los Andes centrales y los Andes centro sur. el caso de la circulación de obsidiana. In: H. Lechtman, ed. 2006. *Esferas de interacción prehistóricas y fronteras nacionales modernas. Los Andes sur centrales.* Lima, Nueva York: IEP; IAR, pp.423–448.

Burger, R.L., 2007. Late Paracas Obsidian Tools from Aminas Altas, Peru. *Andean Past,* 8, pp.477–492.

Burger, R.L., 2013. Some Thought on Mining and Quarrying in the Ancient Andes. In: N. Tripcevich and K. J. Vaughn, eds. 2013. *Mining and Quarrying in the Ancient Andes. Sociopolitical, Economic and Symbolic Dimensions.* New York, NY: Springer, pp.325–334.

Burger, R.L. and Asaro, F., 1977. Trace element analysis of obsidian artifacts from the Andes. New perspectives on pre-Hispanic economic interaction in Peru and Bolivia.

Burger, R.L. and Glascock, M.D., 2000. Locating the Quispisisa Obsidian Source in the Department of Ayacucho, Peru. *Latin American Antiquity,* 11(3), pp.258–268.

Burger, R.L. and Glascock, M.D., 2007. The Sourcing of Archaic Obsidian from Kasapata, Department of Cuzco. In: B.S. Bauer, ed. 2006. *Kasapata and the Archaic Period of the Cuzco Valley*. Los Angeles, CA: Cotsen Institute of Archaeology Press, pp.118–121.

Burger, R.L. and Gordon, R., 1998. Early Central Andean Metalworking from Mina Perdida, Peru. *Science,* 282, pp.1108–1110.

Burger, R.L. and Lechtman, H., 1996. Chavín. In: E. H. Boone, ed. 1996. *Andean art at Dumbarton Oaks.* Washington, D.C.: Dumbarton Oaks Research Library and Collection, pp.45–86.

Burger, R.L., Mohr Chavez, K.L. and Chavez, S.J., 2000. Through the Glass Darkly: Prehispanic Obsidian Procurement and Exchange in Southern Peru and Northern Bolivia. *Journal of World Prehistory,* 14(3), pp.267–362.

Burger, R.L., Asaro, F., Michel, H.V., Stross, F.H. and Salazar, E., 1994. An Initial Consideration of Obsidian Procurement and Exchange in Prehispanic Ecuador. *Latin American Antiquity,* 5(3), pp.228–255.

Burger, R.L., Schreiber, K., Jeanne, K., Glascock, M.D. and Ccencho, J., 1998. The Jampatilla Obsidian Source. Identifying the Geological Source of Pampas type Obsidian Artifacts from Southern Peru. *Andean Past,* 5, pp.225–239.

Burley, D.V., Sheppard, P.J. and Simonin, M., 2011. Tongan and Samoan volcanic glass: pXRF analysis and implications for constructs of ancestral Polynesian society. *Journal of Archaeological Science,* 38(10), pp.2625–2632.

Buzon, M.R., Conlee, C.A., Simonetti, A. and Bowen, G.J., 2012. The consequences of Wari contact in the Nasca region during the Middle Horizon. Archaeological, skeletal, and isotopic evidence. *Journal of Archaeological Science,* 39, pp.2627–2636.

Caley, E.R. and Easby jr., D.T., 1959. The Smelting of Sulfied Ores of Copper in Preconquest Peru. *American Antiquity,* 25(1), pp.59–65.

Capriles, J.M., and Tripcevich, N. 2016. *The Archaeology of Andean Pastoralism.* Albuquerque, NM: University of New Mexico Press.

Carmichael, P.H., 1998. Nasca Ceramic. Production and Social Context. In: I. Shimada, ed. 1998. *Andean ceramics: technology, organization, and approaches.* Philadelphia, PA: Museum Applied Science Center for Archaeology, University of Pennsylvania Museum of Archaeology and Anthropology, pp.213–231.

Castro de la Mata Guerra García, P. and Velarde Dellepiane, M.I., 2013. *Producción metalúrgica en la costa sur, desde el Horizonte Temprano al Horizonte Medio.* (Unpublished project report). Lima: Instituto Nacional de Cultura.

Castro de la Mata Guerra García, P., Reindel, M. and Isla Cuadrado, J., 2012. Proyecto Arqueológico Palpa-Lucanas. Informe final. Temporada 2010-2011. (Unpublished project report). Lima: Instituto Nacional de Cultura.

Cecil, L.G., Moriarty, M.D., Speakman, R.J. and Glascock, M.D., 2007. Feasibility of Field-Portable XRF to Identify Obsidian Sources in Central Peten, Guatemala. In: M. Glascock, ed. 2007. *Archaeological chemistry. Analytical techniques and archaeological interpretation.* Washington, DC: American Chemical Society, pp.506–521.

Cesareo, R., Calza, C., Dos Anjos, M., Lopes, R.T., Bustamante, A., Fabian S., Alva, W. and Chero Z., L., 2010. Pre-Columbian alloys from the royal tombs of Sipan. Energy dispersive X-ray fluorescence analysis with a portable equipment. *Applied Radiation and Isotopes,* 68, pp.525–528.

Chapdelaine, C., 2011. Recent Advances in Moche Archaeology. *Journal of Archaeological Research,* 19, pp.191–231.

Charalambous, A., Kassianidou, V. and Papasavvas, G., 2014. A compositional study of Cypriot bronzes dating to the Early Iron Age using portable X-ray fluorescence spectrometry (pXRF). *Journal of Archaeological Science,* 46, pp.205–216.

Childs, S.T., 1994. Native Copper Technology and Society in Eastern North America. In: D.A. Scott and P. Meyers, eds. 1994. *Archaeometry of pre-Columbian sites and artifacts. Proceedings of a symposium organized by the UCLA Institute of Archaeology and the Getty Conservation Institute, Los Angeles, California, March 23-27, 1992.* Marina Del Rey, CA: Getty Conservation Institute, pp.229–254.

Climent-Font, A., Demortier, G., Palacio, C., Montero, I., Ruvalcaba-Sil, J.L. and Diaz, D., 1998. Characterisation of Archaeological Bronzes Using PIXE, PIGE , RBS and AES Spectrometries. *Nuclear Instruments & Methods in Physics Research,* 134, pp.229–236.

Conlee, C.A., 2003. Local Elites and the Reformation of Late Intermediate Perios Sociopolitcal and Economic Organisation in Nasca, Peru. *Latin American Antiquity,* 14(1), pp.47–65.

Conlee, C.A., Buzon, M.R., Gutierrez, A.N., Simonetti, A. and Creaser, R.A., 2009. Identifying foreigners versus locals in a burial population from Nasca, Peru. An investigation using strontium isotope analysis. *Journal of Archaeological Science,* [e-journal] 36(12), pp.2755–2764. http://dx.doi.org/10.1016/j.jas.2009.08.016.

Commission on isotopic abundances and atomic weights, 2020. CIAAW. Atomic weights of the elements 2020. Available at <https://www.ciaaw.org/atomic-weights.htm>.

Cooke, C.A., Balcom, P.H., Biester, H. and Wolfe, A.P., 2009. Over three millennia of mercury pollution in the Peruvian

Andes. *Proceedings of the National Academy of Sciences of the United States of America,* [e-journal] 106(22), pp.8830–8834. http://dx.doi.org/10.1073/pnas.0900517106.

Cooke, C.A., Balcom, P.H., Kerfoot, C., Abbott, M.B. and Wolfe, A.P., 2011. Pre-Colombian Mercury Pollution Associated with the Smelting of Argentiferous Ores in the Bolivian Andes. *AMBIO,* 40, pp.18–25.

Covey, R.A., 2000. Inka Administration of the Far South Coast of Peru. *Latin American Antiquity,* 11(2), pp.119–138.

Covey, R.A., 2008. Multiregional Perspectives on the Archaeology of the Andes During the Late Intermediate Period (c. A.D. 1000–1400). *Journal of Archaeological Research,* 16, pp.287–338.

Covey, R.A., 2008. The Inca Empire. In: H. Silverman and W.H. Isbell, eds. 2008. *Handbook of South American archaeology.* New York, NY: Springer, pp.809–830.

Craddock, B., 1990. The Experimental Hafting of Stone Mining Hammers. In: P. Crew and S. Crew, eds. 1990. *Early mining in the British Isles. Proceedings of the Early Mining Workshop at Plas Tan y Bwlch, Snowdonia National Park Study Centre, 17-19 November, 1989.* Tan y Bwlch, Gwynedd: Plas Tan y Bwlch, Snowdonia National Park Study Centre, pp.58–58.

Craddock, P.T. and Lang, J., eds., 2003. *Mining and metal production through the ages.* London: British Museum Press.

Craddock, B.R., Cartwright, P.T., Craddock, P.T. and Wray, W.B., 2003. Hafted Stone Mining Hammer from Chupuicamata, Chile. In: P.T. Craddock and J. Lang, eds. 2003. *Mining and metal production through the ages.* London: British Museum Press, pp.52–68.

Craig, A.K. and West, R.C., eds., 1994. *In quest of mineral wealth. Aboriginal and colonial mining and metallurgy in Spanish America.* Baton Rouge, LA: Geoscience Publications, Dept. of Geography and Anthropology, Louisiana State University.

Craig, N., Speakman, R.J., Popelka-Filcoff, R.S., Glascock, M.D., Robertson, J D., Shackley, M.S. and Aldenderfer, M.S., 2007. Comparison of XRF and PXRF for analysis of archaeological obsidian from southern Peru. *Journal of Archaeological Science,* 20, pp.1–13.

Craig, N., Speakman, R.J., Popelka-Filcoff, RS., Aldenderfer, M. S., Flores Blanco, L., Brown Vega, M., Glascock, M.D. and Stanish, C., 2010. Macusani obsidian from southern Peru: A characterization of its elemental composition with a demonstration of its ancient use. *Journal of Archaeological Science,* 37, pp.569–576.

Crew, P. and Crew, S., eds., 1990. *Early mining in the British Isles. Proceedings of the Early Mining Workshop at Plas Tan y Bwlch, Snowdonia National Park Study Centre, 17-19 November, 1989.* Tan y Bwlch, Gwynedd: Plas Tan y Bwlch, Snowdonia National Park Study Centre.

Cruz, P. and Vacher, J.-J., eds., 2008. *Mina y metalurgia en los Andes del Sur. desde la epoca prehispanica hasta el sieglo XVII.* Sucre.

De Francesco, A.M., Bocci, M., Crisci, G.M. and Francaviglia, V., 2012. Obsidian Provenance at several Italian and Corsican Archaeological Sites using the Non-destructive X-ray Fluorescence Method. In: I. Liritzis and C.M. Stevenson, eds. 2012. *Obsidian and ancient manufactured glasses.* Albuquerque: University of New Mexico Press, pp.115–129.

De Nigris, M.R. and Puche Riart, O., 2013. Molinos Mineros de Tradición Andina. *De Re Metallica,* 20, pp.1–12.

Delange, E., Meyohas, M.E. and Aucounturier, M., 2005. The Statue of Karomama: A Testimony of the Skill of Egyptian Metallurgists in Polychrome Bronze Statuary. *Journal of Cultural Heritage,* 6(2), pp.99–113.

DeLeonardis, L. and Glascock, M.D., 2013. From Queshqa to Callango. A Paracas Obsidian Assemblage from the lower Ica Valley, Peru. *Nawpa Pacha,* 33(2), pp.1–29.

Denker, A., Bohne, W., Opitz-Coutureau, J., Rauschenberg, J., Rohrich, J. and Strub, E., 2005. Influence of Corrosion Layers on Quantitative Analysis. *Nuclear Instruments & Methods in Physics Research,* 239, pp.65–70.

Desaulty, A.-M., Telouk, P., Albalat, E. and Albarède, F., 2011. Isotopic Ag–Cu–Pb record of silver circulation through 16th-18th century Spain. *Proceedings of the National Academy of Sciences of the United States of America,* [e-journal] 108(22), pp.9002–9007. http://dx.doi.org/10.1073/pnas.1018210108.

Deutsches Archäologisches Institut, ed., 2008. *Jahresbericht 2007.* München: Hirmer.

Deutsche Welle, 2016. *Notstand wegen Quecksilberverseuchung in Peru*. [online] Available at: <https://p.dw.com/p/1ItKH> [Accessed 9 May 2021].

Dewey, J.F. and Lamb, S.H., eds., 1993. *Second International Symposium on Andean Geodynamics.* Amsterdam.

Dillehay, T.D., 2008. Profiles in Pleistocene History. In: H. Silverman and W.H. Isbell, eds. 2008. *Handbook of South American archaeology.* New York: Springer, pp.29–44.

Dillehay, T.D., 2009. Probing deeper into first American studies. *PNAS,* 106(4), pp.971–978.

Dillehay, T.D., Caldern, G.A. and Politis, G., 1992. Earliest hunters and gatherers of South America. *Journal of World Prehistory,* [e-journal] 6(2), pp.145–204. http://dx.doi.org/10.1007/BF00975549.

Dillehay, T.D., Rossen, J., Maggard, G., Stackelbeck, K. and Netherly, P., 2003. Localization and possible social aggregation in the Late Pleistocene and Early Holocene on the north coast of Peru. *Quaternary International,* 109-110, pp.3–11.

Dillian, C.D. and White, C.L., eds., 2009. *Trade and Exchange. Archaeological Studies from History and Prehistory.* New York, NY: Springer New York.

Downey, J.T., 2010. Working with Expendient Lithic Technologies in the Northern Highlands of Peru. *Explorations in Anthropology,* 10(2), pp.77–95.

Duran, V., Giesso, M., Glascock, M.D., Neme, G., Gil, A. and Sanhueza R., L., 2004. Estudio de fuentes de aprovisionamiento y redes de distribución de obsidiana durante el Holoceno Tardío en el sur de Mendoza (Argentina). *Estudios Atacameños,* pp.25–43.

Dussubieux, L. and Walder, H., 2015. Identifying American native and European smelted coppers with pXRF. A case study of artifacts from the Upper Great Lakes region. *Journal of Archaeological Science,* 59, pp.169–178.

Dussubieux, L., Deraisme, A., Frot, G., Stevenson, C.M., Creech, A. and Bienvenu, Y., 2008. LA-ICP-MS, SEM-EDS and EPMA Analyses of eastern North American copper-based artifacts. Impact of corrosion and heterogeneity on the reliability of the LA-ICP-MS compositional results. *Archaeometry,* 50, pp.643–657.

Dutton, L.A., 1990. Surface Remains of Early Mining on the Great Orme. In: P. Crew and S. Crew, eds. 1990. *Early mining in the British Isles. Proceedings of the Early Mining Workshop at Plas Tan y Bwlch, Snowdonia National Park Study Centre, 17-19 November, 1989.* Tan y Bwlch, Gwynedd: Plas Tan y Bwlch, Snowdonia National Park Study Centre, pp.11–14.

Earle, T.K. and Ericson, J.E., eds., 1977. *Exchange systems in prehistory.* New York.

Eeckhout, P. and Owens, L.S., eds., 2015. *Funerary practices and models in the ancient Andes. The return of the living dead.* New York, NY: Cambridge University Press.

Eerkens, J.W., Vaughn, K.J. and Linares Grados, M., 2009. Pre-Inca mining in the Southern Nasca Region, Peru. *Antiquity,* 83, pp.738–750.

Eerkens, J.W., Vaughn, K.J., Carpenter, T.R., Conlee, C.A., Linares Grados, M. and Schreiber, K., 2008. Obsidian hydration dating on the South Coast of Peru. *Journal of Archaeological Science,* 35, pp.2231–2239.

Eerkens, J.W., Vaughn, K.J., Linares Grados, M., Conlee, C.A., Schreiber, K., Glascock, M.D. and Tripcevich, N., 2010. Spatio-temporal patterns in obsidian consumption in the Southern Nasca Region, Peru. *Journal of Archaeological Science,* 37, pp.825–832.

Eerkens, J.W., Barfod, G.H., Vaughn, K.J., Williams, P.R. and Lesher, C.E., 2014. Iron isotope analysis of red and black pigments on pottery in Nasca, Peru. Archaeological and Anthropological Sciences*,* 6(4), pp.241–254.

Eitel, B., 2007. Kulturentwicklung am Wüstenrand. Aridisierung als Anstoß für frühgeschichtliche Innovation und Migration. In: G.A. Wagner, ed. 2007. *Einführung in die Archäometrie.* Berlin: Springer, pp.301–319.

Eitel, B., Hecht, S., Mächtle, B., Schukraft, G., Kadereit, A., Wagner, G.A., Kromer, B., Unkel, I. and Reindel, M., 2005. Geoarchaeological Evidence from desert Loess in the Nazca-Palpa Region, Southern Peru. Palaeoenviromental Changes and their impact on Pre-Columbian Cultures. *Archaeometry,* 47(1), pp.137–158.

Eitel, B. and Mächtle, B., 2009. Man and Enviroment in the Eastern Atacama Desert (Southern Peru). Holocene Climate Changes and Theri Impact on Pre-Columbian Cultures. In: B. Herrmann, M. Reindel and G.A. Wagner, eds. 2009. *New Technologies for Archaeology. Multidisciplinary Investigations in Palpa and Nasca, Peru.* Berlin, Heidelberg: Springer, pp.17–37.

Engel, F., 1957a. Sites et établissements sans céramique de la côte péruvienne. *Journal de la Société des Américanistes,* 46, pp.67–156.

Engel, F., 1957b. Early Sites on the Peruvian Coast. *Southwestern Journal of Anthropology,* 13(1), pp.54–68.

Engel, F., 1966. *Paracas : cien siglos de cultura peruana.* Lima.

Engel, F., 1983. *Stone typology.* [S.l.]: [s.n.].

Ericson, J.E. and Baugh, T.G., eds., 1993. *The American Southwest and Mesoamerica. Systems of prehistoric exchange.* New York: Plenum Press

Fehren-Schmitz, L., Hummel, S. and Herrman, B., 2009. Who Were the Nasca? Population Dynamics in Pre-Columbian Southern Peru Revealed by Ancient DNA Analyses. In: B. Herrmann, M. Reindel and G.A. Wagner, eds. 2009. *New Technologies for Archaeology. Multidisciplinary Investigations in Palpa and Nasca, Peru.* Berlin, Heidelberg: Springer, pp.159–172.

Fehren-Schmitz, L., Reindel, M., Tomasto Cagigao, E., Hummel, S. and Herrmann, B., 2010. Pre-Columbian Population Dynamics in Coastal Southern Peru. A Diachronic Investigation of mtDNA Patterns in the Palpa Region by Ancient DNA Analysis. *American Journal of Physical Anthropology,* 141, pp.208–221.

Fehren-Schmitz, L., Warnberg, O., Reindel, M., Seidenberg, V., Tomasto Cagigao, E., Isla Cuadrado, J., Hummel, S. and Herrmann, B., 2011. Diachronic Investigations of Mitochondrial and Y-Chromosomal Genetic Markers in Pre-Columbian Andean Highlanders from South Peru. *Annals of Human Genetics,* [e-journal] 75(2), pp.266–283. http://dx.doi.org/10.1111/j.1469-1809.2010.00620.x.

Ferguson, J.R., 2012. X-Ray fluorescence of obsidian. Approaches to calibration and the analysis of small samples. In: A.N. Shugar and J.L. Mass, eds. 2012. *Handheld XRF for art and archaeology.* Leuven, Belgium: Leuven University Press, pp.401–422.

Fernandes, R., van Os, B.J.H. and Huisman, H.D.J., 2013. The use of Hand-Held XRF for investigating the composition and corrosion of Roman copper-alloyed artifacts. *Heritage Science,* [e-journal] 1, pp.1–7. http://dx.doi.org/10.1186/2050-7445-1-30.

Fields, V. M., Zamudio-Taylor, V. and Beltrán, M., eds., 2001. *The road to Aztlan. Art from a mythic homeland.* Los Angeles, Calif.: Los Angeles City Museum of Art.

Figueroa, V., Salazar, D., Salinas, H., Núnez-Regueiro, P. and Manriquez, G., 2013. Pre-Hispanic Mining Ergology of Northern Chile. An Archaeological Perspective. *Revista Chilena de Antropología,* 45(1), pp. 61–81.

Flenniken, J. J. and Raymond, A. W., 1986. Morphological Projectile Point Typology: Replication Experimentation and TechnologicalAnalysis. *American Antiquity,* 51(3), pp. 603–614.

Forster, N. and Grave, P., 2012. Non-destructive PXRF analysis of museum-curated obsidian from the Near East. *Journal of Archaeological Science,* 39(3), pp. 728–736.

Frahm, E., 2013a. Validity of “off-the-shelf” handheld portable XRF for sourcing Near Eastern obsidian chip debris. *Journal of Archaeological Science,* 40, pp.1080–1092.

Frahm, E., 2013b. Is obsidian sourcing about geochemistry or archaeology? A reply to Speakman and Shackley. *Journal of Archaeological Science,* 40, pp.1444–1448.

Frahm, E. and Doonan, R.C.P., 2013. The technological versus methodological revolution of portable XRF in archaeology. *Journal of Archaeological Science,* 40, pp.1425–1434.

Frahm, E. and Feinberg, J.M., 2013. Empires and resources. Central Anatolian obsidian at Urkesh (Tell Mozan, Syria) during the Akkadian period. *Journal of Archaeological Science,* 40, pp.1122–1135.

Frahm, E., Schmidt, B.A., Gasparyan, B., Yeritsyan, B., Karapetian, S., Meliksetian, K. and Adler, D.S., 2014. Ten seconds in the field. Rapid Armenian obsidian sourcing with portable XRF to inform excavations and surveys. *Journal of Archaeological Science,* 41, pp.333–348.

Frame, M., ed., 2007. *Hilos del pasado. El aporte francés al legado Paracas.* Lima: Instituto Nacional de Cultura.

Gale, D., 1990. Prehistoric Stone Mining Tools from Alderley Edge. In: P. Crew and S. Crew, eds. 1990. *Early mining in the British Isles. Proceedings of the Early Mining Workshop at Plas Tan y Bwlch, Snowdonia National Park Study Centre, 17-19 November, 1989.* Tan y Bwlch, Gwynedd: Plas Tan y Bwlch, Snowdonia National Park Study Centre, pp.47–48.

Gale, D., 1995. A comparative Study of the eraliest European copper Mining Tools. In: P. Petrovic and S. Durdekanovic, eds. 1995. *Ancient Mining and Metallurgy in southeast Europe.* Belgrade: Baka Bor, pp.47–52.

Gero, J.M., 1983. *Material culture and the reproduction of social complexity. a lithic example from the peruvian formative*. PhD. University of Massachusetts.

Giesso, M., 2003. Stone Tool Production in the Tiwanaku Heartland. In: A. Kolata, ed. 2003. *Tiwanaku and its hinterland. Archaeology and paleoecology of an Andean civilization. Vol. 2, Urban and rural archaeology.* Washington, D.C, Chesham: Smithsonian Institution; Combined Academic, pp.363–383.

Giesso, M., Berón, M.A. and Glascock, M.D., 2008. Obsidian in Western Pampas, Argentina. Source Characterization and Provisioning Strategies. *Bulletin of the International Association of Obsidian Studies,* 37(1), pp.15–18.

Giesso, M., Duran, V., Neme, G., Glascock, M.D., Cortegoso, V., Gil, A. and Sanhueza, L., 2011. A Study of Obsidian source usage in the central Andes of Argentina and Chile. *Archaeometry,* [e-journal] 53(1), pp.1–21. http://dx.doi.org/10.1111/j.1475-4754.2010.00555.x.

Glascock, M.D., 1994. New World Obsidian. Recent Investigations. In: D.A. Scott and P. Meyers, eds. 1994. *Archaeometry of pre-Columbian sites and artifacts. Proceedings of a symposium organized by the UCLA Institute of Archaeology and the Getty Conservation Institute, Los Angeles, Califor-*

nia, March 23-27, 1992. Marina Del Rey, CA: Getty Conservation Institute, pp.113–134.

Glascock, M.D., 2002. Obsidian Provenance Research in the Americas. *Accounts of Chemical Research,* 35, pp.611–617.

Glascock, M.D., ed., 2007. *Archaeological chemistry. Analytical techniques and archaeological interpretation.* Washington, DC: American Chemical Society.

Glascock, M.D. and Giesso, M., 2012. New Perspectives on Obsidian Procurement and Exchange at Tiwanaku, Bolivia. In: I. Liritzis and C.M. Stevenson, eds. 2012. *Obsidian and ancient manufactured glasses.* Albuquerque: University of New Mexico Press, pp.86–96.

Glascock, M.D., Braswell, G. and Cobean, R.H., 1998. A Systematic Approach to Obsidian Source Characterization. In: M.S. Shackley, ed. 1998. Archaeological Obsidian Studies: Method and Theory. New York, NY: Kluwer Academic and Plenum Press, pp.15-65.

Glascock, M.D., Speakman, R.J. and Burger, R.L., 2007. Sources of Archaeological Obsidian in Peru. Descriptions and Geochemistry. In: M.D. Glascock, ed. 2007. *Archaeological chemistry. Analytical techniques and archaeological interpretation.* Washington, DC: American Chemical Society, pp.522–552.

Glascock, M.D., Speakman, R.J. and Neff, H., 2007. Archaeometry at the University of Missouri Research Reactor and the provenance of obsidian artifacts in North America. *Archaeometry*, 49(2), pp.343-357.

Goldstein, J.I., Newbury, D.E., Michael, J.R., Ritchie, N.W.M., Scott, J.H.J. and Joy, D.C., 2018. *Scanning electron microscopy and x-ray microanalysis*. 4th ed. New York, NY: Springer.

Goldstein, D.J. and Shimada, I., 2007. Middle Sican Multicraft Production. Resource Management and Labor Organization. In: I. Shimada, ed. 2007. *Craft production in complex societies. Multicraft and producer perspectives.* Salt Lake City, UT: University of Utah Press, pp.44–67.

Golitko, M., Meierhoff, J. and Terrell, J., 2010. Chemical characterization of sources of obsidian from the Sepik coast (PNG). *Archaeology in Oceania*, 45, pp.120–129.

González, L.R., 2004. *Bronces sin nombre. La metalurgia prehispánica en el noroeste argentino.* Buenos Aires: Ediciones Fundación CEPPA.

Gonzalez, L.R., 2008. La rebellion de los bronces. Estudios sobre metalurgia prehispanica en el noroeste argentino. In: P. Cruz and J.-J. Vacher, eds. 2008. *Mina y metalurgia en los Andes del Sur. desde la epoca prehispanica hasta el sieglo XVII*. Lima: Inst. Francés de Estudios Andinos, pp.57–89.

González, L.R., 2010. Fuegos Sagrados. El Taller metalúrgico del Sitio 15 de Rincón chico (Catamarca, Argentina). *Boletín del Museo Chileno de Arte Precolombino,* 15(1), pp.47–62.

Goodale, N., Bailey, D. G., Jones, G.T., Prescott, C., Scholz, E., Stagliano, N. and Lewis, C., 2012. pXRF: a study of inter-instrument performance. *Journal of Archaeological Science,* 39, pp.875–883.

Gordon, R. and Knopf, R., 2006. Metallurgy of Bronze used in tools from Machu Picchu, Peru. *Archaeometry,* 48(1), pp.57–76.

Gordon, R. and Knopf, R., 2007. Late horizon silver, copper, and tin from Machu Picchu, Peru. *Journal of Archaeological Science,* 34, pp.38–47.

Graffam, G., Carevic, A. and Rivera, M.A., 1997. Evidencias metalúrgicas de fundición de cobre en el sitio formativo tardío de Ramaditas, quebrada de Guatacondo, Provincia de Iquique, Chile. *Estudios Atacameños,* 12, pp.47–59.

Graffam, G., Rivera, M.A. and Carevic, A., 1996. Ancient Metallurgy in the Atacama. Evidence for copper smelting during Chile´s early ceramic period. *Latin American Antiquity,* 7(2), pp.101–113.

Gräfingholt, B., 2011. *Obsidian Projectile Points in the Palpa-Region, Peru.* Master thesis. Ruhr-Universität Bochum.

Grossman, J.W., 1972a. *Early Ceramic Cultures of Andahuaylas, Apurimac, Peru*. PhD. University of California, Berkeley.

Grossman, J.W., 1972b. An Ancient Gold Worker's Tool kit. The Earliest Metal Technology in Peru. *Archaeology,* 25(4), pp.270–275.

Gudiño, A., Correal Urrego, G., Herrera, R.S. and Glascock, M.D., 2001. Composition Analysis of an Obsidian Artifact from Pubenza, Colombia. IAOS Bulletin 26/2001, 6–8.

Gunnesch, K.A., Baumann, A. and Gunnesch, M., 1990. Lead Isotope Variations across the Central Peruvian Andes. *Economic Geology,* 85(7), pp.1354–1401.

Gustafson, L.B., Vidal, C.E., Pinto, R. and Noble, D.C., 2004. Porphyry-Epithermal Transition, Cajamarca Region, Northern Peru. In: R.H. Sillitoe, J. Perelló, and C.E. Vidal, eds. 2004. *Andean metallogeny. New discoveries, concepts, and updates.* Littleton, CO: Society of Economic Geologists, pp.279–300.

Hahn, J., 1993. *Erkennen und Bestimmen von Stein- und Knochenartefakten. Einführung in die Artefaktmorphologie.* 2nd ed. Tübingen: Verl. Archaeologica Venatoria.

Hall, E.T., 1960. X-ray fluorescent analysis applied to archaeology. *Archaeometry,* 3, pp.29–37.

Hall, E.T., Banks, M.S. and Stern, J.M., 1964. Uses of X-ray fluorescent analysis in archaeology. *Archaeometry,* 7, pp.84–89.

Hauptmann, A., 1985. 5000 Jahre Kupfer im Oman. Der Anschnitt, Beiheft 4. Bochum: Deutsches Bergbau-Museum.

Hauptmann, A., 2011. Erz- und Minerallagerstätten der Anden. In: R. Slotta and I. Schnepel, eds. 2011. *Schätze der Anden. Chiles Kupfer für die Welt. Katalog der Ausstellung des Deutschen Bergbau-Museums Bochum 8. Mai 2011 bis 19. Februar 2012.* Bochum: Deutsches Bergbau-Museum, pp.27–42.

Hauptmann, A., 2011. Zur Geologie von Chile. Plattentektonik, Vulkane, Erdbeben. In: R. Slotta and I. Schnepel, eds. 2011. *Schätze der Anden. Chiles Kupfer für die Welt. Katalog der Ausstellung des Deutschen Bergbau-Museums Bochum 8. Mai 2011 bis 19. Februar 2012.* Bochum: Deutsches Bergbau-Museum, pp.17–26.

Hauptmann, A., 2014. The Investigation of Arachaeometallurgical Slag. In: B.W. Roberts and C.P. Thornton, eds. 2014. *Archaeometallurgy in global perspective. Methods and syntheses.* New York, NY: Springer, pp.91–105.

Hauptmann, A. and Modarressi-Tehrani, D., eds., 2015. *Archaeometallurgy in Europe III. Proceedings of the 3rd international conference June 29 – July 1, 2011.* Bochum: Deutsches Bergbau-Museum.

Healan, D.M., 1997. Pre-Hispanic quarrying in the Ucareo-Zinapecuaro Obsidian Source Area. *Ancient Mesoamerica,* 8, pp.77–100.

Hecht, N., 2009. Of Layers and Sherds. A Context-Based Relative Chronology of the Nasca Style Pottery from Palpa. In: B. Herrmann, M. Reindel, and G.A. Wagner, eds. 2009. *New Technologies for Archaeology. Multidisciplinary Investigations in Palpa and Nasca, Peru.* Berlin, Heidelberg: Springer, pp.207–230.

Herrmann, B., Reindel, M. and Wagner, G.A., eds., 2009. *New Technologies for Archaeology. Multidisciplinary Investigations in Palpa and Nasca, Peru*. Berlin, Heidelberg: Springer Berlin Heidelberg. [e-book] http://dx.doi.org/10.1007/978-3-540-87438-6.

Hirth, K., Cyphers, A., Cobean, R., de Leon, J. and Glascock, M.D., 2013. Early Olmec obsidian trade and economic organization at San Lorenzo. *Journal of Archaeological Science,* 40, pp.2784–2798.

Hörz, G. and Kallfass, M., 2000. The treasure of gold and silver artifacts from the Royal Tombs of Sipán, Peru. A study on the Moche metalworking techniques. *Materials Characterization,* 45, pp.391–420.

Hosler, D., 2009. West Mexican Metallurgy. Revisited and Revised. *Journal of World Prehistory,* [e-journal] 22(3), pp.185–212. http://dx.doi.org/10.1007/s10963-009-9021-7.

Hughes, R., 1993. Artificial Patination. In: S. La Niece and P.T. Craddock, eds. 1993. *Metal plating and patination. Cultural, technical, and historical developments.* Oxford, Boston: Butterworth-Heinemann, pp.1–18.

Iribarren, J., 1973. Una Mina de Explotación Incaica: El Salvador– Provincia de Atacama. In: *Actas del VI Congreso de Arqueología Chilena Octubre 1971*. Santiago de Chile: Editorial Universitaria*,* pp.267–283.

Isbell, W.H., 2008. Wari and Tiwanaku. International Identities in the Central Andean Middle Horizon. In: H. Silverman and W.H. Isbell, eds. 2008. *Handbook of South American archaeology.* New York, NY: Springer, pp.731–760.

Isbell, W.H. and Silverman, H., eds., 2002-2006. *Andean archaeology.* New York, NY: Springer.

Isla Cuadrado, J., 2009. From Hunters to Regional Lords: Funerary Practices in Palpa, Peru. In: B. Herrmann, M. Reindel, and G.A. Wagner, eds. 2009. *New Technologies for Archaeology. Multidisciplinary Investigations in Palpa and Nasca, Peru.* Berlin, Heidelberg: Springer, pp.119–139.

Isla Cuadrado, J. and Reindel, M., 2002-2006. Burial Patterns and Sociopolitical Organization in Nasca 5 Society. In: W.H. Isbell and H. Silverman, eds. 2002-2006. *Andean archaeology.* New York: Springer, pp.374–400.

Jennings, J. and Glascock, M. D., 2002. Description and Method of Exploitation of the Alca Obsidian Source, Peru. *Latin American Antiquity,* 13(1), pp.107–118.

Jia, P.W., Doelman, T., Chen, C., Zhao, H., Lin, S.C., Torrence, R. and Glascock, M.D., 2010. Moving sources: A preliminary study of volcanic glass artifact distributions in northeast China using PXRF. *Journal of Archaeological Science,* 37(7), pp.1670–1677.

Johnson, L.L., Behm, J.A., Bordes, F., Cahen, D., Crabtree, D.E., Dincauze, D.F., Hay, C.A., Hayden, B., Hester, T.R., Katz, P R., Knudson, R., McManamon, F.P., Malik, S.C., Müller-Beck, H., Newcomer, M.H., Paddayya, K., Price-Beggerly, P., Ranere, A.J., Sankalia, H.D. and Sheets, P.D., 1978. A History of Flint-Knapping Experimentation, 1838-1976 [and Comments and Reply]. *Current Anthropology,* [e-journal] 19(2), pp.337–372. http://dx.doi.org/10.1086/202078.

Kamenov, G., MacFarlane, A.W. and Riciputi, L., 2002. Sources of Lead in the San Cristobal, Pulacayo, and Potosí Mining Districts, Bolivia, and a Reevaluation of Regional Ore Lead Isotope Provinces. *Economic Geology,* 97, pp.573–592.

Kellett, L.C., Golitko, M. and Bauer, B.S., 2013. A provenance study of archaeological obsidian from the Andahuaylas region of southern Peru. *Journal of Archaeological Science,* 40, pp.1890–1902.

Kiehn, A.V., Brook, G.A., Glascock, M.D., Dake, J.Z., Robins, L.H., Campbell, A.C. and Murphy, M.L., 2007. Fingerprinting Specular Hematite from Mines in Botswana Southern Africa. In: M.D. Glascock, ed. 2007. *Archaeological chemistry. Analytical techniques and archaeological interpretation.* Washington, DC: American Chemical Society, pp.460–479.

Klink, C., 2006. The Lithic Assemblage at Kasapata. In: B.S. Bauer, ed. 2006. *Kasapata and the archaic period of the Cuzco Valley.* Los Angelos, CA: Cotsen Institute of Archaeology at UCLA, pp.31–77.

Klink, C. and Aldenderfer, M.S., 2005. A Projectile Point Chronology for the South-Central Andean Highlands. In: C. Stanish, A.B. Cohen, and M.S. Aldenderfer, eds. 2005. *Advances in Titicaca Basin archaeology.* Los Angeles, CA: Cotsen Institute of Archaeology at UCLA, pp.25–54.

Knight, C.L.F., Cuéllar, A.M., Glascock, M.D., Hall, M.L. and Mothes, P.A., 2011. Obsidian source characterization in the Cordillera Real and eastern piedmont of the north Ecuadorian Andes. *Journal of Archaeological Science*, [e-journal] 38(5), pp.1069-1079. http://dx.doi.org/10.1016/j.jas.2010.12.002.

Kolata, A., ed., 2003. *Tiwanaku and its hinterland. Archaeology and paleoecology of an Andean civilization. Vol. 2, Urban and rural archaeology.* Washington, DC, et al.: Smithsonian Institution Press.

Kontak, D.J., Cumming, G.L., Krstic, D., Clark, A.H. and Farrar, E., 1990. Isotopic Composition of Lead in Ore Deposits of the Cordillera Oriental, Southeastern Peru. *Economic Geology,* 85(7), pp.1584–1603.

Körlin, G., Prange, M., Stöllner, T. and Yalçın, Ü., eds., 2016. *From bright ores to shiny metals. Festschrift for Andreas Hauptmann on the occasion of 40 years research in archaeometallurgy and archaeometry.* Rahden/Westf.: Marie Leidorf.

Kuramoto, J.R., 2001. Artisanal and Informal Mining in Peru. *Mining, Minerals and Sustainable Development, (*82), pp.1–53.

La Niece, S. and Craddock, P.T., eds., 1993. *Metal plating and patination. Cultural, technical, and historical developments.* Oxford, Boston, MA: Butterworth-Heinemann.

Laguens, A.G., Giesso, M., Bonnin, M.I. and Glascock, M.D., 2007. Más allá del horizonte. Cazadores-recolectores e intercambio a larga distancia en Intihuasi (provincia de San Luis, Argentina). *Intersecciones en Antropología,* 8, pp.7–26.

Lambers, K., 2006. *The Geoglyphs of Palpa, Peru. Documentation, Analysis and Interpretation.* Aichwald: Lindensoft.

Lange, C.H., ed., 1985. *Southwestern Culture History: Collected Papers in Honor of Albert H. Schroeder.* Santa Fe, NM: Ancient City Press.

Lanning, E.P., 1963. A Pre-Agricultural Occupation on the Central Coast of Peru. *American Antiquity,* 28(3), pp.360–371.

Lanning, E.P. and Hammel, E.A., 1961. Early Lithic Industries of Western South America. *American Antiquity,* 27(2), pp.139–154.

Lavallee, D., Julien, M., Wheeler, J. and Karlin, C., eds., 1995. *Telarmachay. Cazadores y pastores prehistoricos de los Andes.* Lima: IFEA, et al.

Lechtman, H., 1976. A Metallurgical Site Survey in the Peruvian Andes. *Journal of Field Archaeology,* 3(1), pp.1–42.

Lechtman, H., 1979. Issues in Andean Metallurgy. In: E.P. Benson, ed. 1979. *Pre-Columbian Metallurgy of South America.* Washington, DC: Dumbarton Oaks Research Library and Collections, Trustees for Harvard University, pp.1–40.

Lechtman, H., 1984. Andean Value Systems and the Development of Prehistoric Metallurgy. *Technology and Culture,* 25(1), pp.1–36.

Lechtman, H., 1991. *America´s vanished metalsmiths.* Santiago de Chile: Museo Chileno de Arte Precolombino.

Lechtman, H., 1991. The Production of Copper-Arsenic Alloys in the Central Andes. Highland Ores and Coastal Smelters? *Journal of Field Archaeology,* 18(1), pp.43–76.

Lechtman, H., 1994. The Materials Science of Material Culture. Examples from the Andean Past. In: D.A. Scott and P. Meyers, eds. 1994. *Archaeometry of pre-Columbian sites and artifacts. Proceedings of a symposium organized by the UCLA Institute of Archaeology and the Getty Conservation*

Institute, Los Angeles, California, March 23-27, 1992. Marina Del Rey, CA: Getty Conservation Institute, pp.3–14.

Lechtman, H., 1996. Arsenic Bronze. Dirty Copper or Chosen Alloy? A View from the Americas. *Journal of Field Archaeology,* 23(4), pp.477–514.

Lechtman, H., 2003. Middle Horizon Bronze: Centres and Outliers. In: L. van Zelsted. 2003. *Patterns and process. a Festschrift in honor of Dr. Edward V. Sayre.* Suitland, MD: Smithsonian Center for Materials Research and Education, pp.248–268.

Lechtman, H., ed., 2006. *Esferas de interacción prehistóricas y fronteras nacionales modernas. Los Andes sur centrales.* Lima,et al.: IEP; IAR.

Lechtman, H., 2014. Andean Metallurgy in Prehistory. In: B.W. Roberts, and C.P. Thornton, eds. 2014. *Archaeometallurgy in global perspective. Methods and syntheses.* New York: Springer, pp.361–422.

Lechtman, H. and Klein, S., 1999. The Production of Copper–Arsenic Alloys (Arsenic Bronze) by Cosmelting. Modern Experiment, Ancient Practice. *Journal of Archaeological Science,* 26, pp.497–526.

Lechtman, H. and MacFarlane, A.W., 2005. La Metalurgia del Bronce en los Andes sur centrales. Tiwanaku y San Perdo de Atacama. *Estudios Atacameños,* 30, pp.7–27.

Lechtman, H. and MacFarlane, A.W., 2006. Bronces y redes de Intercambio andino durante el Horizonte Medio. Tiwanaku y San Pedro de Atacama. In: H. Lechtman, ed. 2006. *Esferas de interacción prehistóricas y fronteras nacionales modernas. Los Andes sur centrales.* Lima, et al.: IEP; IAR, pp.503–539.

Lenntech. *Chemical elements alphabetically listed*. [online]. Available at: <https://www.lenntech.com/periodic/name/alphabetic.htm> [Accessed 13 May 2021].

León Canales, E., 2007. Lascas de obsidiana tipo kombewa de Wari Kayan, Paracas. In: M. Frame, ed. 2007. *Hilos del pasado. El aporte francés al legado Paracas.* Lima: Instituto Nacional de Cultura, pp.75–77.

León Canales, E., 2007. *Orígenes Humanos en los Andes del Perú.* Lima: Universidad de San Martín de Porres, Escuela Profesional de Turismo y Hotelería.

Liritzis, I. and Stevenson, C.M., eds., 2012. *Obsidian and ancient manufactured glasses.* Albuquerque, NM: University of New Mexico Press.

Lothrop, S.K., 1937. Gold and Silver from Southern Peru and Bolivia. *Journal of the Royal Anthropological Institute,* 67, pp.303–325.

Lothrop, S.K., 1950. Metalworking Tools from the Central Coast of Peru. *American Antiquity,* 16(2), pp.160–164.

Lothrop, S.K., 1951. Gold Artifacts of Chavin style. *American Antiquity,* 16(3), pp.226–240.

MacCurdy, G.G., 1900. The Obsidian Razor of the Aztecs. *American Anthropologist,* 2(3), pp.417–421.

MacFarlane, A.W. and Petersen, U., 1990. Pb Isotopes of the Hualgayoc Area, Northern Peru. Implications for Metal Provenance and Genesis of a Cordilleran Polymetallic Mining District. *Economic Geology,* 85(7), pp.1303–1327.

MacFarlane, A.W. and Lechtman, H., 2014. Andean Ores, Bronze Artifacts, and Lead Isotopes. Constraints on Metal Sources in Their Geological Context. *Journal of Archaeological Method and Theory,* [e-journal] 23, pp.1–72. https://doi.org/10.1007/s10816-014-9225-8.

MacFarlane, A.W., Marcet, P., LeHuray, A.P. and Petersen, U., 1990. Lead Isotope Provinces of the Central Andes Inferred from Ores and Crustal Rocks. *Economic Geology,* 85, pp.1857–1880.

Mächtle, B., Eitel, B., Schukraft, G. and Ross, K., 2009. Build on Sand. Climatic Oscillation and Water Harvesting During the Late Intermediate Period. In: B. Herrmann, M. Reindel, and G.A. Wagner, eds. 2009. *New Technologies for Archaeology. Multidisciplinary Investigations in Palpa and Nasca, Peru.* Berlin, Heidelberg: Springer, pp.39–46.

Mächtle, B., Unkel, I., Eitel, B., Kromer, B. and Schiegl, S., 2010. Molluscs as evidence for a late Pleistocene and early Holocene humid period in the southern coastal desert of Peru (14.5°S). *Quaternary Research,* 73, pp.39–47.

Maggard, G.J., 2010. *Late Pleistocene-early Holocene Colonization and Regionalization in Northern Peru. Fishtail and Paijan complexes of the lower Jequetepeque Valley.* PhD. University of Kentucky. Available at: <https://uknowledge.uky.edu/gradschool_diss/87/> [Accessed 16 June 2021].

Maksaev, V., Townley, B., Palacios, C. and Camus, F., 2007. Metallic ore deposits. In: T. Moreno and W. Gibbons, eds. 2007. *The geology of Chile.* London, Tulsa, OK: Geological Society, pp.179–200.

Maksaev, V., Munizaga, F., McWilliams, M., Fanning, M., Mathur, R., Ruiz, J. and Zentilli, M., 2004. New Chronology for El Teniente, Chilean Andes, from U-Pb, 40Ar/39Ar, Re-Os, and Fission-Track Dating. Implications for the Evolution of a Supergiant Porphyry Cu-Mo Deposit. In: R.H. Sillitoe, J. Perelló, and C.E. Vidal, eds. 2004. *Andean metallogeny. New discoveries, concepts, and updates.* Littleton, CO: Society of Economic Geologists, pp.15–54.

Maldonado, B. and Rehren, T., 2011. Die Entwicklung der Kupfergewinnung in den südlichen Zentralanden von den frühsten präkolumbischen Anfängen bis in die Neuzeit. In: R. Slotta, and I. Schnepel, eds. 2011. *Schätze der Anden. Chiles Kupfer für die Welt. Katalog der Ausstellung des Deutschen Bergbau-Museums Bochum 8. Mai 2011 bis 19. Februar 2012.* Bochum: Deutsches Bergbau-Museum, pp.235–244.

Malpass, M.A., 1986. The Paijan Occupation of the Casma Valley, Peru. *Nawpa Pacha,* 24, pp.99–110.

Mantler, M. and Schreiner, M., 2000. X-Ray Fluorescence Spectrometry in Art and Archaeology. *X-Ray Spectrometry,* 29(1), pp.3–17.

Marshall, G., 1964. *Notes on the examination of some pre colombian metal samples.* Lima.

Martinón-Torres, M., Valcárcel Rojas, R., Sáenz Samper, J. and Filomena Guerra, M., 2012. Metallic encounters in Cuba. The technology, exchange and meaning of metals before and after Columbus. *Journal of Anthropological Archaeology,* 31, pp.439–454.

Mathien, F.J., 2001. The Organization of Turquoise Production and Consumption by Prehistoric Chacoans. *American Antiquity,* 66(1), pp.103–118.

Mathien, F.J. and Warren, H., 1985Prehistoric and Historic Turquoise Mining in the Cerrillos District. Time and Place. In: C.H. Lange, ed. 1985. *Southwestern Culture History: Collected Papers in Honor of Albert H. Schroeder.* Santa Fe, NM: Ancient City Press, pp.93–127.

Matos, R.M., ed., 1960. *Antiguo Peru: Espacio y Tiempo.* Lima: Liberia-Editorial Juan Mejía Baca.

Mauss, M. and Evans-Pritchard, E.E., 2016. *Die Gabe. Form und Funktion des Austauschs in archaischen Gesellschaften.* 11th ed. Frankfurt am Main: Suhrkamp.

Mayer-Okes, W.J., 1966. El Inga Projectile Points-Surface Collections. *American Antiquity,* 31(5), pp.644–661.

McCoy, M.D., Mills, P.R., Lundblad, S., Rieth, T., Kahn, J.G. and Gard, R., 2011. A cost surface model of volcanic glass quarrying and exchange in Hawai‘i. *Journal of Archaeological Science,* 38(10), pp.2547–2560.

Melcher, M., Schreiner, M., Bühler, B., Pülz, A.M. and Muss, U., 2009. Investigation of ancient gold objects from Artemision at Ephesus using portable μ-XRF. *ArchéoSciences,* 33, pp.169–175.

Meller, H., Risch, R. and Pernicka, E., eds., 2014. *Metalle der Macht – frühes Gold und Silber. 6. Mitteldeutscher Archäologentag vom 17. bis 19. Oktober 2013 in Halle (Saale) = Metals of power – early gold and silver.* Halle (Saale): Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt Landesmuseum für Vorgeschichte.

Menzel, D., Rowe, J.H. and Dawson, L.E., 1964. *The Paracas pottery of Ica. A Study in Style and Time.* Berkeley.

Merkel, J.F., Shimada, I. and Doonan, R.C.P., 1994. Pre-Hispanic Copper Alloy Production at Batan Grande, Peru. Interpretation of the Analytical Data for Ore Samples. In: D.A. Scott, and P. Meyers, eds. 1994. *Archaeometry of pre-Columbian sites and artifacts. Proceedings of a symposium organized by the UCLA Institute of Archaeology and the Getty Conservation Institute, Los Angeles, California, March 23-27, 1992.* Marina Del Rey, CA: Getty Conservation Institute, pp.199–228.

Merlet, C., 1994. An accurate computer correction program for quantitative electron probe microanalysis. *Microchimica Acta,* [e-journal] 114-115(1), pp.363–376. http://dx.doi.org/10.1007/BF01244563.

Millhauser, J.K., Rodríguez-Alegría, E. and Glascock, M.D., 2011. Testing the accuracy of portable X-ray fluorescence to study Aztec and Colonial obsidian supply at Xaltocan, Mexico. *Journal of Archaeological Science,* 38, pp.3141–3152.

Montoya, M., Garcia, W. and Caides, J., 1994. *Geología de los Cuadrangulos de Lomitas, Palpa, Nasca y Puquio.* Lima: Instituto Geológico, Minero y Metalúrgico. [online] Available at: <https://repositorio.ingemmet.gob.pe/handle/20.500.12544/174#files> [accessed 16 June 2021].

Moore, J.D., 2010. Making a huaca. *Journal of Social Archaeology,* [e-journal] 10(3), pp.398–422. http://dx.doi.org/10.1177/1469605310381550.

Moreno, T. and Gibbons, W., eds., 2007. *The geology of Chile.* London, et al.: Geological Society.

Morteani, G. and Northover, J.P., eds., 1995. *Prehistoric gold in Europe. Mines, metallurgy and manufacture*. Dordrecht, et al.: Kluwer.

Mourre, V., Villa, P. and Henshilwood, C.S., 2010. Early use of pressure flaking on lithic artifacts at Blombos Cave, South Africa. *Science,* [e-journal] 330(6004), pp.659–662. http://dx.doi.org/10.1126/science.1195550.

Muelle, J.C. and Wells, J.R., 1939. *Las pinturas del templo de Pachacámac.* Lima: Museo Nacional.

Mujica Gallo, M., 1967. *Gold in Peru. Meisterwerke der Goldschmiedekunst aus der Prä-Inkazeit, dem Inkareich und der* Übergangsära. 2nd ed: Recklinghausen: Bongers.

Mukasa, S.B., Vidal, C.E. and Injoque-Espinoza, J., 1990. Pb Isotope Bearing on the Metallogenesis of Sulfide Ore Deposits in Central and Southern Peru. *Economic Geology,* 85(7), pp.1438–1446.

Munsell Color Company, 2010. *The Munsell Book of Color, Glossy Collection*.

Murra, J.V., 1984. Andean Societies. *Annual Review of Anthropology,* 13, pp.119–141.

Murra, J.V., 1986. The expansion of the Inka state. Armies, war, and rebellions. In: J.V. Murra, N. Wachtel and J. Revel, eds. 1986. *Anthropological history of Andean polities.* Cambridge, et al.: Cambridge University Press, pp.49–58.

Murra, J.V., Wachtel, N. and Revel, J., eds., 1986. *Anthropological history of Andean polities.* Cambridge, et al.: Cambridge University Press.

Nazaroff, A.J., Prufer, K.M. and Drake, B.L., 2010. Assessing the applicability of portable X-ray fluorescence spectrometry for obsidian provenance research in the Maya lowlands. *Journal of Archaeological Science,* 37, pp.885–895.

Nicholas, M. and Manti, P., 2014. Testing the applicability of handheld portable XRF to the characterisation of archaeological copper alloys. In: J. Bridgland, ed. 2014. *ICOM-CC 17th Triennial Conference Preprints, Melbourne, 15–19 September 2014.* Paris: International Council of Museums, pp.1–13. Available at <https://www.icom-cc-publications-online.org/1381/Testing-the-applicability-of-hand-held-portable-XRF-to-the-characterisation-of-archaeological-copper-alloys-> [accessed 16 June 2021].

Niederschlag, E., Pernicka, E., Seifert, T. and Bartelheim, M., 2003. The determination of Lead Isotope Ratios by Multiple collector ICP-MS. A Case Study of Early Bronze Age Artifacts and their possible relation with Ore deposits of the Erzgebirge. *Archaeometry,* 45(1), pp.61–100.

Nriagu, J.O., 1994. Mercury pollution from the past mining of gold and silver in the Americas. *The Science of the Total Environment,* 149, pp.167–181.

Nuñez, L., 1999. Valoración minero-metalúrgica circumpuneña. Menas y mineros para el Inka rey. *Estudios Atacameños,* 18, pp.177–221.

Nuñez, L., 2006. La orientación minero-metalúrgica de la producción atacameña y sus relaciones fronterizas. In: H. Lechtman, ed. 2006. *Esferas de interacción prehistóricas y fronteras nacionales modernas. Los Andes sur centrales.* Lima, et al.: IEP; IAR, pp.205–260.

Nuñez, L., 2011. Der prähistorische Bergbau in der Atacama-Wüste (Nordchile). In: R. Slotta, and I. Schnepel, eds. 2011. *Schätze der Anden. Chiles Kupfer für die Welt. Katalog der Ausstellung des Deutschen Bergbau-Museums Bochum 8. Mai 2011 bis 19. Februar 2012.* Bochum: Deutsches Bergbau-Museum, pp.213–224.

Nuñez, L., Agüero P., C., Cases C., B., De Souza H., P., 2003. El Campamento minero Chuquicamata-2 y la explotación cuprífera prehinspánica en el desierto de Atacama. *Estudios Atacameños*, 25, pp.7–34

Núñez Atencio, L. and Dillehay, T.D., 1995. *Movilidad giratoria, armonía social y desarrollo en los Andes Meridionales: patrones de tráfico e interacción económica. Ensayo.* 2nd ed. Antofagasta: Univ. Católica del Norte.

O´Brien, W., 2004. Coarse Stone Tools. In: W. O´Brien, and A.L. Brindley, eds. 2004. *Ross Island. mining, metal and society in early Ireland.* Galway: Department of Archaeology, National University of Ireland, Galway, pp.338–360.

O'Brien, W. and Brindley, A.L., 1994. *Mount Gabriel. Bronze Age mining in Ireland.* Galway: Galway University Press.

O´Brien, W. and Brindley, A.L., eds., 2004. *Ross Island. mining, metal and society in early Ireland.* Galway: Department of Archaeology, National University of Ireland, Galway.

Odell, G.H., ed., 1996. *Stone tools. Theoretical insights into human prehistory.* New York: Plenum.

Odell, G.H., 2001. Stone Tool Research at the End of the Millennium: Classification, Function, and Behavior. *Journal of Archaeological Research,* [e-journal] 9(1), pp.45–100. http://dx.doi.org/10.1023/A:1009445104085.

Ogburn, D., 2011. Obsidian in southern Ecuador. The Carboncillo source. *Latin American Antiquity,* 22(1), pp.97–120.

Ogburn, D., Connell, S. and Gifford, C., 2009. Provisioning of the Inka army in wartime. obsidian procurement in Pambamarca, Ecuador. *Journal of Archaeological Science,* 36, pp.740–751.

Owen, B. and Goldstein, P.S., 2001. Tiwanaku en Moquegua: Interacciones Regionales y Colapso. *Boletin de Arqueologia PUCP,* 5, pp.169–188.

Patterson, C.C., 1971. Native Copper, Silver, and Gold Accessible to Early Metallurgists. *American Antiquity,* 36(3), pp.286–321.

Paulsen, A.C., 1974. The Thorny Oyster and the Voice of God. Spondylus and Strombus in Andean Prehistory. *American Antiquity,* [e-journal] 39(4/1), pp.597–607. http://dx.doi.org/10.2307/278907.

Pernicka, E., 2014a. Possibilites and limitations of provenance studies of ancient silver and gold. In: H. Meller, R. Risch, and E. Pernicka, eds. 2014. *Metalle der Macht – frühes Gold und Silber. 6. Mitteldeutscher Archäologentag vom 17. bis 19. Oktober 2013 in Halle (Saale) = Metals of power – early gold and silver.* Halle (Saale): Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte, pp.153–164.

Pernicka, E., 2014b. Provenance Determination of Archaeological Metal Objects. In: B W. Roberts, and C.P. Thornton, eds. 2014. *Archaeometallurgy in global perspective. Methods and syntheses.* New York, NY: Springer, pp.239–268.

Petersen, G., 2010. *Mining and metallurgy in ancient Perú.* Boulder, CO: Geological Society of America.

Petersen, U., 1965. Regional Geology and major Ore Deposits of Central Peru. *Economic Geology,* 60(3), pp.407–476.

Petersen, U., 1979. Metallogenesis in South America. Progress and Problems. *Episodes,* 4, pp.3–11.

Petersen, U., 1990. A Special Issue Devoted to the Mineral Deposits of Peru Preface. *Economic Geology,* 85(7), pp.1287–1295.

Petersen, U., MacFarlane, A.W. and Danielson, A., 1993. Lead Isotopic Provinces in Peru, Bolivia and Northern Chile. In: J.F. Dewey, and S.H. Lamb, eds. 1993. *Second International Symposium on Andean Geodynamics.* Amsterdam, pp.477–480.

Petrovic, P. and Durdekanovic, S., eds., 1995. *Ancient Mining and Metallurgy in southeast Europe.* Belgrade: Baka Bor.

Phillips, S.C. and Speakman, R.J., 2009. Initial source evaluation of archaeological obsidian from the Kuril Islands of the Russian Far East using portable XRF. *Journal of Archaeological Science,* 36, pp.1256–1263.

Pickin, J., 1988. Stone tools and early mining in Wales. *Archaeology in Wales,* 28, pp.18–19.

Pickin, J., 1990. Stone Tools and Early Metal Mining in England and Wales. In: P. Crew and S. Crew, eds. 1990. *Early mining in the British Isles. Proceedings of the Early Mining Workshop at Plas Tan y Bwlch, Snowdonia National Park Study Centre, 17-19 November, 1989.* Tan y Bwlch, Gwynedd: Plas Tan y Bwlch, Snowdonia National Park Study Centre, pp.39–42.

Piorek, S., 2008. Alloy Identification and Analysis with a Field-Portable XRF Analyser. In: P.J. Potts and M. West, eds. 2008. *Portable x-ray fluorescence spectrometry. Capabilities for in situ analysis.* Cambridge, UK: Royal Society of Chemistry, pp.98–140.

Politis, G., ed., 1992. *Arqueología en América Latina hoy.* Bogotá: Fondo de Promoción de la Cultura.

Pollard, A.M. and Bray, P., 2014. Chemical and Isotopic Studies of Ancient Metals. In: B.W. Roberts and C.P. Thornton, eds. 2014. *Archaeometallurgy in global perspective. Methods and syntheses.* New York, NY: Springer, pp.217–238.

Popelka-Filcoff, R.S., Craig, N., Glascock, M.D., Robertson, J.D., Aldenderfer, M.S. and Speakman, R.J., 2007. Instrumental Neutron Activation Analysis of Ocher Artifacts from Jiskairumoko, Peru. In: M.D. Glascock, ed. 2007. *Archaeological chemistry. Analytical techniques and archaeological interpretation.* Washington, DC: American Chemical Society, pp.480–505.

Potts, P.J., 2008. Introduction, Analytical Instrumentation and Application Overview. In: P.J. Potts, and M. West, eds. 2008. *Portable x-ray fluorescence spectrometry. Capabilities for in situ analysis.* Cambridge, UK: Royal Society of Chemistry, pp.1–12.

Potts, P.J. and West, M., eds., 2008. *Portable x-ray fluorescence spectrometry. Capabilities for in situ analysis.* Cambridge, UK: Royal Society of Chemistry.

Prange, M., Modarressi-Tehrani, D. and Demant, D., 2016. Shooting Straight. Some Thoughts on the Benefits and Challenges of Working with pXRF. In: G. Körlin, M. Prange, T. Stöllner and Ü. Yalçın, eds. 2016. *From bright ores to shiny metals. Festschrift for Andreas Hauptmann on the occasion of 40 years research in archaeometallurgy and archaeometry.* Der Anschnitt, Beiheft, 29. Rahden/Westf.: Marie Leidorf, pp.247–256.

Proulx, D.A., 2006. *A sourcebook of Nasca ceramic iconography.* Iowa City, IA: University of Iowa Press.

Proulx, D.A., 2008. Paracas and Nasca. Regional Cultures on the South Coast of Peru. In: H. Silverman, and W.H. Isbell, eds. 2008. *Handbook of South American archaeology.* New York, NY: Springer, pp.563–585.

Rademaker, K., Hodgins, G., Moore, K., Zarrillo, S., Miller, C., Bromley, G.R.M., Leach, P., Reid, D.A., Yépez Álvarez, W. and Sandweiss, D.H., 2014. Paleoindian settlement of the high-altitude Peruvian Andes. *Science,* [e-journal] 346(6208), pp.466–469. http://dx.doi.org/10.1126/science.1258260.

Ravines, R., 1972. Secuencia y cambios en los Artifactos Liticos del Sur del Peru. *Revista del Museo Nacional,* 38, pp.133–184.

Rees, C. and De Souza P., 2004. Producción Lítica durante el Período Formativo en la Subregíon del Río Salado. In: C.M. Santoro and V.G. Standen, eds, 2004. *Actas del XV Congreso Nacional de Arqueología Chilena, Arica, octubre 2000. Tomo I – Simposios.* Chungara – Revista Chilena de Antropología, 36, Numero Especial, pp.453–465.

Rehren, T., 2011. Zur frühen Gewinnung von Silber in Südamerika. In: R. Slotta and I. Schnepel, eds. 2011. *Schätze der Anden. Chiles Kupfer für die Welt. Katalog der Ausstellung des Deutschen Bergbau-Museums Bochum 8. Mai 2011 bis 19. Februar 2012.* Bochum: Deutsches Bergbau-Museum, pp.257–264.

Rehren, T. and Temme, M., 1994. Pre-Columbian Gold Processing at Putushio, South Ecuador. The Archaeometallurgical Evidence. In: D.A. Scott, and P. Meyers, eds. 1994. *Archaeometry of pre-Columbian sites and artifacts. Proceedings of a symposium organized by the UCLA Institute of Archaeology and the Getty Conservation Institute, Los Angeles, California, March 23-27, 1992.* Marina Del Rey, CA: Getty Conservation Institute, pp.267–284.

Reindel, M., 1997. Archäologische Untersuchungen zur Nasca-Kultur und ihren Bodenzeichnungen in Süd-Peru. In: Schweizerisch-Liechtensteinische Stiftung für Archäologische Forschungen im Ausland (SLSA), ed. 1997. Jahresbericht 1996. Zürich and Vaduz: SLSA, pp.79-94.

Reindel, M., 2007. Entdeckungen in Amerika. Archäometrische Forschungen in Mexiko, Ekuador und Peru. In: G.A. Wagner, ed. 2007. *Einführung in die Archäometrie.* Berlin: Springer, pp.321–338.

Reindel, M., 2008. Ausgrabungen und Forschungen der Kommission für Archäologie Außereuropäischer Kulturen, Bonn. Andentransekt 1 (Peru). In: Deutsches Archäologisches Institut, ed. 2008. *Jahresbericht 2007.* München: Hirmer, pp.297–300.

Reindel, M., 2009a. Life at the Edge of the Desert. Archaeological Reconstruction of the Settlement History in the Valleys of Palpa, Peru. In: B. Herrmann, M. Reindel, and G.A. Wagner, eds. 2009. *New Technologies for Archaeology. Multidisciplinary Investigations in Palpa and Nasca, Peru.* Berlin, et al.: Springer, pp.439–461.

Reindel, M., 2009b. Ausgrabungen und Forschungen der Kommission für Archäologie Außereuropäischer Kulturen, Bonn: Andentransekt 1 (Peru). *Archäologischer Anzeiger, 2009(*2), pp.347–350.

Reindel, M., 2011. Die vorspanische Kulturentwicklung im Andenraum. Ein Überblick. In: R. Slotta, and I. Schnepel, eds. 2011. *Schätze der Anden. Chiles Kupfer für die Welt. Katalog der*

Ausstellung des Deutschen Bergbau-Museums Bochum 8. Mai 2011 bis 19. Februar 2012. Bochum: Deutsches Bergbau-Museum, pp.159–180.

Reindel, M. and Isla Cuadrado, J.A., 1999. *Proyecto Arqueológico Palpa. Informefinal. Temporada 1998*. (Unpublished project report, submitted to the Instituto Nacional de Cultura [Lima]).

Reindel, M. and Isla Cuadrado, J.A., 2000. *Proyecto Arqueológico Palpa. Informe final. Temporada 1999*. (Unpublished project report, submitted to the Instituto Nacional de Cultura [Lima]).

Reindel, M. and Isla Cuadrado, J., 2001. Los Molinos und La Muna. Zwei Siedlungszentren der Nasca-Kultur in Palpa, Südperu. *Beiträge zur Allgemeinen und Vergleichenden Archäologie,* 21, pp.241–319.

Reindel, M. and Isla Cuadrado, J., 2003. Jauranga. Un sitio Paracas en el valle de Palpa, costa sur del Perú. *Beiträge zur Allgemeinen und Vergleichenden Archäologie,* 23, pp.227–274.

Reindel, M. and Isla Cuadrado, J., 2009. El Periodo Inicial en Pernil Alto, Palpa, sur del Peru. *Boletin de Arqueologia PUCP,* 13(259-288).

Reindel, M. and Wagner, G.A., 2009. New Methods and Technologies of Natural Sciences for Archaeological Investigations in Nasca and Palpa, Peru. In: B. Herrmann, M. Reindel, and G.A. Wagner, eds. 2009. *New Technologies for Archaeology. Multidisciplinary Investigations in Palpa and Nasca, Peru.* Berlin, Heidelberg: Springer Berlin Heidelberg, pp.1–13.

Reindel, M., Isla Cuadrado, J.A. and De La Torre, J.C., 2004. *Proyecto Arqueológico Nasca-Palpa. Informe final. Temporada 2003.* (Unpublished project report, submitted to the Instituto Nacional de Cultura [Lima]).

Reindel, M., Isla Cuadrado, J.A. and De La Torre, J.C., 2005. *Proyecto Arqueológico Nasca-Palpa. Informe final. Temporada 2004.* (Unpublished project report, submitted to the Instituto Nacional de Cultura [Lima]).

Reindel, M., Isla Cuadrado, J.A. and Linares Grados, M., 2006. *Proyecto Arqueológico Nasca-Palpa. Informe final. Temporada 2005.* (Unpublished project report, submitted to the Instituto Nacional de Cultura [Lima]).

Reindel, M., Isla Cuadrado, J.A. and Tomasto Cagigao, E., 2001. *Proyecto Arqueológico Nasca-Palpa. Informe final. Temporada 2000.* (Unpublished project report, submitted to the Instituto Nacional de Cultura [Lima]).

Reindel, M., Isla Cuadrado, J.A. and Tomasto Cagigao, E., 2002. *Proyecto Arqueológico Nasca-Palpa. Informe final. Temporada 2001.* (Unpublished project report, submitted to the Instituto Nacional de Cultura [Lima]).

Reindel, M., Solis Quinteros, P. and Isla Cuadrado, J.A., 2008. *Proyecto Arqueológico Nasca-Palpa. Informe final. Temporada 2007.* (Unpublished project report, submitted to the Instituto Nacional de Cultura [Lima]).

Reindel, M., Solis Quinteros, P. and Isla Cuadrado, J.A., 2010. *Proyecto Arqueológico Palpa-Lucanas. Informe final. Temporada 2009.* (Unpublished project report, submitted to the Instituto Nacional de Cultura [Lima]).

Reindel, M., Stöllner, T. and Gräfingholt, B., 2013. Mining Archaeology in the Nasca and Palpa region, south coast of Peru. In: N. Tripcevich, and K J. Vaughn, eds. 2013. *Mining and Quarrying in the Ancient Andes. Sociopolitical, Economic and Symbolic Dimensions.* New York, NY: Springer, pp.299–322.

Riciputi, L.R., Elam, J.M., Anovitz, L.M. and Cole, D.R., 2002. Obsidian Diffusion Dating by Secondary Ion Mass Spectrometry. A Test using Results from Mound 65, Chalco, Mexico. *Journal of Archaeological Science,* 29, pp.1055–1075.

Rick, J.W., ed., 1980. *Prehistoric hunters of the high Andes.* New York, NY: Acad. Pr.

Rick, J.W., 1996. Projectile Points, Style, and Social Process in the Preceramic of Central Peru. In: G. H. Odell, ed. 1996. *Stone tools. Theoretical insights into human prehistory.* New York, NY: Plenum, pp.245–278.

Rivera, M.A., 1995-96. Arica en las rutas de tráfico de Potosí. Algunas consideraciones sobre la sociedad andina del sieglo XVIII. *Revista Chilena de Antropología,* 13, pp.99–136.

Rivera, M.A., 2008. The Archaeology of Northern Chile. In: H. Silverman and W.H. Isbell, eds. 2008. *Handbook of South American archaeology.* New York, NY: Springer, pp.963–977.

Rivera, S.L. and Parado, R., 2004. Discovery and Geology of the Toki Porphyry Copper Deposit, Chuquicamata District, Northern Chile. In: R.H. Sillitoe, J. Perelló and C.E. Vidal, eds. 2004. *Andean metallogeny. New discoveries, concepts, and updates.* Littleton, CO: Society of Economic Geologists, pp.199–212.

Roberts, B.W. and Thornton, C.P., eds., 2014. *Archaeometallurgy in global perspective. Methods and syntheses.* New York, NY: Springer.

Roberts, G., 1960. X-ray microanalyser. *Archaeometry,* 3, pp.36–37.

Rogers, A.K., 2008. Obsidian hydration dating: accuracy and resolution limitations imposed by intrinsic water variability. *Journal of Archaeological Science*, 35, pp.2009–2016.

Root, W.C., 1949. The Metallurgy of the Southern Coast of Peru. *American Antiquity,* 15(1), pp.10–37.

Root, W.C., 1951. Gold-Copper Alloys in Ancient America. *Journal of Chemical Education,* 28, pp.76–78.

Rosenbaum, G., Giles, D., Saxon, M., Betts, P.G., Weinberg, R.F. and Duboz, C., 2005. Subduction of the Nazca Ridge and the Inca Plateau. Insights into the formation of ore deposits in Peru. *Earth and Planetary Science Letters,* 239, pp.18–32.

Rowe, J.H., 1960. Nuevos datos relativos a la cronología del Estilo Nasca. In: R.M. Matos, ed. 1960. *Antiguo Peru: Espacio y Tiempo.* Lima: Liberia-Editorial Juan Mejía Baca, pp.29–45.

Sáenz Samper, J. and Martinón-Torres, M., 2011. Gold in America. In: R. Slotta, and I. Schnepel, eds. 2011. *Schätze der Anden. Chiles Kupfer für die Welt. Katalog der Ausstellung des Deutschen Bergbau-Museums Bochum 8. Mai 2011 bis 19. Februar 2012.* Bochum: Deutsches Bergbau-Museum, pp.245–256.

Salazar, D., 2003-2004. Arqueología de la Minería. Propuesta de un Marco Teórico. *Revista Chilena de Antropología,* 17, pp.125–149.

Salazar, D., 2008. La Producción Minera en San José del Abra durante el Período Tardío Atacameño. *Estudios Atacameños,* 36, pp.43–72.

Salazar, D., Berenguer, J. and Vega, G., 2013. Paisajes Minero-Metalúrgicos Incaicos en Atacama y el Altiplano Sur de Tarapacá. *Revista Chilena de Antropología,* 45(1), pp.83–103.

Salazar, D., Borie, C. and Oñate, C., 2013. Mining, Commensal Politics, and Ritual under Inca Rule in Atacama, Northern Chile. In: N. Tripcevich, and K. J. Vaughn, eds. 2013. *Mining and Quarrying in the Ancient Andes. Sociopolitical, Economic and Symbolic Dimensions.* New York, NY: Springer, pp.253–274.

Salazar, D. and Salinas, H., 2008. Tradición y transformación en la organización de los sistemas de producción mineros en el norte de Chile prehispanicó. San José del Abra, siglos I al XVI d. C. In: P. Cruz, and J.-J. Vacher, eds. 2008. *Mina y metalurgia en los Andes del Sur. desde la epoca prehispanica hasta el sieglo XVII.* Sucre, pp.163–200.

Salazar, D. and Vilches, F., 2014. La arqueología de la minería en el centro-sur andino: Balance y perspectivas. *Estudios*

Atacameños, [e-journal] 48, pp.5–21. http://dx.doi.org/10.4067/S0718-10432014000200003.

Salazar, D., Castro, V., Michelow, J., Salinas, H., Figueroa, V. and Mille, B., 2010a. Minería y Metalurgia en la Costa Arreica de la Región de Antofagasta, Norte de Chile. *Boletín del Museo Chileno de Arte Precolombino,* 15(1), pp.9–23.

Salazar, D., Figueroa, V., Mille, B., Morata, D. and Salinas, H., 2010b. Metalurgia Prehispánica en las sociedades costeras del norte de Chile (Quebrada Mamilla, Tocopilla). *Estudios Atacameños,* 40, pp.23–42.

Salazar, D., Figueroa, V., Morata, D., Mille, B., Germán, M. and Cifuentes, A., 2011a. Metalurgia en San Pedro de Atacama Durante el Período Medio. Nuevos Datos, Nuevas Preguntas. *Revista Chilena de Antropología,* 23(1), pp.123–148.

Salazar, D., Jackson, D., Guendon, J.L., Salinas, H., Morata, D., Figueroa, V., Manriquez, G. and Castro, V., 2011b. Early Evidence (ca. 12,000 BP) for Iron Oxide Mining on the Pacific Coast of South America. *Current Anthropology,* 52(3), pp.463–475.

Salazar, D., Niemeyer, H.M., Horta, H., Figueroa, V. and Manriquez, G., 2014. Interaction, social identity, agency and change during Middle Horizon San Pedro de Atacama (northern Chile). A multidimensional and interdisciplinary perspective. *Journal of Anthropological Archaeology,* 35, pp.135–152.

Salazar, D., Salinas, H., Guendon, J.L., Jackson, D. and Figueroa, V., 2013. Hunter-Gatherer-Fischer Mining during the Archaic Period in Coastal Northern Chile. In: N. Tripcevich, and K. J. Vaughn, eds. 2013. *Mining and Quarrying in the Ancient Andes. Sociopolitical, Economic and Symbolic Dimensions.* New York, NY: Springer, pp.137–156.

Salazar, E., 1992. El Intercambio de Obsidiana en el Ecuador Precolumbino. Perspectivas Teóretico-Metodológicas. In: G. Politis, ed. 1992. *Arqueología en América Latina hoy.* Bogotá: Fondo de Promoción de la Cultura, pp.116–131.

Santi, P., Renzulli, A. and Oddone, M., 2010. Increasing data (INAA) on Ecuadorian obsidian artifacts: preliminary provenance and a clue for pre-Columbian eastward trade. *Journal of Archaeological Science,* 37, pp.1753–1760.

Saunders, N.J., 2004. The cosmic Earth. Materiality and Mineralogy in the Americas. In: N. Boivin and M.A. Owoc, eds. 2004. *Soils, stones and symbols. Cultural perceptions of the mineral world.* London: UCL, pp.123–142.

Schlosser, S., Kovacs, R., Pernicka, E., Günther, D. and Tellenbach, M., 2009. Fingerprints in Gold. In: B. Herrmann, M. Reindel and G.A. Wagner, eds. 2009. *New Technologies for Archaeology. Multidisciplinary Investigations in Palpa and Nasca, Peru.* Berlin, et al.: Springer, pp.409–435.

Schreiber, K., 2000. Los Wari en su Contexto Local. Nasca y Sondondo. *Boletin de Arqueologia PUCP,* 4, pp.425–447.

Schröder, G., 1957. Hallazgos de artifactos de piedra en el Peru y los problemas del poblamiento de America. *Revista del Museo Nacional,* 26, pp.290–294.

Schulze, N., 2013. How “Real” Does It Get? Portable XRF Analysis of Thin-Walled Copper Bells from the Aztec Templo Mayor, Tenochtitlan, Mexico. In: A.N. Shugar, and S.E. Simmons, eds. 2013. *Archaeometallurgy in Mesoamerica. Current approaches and new perspectives.* Boulder, CO: University Press of Colorado, pp.203–226.

Scott, D.A. and Meyers, P., eds., 1994. *Archaeometry of pre-Columbian sites and artifacts. Proceedings of a symposium organized by the UCLA Institute of Archaeology and the Getty Conservation Institute, Los Angeles, California, March 23-27, 1992.* Marina Del Rey, CA: Getty Conservation Institute.

Seelenfreund, A., Rees, C., Bird, R., Bailey, G., Barcena, R. and Duran, V., 1996. Trace-Element Analysis of Obsidian Sources and Artifacts of Central Chile (Maule River Basin) and Western Argentina (Colorado River). *Latin American Antiquity,* 7(1), pp.7–20.

Seelenfreund, A., Miranda, J., Dinator, M.I. and Morales, J.R., 2002. The provenance of archaeological obsidian artifacts from Northern Chile determined by source-induced X-ray fluorescence. *Journal of Radioanalytical and Nuclear Chemistry,* 251(1), pp.15–19.

Sellet, F., 2004. Beyond the point. Projectile manufacture and behavioral inference. *Journal of Archaeological Science,* [e-journal] 31(11), pp.1553–1566. http://dx.doi.org/10.1016/j.jas.2004.03.016.

Sepúlveda R., M.A., Romero Guevara, Á.L. and Briones, L., 2005. Tráfico de caravanas, arte rupestre y ritualidad en la Quebrada de Suca (extremo Norte de Chile). *Chungará,*[e-journal] 37(2), pp.225–243. http://dx.doi.org/10.4067/S0717-73562005000200008.

Shackley, M., ed., 1998a. *Archaeological obsidian studies. Method and theory.* New York, et al.: Plenum Press.

Shackley, M.S., 1998b. Geochemical Differentiation and Prehistoric Procurement of Obsidian in the Mount Taylor Volcanic Field, Northwest New Mexico. *Journal of Archaeological Science,* 25, pp.1073–1082.

Shackley, M.S., 2011a. An introduction to X-Ray Fluorescence (XRF) Analysis in Archaeology. In: M.S. Shackley, ed. 2011. *X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology.* New York, NY: Springer Science+Business Media, LLC, pp.7–44.

Shackley, M.S., ed., 2011b. *X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology.* New York, NY: Springer Science+Business Media, LLC.

Shadle, M., 2013. Theology and the origins of Conflict. The Shining Path insurgency in Peru, 1980–2000. *Political Theology,* 14(3), pp.284–303.

Sheppard, P.J., Irwin, G.J., Lin, S.C. and McCaffrey, C P., 2011. Characterization of New Zealand obsidian using PXRF. *Journal of Archaeological Science,* 38(1), pp.45–56.

Shimada, I., 1981. The Batan Grande-La Leche Archaeological Project: The First Two Seasons. *Journal of Field Archaeology,* 8(4), pp.405–446.

Shimada, I., 1994. Pre-Hispanic Metallurgy and Mining in the Andes. Recent advances and future tasks. In: A.K. Craig and R.C. West, eds. 1994. *In quest of mineral wealth. Aboriginal and colonial mining and metallurgy in Spanish America.* Baton Rouge, LA: Geoscience Publications, Dept. of Geography and Anthropology, Louisiana State University, pp.37–74.

Shimada, I., ed., 1998. *Andean ceramics: technology, organization, and approaches.* Philadelphia: MASCA.

Shimada, I., ed., 2007. *Craft production in complex societies. Multicraft and producer perspectives.* Salt Lake City, UT: University of Utah Press.

Shimada, I., 2013. Discussion: Mineral Resources and Pre-Hispanic Mining. In: N. Tripcevich, and K.J. Vaughn, eds. 2013. *Mining and Quarrying in the Ancient Andes. Sociopolitical, Economic and Symbolic Dimensions.* New York, NY: Springer, pp.335–354.

Shimada, I. and Craig, A.K., 2013. The Style, Technology and Organization of Sicán Mining and Metallurgy, Northern Peru. Insights from Holistic Study. *Revista Chilena de Antropología,* 45(1), pp.3–31.

Shimada, I., Epstein, S. and Craig, A. K., 1982. Batán Grande. A Prehistoric Metallurgical Center in Peru. *Science,* 218, pp.952–959.

Shimada, I. and Merkel, J.F., 1991a. Copper-alloy metallurgy in Ancient Peru. *Scientific American,* 265, pp.62–68.

Shimada, I. and Merkel, J.F., 1991b. Die Metallurgie von Kupferlegierungen im alten Peru. *Spektrum der Wissenschaft,* 8, pp.126–133.

Shimada, M. and Shimada, I., 1985. Prehistoric Llama Breeding and Herding on the North Coast of Peru. *American Antiquity,* 50(1), pp.3–26.

Shugar, A.N. and Mass, J.L., eds., 2012. *Handheld XRF for art and archaeology.* Leuven, Belgium: Leuven University Press.

Shugar, A.N. and Mass, J.L., 2012. Introduction. In: A.N. Shugar, and J.L. Mass, eds. 2012. *Handheld XRF for art and archaeology.* Leuven: Leuven University Press, pp.17–36.

Shugar, A.N. and Simmons, S.E., eds., 2013. *Archaeometallurgy in Mesoamerica. Current approaches and new perspectives.* Boulder, CO: University Press of Colorado.

Sillitoe, R.H., 1988. Epochs of intrusion-related copper mineralization in the Andes. *Journal of South American Earth Sciences,* 1(1), pp.89–108.

Sillitoe, R.H., 2004. Musings on Future Exploration Targets and Strategies in the Andes. In: R.H. Sillitoe, J. Perelló and C.E. Vidal, eds. 2004. *Andean metallogeny. New discoveries, concepts, and updates.* Littleton, CO: Society of Economic Geologists, pp.1–14.

Sillitoe, R.H., Perelló, J. and Vidal, C.E., eds., 2004. *Andean metallogeny. New discoveries, concepts, and updates.* Littleton, CO: Society of Economic Geologists.

Silverman, H., 2002. *Ancient Nasca settlement and society.* Iowa City, IA: University of Iowa Press.

Silverman, H. and Isbell, W.H., eds., 2008. *Handbook of South American archaeology.* New York: Springer.

Slotta, R. and Schnepel, I., eds., 2011. *Schätze der Anden. Chiles Kupfer für die Welt. Katalog der Ausstellung des Deutschen Bergbau-Museums Bochum 8. Mai 2011 bis 19. Februar 2012.* Bochum: Deutsches Bergbau-Museum.

Sociedad Chilena de Arqueología, ed., 2010. *Actas del XVII Congreso Nacional de Arqueología.* Valdivia: Ediciones Kultúran.

Soßna, V., 2014. *Impacts of climate variability on Pre-Hispanic settlement behavior in South Peru.* PhD. Christian-Albrecht-UniversitätKiel. Available at: <https://macau.uni-kiel.de/receive/diss_mods_00014855?lang=en> Accessed 17 June 2021].

Speakman, R.J. and Neff, H., eds., 2005. *Laser ablation ICP-MS in archaeological research.* Albuquerque, N.M.: University of New Mexico Press.

Speakman, R.J., Glascock, M.D., Tykot, R.H., Descantes, C., Thatcher, J.J., Skinner, C.E. and Lienhop, K.M., 2007. Selected Applications of Laser Ablation Inductively Coupled Plasma-Mass Spectrometry to Archaeological Research. In: M.D. Glascock, ed. 2007. *Archaeological chemistry. Analytical techniques and archaeological interpretation.* Washington, DC: American Chemical Society, pp.275–296.

Speakman, R.J., Williams, P.R., Aldenderfer, M.S., Popelka-Filcoff, R.S., Robertson, J.D., Goldstein, P.S. and Glascock, M.D., 2006. *Portable-XRF (PXRF) analysis of Tiwanaku and Wari metal objects from the Osmore River drainage, Peru.* Washington, DC: American Chemical Society.

Spence, M.W., 1967. The Obsidian Industry of Teotihuacan. *American Antiquity,* 32(4), pp.507–514.

Speth, J.D., 1972. Mechanical Basis of Percussion Flaking. *American Antiquity,* [e-journal] 37(1), pp.34–60. http://dx.doi.org/10.2307/278884.

Stackelbeck, K.L., 2008. Adaptational flexibility and processes of emerging complexity: early to mid-Holocene Foragers in the lower Jequetepeque valley, northern Peru. PhD. University of Kentucky. Available at: <https://uknowledge.uky.edu/gradschool_diss/583> [Accessed 23 June 2021].

Stanish, C., 2001. The Origin of State Societies in South America. *Annual Review of Anthropology,* 30, pp.41–64.

Stanish, C., Cohen, A.B. and Aldenderfer, M.S., eds., 2005. *Advances in Titicaca Basin archaeology.* Los Angeles, CA: Cotsen Institute of Archaeology at UCLA.

Stanish, C., Burger, R.L., Cipolla, L.M., Glascock, M.D. and Quelima, E., 2002. Evidence for Early Long-Distance Obsidian Exchange and Watercraft Use from the Southern Lake Titicaca Basin of Bolivia and Peru. *Latin American Antiquity,* 13(4), pp.444–454.

Stanish, C., de la Vega, E., Moseley, M., Williams, P.R., Chávez J., C., Vining, B. and LaFavre, K., 2010. Tiwanaku trade patterns in southern Peru. *Journal of Anthropological Archaeology,* 29, pp.524–532.

Stevens, N. and Codding, B., 2013. Inferring the Function of Projectile Points from the Central Coast of Alta California. *California Archaeology,* [e-journal] 1(1), pp.7–27. http://dx.doi.org/10.1179/cal.2009.1.1.7.

Stevenson, D.P., Stross, F.H. and Heizer, R.F., 1971. An Evaluation of X-ray Fluorescence Analysis as a Method for correlating Obsidian Artifacts with Source Location. *Archaeometry,* 13(1), pp.17–25.

Stöllner, T., 1999. „Kulturwandel - Chronologie - Methode“. Ein Diskussionsbeitrag am Beispiel der Hallstatt-Latènekultur. *Prähistorische Zeitschrift,* 74(2), pp.194–218.

Stöllner, T., 2008. Montan-Archaeology and Research on Old Mining. Just a Contribution to Economic History? In: Ü. Yalçın, ed. 2008. *Anatolian Metal IV. Beiträge des im Februar 2005 in Bochum veranstalteten internationalen Symposiums „Anatolian Metal IV“ (11. Oktober 1933 – 19. Januar 2008).* Der Anschnitt, Beiheft, 21. Bochum: Deutsches Bergbau-Museum, pp.149–178.

Stöllner, T., 2009. Gold in Southern Peru? Perspectives of Research into Mining Archaeology. In: B. Herrmann, M. Reindel and G.A. Wagner, eds. 2009. *New Technologies for Archaeology. Multidisciplinary Investigations in Palpa and Nasca, Peru.* Berlin, et al.: Springer, pp.393–407.

Stöllner, T., 2011. Präkolumbischer Bergbau in den Anden. In: R. Slotta and I. Schnepel, eds. 2011. *Schätze der Anden. Chiles Kupfer für die Welt. Katalog der Ausstellung des Deutschen Bergbau-Museums Bochum 8. Mai 2011 bis 19. Februar 2012.* Bochum: Deutsches Bergbau-Museum, pp.181–212.

Stöllner, T., 2014. Methods of Mining Archaeology (Montanarchäologie). In: B.W. Roberts, and C.P. Thornton, eds. 2014. *Archaeometallurgy in global perspective. Methods and syntheses.* New York, NY: Springer, pp.133–159.

Stöllner, T., 2015. Humans approach to resources. Old World mining between technological innovations, social change and economical structures. A key note lecture. In: A. Hauptmann, and D. Modarressi-Tehrani, eds. 2015. *Archaeometallurgy in Europe III. Proceedings of the 3rd international conference; June 29 – July 1, 2011.* Der Anschnitt, Beiheft, 26. Bochum: Deutsches Bergbau-Museum, pp.63–82.

Stöllner, T. and Reindel, M., 2007. Vorspanische Goldgewinnung im Bereich von Palpa-Nasca? Bericht über eine einwöchige Prospektionskampagne an der Südküste Perus. *Der Anschnitt,* 59(1), pp.2–12.

Stöllner, T., Gambasize, I., Hauptmann, A., Mindiasvili, G., Gogocuri, G. and Steffens, G., 2010. Goldbergbau in Südostgeorgien. Neue Forschungen zum frühbronzezeitlichen Bergbau in Georgien. In: S. Hansen, ed. 2010. *Von Majkop bis Trialeti. Gewinnung und Verbreitung von Metallen und Obsidian in Kaukasien im 4.-2. Jt. v. Chr.: Beiträge des Internationalen Symposiums in Berlin vom 1.-3. Juni 2006.* Bonn: Habelt, pp.103–137.

Stöllner, T., Reindel, M., Gassman, G., Gräfingholt, B. and Isla Cuadrado, J., 2013. Precolumbian Raw-Material Exploitation in Southern Peru. *Revista Chilena de Antropología,* 45(1), pp.105–129.

Stone, B.J., 1983. *The Socio-Economic Implications of Lithic Evidence from Huari, Peru:* Binghamton.

Straus, L.G., Meltzer, D.J. and Goebel, T., 2005. Ice Age Atlantis? Exploring the Solutrean-Clovis 'connection'. *World Archaeology,* 37(4), pp.507–532.

Swann, C.P., Fleming, S.J. and Jaksic, M., 1992. Recent applications of PIXE spectrometry in archaeology I. Characterization of bronzes with special consideration of the influence of corrosion processes on data reliability. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms,* [e-journal] 64(1-4), pp.499–504. http://dx.doi.org/10.1016/0168-583X(92)95523-T.

Swenson, E.R. and Warner, J.P., 2012. Crucibles of power. Forging copper and forging subjects at the Moche Ceremonial Center of Huaca Colorada, Peru. *Journal of Anthropological Archaeology,* 31, pp.314–333.

Tello, J.C., 1959. *Paracas – primera parte. Publication del Proyecto 8b. del Programa 1941-42 del Institute of Andean Research of New York.* Lima.

Tello, J.C. and Mejía Xesspe, T., 1979. *Paracas, segunda parte. Cavernas y Necrópolis.* Lima.

Tenorio, D., Cabral, A., Bosch, P., Jimenez Reyes, M. and Bulbulian, S., 1998. Differences in Coloured Obsidians from Sierra de Pachuca, Mexico. *Journal of Archaeological Science,* 25, pp.229–234.

Tereygeol, F. and Castro, C., 2008. La metalurgia prehispanica de la plata en Potosi. In: P. Cruz and J.-J. Vacher, eds. 2008. *Mina y metalurgia en los Andes del Sur. desde la epoca prehispanica hasta el sieglo XVII.* Sucre, pp.11–28.

Thomsen, V., 2007. Basic Fundamental Parameters in X-Ray Fluorescence. *Spectroscopy,* 22(5), pp.46–50.

Timberlake, S., 1990. Excavations and Fieldwork on Copa Hill, Cwmystwyth, 1989. In: P. Crew and S. Crew, eds. 1990. *Early mining in the British Isles. Proceedings of the Early Mining Workshop at Plas Tan y Bwlch, Snowdonia National Park Study Centre, 17-19 November, 1989.* Tan y Bwlch, Gwynedd: Plas Tan y Bwlch, Snowdonia National Park Study Centre, pp.22–29.

Timberlake, S. and Craddock, B.R., 2003. Hammer-Stones. In: S. Timberlake, and T. Mighall, eds. 2003. *Excavations on Copa Hill, Cwmystwyth (1986-1999). An early Bronze Age copper mine within the uplands of Central Wales.* Oxford: Archaeopress, pp.86–98.

Timberlake, S. and Mighall, T., eds., 2003. *Excavations on Copa Hill, Cwmystwyth (1986-1999). An early Bronze Age copper mine within the uplands of Central Wales.* Oxford: Archaeopress.

Tomasto Cagigao, E., Reindel, M. and Isla Cuadrado, J.A., 2007. *Proyecto Arqueológico Nasca-Palpa. Informe final. Temporada 2006.* (Unpublished project report, submitted to the Instituto Nacional de Cultura [Lima]).

Tomasto Cagigao, E., Reindel, M. and Isla Cuadrado, J.A., 2009. *Proyecto Arqueológico Palpa-Lucanas. Informe final. Temporada 2008.* (Unpublished project report, submitted to the Instituto Nacional de Cultura [Lima]).

Tomasto Cagigao, E., Reindel, M. and Isla Cuadrado, J.A., 2015. Paracas funerary practices in Palpa, South Coast of Perú. In: P. Eeckhout and L.S. Owens, eds. 2015. *Funerary practices and models in the ancient Andes. The return of the living dead.* New York, NY: Cambridge University Press, pp.69–86.

Tripcevich, N., 2007. *Quarries, Caravans, and Routes to Complexity. Prehispanic Obsidian in the South-Central Andes.* PhD. University of California Santa Barbara. Available at: <https://escholarship.org/uc/item/3m37097d> [Accessed 17 June 202].

Tripcevich, N., 2009. Exotic Goods, Chivay Obsidian, and Sociopolitical Change in the South-Central Andes. In: C.D. Dillian and C.L. White, eds. 2009. *Trade and Exchange. Archaeological Studies from History and Prehistory.* New York, NY: Springer, pp.59–73.

Tripcevich, N. and Contreras, D.A., 2011. Quarrying evidence at the Quispisisa Obsidian source, Ayacucho, Peru. *Latin American Antiquity,* 22(1), pp.121–136.

Tripcevich, N. and Contreras, D.A., 2013. Archaeological Approaches to Obsidian Quarries. Investigations at the Quispisisa Source. In: N. Tripcevich, and K.J. Vaughn, eds. 2013. *Mining and Quarrying in the Ancient Andes. Sociopolitical, Economic and Symbolic Dimensions.* New York, NY: Springer, pp.23–44.

Tripcevich, N., Eerkens, J.W. and Carpenter, T.R., 2012. Obsidian hydration at high elevation. Archaic quarrying at the Chivay source, southern Peru. *Journal of Archaeological Science,* 39, pp.1360–1367.

Tripcevich, N. and Mackay, A., 2011. Procurement at the Chivay obsidian source, Arequipa, Peru. *World Archaeology,* 43(2), pp.271–297.

Tripcevich, N. and Vaughn, K.J., eds., 2013. *Mining and Quarrying in the Ancient Andes. Sociopolitical, Economic and Symbolic Dimensions.* New York, NY: Springer.

Tschopik Jr., H., 1946. Some Notes on Rock Shelter Sites near Huancayo, Peru. *American Antiquity,* 12(2), pp.73–80.

Uhle, M., 1902. Types of Culture in Peru. *American Anthropologist,* 4(4), pp.753–759.

Uhle, M., Stübel, A., Reiß, W. and Koppel, B., 1889. *Kultur und Industrie südamerikanischer Völker, Bd.1: Die alte Zeit* Leipzig: Asher.

Unkel, I., 2006. *AMS-14C-Analysen zur Rekonstruktion der Landschafts- und Kulturgeschichte in der Region Palpa (S-Peru).* Heidelberg: Universität Heidelberg, Geographisches Institut.

Unkel, I. and Kromer, B., 2009. The Colck in the Corn Cob. On the Development of a Chronology of the Paracas and Nasca Period based on Radiocarbon Dating. In: B. Herrmann, M. Reindel and G.A. Wagner, eds. 2009. *New Technologies for Archaeology. Multidisciplinary Investigations in Palpa and Nasca, Peru.* Berlin, et al.: Springer, pp.231–244.

Unkel, I., Kromer, B., Reindel, M., Wacker, M. and Wagner, G.A., 2007. A chronology of the pre-Columbian Paracas- and Nazca-culture in South Peru based on AMS-14C dating. *Radiocarbon,* 49(2), pp.551–564.

Unkel, I., Reindel, M., Gorbahn, H., Isla Cuadrado, J., Kromer, B. and Sossna, V., 2012. A comprehensive numerical chronology for the pre-Columbian cultures of the Palpa valleys, south coast of Peru. *Journal of Archaeological Science,* 39, pp.2294–2303.

Valdez, F., 2008. Inter-zonal Relationships in Ecuador. In: H. Silverman, and W.H. Isbell, eds. 2008. *Handbook of South American archaeology.* New York, NY: Springer, pp.865–888.

van Buren, G.E., 1974. *Arrowheads and Projectile Points With a Classification Guide for Lithic Artifacts.* Garden Grove, CA: Arrowhead Pub. Co.

van Gijseghem, H., 2006. A Frontier Perspective on Paracas Society and Nasca Ethnogenesis. *Latin American Antiquity,* [e-journal] 17(4), pp.419–444. http://dx.doi.org/10.2307/25063066.

van Gijseghem, H., Vaughn, K.J., Whalen, V.H., Linares Grados, M. and Olano Canales, J., 2013. Economic, Social, and Ritual Aspects of Copper Mining in Ancient Peru. An Upper Ica Valley Case Study. In: N. Tripcevich, and K. J. Vaughn, eds. 2013. *Mining and Quarrying in the Ancient Andes. Sociopolitical, Economic and Symbolic Dimensions.* New York, NY: Springer, pp.275–298.

van Zelst, L., ed., 2003. *Patterns and process. a Festschrift in honor of Dr. Edward V. Sayre.* Washington, DC: Smithsonian Center for Materials Research and Education.

Vaughn, K.J. and Glascock, M.D., 2005. Exchange of Quispisisa Obsidian in Nasca. New Evidence from Marcaya. *Andean Past,* 7, pp.93–110.

Vaughn, K. J. and Tripcevich, N., 2013. An Introducion to Mining and Quarrying in the Ancient Andes. Sociopolitical, Economic and Symbolic Dimensions. In: N. Tripcevich, and K. J. Vaughn, eds. 2013. *Mining and Quarrying in the Ancient Andes. Sociopolitical, Economic and Symbolic Dimensions.* New York, NY: Springer, pp.3–22.

Vaughn, K.J., Conlee, C.A., Neff, H. and Schreiber, K., 2005. A compositional Analysis of Nasca Pigments. Implications for craft production on the pre-hispanic south Coast of Peru. In: R.J. Speakman and H. Neff, eds. 2005. *Laser ablation ICP-MS in archaeological research.* Albuquerque, N.M.: University of New Mexico Press, pp.139–153.

Vaughn, K.J., Linares Grados, M., Eerkens, J. W. and Edwards, M. J., 2007. Hematite mining in the ancient Americas: Mina primavera, a 2,000 year old Peruvian mine. *JOM,* 59(12), pp.16–20.

Vaughn, K.J., van Gijseghem, H., Linares Grados, M. and Eerkens, J. W., 2013a. Minería de Hematita en la costa sur del Perú. Investigaciones arqueológicas en Mina Primavera. *Revista Chilena de Antropología,* 45(1), pp.131–142.

Vaughn, K.J., van Gijseghem, H., Whalen, V.H., Eerkens, J.W. and Linares Grados, M., 2013b. The Organization of Mining in Nasca During the Early Intermediate Period. Recent Evidence from Mina Primavera. In: N. Tripcevich, and K. J. Vaughn, eds. 2013. *Mining and Quarrying in the Ancient Andes. Sociopolitical, Economic and Symbolic Dimensions.* New York, NY: Springer, pp.157–182.

Wadsak, M., Constantinides, I., Vittiglio, G., Adriaens, A., Janssens, K., Schreiner, M., Adams, F.C., Brunella, P. and Wuttmann, M., 2000. Multianalytical Study of Patina Formed on Archaeological Metal Objects from Bliesbruck-Reinheim. *Microchimica Acta,* [e-journal] 133(1-4), pp.159–164. http://dx.doi.org/10.1007/s006040070086.

Wagner, G.A., ed., 2007. *Einführung in die Archäometrie.* Berlin: Springer.

Wagner, G.A. and Weisgerber, G., 1988. *Antike Edel- und Buntmetallgewinnung auf Thasos.* Bochum: Deutsches Bergbau-Museum.

Wagner, H.R., 1942. *The discovery of New Spain in 1518 by Juan de Grijalva. Translation of the original texts with an Introduction and Notes by Henry R. Wagner.* Berkeley, CA: Cortes Society.

Weigand, P., 1994. Observations on Ancient Mining within the Northwestern Regions of the Mesoamerican Civilization, with Emphasis on Turquoise. In: A.K. Craig and R.C. West, eds. 1994. *In quest of mineral wealth. Aboriginal and colonial mining and metallurgy in Spanish America.* Baton Rouge, LA: Geoscience Publications, Dept. of Geography and Anthropology, Louisiana State University, pp.21–35.

Weigand, P. and Garcia de Weigand, A., 2001. A macroeconomic Study of the Relationships between the ancient Cultures of the American Southwest and Mesoamerica. In: V.M. Fields, V. Zamudio-Taylor and M. Beltrán, eds. 2001. *The road to Aztlan. Art from a mythic homeland.* Los Angeles, CA: Los Angeles City Museum of Art, pp.184–195.

Weigand, P. and Harbottle, G., 1993. The Role of Turquoise in the Ancient Mesoamerican Trade Structure. In: J.E. Ericson, and T.G. Baugh, eds. 1993. *The American Southwest and Mesoamerica. Systems of prehistoric exchange.* New York, NY: Plenum Press, pp.159–178.

Weigand, P., Harbottle, G. and Sayre, E.V., 1977. Turquoise Sources and Source Analysis. Mesoamerika and the Southwestern USA. In: T.K. Earle, and J.E. Ericson, eds. 1977. *Exchange systems in prehistory.* New York, et al.: Academic Press, pp.15–34.

Weisgerber, G., 2006. Chuquicamata und anderer indianischer Bergbau vor Kolumbus. *Der Anschnitt,* 58, pp.1–17.

Weisgerber, G. and Pernicka, E., 1995. Ore Mining in Prehistoric Europe: An Overview. In: G. Morteani, and J.P. Northover, eds. 1995. *Prehistoric gold in Europe. Mines, metallurgy and manufacture*. Dordrecht, et al.: Kluwer, pp.159–183.

Westfall, C. and González, C., 2010. Mina Las Turquesas. un asentamiento minero lapidario preincaico en el extremo meridional circumpuneno, region de Atacama, Chile. In: Sociedad Chilena de Arqueología, ed. 2010. *Actas del XVII Congreso Nacional de Arqueología.* Valdivia: Ediciones Kultúran, pp.1073–1084.

Wetter, A., 2005. *Paracas-Keramik aus Jauranga. Grundlagen zur Klassifikation formativzeitlicher Keramik der Südküste Perus. Master's thesis.* Bonn: Rheinische Friedrich-Wilhelms-Universität.

Williams, P.R., 2001. Cerro Baúl. A Wari Center on the Tiwanaku Frontier. *Latin American Antiquity,* [e-journal] 12(1), pp.67–83. http://dx.doi.org/10.2307/971758.

Williams, P.R., Dussubieux, L. and Nash, D., 2012. Provenance of Peruvian Wari Obsidian. Comparing INAA, LA-ICP-MS, and Portable XRF. In: I. Liritzis, and C. M. Stevenson, eds. 2012. *Obsidian and ancient manufactured glasses.* Albuquerque, NM: University of New Mexico Press, pp.75–85.

Williams-Thorpe, O., 2008. The Application of Portable X-Ray Fluorescence Analysis to Archaeological Lithic Provenancing. In: P.J. Potts, and M. West, eds. 2008. *Portable x-ray fluorescence spectrometry. Capabilities for in situ analysis.* Cambridge, UK: Royal Society of Chemistry, pp.174–205.

Wilson, W.E. and Petrov, A., 1999. Famous mineral localities: Cerro Rico de Potosi, Bolivia. *The Mineral Record,* 1, pp.9–36.

Yacobaccio, H.D., Escola, P.S., Pereyra, F.X., Lazzari, M. and Glascock, M.D., 2004. Quest for ancient routes. obsidian sourcing research in Northwestern Argentina. *Journal of Archaeological Science,* 31, pp.193–204.

Yalçın, Ü., ed., 2008. *Anatolian Metal IV. Beiträge des im Februar 2005 in Bochum veranstalteten internationalen Symposiums „Anatolian Metal IV" (11. Oktober 1933 – 19. Januar 2008).* Der Anschnitt, Beiheft, 21. Bochum: Deutsches Bergbau-Museum.

Zhu, Z., 2016. Gold in iron oxide copper-gold deposits. *Ore Geology Reviews,* 72(1), pp.37–42.

Zori, C., 2011. *Metals for the Inka. Craft Production and Empire in the Quebrada de Tarapacá, Northern Chile*. PhD. University of California.

Zori, C. and Tropper, P., 2013. Silver lining. Evidence for Inka silver refining in northern Chile. *Journal of Archaeological Science,* 40, pp.3282–3292.

Zori, C., Tropper, P. and Scott, D.A., 2013. Copper production in late prehispanic northern Chile. *Journal of Archaeological Science,* 40, pp.1165–1175.

Tables

Tab. 5: Element concentration of 40 obsidian samples from the Jichaja Parco obsidian quarry in the highland region near Hunaca Sancos (Peru) and standard deviations for the pXRF. In-situ nondestructive analysis were perfomed using a Niton XL3t GOLDD device. Samples were provided by the Deutsches Bergbau-Museum Bochum (DBM). (LOD = Limit of Detection).

SAMPLE	Bal (%)	Ba (%)	Zr (%)	Sr (%)	Rb (%)	Bi (%)	Pb (%)	Zn (%)	Fe (%)	Cr (%)	V (%)	Ti (%)	Ca (%)	K (%)	Cl (%)	Al (%)	P (%)	Si (%)
Average Error pXRF	**0.861**	**0.005**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.011**	**0.001**	**0.001**	**0.002**	**0.010**	**0.034**	**0.006**	**0.255**	**0.041**	**0.219**
Jichja Parco 80001575225	55.844	0.077	0.01	0.012	0.016	0.003	0.002	0.003	0.529	0.005	0.005	0.088	0.406	3.276	0.077	5.631	< LOD	33.901
Jichja Parco 80001575225	62.489	0.062	0.008	0.011	0.013	0.002	< LOD	0.002	0.403	0.005	0.004	0.07	0.354	2.742	0.088	3.916	< LOD	29.748
Jichja Parco 80001575225	88.606	0.058	0.007	0.008	0.01	< LOD	< LOD	< LOD	0.207	0.004	0.002	0.035	0.13	1.158	0.229	< LOD	< LOD	9.441
Jichja Parco 80001575225	46.719	0.078	0.01	0.013	0.017	0.002	0.002	0.003	0.563	0.005	0.005	0.091	0.46	3.638	0.074	7.459	< LOD	40.759
Jichja Parco 80001575225	57.831	0.07	0.009	0.012	0.015	0.002	0.002	0.002	0.478	0.005	0.004	0.079	0.384	2.994	0.068	5.088	< LOD	32.878
Jichja Parco 80001575225	60.292	0.069	0.009	0.011	0.015	0.002	< LOD	0.003	0.437	0.005	0.004	0.077	0.366	3.044	0.078	4.38	< LOD	31.134
Jichja Parco 80001575225	53.35	0.076	0.009	0.012	0.016	0.003	< LOD	0.002	0.513	0.005	0.004	0.084	0.43	3.239	0.061	5.727	< LOD	36.37
Jichja Parco 80001575225	52.67	0.08	0.01	0.012	0.016	0.003	0.002	0.002	0.561	0.005	0.004	0.094	0.418	3.384	0.073	6.326	< LOD	36.257
Jichja Parco 80001575225	63.963	0.072	0.008	0.011	0.014	< LOD	< LOD	0.002	0.427	0.005	0.004	0.071	0.351	2.735	0.117	3.58	< LOD	28.556
Jichja Parco 80001575225	56.511	0.077	0.01	0.013	0.015	0.002	0.002	0.003	0.612	0.005	0.004	0.093	0.405	2.839	0.055	6.478	0.053	32.74
Jichja Parco 80001575225	53.021	0.074	0.01	0.013	0.016	0.002	< LOD	0.002	0.542	0.004	0.004	0.087	0.425	3.228	0.071	6.505	0.047	35.881
Jichja Parco 80001575225	56.897	0.074	0.009	0.012	0.015	0.002	< LOD	0.002	0.52	0.005	0.004	0.086	0.406	3.082	0.065	5.714	< LOD	33.029
Jichja Parco 80001575225	52.137	0.072	0.01	0.013	0.017	0.003	< LOD	0.002	0.542	0.005	0.005	0.088	0.444	3.446	0.085	6.279	< LOD	36.738
Jichja Parco 80001575225	50.891	0.083	0.01	0.012	0.016	0.003	< LOD	0.003	0.57	0.005	0.004	0.086	0.415	3.26	0.066	6.785	0.061	37.672
Jichja Parco 80001575225	51.601	0.08	0.01	0.013	0.016	0.003	0.002	0.003	0.609	0.005	0.005	0.092	0.438	3.213	0.07	6.566	< LOD	37.168
Jichja Parco 80001575226	48.762	0.079	0.01	0.012	0.017	0.003	0.002	0.003	0.545	0.005	0.005	0.09	0.374	3.718	0.053	7.525	0.05	38.68
Jichja Parco 80001575226	51.297	0.077	0.01	0.013	0.016	0.003	< LOD	0.002	0.537	0.005	0.004	0.087	0.418	3.334	0.046	7.391	< LOD	36.657
Jichja Parco 80001575226	50.336	0.083	0.01	0.013	0.016	0.002	< LOD	0.002	0.532	0.005	0.004	0.09	0.43	3.409	0.063	6.819	< LOD	38.087
Jichja Parco 80001575226	47.449	0.076	0.01	0.013	0.016	0.002	< LOD	< LOD	0.515	0.005	0.004	0.087	0.432	3.249	0.055	7.712	0.054	40.254
Jichja Parco 80001575226	53.002	0.072	0.01	0.013	0.017	0.003	< LOD	0.002	0.603	0.005	0.004	0.095	0.432	3.257	0.06	6.477	< LOD	35.841
Jichja Parco 80001575226	53.962	0.08	0.009	0.012	0.015	0.002	< LOD	0.003	0.557	0.005	0.005	0.095	0.39	3.004	0.07	7.709	< LOD	33.974
Jichja Parco 80001575226	51.434	0.079	0.01	0.013	0.017	0.002	0.002	0.003	0.678	0.005	0.004	0.103	0.435	3.237	0.065	7.582	0.042	36.225
Jichja Parco 80001575227	52.722	0.077	0.01	0.013	0.016	0.003	< LOD	0.003	0.515	0.005	0.005	0.086	0.439	3.335	0.178	6.295	< LOD	36.191
Jichja Parco 80001575228	48.403	0.074	0.01	0.013	0.017	< LOD	< LOD	0.003	0.534	0.006	0.004	0.088	0.445	3.438	0.069	7.15	< LOD	39.624
Jichja Parco 80001575228	52.209	0.081	0.01	0.012	0.016	0.002	< LOD	0.002	0.539	0.005	0.005	0.091	0.409	3.186	0.054	7.024	0.053	36.246
Jichja Parco 80001575228	58.301	0.079	0.009	0.012	0.015	0.002	< LOD	< LOD	0.549	0.005	0.004	0.086	0.407	3.1	0.057	5.252	< LOD	32.004
Jichja Parco 80001575228	52.262	0.079	0.01	0.012	0.016	0.002	0.002	0.003	0.51	0.005	0.004	0.086	0.422	3.269	0.091	6.489	< LOD	36.646
Jichja Parco 80001575228	53.496	0.077	0.01	0.012	0.016	< LOD	< LOD	0.002	0.495	0.005	0.004	0.084	0.414	3.274	0.099	5.967	< LOD	35.935
Jichja Parco 80001575228	55.755	0.078	0.009	0.012	0.015	0.002	0.002	0.003	0.548	0.005	0.005	0.097	0.375	2.61	0.084	6.716	< LOD	33.579
Jichja Parco 80001575228	57.649	0.076	0.009	0.012	0.015	0.002	< LOD	0.003	0.514	0.005	0.004	0.085	0.395	3.119	0.087	5.439	< LOD	32.51
Jichja Parco 80001575228	55.608	0.084	0.01	0.012	0.016	0.003	< LOD	0.003	0.537	0.006	0.005	0.087	0.406	3.205	0.074	5.736	< LOD	34.116
Jichja Parco 80001575228	55.799	0.073	0.01	0.012	0.016	0.002	0.002	0.003	0.528	0.005	0.004	0.086	0.422	3.319	0.076	5.605	< LOD	33.955

SAMPLE	Bal (%)	Ba (%)	Zr (%)	Sr (%)	Rb (%)	Bi (%)	Pb (%)	Zn (%)	Fe (%)	Cr (%)	V (%)	Ti (%)	Ca (%)	K (%)	Cl (%)	Al (%)	P (%)	Si (%)
Average Error pXRF	**0.861**	**0.005**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.011**	**0.001**	**0.001**	**0.002**	**0.010**	**0.034**	**0.006**	**0.255**	**0.041**	**0.219**
Jichja Parco 80001575228	55.505	0.077	0.01	0.012	0.016	0.002	0.002	0.002	0.524	0.005	0.004	0.088	0.402	3.164	0.071	5.454	< LOD	34.565
Jichja Parco 80001575228	55.863	0.077	0.01	0.012	0.016	0.003	< LOD	0.003	0.568	0.005	0.005	0.089	0.428	3.286	0.079	5.488	< LOD	33.961
Jichja Parco 80001575228	51.459	0.075	0.01	0.012	0.016	< LOD	0.002	0.003	0.534	0.005	0.004	0.086	0.423	3.381	0.074	6.524	< LOD	37.284
Jichja Parco 80001575228	56.336	0.099	0.009	0.011	0.014	< LOD	< LOD	< LOD	0.441	0.005	0.004	0.079	0.359	2.662	0.073	5.702	< LOD	34.183
Jichja Parco 80001575228	55.217	0.078	0.009	0.012	0.016	0.002	< LOD	0.003	0.533	0.004	0.004	0.088	0.41	3.139	0.083	6.072	< LOD	34.229
Jichja Parco 80001575228	54.975	0.073	0.009	0.012	0.015	0.002	< LOD	0.003	0.51	0.005	0.004	0.089	0.394	2.993	0.076	5.703	< LOD	35.046
Jichja Parco 80001575228	45.66	0.088	0.01	0.013	0.016	0.003	0.002	0.003	0.557	0.006	0.006	0.108	0.415	2.857	0.044	10.792	0.057	39.274
Jichja Parco 80001575229	52.44	0.075	0.01	0.012	0.016	0.003	< LOD	0.003	0.516	0.006	0.005	0.093	0.433	3.134	0.113	6.183	0.058	36.827

*Tab. 6: Element concentration of 365 obsidian artifacts from the Projecto Arqueologo de Palpa (PAP) and standard deviation of the pXRF. **In-situ** nondestructive analyses were perfomed using a Niton XL3t GOLDD device. Samples were provided by the PAP. (LOD = Limit of Detection).*

PAP-No.	Sub-No.	Periods	Type	Bal (%)	Zr (%)	Sr (%)	Rb (%)	Bi (%)	Pb (%)	Zn (%)	Cu (%)	Fe (%)	Mn (%)	V (%)	Ti (%)	Source
		Average Error pXRF		**0.078**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.005**	**0.003**	**0.020**	**0.078**	
3167		Archaic	7 A	98.30	0.01	0.013	0.017	0.002	0.002	0.003	< LOD	0.549	< LOD	0.189	0.863	Jichja Parco
3801	2	Archaic	3 H V I	97.40	0.009	0.012	0.015	0.002	< LOD	0.002	< LOD	0.48	< LOD	0.374	1.638	Jichja Parco
4375		Archaic	7 A	97.29	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.544	< LOD	0.38	1.668	Jichja Parco
751	6	Archaic/Initial Period	4 A	95.99	0.009	0.013	0.016	0.002	0.002	0.003	< LOD	0.532	0.018	0.626	2.714	Jichja Parco
767	7	Archaic/Initial Period	4 A	94.33	0.008	0.011	0.014	0.002	0.002	0.004	0.002	0.545	0.043	0.905	4.051	Jichja Parco
783		Archaic/Initial Period	4 A	96.24	0.009	0.012	0.016	0.002	<LOD	0.003	< LOD	0.505	0.013	0.583	2.533	Jichja Parco
785	3	Archaic/Initial Period	4 A	93.76	0.008	0.011	0.013	< LOD	0.002	0.004	0.003	0.454	0.054	1.031	4.581	Jichja Parco
800	6	Archaic/Initial Period	4 A	95.98	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.532	0.019	0.629	2.721	Jichja Parco
830	3	Archaic/Initial Period	4 A	95.80	0.009	0.012	0.015	0.002	0.002	0.003	< LOD	0.524	0.02	0.651	2.884	Jichja Parco
1032	2	Archaic/Initial Period	4 A	94.53	0.009	0.012	0.015	0.002	0.003	0.004	0.002	0.536	0.045	0.868	3.901	Jichja Parco
1779	2	Archaic/Initial Period	4 A	94.92	0.008	0.011	0.014	< LOD	< LOD	0.002	< LOD	0.474	0.03	0.785	3.675	Jichja Parco
180	1	Initial Period/Transition	5 B	95.11	0.009	0.012	0.014	0.002	0.002	0.003	< LOD	0.498	0.031	0.778	3.466	Jichja Parco
588		Initial Period/Transition	5 B	97.31	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.517	< LOD	0.383	1.676	Jichja Parco
760	1	Initial Period/Transition	5 B	95.50	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.524	0.026	0.713	3.112	Jichja Parco
761		Initial Period/Transition	5 B	96.56	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.532	0.006	0.516	2.26	Jichja Parco
770	2	Initial Period/Transition	5 B	96.18	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.553	0.013	0.585	2.547	Cerro Huenul
797		Initial Period/Transition	5 B	95.10	0.009	0.012	0.015	0.002	0.002	0.003	< LOD	0.533	0.032	0.777	3.437	Jichja Parco
831	4	Initial Period/Transition	5 B	95.84	0.009	0.012	0.015	0.002	< LOD	0.002	< LOD	0.479	0.018	0.666	2.877	Jichja Parco
837		Initial Period/Transition	5 B	97.30	0.01	0.012	0.016	0.002	< LOD	0.002	< LOD	0.524	< LOD	0.383	1.677	Jichja Parco
1767		Initial Period/Transition	5 B	95.70	0.008	0.011	0.014	0.002	< LOD	0.003	< LOD	0.462	0.009	0.586	3.125	Jichja Parco
4052		Initial Period/Transition	5 D V I	95.99	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.507	0.017	0.625	2.742	Jichja Parco
526	2	Middle Paracas	2 C V I	95.21	0.009	0.011	0.014	0.002	< LOD	0.003	< LOD	0.469	0.028	0.776	3.392	Jichja Parco
1014		Middle Paracas	2 C V I	96.47	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.601	0.009	0.521	2.28	Jichja Parco
1037	1	Middle Paracas	2 H V III	96.56	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.546	0.008	0.517	2.246	Jichja Parco
2430	1	Middle Paracas	3 D	96.85	0.009	0.013	0.016	0.002	0.002	0.002	< LOD	0.521	< LOD	0.46	2.041	Jichja Parco
3823	2	Middle Paracas	2 H V III	93.68	0.007	0.01	0.012	< LOD	0.002	0.004	0.004	0.409	0.05	1.038	4.709	Jichja Parco
3823	3	Middle Paracas	2 K	95.18	0.009	0.012	0.015	0.002	0.004	0.003	< LOD	0.532	0.013	0.598	2.622	Jichja Parco
3823	4	Middle Paracas	2 H V III	95.89	0.009	0.011	0.014	< LOD	0.003	0.003	< LOD	0.481	0.028	0.776	3.419	no origin
3823	5	Middle Paracas	2 K	96.11	0.009	0.012	0.016	0.002	< LOD	0.002	< LOD	0.562	0.017	0.64	2.773	Jichja Parco
3823	6	Middle Paracas	1 D	95.96	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.521	0.02	0.634	2.743	Jichja Parco
3870		Middle Paracas		97.33	0.009	0.012	0.015	0.002	< LOD	0.002	< LOD	0.456	< LOD	0.392	1.714	Jichja Parco
3876		Middle Paracas	2 K	96.52	0.009	0.012	0.015	0.002	< LOD	0.002	< LOD	0.477	< LOD	0.54	2.335	Jichja Parco
3881		Middle Paracas	2 I V I	97.01	0.009	0.012	0.015	0.002	< LOD	0.002	< LOD	0.483	< LOD	0.446	1.948	Jichja Parco

PAP-No.	Sub-No.	Periods	Type	Bal (%)	Zr (%)	Sr (%)	Rb (%)	Bi (%)	Pb (%)	Zn (%)	Cu (%)	Fe (%)	Mn (%)	V (%)	Ti (%)	Source
		Average Error pXRF		**0.078**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.005**	**0.003**	**0.020**	**0.078**	
509		Late Paracas	2 A	95.52	0.008	0.011	0.014	< LOD	0.003	0.003	< LOD	0.484	0.023	0.708	3.141	Jichja Parco
586		Late Paracas	2 F	93.79	0.007	0.01	0.011	< LOD	0.002	0.004	0.004	0.389	0.049	1.019	4.639	Cerro Huenul
628	2	Late Paracas	2 C V II	94.02	0.008	0.011	0.013	< LOD	0.002	0.004	0.003	0.451	0.05	0.981	4.381	Jichja Parco
764	1	Late Paracas	5 A V I	96.59	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.513	0.007	0.515	2.25	Jichja Parco
767	5	Late Paracas	5 A	97.46	0.01	0.013	0.017	0.002	< LOD	0.003	< LOD	0.554	< LOD	0.344	1.521	Jichja Parco
771	2	Late Paracas	3 F	94.97	0.009	0.011	0.014	< LOD	0.002	0.003	< LOD	0.473	0.032	0.81	3.596	Jichja Parco
774	1	Late Paracas	5 A V I	93.92	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.535	0.007	0.522	2.28	Jichja Parco
774	2	Late Paracas	3 F	96.53	0.008	0.011	0.014	< LOD	0.003	0.004	0.003	0.484	0.054	0.986	4.433	Jichja Parco
785	4	Late Paracas	3 F	94.20	0.008	0.011	0.014	< LOD	0.003	0.004	0.003	0.505	0.047	0.927	4.197	no origin
795		Late Paracas	5 A	95.68	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.558	0.022	0.676	2.938	Jichja Parco
800	2	Late Paracas	5 A	93.51	0.007	0.01	0.012	< LOD	0.003	0.005	0.005	0.444	0.054	1.036	4.83	Jichja Parco
800	3	Late Paracas	5 A V I	97.13	0.01	0.013	0.017	0.002	0.002	0.003	< LOD	0.608	< LOD	0.393	1.739	Jichja Parco
824		Late Paracas	5 A V I	95.56	0.009	0.012	0.015	0.003	< LOD	0.003	< LOD	0.489	0.024	0.712	3.087	Jichja Parco
914	1	Late Paracas	5 A V I	94.28	0.01	0.013	0.016	0.002	< LOD	0.002	< LOD	0.525	0.021	0.661	2.863	Jichja Parco
914	2	Late Paracas	5 A V I	95.81	0.008	0.012	0.014	0.002	0.002	0.003	< LOD	0.507	0.048	0.938	4.108	Jichja Parco
1057	2	Late Paracas	2 A	96.00	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.525	0.017	0.625	2.707	Jichja Parco
1778		Late Paracas	2 F	97.26	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.516	< LOD	0.388	1.719	Jichja Parco
1902	2	Late Paracas		96.84	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.507	< LOD	0.474	2.062	Jichja Parco
1914	1	Late Paracas	1 A V I	96.01	0.008	0.011	0.014	< LOD	< LOD	0.002	< LOD	0.454	0.02	0.686	3.201	Jichja Parco
1914	2	Late Paracas		95.52	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.493	0.011	0.568	2.795	Jichja Parco
1915		Late Paracas	2 B	96.22	0.009	0.012	0.015	0.002	< LOD	0.002	< LOD	0.479	0.011	0.586	2.59	Jichja Parco
1928		Late Paracas	3 H	97.39	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.539	< LOD	0.363	1.594	Jichja Parco
1938	2	Late Paracas	3 H	94.33	0.007	0.01	0.012	< LOD	< LOD	0.002	< LOD	0.443	0.031	0.833	4.253	Jichja Parco
1951		Late Paracas	3 H	96.75	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.516	< LOD	0.485	2.121	Jichja Parco
1957		Late Paracas		94.89	0.008	0.011	0.014	< LOD	< LOD	0.002	< LOD	0.451	0.027	0.767	3.745	Jichja Parco
1961	2	Late Paracas	2 B	96.36	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.492	0.008	0.566	2.449	Jichja Parco
1964		Late Paracas		96.28	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.508	0.012	0.572	2.503	Jichja Parco
1986	2	Late Paracas	2 F	95.80	0.009	0.011	0.015	0.002	< LOD	0.003	< LOD	0.474	0.014	0.632	2.965	Jichja Parco
2225	2	Late Paracas	2 F	97.53	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.531	< LOD	0.336	1.491	Jichja Parco
2237	4	Late Paracas	2 B	97.66	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.506	< LOD	0.299	1.426	Jichja Parco
2257		Late Paracas		95.65	0.009	0.012	0.015	0.002	< LOD	0.002	< LOD	0.5	0.022	0.699	3.007	Jichja Parco
2279		Late Paracas		95.63	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.505	0.023	0.699	3.024	Jichja Parco
2280		Late Paracas	3 F	94.49	0.008	0.01	0.012	< LOD	< LOD	0.002	< LOD	0.399	0.03	0.801	4.168	no origin
2282	1	Late Paracas	2 F	93.97	0.008	0.01	0.013	< LOD	< LOD	0.002	< LOD	0.437	0.041	0.901	4.534	Jichja Parco
2292		Late Paracas	5 C V II	96.28	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.532	0.01	0.545	2.509	Jichja Parco

PAP-No.	Sub-No.	Periods	Type	Bal (%)	Zr (%)	Sr (%)	Rb (%)	Bi (%)	Pb (%)	Zn (%)	Cu (%)	Fe (%)	Mn (%)	V (%)	Ti (%)	Source
Average Error pXRF				**0.078**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.005**	**0.003**	**0.020**	**0.078**	
2293		Late Paracas		94.78	0.008	0.01	0.013	< LOD	< LOD	0.002	< LOD	0.416	0.029	0.819	3.845	Jichja Parco
2296		Late Paracas	2 F	96.91	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.511	< LOD	0.451	2.001	Jichja Parco
2297		Late Paracas		97.90	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.524	< LOD	0.271	1.202	Jichja Parco
2310		Late Paracas		97.44	0.01	0.013	0.016	0.002	< LOD	0.003	< LOD	0.503	< LOD	0.361	1.583	Jichja Parco
2322	1	Late Paracas	5 C V II	95.92	0.01	0.013	0.016	0.002	< LOD	0.003	< LOD	0.535	< LOD	0.395	1.73	Jichja Parco
2322	2	Late Paracas	1 F V II	97.22	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.51	0.017	0.635	2.795	Jichja Parco
2410		Late Paracas	3 F	96.38	0.009	0.012	0.015	< LOD	< LOD	0.003	< LOD	0.5	0.009	0.556	2.435	Jichja Parco
2430	2	Late Paracas	3 F	97.09	0.009	0.012	0.015	< LOD	< LOD	0.002	< LOD	0.466	< LOD	0.431	1.899	Jichja Parco
2707	6	Late Paracas	2 L	97.26	0.01	0.013	0.016	0.002	< LOD	0.003	< LOD	0.528	< LOD	0.385	1.706	Jichja Parco
2722	1	Late Paracas	2 H V II	97.75	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.522	0.013	0.574	2.583	Jichja Parco
2722	2	Late Paracas	2 H V IV	96.18	0.01	0.013	0.017	0.002	< LOD	0.003	< LOD	0.534	< LOD	0.294	1.309	Jichja Parco
2740	2	Late Paracas	2 F	97.38	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.526	< LOD	0.364	1.616	Jichja Parco
2904	6	Late Paracas	5 A V I	95.60	0.009	0.012	0.015	0.002	0.002	0.003	< LOD	0.508	0.013	0.601	2.624	Jichja Parco
2904	9	Late Paracas	2 F	96.13	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.498	0.023	0.706	3.056	Jichja Parco
3855		Late Paracas	5 A	93.49	0.007	0.01	0.011	< LOD	0.003	0.005	0.004	0.43	0.054	1.051	4.858	Cerro Huenul
3866	2	Late Paracas	5 A	95.79	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.534	0.018	0.663	2.878	Jichja Parco
4155	3	Late Paracas	2 A	97.43	0.01	0.013	0.016	0.002	< LOD	0.002	< LOD	0.504	< LOD	0.364	1.594	Jichja Parco
4196	1	Late Paracas	2 A V I	95.37	0.009	0.007	0.012	< LOD	< LOD	0.004	< LOD	0.471	0.04	0.754	3.249	Jichja Parco
4196	2	Late Paracas	2 A	95.79	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.521	< LOD	0.425	1.854	Jichja Parco
4196	3	Late Paracas	2 A	96.24	0.01	0.013	0.016	0.002	< LOD	0.003	< LOD	0.53	0.008	0.528	2.299	Jichja Parco
4196	4	Late Paracas	2 C V II	96.45	0.009	0.012	0.016	0.002	< LOD	0.002	< LOD	0.503	0.022	0.672	2.895	Jichja Parco
4196	5	Late Paracas	2 B	95.92	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.511	0.012	0.584	2.529	Jichja Parco
4196	6	Late Paracas	2 A	96.48	0.01	0.013	0.017	0.002	0.002	0.003	< LOD	0.565	0.01	0.526	2.292	Jichja Parco
4196	7	Late Paracas	2 A V I	97.08	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.513	0.008	0.545	2.363	Jichja Parco
4196	8	Late Paracas	2 A V I	97.44	0.01	0.013	0.017	0.003	0.002	0.003	< LOD	0.555	< LOD	0.348	1.533	Puzolana
4196	9	Late Paracas	2 A	96.51	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.526	< LOD	0.429	1.886	Jichja Parco
4196	10	Late Paracas	2 A	97.04	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.49	0.017	0.65	2.801	Jichja Parco
4761	4	Late Paracas	2 C V II	96.91	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.49	< LOD	0.445	2.032	Jichja Parco
4765		Late Paracas	2 B	97.04	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.515	< LOD	0.435	1.889	Jichja Parco
4819	1	Late Paracas	5 A	96.74	0.009	0.012	0.015	< LOD	< LOD	0.002	< LOD	0.512	< LOD	0.48	2.149	Jichja Parco
751	4	Early Horizon	1 G V I	93.23	0.006	0.01	0.011	< LOD	0.003	0.006	0.005	0.431	0.056	1.081	5.087	Cerro Huenul
760	2	Early Horizon	2 D	95.14	0.009	0.012	0.015	0.002	0.002	0.003	< LOD	0.5	0.033	0.787	3.418	Jichja Parco
767	1	Early Horizon	1 G	94.45	0.008	0.011	0.014	< LOD	0.002	0.003	0.002	0.456	0.042	0.914	4.024	Jichja Parco
777	2	Early Horizon	1 G	94.01	0.008	0.011	0.013	< LOD	0.003	0.004	0.004	0.487	0.048	0.951	4.379	Jichja Parco
800	5	Early Horizon	6 A	95.26	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.537	0.03	0.763	3.288	Jichja Parco

PAP-No.	Sub-No.	Periods	Type	Bal (%)	Zr (%)	Sr (%)	Rb (%)	Bi (%)	Pb (%)	Zn (%)	Cu (%)	Fe (%)	Mn (%)	V (%)	Ti (%)	Source
		Average Error pXRF		**0.078**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.005**	**0.003**	**0.020**	**0.078**	
800	7	Early Horizon	1 G	97.46	0.01	0.013	0.016	0.002	< LOD	0.003	< LOD	0.528	< LOD	0.352	1.549	Cerro Huenul
828	2	Early Horizon	1 G	95.56	0.009	0.012	0.015	0.003	< LOD	0.003	< LOD	0.489	0.024	0.712	3.087	Jichja Parco
1780	1	Early Horizon	2 D	95.00	0.008	0.011	0.014	0.002	< LOD	0.003	< LOD	0.47	0.029	0.771	3.609	Jichja Parco
1802		Early Horizon	2 D	97.27	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.486	< LOD	0.395	1.741	Jichja Parco
1975		Early Horizon	2 D	96.30	0.009	0.012	0.015	< LOD	< LOD	0.003	< LOD	0.475	0.008	0.567	2.531	Jichja Parco
2315	1	Early Horizon	2 F V I	97.48	0.009	0.013	0.016	0.002	< LOD	0.003	< LOD	0.497	< LOD	0.354	1.554	Jichja Parco
2403	3	Early Horizon	2 D	96.19	0.009	0.012	0.016	0.002	< LOD	0.002	< LOD	0.502	0.012	0.58	2.599	Jichja Parco
2703	2	Early Horizon	2 D	95.79	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.483	0.02	0.659	2.925	Jichja Parco
2707	4	Early Horizon	2 D	96.76	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.526	< LOD	0.48	2.113	Jichja Parco
2740	1	Early Horizon	2 D	96.86	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.53	< LOD	0.46	2.022	Jichja Parco
3801	1	Early Horizon	2 F V I	96.54	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.508	0.008	0.527	2.291	Jichja Parco
3830	1	Early Horizon	1 G V I	94.48	0.008	0.012	0.014	0.002	0.002	0.004	0.003	0.524	0.043	0.889	3.945	Jichja Parco
3830	2	Early Horizon	6 A	96.81	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.505	< LOD	0.48	2.087	Jichja Parco
3866	1	Early Horizon	1 G	94.55	0.008	0.011	0.014	< LOD	< LOD	0.003	< LOD	0.516	0.04	0.886	3.89	Jichja Parco
4153	2	Early Horizon	1 G	94.29	0.008	0.011	0.014	< LOD	0.002	0.004	0.002	0.5	0.045	0.923	4.12	Jichja Parco
4766	1	Early Horizon	2 F V I	97.27	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.518	< LOD	0.389	1.706	Jichja Parco
4766	2	Early Horizon		97.99	0.01	0.013	0.016	0.002	< LOD	0.003	< LOD	0.541	< LOD	0.247	1.112	Jichja Parco
4818	2	Early Horizon	1 G	98.14	0.01	0.013	0.016	0.002	0.002	0.002	< LOD	0.523	< LOD	0.224	1.008	Jichja Parco
556	4	Initial Period/Early Intermediate Period	1 F	92.72	0.006	0.01	0.011	< LOD	0.003	0.006	0.006	0.435	0.069	1.179	5.475	Jichja Parco
2955		Initial Period/Early Intermediate Period	1 F	95.03	0.009	0.012	0.015	0.002	0.002	0.003	< LOD	0.501	0.031	0.796	3.519	Jichja Parco
11		Early Horizon/Early Intermediate Period	1 E	94.95	0.008	0.011	0.014	0.002	0.002	0.007	< LOD	0.498	0.034	0.808	3.584	Jichja Parco
19		Early Horizon/Early Intermediate Period	2 E	93.10	0.006	0.009	0.01	< LOD	0.003	0.005	0.005	0.385	0.059	1.131	5.21	Cerro Huenul
180	2	Early Horizon/Early Intermediate Period	3 G	95.03	0.009	0.012	0.015	< LOD	< LOD	0.003	< LOD	0.505	0.035	0.806	3.505	Jichja Parco
180	4	Early Horizon/Early Intermediate Period	3 G	96.57	0.009	0.012	0.015	< LOD	< LOD	0.003	< LOD	0.485	< LOD	0.528	2.293	Jichja Parco
196		Early Horizon/Early Intermediate Period	2 A V I	96.98	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.518	< LOD	0.443	1.933	Jichja Parco
462	1	Early Horizon/Early Intermediate Period	2 E	97.28	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.53	< LOD	0.382	1.693	Jichja Parco
601	1	Early Horizon/Early Intermediate Period	4 B	93.57	0.007	0.011	0.012	< LOD	0.002	0.004	0.003	0.447	0.056	1.052	4.751	Jichja Parco
751	1	Early Horizon/Early Intermediate Period	1 B	96.19	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.537	0.014	0.584	2.549	Jichja Parco
767	2	Early Horizon/Early Intermediate Period	2 H	95.01	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.536	0.038	0.805	3.485	Jichja Parco
770	3	Early Horizon/Early Intermediate Period	1 B	95.99	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.488	0.016	0.627	2.758	Jichja Parco
770	7	Early Horizon/Early Intermediate Period	2 E	96.02	0.009	0.013	0.016	0.002	0.002	0.003	< LOD	0.556	0.015	0.613	2.676	Jichja Parco
771	1	Early Horizon/Early Intermediate Period	1 B	96.50	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.538	0.009	0.53	2.298	Jichja Parco
777	1	Early Horizon/Early Intermediate Period	2 H	96.83	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.533	< LOD	0.467	2.042	Jichja Parco
814		Early Horizon/Early Intermediate Period	1 E	94.64	0.008	0.011	0.014	< LOD	0.002	0.004	0.002	0.491	0.038	0.854	3.858	Jichja Parco
819	1	Early Horizon/Early Intermediate Period	1 E	96.73	0.009	0.011	0.015	< LOD	< LOD	0.002	< LOD	0.469	< LOD	0.5	2.184	Jichja Parco

PAP-No.	Sub-No.	Periods	Type	Bal (%)	Zr (%)	Sr (%)	Rb (%)	Bi (%)	Pb (%)	Zn (%)	Cu (%)	Fe (%)	Mn (%)	V (%)	Ti (%)	Source
Average Error pXRF				**0.078**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.005**	**0.003**	**0.020**	**0.078**	
830	1	Early Horizon/Early Intermediate Period	1 E	96.02	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.508	0.018	0.624	2.705	Jichja Parco
843	2	Early Horizon/Early Intermediate Period	2 H V I	95.69	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.501	0.02	0.687	2.987	Jichja Parco
928	2	Early Horizon/Early Intermediate Period	4 B	95.27	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.503	0.03	0.761	3.312	Jichja Parco
1006		Early Horizon/Early Intermediate Period	1 F V I	96.89	0.01	0.013	0.016	0.002	0.002	0.002	< LOD	0.528	< LOD	0.455	2.001	Jichja Parco
1010	2	Early Horizon/Early Intermediate Period	1 B	96.93	0.01	0.013	0.016	0.002	< LOD	0.003	< LOD	0.529	< LOD	0.451	1.97	Jichja Parco
1015		Early Horizon/Early Intermediate Period	4 B	93.54	0.007	0.011	0.012	< LOD	0.003	0.005	0.004	0.447	0.054	1.053	4.788	Jichja Parco
1057	1	Early Horizon/Early Intermediate Period	1 B	96.76	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.506	< LOD	0.489	2.122	no origin
1057	3	Early Horizon/Early Intermediate Period	1 B	94.81	0.004	0.013	0.011	< LOD	0.002	0.003	< LOD	0.44	0.047	0.852	3.741	Jichja Parco
1902	3	Early Horizon/Early Intermediate Period	2 H	96.50	0.007	0.01	0.012	< LOD	< LOD	0.002	< LOD	0.415	0.039	0.893	4.629	Jichja Parco
1902	4	Early Horizon/Early Intermediate Period	2 H V I	93.91	0.009	0.012	0.016	0.002	< LOD	0.002	< LOD	0.513	0.008	0.533	2.322	Jichja Parco
1903		Early Horizon/Early Intermediate Period	3 G	97.10	0.01	0.012	0.016	0.002	< LOD	0.002	< LOD	0.52	< LOD	0.419	1.842	Jichja Parco
1938	1	Early Horizon/Early Intermediate Period	1 B	96.28	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.529	0.009	0.55	2.509	Jichja Parco
1939		Early Horizon/Early Intermediate Period	1 B	95.95	0.009	0.012	0.015	< LOD	< LOD	0.002	< LOD	0.493	0.017	0.623	2.8	Jichja Parco
1961	1	Early Horizon/Early Intermediate Period	3 G	97.02	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.507	< LOD	0.438	1.917	Jichja Parco
1986	1	Early Horizon/Early Intermediate Period	1 F V I	96.70	0.009	0.011	0.015	0.002	< LOD	0.002	< LOD	0.486	0.025	0.717	3.375	Jichja Parco
1986	3	Early Horizon/Early Intermediate Period	1 F V I	95.28	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.516	< LOD	0.49	2.164	Jichja Parco
2237	3	Early Horizon/Early Intermediate Period	3 G	94.64	0.008	0.011	0.014	0.002	< LOD	0.003	< LOD	0.481	0.033	0.791	3.937	Jichja Parco
2350	2	Early Horizon/Early Intermediate Period	2 G	95.92	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.509	0.013	0.604	2.834	Jichja Parco
2403	1	Early Horizon/Early Intermediate Period	8 A	94.51	0.008	0.01	0.013	< LOD	< LOD	0.003	< LOD	0.448	0.024	0.739	4.014	Jichja Parco
2403	4	Early Horizon/Early Intermediate Period	2 H	94.66	0.008	0.01	0.013	< LOD	< LOD	0.003	< LOD	0.48	0.026	0.764	4.109	Jichja Parco
2702		Early Horizon/Early Intermediate Period	2 I V I	96.05	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.517	0.018	0.607	2.686	Jichja Parco
2703	1	Early Horizon/Early Intermediate Period	2 H	94.17	0.007	0.01	0.013	< LOD	< LOD	0.002	< LOD	0.406	0.034	0.848	4.425	Jichja Parco
2707	3	Early Horizon/Early Intermediate Period	2 H	96.91	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.517	< LOD	0.439	2.017	Jichja Parco
2733		Early Horizon/Early Intermediate Period	3 G	97.16	0.009	0.012	0.015	< LOD	< LOD	0.003	< LOD	0.496	< LOD	0.404	1.822	Jichja Parco
2813		Early Horizon/Early Intermediate Period	1 F V I	94.14	0.008	0.011	0.013	< LOD	0.003	0.004	0.003	0.475	0.044	0.927	4.29	Jichja Parco
3604		Early Horizon/Early Intermediate Period	1 E	96.95	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.528	< LOD	0.446	1.952	Jichja Parco
3856		Early Horizon/Early Intermediate Period	2 E	95.03	0.008	0.011	0.014	< LOD	0.002	0.004	0.003	0.465	0.029	0.778	3.573	Jichja Parco
4150	2	Early Horizon/Early Intermediate Period	1 E	95.84	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.48	0.018	0.659	2.878	Jichja Parco
4159	1	Early Horizon/Early Intermediate Period	2 H	94.74	0.008	0.011	0.014	< LOD	< LOD	0.003	< LOD	0.47	0.039	0.867	3.763	Jichja Parco
349		Middle Nasca	3 E V I	96.29	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.517	0.013	0.57	2.481	Jichja Parco
534		Middle Nasca	2 J V I	94.76	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.48	0.039	0.861	3.738	Jichja Parco
1180	3	Middle Nasca	2 J V I	93.87	0.008	0.011	0.014	0.002	0.002	0.003	0.002	0.477	0.054	1.015	4.459	Jichja Parco
1180	5	Middle Nasca		97.18	0.01	0.013	0.016	0.003	< LOD	0.003	< LOD	0.533	< LOD	0.405	1.767	Jichja Parco
2416		Middle Nasca		97.12	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.535	< LOD	0.413	1.807	Jichja Parco
556	2	Late Nasca	3 A V II	94.47	0.008	0.011	0.013	< LOD	0.002	0.003	0.003	0.44	0.04	0.897	4.036	Jichja Parco

PAP-No.	Sub-No.	Periods	Type	Bal (%)	Zr (%)	Sr (%)	Rb (%)	Bi (%)	Pb (%)	Zn (%)	Cu (%)	Fe (%)	Mn (%)	V (%)	Ti (%)	Source
		Average Error pXRF		**0.078**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.005**	**0.003**	**0.020**	**0.078**	
12		Early Horizon/Middle Horizon	1 K	96.89	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.535	< LOD	0.458	1.996	Jichja Parco
17		Early Horizon/Middle Horizon	3 D V I	93.35	0.006	0.011	0.011	< LOD	0.003	0.005	0.005	0.405	0.054	1.066	5.009	Cerro Huenul
63		Early Horizon/Middle Horizon	1 H	96.67	0.01	0.013	0.016	0.002	< LOD	0.003	< LOD	0.547	< LOD	0.495	2.161	Jichja Parco
70		Early Horizon/Middle Horizon	1 A	95.13	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.511	0.033	0.784	3.425	Jichja Parco
93		Early Horizon/Middle Horizon	1 C	97.09	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.516	< LOD	0.424	1.854	Jichja Parco
365	2	Early Horizon/Middle Horizon	1 C	95.22	0.009	0.012	0.015	0.002	0.003	0.004	0.003	0.521	0.033	0.735	3.364	Jichja Parco
583	1	Early Horizon/Middle Horizon	1 K	95.18	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.566	0.034	0.769	3.327	Jichja Parco
628	1	Early Horizon/Middle Horizon	3 D V I	97.07	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.555	< LOD	0.417	1.832	Jichja Parco
675		Early Horizon/Middle Horizon	1 K	94.07	0.008	0.011	0.013	< LOD	0.003	0.004	0.003	0.47	0.048	0.951	4.336	Jichja Parco
752		Early Horizon/Middle Horizon	1 K	94.94	0.009	0.012	0.015	< LOD	0.002	0.003	< LOD	0.49	0.034	0.818	3.596	Jichja Parco
767	8	Early Horizon/Middle Horizon	1 C	96.60	0.01	0.012	0.016	0.002	0.002	0.002	< LOD	0.502	< LOD	0.518	2.254	Jichja Parco
780	3	Early Horizon/Middle Horizon	1 H	97.00	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.527	< LOD	0.436	1.921	Jichja Parco
828	1	Early Horizon/Middle Horizon	3 D V I	94.88	0.009	0.012	0.015	0.002	0.002	0.003	< LOD	0.489	0.035	0.835	3.64	Jichja Parco
828	4	Early Horizon/Middle Horizon	1 K	95.58	0.007	0.01	0.011	< LOD	0.003	0.005	0.005	0.405	0.057	1.097	5.112	Jichja Parco
828	6	Early Horizon/Middle Horizon	3 D V I	93.21	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.515	0.024	0.707	3.049	Cerro Huenul
873	4	Early Horizon/Middle Horizon	1 H	94.31	0.008	0.011	0.013	< LOD	0.002	0.003	0.003	0.442	0.041	0.923	4.169	Jichja Parco
894		Early Horizon/Middle Horizon	1 A	95.76	0.009	0.013	0.017	0.002	0.002	0.003	< LOD	0.56	0.023	0.664	2.873	Jichja Parco
907		Early Horizon/Middle Horizon	1 K	97.36	0.01	0.012	0.016	< LOD	< LOD	0.002	< LOD	0.476	< LOD	0.383	1.673	Jichja Parco
1054		Early Horizon/Middle Horizon	1 C	96.89	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.529	< LOD	0.458	1.998	Jichja Parco
1060		Early Horizon/Middle Horizon	1 H	94.09	0.008	0.011	0.013	< LOD	0.002	0.004	0.003	0.474	0.044	0.951	4.32	Jichja Parco
1180	4	Early Horizon/Middle Horizon	1 K	94.83	0.009	0.012	0.015	0.002	0.002	0.003	0.003	0.491	0.035	0.829	3.69	Jichja Parco
1365		Early Horizon/Middle Horizon	1 A	96.21	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.537	0.011	0.587	2.536	Jichja Parco
1779	1	Early Horizon/Middle Horizon	1 H	95.94	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.552	0.016	0.616	2.759	Jichja Parco
2225	1	Early Horizon/Middle Horizon	1 A	94.88	0.008	0.01	0.013	< LOD	< LOD	0.002	< LOD	0.425	0.025	0.729	3.83	Jichja Parco
2237	2	Early Horizon/Middle Horizon	3 B V I	95.01	0.008	0.011	0.013	< LOD	< LOD	0.002	< LOD	0.431	0.024	0.758	3.658	Jichja Parco
2350	1	Early Horizon/Middle Horizon	3 B V I	92.74	0.006	0.008	0.01	< LOD	< LOD	0.002	< LOD	0.348	0.053	1.043	5.705	Jichja Parco
2411		Early Horizon/Middle Horizon	1 K	97.70	0.017	0.026	0.014	< LOD	0.003	0.005	< LOD	0.869	< LOD	0.23	1.056	Lisahuacho
2707	2	Early Horizon/Middle Horizon	1 H	97.81	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.53	< LOD	0.287	1.266	Jichja Parco
2904	7	Early Horizon/Middle Horizon	3 D V I	96.33	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.516	0.011	0.561	2.461	Jichja Parco
3751		Early Horizon/Middle Horizon	3 D V I	94.74	0.008	0.011	0.014	< LOD	0.002	0.003	0.002	0.468	0.036	0.846	3.785	Jichja Parco
3910		Early Horizon/Middle Horizon	3 B V I	95.02	0.009	0.011	0.014	< LOD	< LOD	0.003	< LOD	0.458	0.033	0.816	3.551	Jichja Parco
4153	1	Early Horizon/Middle Horizon	1 C	95.59	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.489	0.023	0.703	3.075	Jichja Parco
4156	3	Early Horizon/Middle Horizon	1 K	94.95	0.009	0.012	0.014	0.002	0.002	0.004	0.002	0.499	0.033	0.794	3.6	Jichja Parco
4159	2	Early Horizon/Middle Horizon	1 A	96.60	0.009	0.012	0.015	0.002	< LOD	0.002	< LOD	0.482	< LOD	0.522	2.271	Jichja Parco
4162		Early Horizon/Middle Horizon		94.96	0.008	0.011	0.014	< LOD	< LOD	0.003	< LOD	0.478	0.035	0.824	3.59	Jichja Parco

PAP-No.	Sub-No.	Periods	Type	Bal (%)	Zr (%)	Sr (%)	Rb (%)	Bi (%)	Pb (%)	Zn (%)	Cu (%)	Fe (%)	Mn (%)	V (%)	Ti (%)	Source
Average Error pXRF				**0.078**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.005**	**0.003**	**0.020**	**0.078**	
4165	3	Early Horizon/Middle Horizon	1 K	95.91	0.01	0.013	0.016	0.002	< LOD	0.003	< LOD	0.519	0.018	0.643	2.789	Jichja Parco
4166	1	Early Horizon/Middle Horizon	1 H	95.91	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.497	0.027	0.744	3.211	Jichja Parco
4166	2	Early Horizon/Middle Horizon	1 K	95.40	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.518	0.018	0.645	2.788	Jichja Parco
4166	3	Early Horizon/Middle Horizon	1 K	96.68	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.53	< LOD	0.499	2.165	Jichja Parco
4167		Early Horizon/Middle Horizon	1 A	96.31	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.524	0.014	0.569	2.464	Jichja Parco
4761	3	Early Horizon/Middle Horizon	1 A	97.59	0.009	0.011	0.015	< LOD	< LOD	0.002	< LOD	0.474	0.017	0.651	2.877	Jichja Parco
4761	7	Early Horizon/Middle Horizon	1 K	95.86	0.01	0.013	0.016	0.002	< LOD	0.003	< LOD	0.52	< LOD	0.33	1.451	Jichja Parco
4763		Early Horizon/Middle Horizon	1 H	97.80	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.526	< LOD	0.283	1.279	Jichja Parco
4764	1	Early Horizon/Middle Horizon	1 A	95.50	0.008	0.011	0.014	0.002	< LOD	0.002	< LOD	0.443	0.017	0.674	3.247	Jichja Parco
4809	1	Early Horizon/Middle Horizon	1 K	97.31	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.53	< LOD	0.378	1.665	Jichja Parco
4810	3	Early Horizon/Middle Horizon	1 A	97.39	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.533	< LOD	0.363	1.595	Jichja Parco
4812		Early Horizon/Middle Horizon	1 K	95.86	0.009	0.012	0.015	0.002	0.002	0.003	< LOD	0.512	0.018	0.643	2.846	Jichja Parco
4819	2	Early Horizon/Middle Horizon	1 C	97.08	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.516	< LOD	0.424	1.861	Jichja Parco
267		Early Intermediate Period/Middle Horizon	2 C	95.58	0.009	0.011	0.015	< LOD	< LOD	0.003	< LOD	0.46	0.023	0.718	3.095	Jichja Parco
751	2	Early Intermediate Period/Middle Horizon	5 C	95.89	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.543	0.015	0.631	2.797	Jichja Parco
763	1	Early Intermediate Period/Middle Horizon	2 A	93.67	0.008	0.011	0.013	0.002	0.002	0.004	0.002	0.513	0.059	1.05	4.588	Jichja Parco
785	1	Early Intermediate Period/Middle Horizon	5 C	93.57	0.007	0.01	0.012	< LOD	0.002	0.004	0.004	0.434	0.053	1.047	4.774	Jichja Parco
843	1	Early Intermediate Period/Middle Horizon	2 C	94.70	0.008	0.011	0.014	< LOD	< LOD	0.003	< LOD	0.453	0.038	0.877	3.818	Jichja Parco
928	1	Early Intermediate Period/Middle Horizon	3 E	96.79	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.51	< LOD	0.48	2.098	Jichja Parco
972	2	Early Intermediate Period/Middle Horizon	3 E	96.61	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.503	0.006	0.515	2.245	Jichja Parco
1109	1	Early Intermediate Period/Middle Horizon	2 C	96.29	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.498	0.011	0.577	2.507	Jichja Parco
4131	2	Early Intermediate Period/Middle Horizon	5 C	96.98	0.01	0.013	0.016	0.002	< LOD	0.003	< LOD	0.532	< LOD	0.439	1.926	Jichja Parco
4155	2	Early Intermediate Period/Middle Horizon	2 C	96.57	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.558	0.006	0.511	2.23	Jichja Parco
4158		Early Intermediate Period/Middle Horizon	5 C	95.12	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.504	0.031	0.796	3.433	Jichja Parco
4761	1	Early Intermediate Period/Middle Horizon	2 C	97.46	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.527	< LOD	0.351	1.544	Jichja Parco
4802		Early Intermediate Period/ Middle Horizon		98.04	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.541	< LOD	0.241	1.074	Jichja Parco
4805		Early Intermediate Period/Middle Horizon	2 C	97.38	0.01	0.012	0.016	0.002	< LOD	0.002	< LOD	0.514	< LOD	0.37	1.622	Jichja Parco
4806	1	Early Intermediate Period/Middle Horizon	3 E	96.33	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.528	0.012	0.557	2.454	Jichja Parco
4810	1	Early Intermediate Period/Middle Horizon	2 C	97.02	0.009	0.012	0.015	0.002	< LOD	0.002	< LOD	0.476	< LOD	0.446	1.941	Jichja Parco
601	2	Wari	3 C	96.07	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.543	0.016	0.607	2.643	Jichja Parco
609	1	Wari	3 C	96.15	0.009	0.012	0.016	0.002	< LOD	0.002	< LOD	0.518	0.015	0.598	2.599	Jichja Parco
760	7	Wari	3 C	96.86	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.508	< LOD	0.468	2.038	Jichja Parco
831	1	Wari	3 B	94.79	0.008	0.011	0.013	< LOD	< LOD	0.002	< LOD	0.441	0.035	0.863	3.755	Jichja Parco
843	3	Wari	3 B	94.96	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.516	0.037	0.825	3.544	Jichja Parco
914	4	Wari	3 C	95.89	0.01	0.013	0.016	0.002	0.003	0.004	< LOD	0.579	0.018	0.614	2.771	Jichja Parco

PAP-No.	Sub-No.	Periods	Type	Bal (%)	Zr (%)	Sr (%)	Rb (%)	Bi (%)	Pb (%)	Zn (%)	Cu (%)	Fe (%)	Mn (%)	V (%)	Ti (%)	Source
		Average Error pXRF		**0.078**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.005**	**0.003**	**0.020**	**0.078**	
972	1	Wari	3 B	96.11	0.01	0.012	0.016	0.002	0.002	0.002	< LOD	0.506	0.013	0.612	2.636	Jichja Parco
1026		Wari	3 C	94.37	0.008	0.012	0.014	< LOD	0.002	0.003	< LOD	0.484	0.046	0.924	4.055	Jichja Parco
1027	1	Wari	3 C	95.76	0.005	0.014	0.012	< LOD	0.002	0.003	< LOD	0.491	0.033	0.679	2.921	Jichja Parco
1084		Wari	3 C	96.22	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.53	0.013	0.582	2.53	Jichja Parco
4138	1	Wari	2 F V II	96.08	0.008	0.011	0.014	< LOD	< LOD	0.003	0.003	0.447	0.039	0.9	3.989	Jichja Parco
4138	2	Wari	3 B	96.06	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.507	0.014	0.62	2.676	Jichja Parco
4138	3	Wari		94.51	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.527	0.015	0.613	2.64	Jichja Parco
4150	1	Wari	3 B	95.55	0.009	0.011	0.015	0.002	< LOD	0.003	< LOD	0.476	0.022	0.722	3.113	Jichja Parco
4154	1	Wari		94.31	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.532	0.009	0.544	2.366	Jichja Parco
4154	2	Wari		96.43	0.007	0.01	0.012	< LOD	0.002	0.004	0.003	0.412	0.04	0.927	4.195	Jichja Parco
4156	1	Wari	3 I V I	94.75	0.008	0.011	0.014	< LOD	< LOD	0.003	< LOD	0.449	0.036	0.863	3.787	Jichja Parco
4156	2	Wari	3 A	94.49	0.008	0.01	0.013	< LOD	0.002	0.003	0.003	0.432	0.038	0.888	4.035	Jichja Parco
4165	1	Wari	3 C	95.66	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.498	0.022	0.698	3.005	Jichja Parco
4165	2	Wari	3 B	95.20	0.009	0.012	0.015	0.002	< LOD	0.002	< LOD	0.485	0.03	0.782	3.381	Jichja Parco
4166	4	Wari	3 C	97.08	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.546	< LOD	0.419	1.835	Jichja Parco
4761	2	Wari	3 B	96.62	0.01	0.013	0.016	0.003	0.002	0.003	< LOD	0.541	< LOD	0.351	1.54	Jichja Parco
4761	5	Wari	3 A V I	97.45	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.513	< LOD	0.356	1.565	Jichja Parco
4761	6	Wari	3 A	97.46	0.009	0.012	0.016	0.003	< LOD	0.003	< LOD	0.517	0.006	0.512	2.228	Jichja Parco
4764	2	Wari	3 A V I	96.26	0.009	0.012	0.015	< LOD	< LOD	0.003	< LOD	0.683	0.009	0.541	2.385	Jichja Parco
4767		Wari	3 I V III	95.61	0.008	0.011	0.014	< LOD	< LOD	0.003	< LOD	0.453	0.019	0.689	3.108	Jichja Parco
4769		Wari	3 A	96.86	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.52	< LOD	0.463	2.032	Jichja Parco
4806	2	Wari	3 C	96.25	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.508	0.012	0.575	2.534	Jichja Parco
4807	1	Wari	2 I	97.03	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.533	< LOD	0.431	1.883	Jichja Parco
4810	2	Wari	2 I	97.17	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.501	< LOD	0.412	1.798	Jichja Parco
15		Early Horizon/Late Horizon	1 J	94.99	0.009	0.012	0.015	0.002	0.002	0.004	0.002	0.535	0.035	0.787	3.532	Jichja Parco
73		Early Horizon/Late Horizon	5 A V II	95.07	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.483	0.032	0.798	3.496	Jichja Parco
180	3	Early Horizon/Late Horizon	5 A V II	94.40	0.008	0.011	0.013	< LOD	0.002	0.004	0.003	0.492	0.039	0.89	4.06	Jichja Parco
526	1	Early Horizon/Late Horizon	1 J	96.74	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.513	< LOD	0.489	2.134	Jichja Parco
546		Early Horizon/Late Horizon	5 A V II	94.41	0.008	0.011	0.014	< LOD	0.003	0.005	0.003	0.48	0.042	0.891	4.057	Jichja Parco
575	2	Early Horizon/Late Horizon	1 J	93.56	0.007	0.01	0.012	< LOD	0.002	0.004	0.004	0.441	0.055	1.05	4.775	Jichja Parco
751	5	Early Horizon/Late Horizon	1 J	94.12	0.008	0.011	0.013	< LOD	0.002	0.004	0.003	0.465	0.043	0.94	4.306	Jichja Parco
760	4	Early Horizon/Late Horizon	1 J	94.52	0.008	0.012	0.014	< LOD	0.003	0.004	0.002	0.508	0.039	0.872	3.936	Jichja Parco
764	2	Early Horizon/Late Horizon	5 A V II	96.57	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.55	0.008	0.514	2.236	Jichja Parco
770	5	Early Horizon/Late Horizon	5 A V II	93.51	0.007	0.01	0.011	< LOD	0.003	0.005	0.004	0.423	0.054	1.046	4.85	Jichja Parco
780	2	Early Horizon/Late Horizon	5 A V II	96.93	0.01	0.013	0.016	0.002	< LOD	0.002	< LOD	0.525	< LOD	0.451	1.972	Jichja Parco

PAP-No.	Sub-No.	Periods	Type	Bal (%)	Zr (%)	Sr (%)	Rb (%)	Bi (%)	Pb (%)	Zn (%)	Cu (%)	Fe (%)	Mn (%)	V (%)	Ti (%)	Source
Average Error pXRF				**0.078**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.005**	**0.003**	**0.020**	**0.078**	
828	5	Early Horizon/Late Horizon	1 J	93.67	0.008	0.011	0.013	< LOD	0.003	0.005	0.004	0.498	0.055	1.015	4.636	Jichja Parco
873	1	Early Horizon/Late Horizon	5 A V II	96.71	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.518	< LOD	0.495	2.153	Jichja Parco
1010	1	Early Horizon/Late Horizon	5 A V II	94.42	0.008	0.011	0.013	< LOD	0.003	0.004	0.004	0.465	0.037	0.882	4.077	Jichja Parco
1108		Early Horizon/Late Horizon	1 J	96.72	0.005	0.014	0.012	< LOD	0.002	0.003	< LOD	0.459	0.015	0.505	2.184	Callejones
2403	2	Early Horizon/Late Horizon	1 J	96.58	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.526	< LOD	0.493	2.278	Jichja Parco
4165	4	Early Horizon/Late Horizon	1 J	95.72	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.533	0.021	0.666	2.939	Jichja Parco
556	1	Early Horizon/Late Intermediate Period	5 C V IV	96.40	0.01	0.013	0.017	0.002	0.002	0.003	< LOD	0.549	0.008	0.545	2.37	Cerro Huenul
751	7	Early Horizon/Late Intermediate Period	5 C V IV	94.92	0.008	0.013	0.014	0.002	0.003	0.004	< LOD	0.527	0.033	0.793	3.6	Jichja Parco
819	2	Early Horizon/Late Intermediate Period	5 C V IV	95.01	0.008	0.011	0.013	< LOD	< LOD	0.003	0.002	0.445	0.029	0.81	3.591	Jichja Parco
830	2	Early Horizon/Late Intermediate Period	5 C V IV	95.62	0.009	0.011	0.014	< LOD	< LOD	0.003	< LOD	0.48	0.02	0.694	3.064	Jichja Parco
3530		Early Horizon/Late Intermediate Period	5 C V IV	95.40	0.009	0.012	0.014	0.002	0.002	0.004	< LOD	0.511	0.026	0.716	3.228	Jichja Parco
1027	2	Late Horizon	5 A	95.78	0.009	0.012	0.015	0.002	0.002	0.003	< LOD	0.509	0.019	0.657	2.917	Callejones
16		Undated Obsidian artifacts	5 C V III	97.53	0.01	0.013	0.017	0.002	< LOD	0.003	< LOD	0.541	< LOD	0.335	1.478	Jichja Parco
43		Undated Obsidian artifacts	5 B V I	96.06	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.528	0.017	0.614	2.659	Jichja Parco
138		Undated Obsidian artifacts	3 D	96.30	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.531	0.012	0.567	2.471	Jichja Parco
152		Undated Obsidian artifacts	3 H	95.81	0.009	0.012	0.015	0.002	< LOD	0.002	< LOD	0.484	0.019	0.67	2.896	Jichja Parco
251		Undated Obsidian artifacts	3 C V I	96.27	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.529	0.014	0.572	2.487	Jichja Parco
278	2	Undated Obsidian artifacts	3 I	96.96	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.523	< LOD	0.446	1.948	Jichja Parco
365	1	Undated Obsidian artifacts	3 D	93.19	0.007	0.01	0.01	< LOD	0.003	0.005	0.005	0.423	0.057	1.083	5.127	Cerro Huenul
398		Undated Obsidian artifacts	3 I V I	92.88	0.006	0.009	0.01	< LOD	0.003	0.005	0.005	0.404	0.063	1.146	5.384	Cerro Huenul
462	2	Undated Obsidian artifacts	3 I V II	94.92	0.009	0.012	0.015	0.002	0.003	0.004	< LOD	0.553	0.037	0.808	3.558	Jichja Parco
556	3	Undated Obsidian artifacts	3 I V II	95.43	0.009	0.012	0.015	< LOD	0.002	0.003	< LOD	0.51	0.027	0.721	3.185	Jichja Parco
575	1	Undated Obsidian artifacts	1 J V I	95.99	0.009	0.012	0.016	0.002	< LOD	0.002	< LOD	0.521	0.019	0.63	2.719	Jichja Parco
576		Undated Obsidian artifacts	3 I V I	94.08	0.008	0.011	0.014	0.002	0.003	0.004	0.003	0.501	0.049	0.953	4.297	Jichja Parco
582		Undated Obsidian artifacts		94.11	0.008	0.011	0.013	0.002	0.002	0.004	0.003	0.488	0.048	0.954	4.283	Jichja Parco
583	2	Undated Obsidian artifacts	3 E V I	96.51	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.588	0.008	0.517	2.258	Jichja Parco
591		Undated Obsidian artifacts	3 I V III	94.20	0.008	0.011	0.013	< LOD	0.002	0.004	0.003	0.471	0.045	0.941	4.224	Jichja Parco
608		Undated Obsidian artifacts		96.49	0.01	0.013	0.017	0.002	0.002	0.003	< LOD	0.556	0.009	0.526	2.291	Jichja Parco
609	3	Undated Obsidian artifacts	3 C V II	96.10	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.55	0.017	0.597	2.61	Jichja Parco
751	3	Undated Obsidian artifacts	1 D	96.54	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.59	0.008	0.509	2.233	Jichja Parco
760	3	Undated Obsidian artifacts	3 C V II	93.81	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.501	0.007	0.557	2.442	Jichja Parco
760	5	Undated Obsidian artifacts	3 I V I	96.07	0.007	0.011	0.013	< LOD	0.003	0.005	0.004	0.536	0.051	0.975	4.507	Jichja Parco
760	6	Undated Obsidian artifacts	3 C V II	96.37	0.01	0.012	0.016	0.002	< LOD	0.002	< LOD	0.502	0.015	0.618	2.672	Jichja Parco
763	2	Undated Obsidian artifacts	3 I V II	95.04	0.009	0.012	0.015	0.002	0.002	0.003	< LOD	0.5	0.033	0.795	3.514	Jichja Parco
766	1	Undated Obsidian artifacts	5 B V I	96.25	0.009	0.012	0.014	0.002	0.002	0.003	< LOD	0.492	0.037	0.832	3.648	Jichja Parco

PAP-No.	Sub-No.	Periods	Type	Bal (%)	Zr (%)	Sr (%)	Rb (%)	Bi (%)	Pb (%)	Zn (%)	Cu (%)	Fe (%)	Mn (%)	V (%)	Ti (%)	Source
		Average Error pXRF		0.078	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.005	0.003	0.020	0.078	
766	2	Undated Obsidian artifacts		94.87	0.009	0.013	0.016	0.002	0.002	0.003	< LOD	0.543	0.01	0.56	2.512	Jichja Parco
767	3	Undated Obsidian artifacts	8 A	97.18	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.523	0.026	0.719	3.102	Jichja Parco
767	6	Undated Obsidian artifacts		95.51	0.01	0.013	0.017	0.002	< LOD	0.003	< LOD	0.543	< LOD	0.398	1.753	Jichja Parco
770	1	Undated Obsidian artifacts	5 B V I	94.16	0.009	0.012	0.015	< LOD	0.002	0.003	< LOD	0.513	0.025	0.741	3.251	Jichja Parco
770	4	Undated Obsidian artifacts	3 I V II	95.35	0.009	0.012	0.015	< LOD	0.002	0.003	< LOD	0.483	0.029	0.781	3.41	Jichja Parco
770	6	Undated Obsidian artifacts		95.18	0.008	0.011	0.014	< LOD	0.003	0.005	0.003	0.475	0.045	0.927	4.272	Jichja Parco
771	3	Undated Obsidian artifacts	8 A	96.25	0.009	0.012	0.015	0.002	0.002	0.003	< LOD	0.635	0.01	0.549	2.432	Jichja Parco
774	3	Undated Obsidian artifacts		95.34	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.545	0.028	0.744	3.218	Jichja Parco
780	1	Undated Obsidian artifacts		96.15	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.526	0.014	0.597	2.587	Jichja Parco
784		Undated Obsidian artifacts	5 D	95.61	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.477	0.021	0.709	3.067	Jichja Parco
785	2	Undated Obsidian artifacts		93.55	0.007	0.011	0.012	< LOD	0.003	0.004	0.004	0.437	0.056	1.047	4.789	no origin
791	1	Undated Obsidian artifacts	5 B V I	95.88	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.532	< LOD	0.457	2.003	Jichja Parco
791	3	Undated Obsidian artifacts	5 D V I	96.13	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.506	0.018	0.65	2.82	Jichja Parco
791	4	Undated Obsidian artifacts	3 I V II	96.88	0.009	0.013	0.016	0.002	0.002	0.003	< LOD	0.515	0.012	0.591	2.626	Jichja Parco
800	4	Undated Obsidian artifacts	5 D V I	93.71	0.007	0.011	0.012	< LOD	0.003	0.004	0.004	0.429	0.053	1.025	4.658	no origin
828	3	Undated Obsidian artifacts	5 E	94.83	0.01	0.012	0.016	0.002	< LOD	0.002	< LOD	0.533	< LOD	0.472	2.051	Jichja Parco
828	7	Undated Obsidian artifacts	5 C V III	96.60	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.54	0.006	0.507	2.221	Jichja Parco
828	9	Undated Obsidian artifacts	3 E V I	96.82	0.009	0.011	0.014	< LOD	< LOD	0.002	< LOD	0.459	0.036	0.855	3.7	Jichja Parco
831	2	Undated Obsidian artifacts	5 E	96.31	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.516	0.014	0.571	2.468	Jichja Parco
831	3	Undated Obsidian artifacts	5 B V I	94.73	0.008	0.012	0.014	< LOD	0.002	0.004	< LOD	0.498	0.037	0.844	3.769	Jichja Parco
836		Undated Obsidian artifacts	3 I V II	96.96	0.01	0.013	0.017	0.002	0.002	0.003	< LOD	0.576	< LOD	0.435	1.904	Jichja Parco
840	1	Undated Obsidian artifacts	5 C V I	94.79	0.01	0.013	0.017	0.003	0.002	0.003	< LOD	0.566	< LOD	0.221	1.004	Jichja Parco
840	2	Undated Obsidian artifacts	3 C V II	98.10	0.008	0.012	0.014	0.002	0.002	0.003	< LOD	0.496	0.037	0.837	3.721	Jichja Parco
843	4	Undated Obsidian artifacts	3 E V I	93.97	0.008	0.011	0.014	< LOD	< LOD	0.003	< LOD	0.477	0.053	1.001	4.375	Jichja Parco
873	2	Undated Obsidian artifacts	5 C V I	96.31	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.476	0.008	0.577	2.507	Jichja Parco
873	3	Undated Obsidian artifacts		96.55	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.513	< LOD	0.526	2.286	Jichja Parco
910	2	Undated Obsidian artifacts	5 C V III	95.51	0.009	0.011	0.014	< LOD	< LOD	0.003	< LOD	0.464	0.023	0.727	3.162	Jichja Parco
912		Undated Obsidian artifacts	3 E V I	95.73	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.538	0.022	0.671	2.916	Jichja Parco
962		Undated Obsidian artifacts	3 I V I	95.95	0.01	0.012	0.016	0.002	0.002	0.003	< LOD	0.531	0.019	0.635	2.747	Jichja Parco
1032	1	Undated Obsidian artifacts	3 I	96.04	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.503	0.017	0.619	2.702	Jichja Parco
1037	2	Undated Obsidian artifacts	3 I V II	96.58	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.524	< LOD	0.516	2.255	Jichja Parco
1056		Undated Obsidian artifacts	1 D V I	96.12	0.01	0.013	0.016	0.002	0.002	0.004	0.003	0.54	0.016	0.598	2.597	Jichja Parco
1066		Undated Obsidian artifacts	1 D	93.63	0.008	0.011	0.014	< LOD	0.002	0.004	0.002	0.486	0.058	1.049	4.66	Jichja Parco
1067	1	Undated Obsidian artifacts	3 E V I	94.04	0.008	0.011	0.014	< LOD	0.002	0.004	< LOD	0.473	0.053	0.982	4.333	Jichja Parco
1067	2	Undated Obsidian artifacts	5 D	95.13	0.009	0.012	0.015	0.002	0.002	0.004	< LOD	0.499	0.032	0.78	3.442	Jichja Parco

PAP-No.	Sub-No.	Periods	Type	Bal (%)	Zr (%)	Sr (%)	Rb (%)	Bi (%)	Pb (%)	Zn (%)	Cu (%)	Fe (%)	Mn (%)	V (%)	Ti (%)	Source
Average Error pXRF				**0.078**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.005**	**0.003**	**0.020**	**0.078**	
1074		Undated Obsidian artifacts	3 H	94.51	0.008	0.011	0.014	0.002	0.002	0.003	< LOD	0.48	0.043	0.899	3.946	Jichja Parco
1081		Undated Obsidian artifacts	5 C V I	93.91	0.008	0.011	0.013	< LOD	0.003	0.004	0.003	0.481	0.053	0.993	4.445	Jichja Parco
1109	2	Undated Obsidian artifacts	3 I	96.24	0.009	0.012	0.016	0.002	0.002	0.003	< LOD	0.504	0.013	0.583	2.534	Jichja Parco
1113		Undated Obsidian artifacts		96.80	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.517	< LOD	0.477	2.083	Jichja Parco
1769		Undated Obsidian artifacts	5 C V I	96.18	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.505	0.011	0.572	2.61	Jichja Parco
2237	1	Undated Obsidian artifacts	2 F V II	95.58	0.009	0.011	0.015	0.002	< LOD	0.002	< LOD	0.495	0.023	0.699	3.086	Jichja Parco
2707	5	Undated Obsidian artifacts		95.11	0.008	0.011	0.015	< LOD	< LOD	0.003	< LOD	0.494	0.029	0.739	3.506	Jichja Parco
2904	8	Undated Obsidian artifacts	3 E V I	96.84	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.518	< LOD	0.471	2.051	Jichja Parco
3551		Undated Obsidian artifacts	3 I	96.11	0.01	0.013	0.017	0.002	0.002	0.003	< LOD	0.542	0.016	0.602	2.607	Jichja Parco
4150	3	Undated Obsidian artifacts	1 I	96.80	0.01	0.013	0.016	0.002	< LOD	0.003	< LOD	0.537	< LOD	0.474	2.062	Jichja Parco
4153	3	Undated Obsidian artifacts		96.18	0.009	0.012	0.016	0.002	< LOD	0.003	< LOD	0.525	0.013	0.592	2.564	Jichja Parco
4155	1	Undated Obsidian artifacts		96.34	0.008	0.011	0.013	< LOD	< LOD	0.002	< LOD	0.421	0.006	0.581	2.54	Jichja Parco
4156	5	Undated Obsidian artifacts	2 G	96.00	0.009	0.012	0.015	0.002	< LOD	0.003	< LOD	0.499	0.017	0.63	2.73	Jichja Parco
4157	1	Undated Obsidian artifacts		92.76	0.006	0.01	0.011	< LOD	0.003	0.006	0.006	0.5	0.069	1.154	5.391	Cerro Huenul
4157	2	Undated Obsidian artifacts		92.95	0.007	0.011	0.012	< LOD	0.003	0.006	0.007	0.494	0.065	1.11	5.252	no origin
4807	2	Undated Obsidian artifacts	1 D V I	97.22	0.01	0.013	0.016	0.002	0.002	0.003	< LOD	0.538	< LOD	0.393	1.729	Jichja Parco
4809	2	Undated Obsidian artifacts	8 A	97.37	0.01	0.012	0.016	0.002	< LOD	0.003	< LOD	0.529	< LOD	0.369	1.618	Jichja Parco

Tab. 7: Element concnetration of 199 metal artifacts from the PAP and standard deviation for the pXRF In-situ nondestructive analyses were perfomed using a Niton XL3t GOLDD device. Samples were provided by the PAP. (LOD = Limit of Detection).

PAP-No.	Sub-No.	Site	Age	Description	Sb (%)	Sn (%)	Cd (%)	Ag (%)	Ru (%)	Mo (%)	Nb (%)	Zr (%)	Bi (%)	Pb (%)	Hg (%)	Au (%)	As (%)	Se (%)	W (%)	Zn (%)	Cu (%)	Ni (%)	Co (%)	Fe (%)	V (%)	S (%)	P (%)
Average Error pXRF					0.017	0.036	0.010	0.511	0.002	0.012	0.008	0.005	0.006	0.011	0.070	0.905	0.069	0.027	0.047	0.016	1.222	0.013	0.056	0.087	0.019	0.069	0.343
1802		Mollake Chico	Early Paracas	anillo de oro	0	0	0	18.707	0	0	0	0	0.142	0.163	0	66.27	0	0	0	0	1.612	0	0	1.886	0	0	7.763
806		806	Paracas	metal	0.284	0.28	0	48.132	0	0	0	0	0.012	0.342	0	0.124	0.028	0	0.103	0.055	37.72	0	0	0.735	0	0	0.992
1056		1056	Late Paracas	aguja de cobre	0	0	0	0	0	0.012	0	0	0	0	0	0	0	0	0	0.12	88.943	0	0	0.156	0	0	0.926
411		Los Molinos	Nasca 3	metal	0	0	0	0	0	0	0.013	0.03	0	0	0	0	0.095	0	0	0.093	96.058	0	0	0.09	0	0	0
401		Los Molinos	Middle Nasca	otros metal	0	0	0	0	0	0.143	0.188	0.181	0	1.062	0	39.426	0	0	0	0.975	2.355	0	0	44.226	0	0	5.758
1180	1	La Muña	Middle Nasca		0.084	0	0	13.007	0	0	0	0	0.105	0	0.389	67.105	0	0	0	0	1.938	0	0	0.036	0	0	15.513
1180	2	La Muña	Middle Nasca		0.109	0	0	13.465	0	0	0	0	0.106	0	0.306	67.106	0	0	0	0	2.002	0	0	0.108	0	0	14.666
1180	3	La Muña	Middle Nasca		0	0	0	0	0	0.437	0.274	0.245	0	0	0	0	0	0	0	1.365	1.209	0	0	35.411	0	0	0
1180	4	La Muña	Middle Nasca		0	0	0	0	0	0	0.005	0.025	0	0	0	0	0.01	0	0	0.114	85.882	0	0	0.395	0	0	0
1180	5	La Muña	Middle Nasca		0	0	0	0	0	0	0	0.009	0	0	0	0	0.02	0	0	0.097	95.006	0	0	0.088	0	0	0.549
1180		La Muña	Middle Nasca	cuentas de metal	0	0	0	14.044	0	0	0.014	0.011	0.104	0.2	0.38	66.481	0	0	0	0	2.056	0	0	4.107	0	0	10.919
1190		La Muña	Middle Nasca	lamina de cobre	0	0	0	48.824	0	0	0	0	0.127	0	0	2.305	0.02	0.02	0.119	0.047	38.837	0	0	0.186	0	0	5.653
		La Muña	Middle Nasca	lamina de oro y plata	0	0	0	19.417	0	0.009	0	0	0.152	0	0	57.588	0	0	0.179	0	4.583	0	0	0.298	0	0	13.659
464	1		Nasca 4-5	tupus de cobre	0	0	0	0	0.007	0	0	0.009	0	0.112	0	0	0.026	0	0	0.123	94.56	0	0	0.038	0	0	0.448
464	2		Nasca 4-5	tupus de cobre	0	0	0	0	0	0.006	0	0	0	0	0	0	0	0	0	0.101	93.229	0	0	0.063	0	0	1.084
468	1	468	Nasca 4-5	tumi	0	0	0	0	0	0.017	0	0	0	0	0	0	0	0	0	0.145	92.505	0	0	0.195	0	0	0
468	2	468	Nasca 4-5	tumi	0	0	0	0	0	0	0.011	0.033	0	0	0	0	0.012	0	0	0.115	94.555	0	0	0.086	0	0	0.397
468	3	468	Nasca 4-5	tumi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.112	91.162	0	0	0.08	0	0	0
1180		La Muña	Nasca 5	laminas de cobre	0	0.137	0	22.746	0	0	0	0	0.019	0	0	0	0.011	0	0.103	0.037	48.676	0	0	0.914	0	0	0
1190	C1	La Muña	Nasca 5	oro en forma de ajies	0	0	0	7.795	0	0	0	0	0.105	0	0	69.213	0	0	0.203	0	2.474	0	0	0.106	0	0	18.302
1190	C2	La Muña	Nasca 5	oro en forma de ajies	0	0	0	8.294	0	0.006	0	0	0.104	0	0	69.676	0	0	0.138	0	2.898	0	0	0.388	0	0	17.358

PAP-No.	Sub-No.	Site	Age	Description	Sb (%)	Sn (%)	Cd (%)	Ag (%)	Ru (%)	Mo (%)	Nb (%)	Zr (%)	Bi (%)	Pb (%)	Hg (%)	Au (%)	As (%)	Se (%)	W (%)	Zn (%)	Cu (%)	Ni (%)	Co (%)	Fe (%)	V (%)	S (%)	P (%)
Average Error pXRF					0.017	0.036	0.010	0.511	0.002	0.012	0.008	0.005	0.006	0.011	0.070	0.905	0.069	0.027	0.047	0.016	1.222	0.013	0.056	0.087	0.019	0.069	0.343
1190	C3	La Muña	Nasca 5	oro en forma de ajies	0	0	0	9.065	0	0	0	0	0.107	0	0	67.415	0	0	0.175	0	3.074	0	0	0.207	0	0	17.611
1190	C4	La Muña	Nasca 5	oro en forma de ajies	0	0	0	8.198	0	0	0	0	0.089	0	0	69.539	0	0	0.197	0	3.127	0	0	0.484	0	0	16.668
1814	1	Mollake Chico	Nasca	tumi	0	1.203	0	0	0	0	0	0	0	0	0	0	0.055	0	0	0.081	84.681	0.018	0	0.196	0	0	1.061
1814	2	Mollake Chico	Nasca	tumi	0	0	0	0	0	0.005	0.006	0.025	0	0	0	0	0	0	0	0.139	89.488	0	0	0.23	0	0	0
1814	3	Mollake Chico	Nasca	tumi	0	0	0	0	0	0	0.01	0.038	0	0	0	0	0	0	0	0.129	94.342	0	0	0.071	0	0	1.378
2595		Chillo	Nasca	aguja de cobre	0	0.151	0	0	0	0.008	0	0	0	0	0	0	0.018	0	0	0.127	71.79	0	0	0.94	0	0	0
2848		Hanaq Pacha	Nasca	aguja de cobre	0	0	0	0	0	0.01	0	0	0	0.045	0	0	0.026	0	0	0.12	84.001	0	0	0.305	0	0	0
4780	1	814	Nasca/Wari	figura zoomorfa de	0	0	0	0	0.006	0.004	0	0.009	0.007	0.177	0	0	6.488	0	0	0.109	52.525	0	0	0.871	0	0	12.957
4780	2	814	Nasca/Wari	tupus de cobre	0	0	0	0	0	0	0	0.016	0	0.026	0	0	1.454	0	0	0.128	66.216	0	0	0.347	0.068	0	13.834
4780	3	814	Nasca/Wari	aguja de cobre	0	0	0	0	0	0.028	0.023	0.017	0	0.063	0	0	1.347	0	0	0.123	57.902	0	0	3.449	0	0	6.783
4780	4	814	Nasca/Wari	tupus pequeño	0.041	0	0	0	0.005	0.004	0	0	0.012	0.091	0	0	1.961	0	0	0.116	71.357	0	0	0.936	0.175	0	10.312
4780	5	814	Nasca/Wari	tupus grande	0	0	0	0	0	0	0	0	0.05	0	0	0	3.256	0	0	0.117	74.681	0	0	0.523	0.089	0	11.096
4799	1	814	Nasca/Wari	material de copa	0	0	0	46.291	0	0	0	0	0.406	0.135	0	0	0	0	0.072	0.025	33.433	0	0	1.161	0.272	0	6.984
4799	2	814	Nasca/Wari	tupus de cobre	0.051	0.034	0	0	0.005	0	0	0	0.017	0.024	0	0	7.055	0	0	0.135	71.869	0	0	0.372	0	0	16.534
4799	3	814	Nasca/Wari	Hallazgo 18	0	0	0	0	0	0.005	0	0	0.064	0.284	0.083	0	1.528	0	0	0.106	67.133	0	0	0.897	0	0	7.853
4799	4	814	Nasca/Wari	figura zoomorfa de	0	0	0	0	0	0	0	0	0.013	0.045	0	0.085	3.973	0	0	0.162	64.214	0	0	1.189	0	0	12.004
4799	5	814	Nasca/Wari	figura zoomorfa de	0	0	0	0	0	0	0	0	0.021	0.278	0	0	4.069	0	0	0.143	68.453	0	0	0.533	0	0	12.107
4799	6	814	Nasca/Wari	Hallazgo 13	0	0	0	0	0	0	0.005	0.018	0.02	0	0	0	0.692	0	0	0.13	59.122	0	0	1.038	0	0	6.586
4799	7	814	Nasca/Wari	tupus de cobre	0	0	0	0	0	0	0	0.013	0.025	0.066	0	0	1.887	0	0	0.149	63.015	0	0	0.631	0.056	0	13.064
4799	8	814	Nasca/Wari	tupus de cobre	0	0	0	0	0	0	0	0.024	0.007	0	0	0	0.857	0	0	0.123	62.259	0.109	0	0.781	0.055	0	14.956
4799	9	814	Nasca/Wari	Hallazgo 17	0	0	0	0	0	0	0	0.009	0.016	0.011	0	0	5.154	0	0	0.145	64.95	0	0	0.412	0	0	13.739
4799	10	814	Nasca/Wari	frag. de tupus	0	0	0	0	0.006	0	0.009	0.026	0.006	0.016	0	0	4.145	0	0	0.12	72.008	0	0	0.251	0	0	13.339
4799	11	814	Nasca/Wari	figurine antropomorfa	0	0	0	0	0.005	0	0.004	0.022	0.007	0.01	0	0	2.036	0	0	0.125	66.027	0	0	0.629	0.033	0	12.47

PAP-No.	Sub-No.	Site	Age	Description	Sb (%)	Sn (%)	Cd (%)	Ag (%)	Ru (%)	Mo (%)	Nb (%)	Zr (%)	Bi (%)	Pb (%)	Hg (%)	Au (%)	As (%)	Se (%)	W (%)	Zn (%)	Cu (%)	Ni (%)	Co (%)	Fe (%)	V (%)	S (%)	P (%)
Average Error pXRF					0.017	0.036	0.010	0.511	0.002	0.012	0.008	0.005	0.006	0.011	0.070	0.905	0.069	0.027	0.047	0.016	1.222	0.013	0.056	0.087	0.019	0.069	0.343
4799	12	814	Nasca/Wari	Hallazgo 14	0	0	0	0	0	0	0	0.014	0.012	0.033	0	0	1.795	0	0	0.138	63.229	0	0	0.597	0.033	0	15.291
4799	13	814	Nasca/Wari	aguja de cobre	0	0	0	0	0.005	0	0	0	0.009	0.011	0	0	3.734	0	0	0.14	70.134	0	0	0.306	0	0	21.306
4799	14	814	Nasca/Wari	aguja de cobre	0	0	0	0	0	0	0	0	0	0.123	0	0	1.763	0	0	0.118	57.28	0	0	3.054	0	0	7.989
4799	15	814	Nasca/Wari	aguja de cobre	0	0	0	0	0	0.017	0	0	0	0.155	0	0	3.839	0	0	0.134	62.246	1.374	0	3.619	0	0	11.442
4953	1	814	Nasca/Wari	tupus de cobre	0	0	0	0	0	0	0	0.017	0.016	0.047	0	0	2.796	0	0	0.137	74.128	0	0	0.392	0	0	15.488
4953	2	814	Nasca/Wari	tupus de cobre	0	0	0	0	0.005	0	0.007	0.021	0.015	0.03	0.079	0	2.24	0	0	0.129	75.511	0	0	0.328	0	0	15.403
49		814	MH	tupus de cobre	0	0	0	0	0.004	0	0	0.045	0.04	0	0	0	1.587	0	0	0.154	38.305	0	0	4.024	0.066	0	5.541
467	1		MH	base de estolica	0	0	0	0	0	0	0	0.012	0	0	0	0	0.024	0	0	0.104	91.254	0.029	0	0.195	0	0	0
467	2		MH	aguaja punzon	0	0	0	0	0	0.02	0.014	0	0	0.105	0	0	1.369	0	0	0.101	89.887	0.044	0	0.273	0	0	0
1177		Los Molinos	MH	cuentas	0	0	0	0	0	0	0	0.01	0	0	0	0	0.031	0	0	0.115	88.175	0	0	0.06	0	0	0.5
3689		Parasmarca	MH	aquaja de cobre	0	0	0	0	0	0.053	0.034	0	0	0	0	0	5.43	0	0	0.085	84.269	0	0	0.181	0	0	1.44
3770		Huaraco	MH	cobre	0	0	0	0	0	0.045	0.042	0.041	0	0	0	0	0.037	0	0	0.141	72.232	0	0	2.083	0	0	0
3910		Lucriche	MH	cobre	0	0	0	64.483	0	0	0	0	0.013	0.026	0.078	0	0.529	0	0	0.032	25.183	0	0	1.142	0	0	1.911
3933		Lucriche	MH	plata	0	0	0	79.215	0	0	0	0	0.011	0.108	0	0	0	0	0	0	5.763	0	0	1.256	0	0	0
3942		Lucriche	MH	laminas de cobre	0	0	0	80.666	0	0	0	0	0.036	0.139	0	0	0	0	0	0	11.814	0	0	1.343	0	0	0
4138	1	Ocoro	MH	tupus de cobre	0	0	0	0	0	0	0	0.009	0.007	0.241	0	0	3.331	0	0	0.084	68.021	0	0	0.394	0	0	8.658
4138	2	Ocoro	MH	tupus de cobre	0.099	0.065	0.026	0	0.006	0	0	0.009	0	0.022	0	0	9.947	0	0	0.063	80.339	0	0	0.125	0	0	4.25
4152		Huayuncalla	MH	tupus de cobre	0	0	0	0	0	0	0	0	0.021	0	0	0	1.4	0	0	0.065	70.028	0.104	0	0.324	0.029	0	3.582
4153		Huayuncalla	MH	pirita	0	0	0	0	0	0	0.023	0.016	0.02	0	0	0	0.027	0	0	0.138	0	0	0	36.116	0	0	0
4153		Huayuncalla	MH		0.028	0	0	0	0	0	0	0.011	0	0.096	0	0	0.992	0	0	0.079	78.093	0.115	0	0.161	0.033	0	5.421
4154		Huayuncalla	MH	tupus de cobre	0	0	0	0	0	0.03	0.02	0.013	0	0.054	0	0	2.914	0	0	0.1	82.373	0	0	0.191	0	0	5.769
4155	1	Huayuncalla	MH	tupus de cobre	0	0	0	0	0	0	0	0.008	0	0.136	0	0	0.581	0	0	0.08	78.169	0	0	0.197	0	0	4.02
4155	2	Huayuncalla	MH	tupus de cobre	0	0	0	0	0	0	0.005	0.013	0	0	0	0	0	0	0	0.102	60.817	0	0	1.013	0.028	0	1.817

PAP-No.	Sub-No.	Site	Age	Description	Sb (%)	Sn (%)	Cd (%)	Ag (%)	Ru (%)	Mo (%)	Nb (%)	Zr (%)	Bi (%)	Pb (%)	Hg (%)	Au (%)	As (%)	Se (%)	W (%)	Zn (%)	Cu (%)	Ni (%)	Co (%)	Fe (%)	V (%)	S (%)	P (%)
Average Error pXRF					0.017	0.036	0.010	0.511	0.002	0.012	0.008	0.005	0.006	0.011	0.070	0.905	0.069	0.027	0.047	0.016	1.222	0.013	0.056	0.087	0.019	0.069	0.343
4155	3	Huayuncalla	MH	tupus de cobre	0	0	0	0	0	0	0	0	0	0	0	0	0.015	0	0	0.072	62.786	0	0	0.577	0.036	0	2.154
4155	4	Huayuncalla	MH	tupus de cobre	0	0	0	0	0	0.018	0.012	0	0.061	0	0	0	1.744	0	0	0.109	56.767	0	0	1.31	0	0	2.133
4156	1	Huayuncalla	MH	tupus de cobre	0	0	0	0	0	0	0.006	0.018	0	0	0	0	0	0	0	0.084	70.848	0	0	0.32	0	0	3.312
4156	2	Huayuncalla	MH	tupus de cobre	0	0	0	0	0	0	0.004	0.017	0.012	0	0	0	0.633	0	0	0.101	68.698	0	0	0.738	0.034	0	2.209
4173	1	814	MH	tupus	0	0	0	0	0.005	0	0	0.02	0.008	0	0	0	1.534	0	0	0.135	57.487	0	0	2.299	0.318	0	3.854
4173	2	814	MH	tupus	0	0	0	0	0	0	0.004	0.01	0	0	0	0	1.221	0	0	0.102	64.431	0	0	0.645	0.101	0	1.949
4173	3	814	MH	tupus	0	0	0	0	0.005	0	0	0.02	0	0.038	0	0	3.612	0	0	0.152	68.246	0	0	0.443	0.377	0	7.02
4173	4	814	MH	tupus	0	0	0	0	0	0	0	0.014	0	0	0	0	0.131	0	0	0.105	81.268	0.025	0	0.383	0	0	1.018
4173	5	814	MH		0	0	0	0	0	0.015	0.011	0.011	0.017	0.105	0	0	0.673	0	0	0.161	48.989	0	0	5.659	0	0	0
4173	6	814	MH	tupus	0	0	0	0	0.006	0	0.004	0.01	0	0.014	0	0	3.977	0	0	0.121	69.138	0	0	0.737	0.115	0	2.725
4173	7	814	MH	tupus	0.03	0.016	0	0	0	0	0.004	0.015	0.005	0	0	0	1.632	0	0	0.097	60.742	0	0	0.803	0.084	0	1.058
4173	8	814	MH	tupus	0	0	0	0	0	0.004	0	0.034	0.025	0	0	0	1.185	0	0	0.149	42.872	0	0	4.442	0.103	0	0.879
4173	9	814	MH	tupus	0	0	0	0	0	0	0.005	0.019	0.009	0.008	0	0	2.399	0	0	0.116	62.545	0	0	1.162	0.136	0	2.333
4173	10	814	MH	tupus	0	0	0	0	0	0	0	0.015	0.006	0	0	0	1.337	0	0	0.116	62.703	0	0	1.194	0.095	0	1.195
4173	11	814	MH	material de cobre	0	0	0	0	0	0	0.004	0.014	0.014	0.607	0	0	3.62	0	0	0.112	61.402	0	0	0.499	0.161	0	5.467
4173	12	814	MH	material de cobre	0	0	0	0	0.005	0	0	0.018	0.005	0.033	0	0	4.328	0	0	0.133	63.218	0	0	0.738	0.296	0	5.553
4173	13	814	MH	tupus	0	0	0	0	0.004	0	0.003	0.01	0.01	0	0	0	0.775	0	0	0.11	58.587	0	0	1.887	0.053	0	0.351
4173	14	814	MH	tupus	0	0	0	0	0	0	0	0	0	0.138	0	0	5.191	0	0	0.129	71.366	0	0	2.152	0.138	0	2.841
4173	15	814	MH	tupus	0	0	0	0	0	0	0.005	0.02	0.008	0.012	0	0	1.83	0	0	0.093	65.108	0	0	0.385	0.13	0	2.085
4173	16	814	MH	tupus	0.044	0.026	0	0	0	0	0	0	0.006	0.035	0	0	5.773	0	0	0.114	71.472	0	0	0.247	0.057	0	2.677
4173	17	814	MH	tupus	0.079	0.057	0.021	0	0.007	0	0	0	0.029	0	0	0	8.523	0	0	0.146	67.602	0	0	0.349	0.177	0	3.852
4173	18	814	MH	tupus	0	0	0	0	0	0.003	0	0.01	0.006	0.014	0	0	2.052	0	0	0.105	62.051	0	0	0.789	0.133	0	1.259
4173	19	814	MH	tupus	0	0	0	0	0	0	0.008	0.017	0	0.018	0	0	2.041	0	0	0.119	72.309	0	0	0.256	0.127	0	5.22

PAP-No.	Sub-No.	Site	Age	Description	Sb (%)	Sn (%)	Cd (%)	Ag (%)	Ru (%)	Mo (%)	Nb (%)	Zr (%)	Bi (%)	Pb (%)	Hg (%)	Au (%)	As (%)	Se (%)	W (%)	Zn (%)	Cu (%)	Ni (%)	Co (%)	Fe (%)	V (%)	S (%)	P (%)
Average Error pXRF					0.017	0.036	0.010	0.511	0.002	0.012	0.008	0.005	0.006	0.011	0.070	0.905	0.069	0.027	0.047	0.016	1.222	0.013	0.056	0.087	0.019	0.069	0.343
4173	20	814	MH	tupus	0	0	0	0	0	0	0	0.032	0.027	0	0	0	2.807	0	0	0.167	52.674	0	0	1.962	0.273	0	4.464
4196		454	MH	lamina de oro	0	0	0	4.198	0	0	0	0	0.072	0	0	76.881	0	0.087	0	0	0.738	0	0	0.237	0	0	15.788
4689		814	MH	tupus de cobre	0	0	0	0	0	0	0.008	0.024	0	0.012	0	0	1.01	0	0	0.08	75.621	0	0	0.562	0	0	2.566
4691		Huayuncalla	MH	tupus de cobre	0	0	0	0	0	0.016	0.011	0.009	0	0.085	0	0	0.38	0	0	0.153	44.489	0.446	0	5.873	0	0	1.174
4693	1	814	MH	tupus de cobre	0	0	0	0	0.004	0	0	0.01	0.009	0	0	0	0.28	0	0	0.116	64.249	0.095	0	1.717	0	0	1.864
4693	2	814	MH	tupus de cobre	0	0	0	0	0	0	0	0	0.008	0.03	0	0	0.994	0	0	0.082	66.972	0	0	0.417	0	0	1.668
4693	3	814	MH	tupus de cobre	0	0	0	0	0	0	0	0	0.004	0	0	0	0.363	0	0	0.072	69.297	0	0	0.405	0.03	0	1.754
4693	4	814	MH	tupus de cobre	0	0	0	0	0	0	0.006	0.019	0	0.061	0	0	0.037	0	0	0.109	59.68	0	0	1.143	0.038	0	2.899
4694	1	814	MH	tupus de cobre	0	0	0	0	0	0	0	0	0.035	0	0	0	0.883	0	0	0.063	71.827	0	0	0.183	0	0	1.948
4694	2	814	MH	tupus de cobre	0	0	0	0	0	0	0	0.013	0	0	0	0	0	0	0	0.093	72.186	0	0	0.464	0	0	0.663
4694	3	814	MH	tupus de cobre	0	0	0	0	0	0	0	0.009	0	0	0	0	0	0	0	0.099	71.737	0	0	0.491	0	0	1.237
4698		814	MH	tupus de cobre	0	0	0	0	0	0	0.006	0.018	0.05	0.011	0	0	1.239	0	0	0.079	63.938	0	0	0.915	0	0	4.678
4700		814	MH	tupus y paleta de	0	0	0	0	0	0.005	0	0.018	0.012	0.016	0	0	0.218	0	0	0.111	51.624	0	0	2.691	0	0	1.455
4702		814	MH	placa doblada de	0	0	0	0	0	0	0	0.01	0	0	0	0	0.015	0	0	0.087	60.821	0	0	0.903	0	0	1.997
4706		814	MH	artifacto de cobre	0	0	0	0	0.004	0	0.004	0.012	0	0.184	0	0	5.842	0	0	0.094	62.881	0	0	0.64	0.05	0	3.137
4709		814	MH	lamina de metal	0.325	7.433	0	0	0	0	0	0	0	0.953	0	0	0	0	0.083	0.121	54.882	0	0	0.506	0	0	2.75
4712		814	MH	placas de metal	0.024	0	0	0	0	0	0	0	0	0	0	0	1.866	0	0	0.072	70.982	0	0	0.284	0	0	1.633
4713		814	MH	frag. de tupus	0	0	0	0	0.004	0.003	0.003	0.011	0.039	0	0	0.956	0.613	0	0.13	0.102	63.135	0	0	0.729	0	0	1.571
4716		814	MH	aguja de metal	0	0	0	0	0	0	0	0.008	0	0	0	0	0	0	0	0.085	66.894	0	0	0.627	0	0	0.867
4720		814	MH	tupus de cobre	0	0	0	0	0	0	0.006	0.012	0	0.008	0	0	0.531	0	0	0.081	70.838	0	0	0.528	0	0	0.97
4734			MH	tupus de cobre	0	0	0	0	0	0.008	0	0	0.03	0	0	0	5.933	0	0	0.098	61.658	0	0	0.765	0.137	0	4.22
4744		814	MH	material de cobre	0	0	0	0	0	0	0	0.02	0.014	0.009	0	0	0.719	0	0	0.123	76.32	0	0	0.757	0.086	0	12.743
4748	1	814	MH	tupus grande	0	0	0	0	0	0	0.011	0.03	0	0.084	0	0	0	0	0	0.09	89.448	0	0	0.158	0	0	2.258

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Average Error pXRF					0.017	0.036	0.010	0.511	0.002	0.012	0.008	0.005	0.006	0.011	0.070	0.905	0.069	0.027	0.047	0.016	1.222	0.013	0.056	0.087	0.019	0.069	0.343
4748	2	814	MH	tupus pequeño de	0	0	0	0	0	0	0	0.022	0.006	0	0	0	0.013	0	0	0.147	74.701	0	0	0.283	0.249	0	11.678
4748	3	814	MH	tupus grande	0	0	0	0	0	0.004	0	0.018	0	0.106	0	0	0	0	0	0.144	74.178	0	0	0.723	0.068	0	9.202
4748	4	814	MH	pinza de cobre	0	0	0	0	0.004	0	0.006	0.021	0	0.017	0	0	3.151	0	0	0.131	72.154	0	0	0.241	0.048	0	10.412
4748	5	814	MH	tupus de cobre	0.045	0	0	0	0.007	0	0	0	0.011	0.016	0	0	6.623	0	0	0.11	74.69	0	0	0.273	0	0	13.847
4748	6	814	MH	gancho	0	0	0	0	0	0	0.007	0.022	0.016	0	0	0	0.482	0	0	0.102	62.354	0	0	0.597	0.085	0	5.556
4748	7	814	MH	tupus de cobre	0	0	0	0	0	0.003	0	0.032	0.005	0	0	0	0.009	0	0	0.134	63.34	0	0	0.966	0.171	0	9.851
4748	8	814	MH	aguja de cobre	0	0	0	0	0	0.017	0	0.021	0	0.143	0	0	2.524	0	0	0.151	61.536	0	0	3.315	0.153	0	9.243
4761		814	MH	lamina de cobre	0	0	0	0	0.004	0.003	0	0.025	0.077	0	0	0	2.932	0	0	0.127	38.471	0	0	4.627	0	0	2.673
4787	1	814	MH	pendientes de cobre	0	0	0	0	0	0.048	0	0	0	0.083	0	0	4.787	0	0	0.152	70.935	0	0	3.469	0	0	5.108
4787	2	814	MH	pendientes de cobre	0	0	0	0	0	0	0	0	0.059	0.045	0	0	2.611	0	0	0.101	86.678	0	0	2.139	0.152	0	0.995
4791		814	MH	frag. pequeño de tupus	0	0	0	0	0	0	0.009	0.024	0.01	0	0	0	0.087	0	0	0.113	74.16	0	0	0.68	0.05	0	4.651
4796		814	MH	tupus de cobre	0	0	0	0	0	0	0	0.008	0	0.065	0	0	1.435	0	0	0.09	77.488	0.018	0	0.272	0.042	0	3.296
4799		814	MH	lamina de Oro	0	0.167	0	18.304	0	0	0.007	0.097	0.185	0	0.606	39.37	0.106	0.574	0	0	1.127	0	0	11.4	0	0	1.644
4830	1	814	MH	tupus de cobre	0	0	0	0	0	0	0	0.01	0	0.017	0	0	3.56	0	0	0.105	67.975	0	0	0.512	0.082	0	8.248
4830	2	814	MH	Malacologico N.I	0.047	0.028	0	0	0	0	0.043	0.005	0.09	0	0	0	0.059	0	0	0.089	0.113	0	0	42.365	0.121	0	1.225
4830	3	814	MH	tupus de cobre	0	0	0	0	0	0.003	0	0	0.017	0.255	0	0	0.886	0	0	0.088	74.1	0.022	0	0.361	0.053	0	2.797
4832		814	MH	frag. de aguja de cobre	0	0	0	0	0	0.011	0	0	0	0.014	0	0	0.014	0	0	0.079	64.694	0	0	1.23	0	0	3.013
4833	1	814	MH	tupus de cobre	0	0	0	0	0	0	0	0.017	0.011	0.03	0	0	2.271	0	0	0.133	72.436	0	0	0.286	0.195	0	15.478
4833	2	814	MH	aguja de cobre	0	0	0	0	0	0	0	0.006	0	0.045	0	0	5.299	0	0	0.102	59.92	0	0	0.862	0.14	0	10.756
4835		814	MH	tupus de cobre	0	0	0	0	0	0.014	0	0	0	0.168	0	0	0.515	0	0	0.125	67.586	0	0	2.631	0	0	1.614
4840	1	814	MH	tupus grande de cobre	0.047	0.04	0	0	0	0	0	0	0.11	0	0	0	7.642	0	0	0.107	76.29	0	0	0.227	0	0	9.56
4840	2	814	MH	pinzas de cobre	0	0	0	0	0	0	0	0.077	0.01	0.029	0	0	1.421	0	0	0.116	66.683	0	0	0.403	0.238	0	14.993
4840	3	814	MH	pinzas de cobre	0	0	0	0	0	0	0	0.018	0.006	0.027	0	0	2.281	0	0	0.115	68.837	0	0	0.264	0.066	0	11.646

PAP-No.	Sub-No.	Site	Age	Description	Sb (%)	Sn (%)	Cd (%)	Ag (%)	Ru (%)	Mo (%)	Nb (%)	Zr (%)	Bi (%)	Pb (%)	Hg (%)	Au (%)	As (%)	Se (%)	W (%)	Zn (%)	Cu (%)	Ni (%)	Co (%)	Fe (%)	V (%)	S (%)	P (%)
Average Error pXRF					0.017	0.036	0.010	0.511	0.002	0.012	0.008	0.005	0.006	0.011	0.070	0.905	0.069	0.027	0.047	0.016	1.222	0.013	0.056	0.087	0.019	0.069	0.343
4840	4	814	MH	tupus grande de cobre	0	0	0	0	0	0	0.004	0.032	0.007	0.014	0	0	1.135	0	0	0.113	67.507	0.025	0	0.716	0	0	9.807
4840	5	814	MH	tupus grande de cobre	0	0	0	0	0	0	0.003	0.022	0	0	0	0	0.052	0	0	0.098	62.878	0	0	0.864	0.119	0	6.764
4840	6	814	MH	pinzas de cobre	0	0	0	0	0	0	0	0.024	0.023	0.016	0	0	2.131	0	0	0.117	78.039	0	0	0.078	0	0	17.395
4840	7	814	MH	tupus de cobre	0	0	0	0	0.006	0	0	0.023	0.01	0	0	0	1.946	0	0	0.136	64.403	0	0	0.744	0.037	0	11.369
4840	8	814	MH	lamina de cobre	0	0	0	0	0	0	0	0.033	0	0	0	0	0.026	0.012	0	0.128	76.233	0	0	0.19	0	0	16.223
4840	9	814	MH	tupus grande de cobre	0.031	0.03	0	0	0	0	0	0.018	0.009	0	0	0	5.133	0	0	0.122	75.643	0	0	0.211	0	0	11.734
4840	10	814	MH	tupus grande de cobre	0.041	0.03	0	0	0.005	0	0	0	0.12	0	0	0	5.338	0	0	0.09	78.056	0	0	0.109	0	0	11.163
4840	11	814	MH	material de cobre	0	0	0	0	0	0	0.008	0.042	0.047	0.016	0	0	2.987	0	0	0.104	69.627	0	0	0.231	0.028	0	17.352
4840	12	814	MH	tupus de cobre	0.075	0.041	0	0	0	0	0	0.01	0	0	0	0	5.877	0	0	0.089	78.87	0	0	0.168	0	0	8.746
4840	13	814	MH	tupus de cobre	0.172	0.087	0.025	0	0.008	0	0	0	0.008	0.012	0	0	13.12	0	0	0.108	67.097	0	0	0.362	0	0	10.905
4840	14	814	MH	tupus de cobre	0	0	0	0	0	0	0.006	0.023	0.006	0	0	0	0.86	0	0	0.107	73.623	0.054	0	0.257	0	0	14.281
4840	15	814	MH	tupus de cobre	0	0	0	0	0	0	0	0.013	0.007	0	0	0	1.616	0	0	0.084	80.367	0	0	0.196	0	0	5.909
4840	16	814	MH	tupus de cobre	0	0	0	0	0.004	0	0	0.011	0.005	0.019	0	0	2.888	0	0	0.12	62.295	0	0	1	0.087	0	10.177
4840	17	814	MH	tupus grande de cobre	0	0.027	0	0	0.007	0	0	0.014	0.01	0.07	0	0	6.132	0	0	0.118	66.577	0	0	0.807	0	0	14.014
4840	18	814	MH	aguja grande de cobre	0	0	0	0	0	0	0	0.022	0	0	0	0	0.039	0	0	0.114	68.333	0	0	0.42	0	0	17.332
4840	19	814	MH	tupus mediano de	0	0	0	0	0	0	0	0.017	0.021	0.022	0	0	2.12	0	0	0.099	67.511	0	0	0.387	0.081	0	10.023
4840	20	814	MH	tupus de cobre	0	0	0	0	0	0	0	0.011	0	0.014	0	0	1.828	0	0	0.099	73.906	0	0	0.172	0.071	0	12.79
4840	21	814	MH	tupus de cobre	0	0	0	0	0	0	0	0.022	0.011	0.016	0	0	2.111	0	0	0.118	74.334	0.02	0	0.321	0	0	14.7
4840	22	814	MH	lamina de cobre	0.235	0.117	0.058	0	0	0	0	0.011	0.013	0	0	0	1.811	0	0	0.119	77.285	0	0	0.171	0	0	14.139
4840	23	814	MH	tupus mediano	0	0	0	0	0	0	0	0.02	0.01	0.018	0	0	2.589	0	0	0.133	77.562	0.031	0	0.248	0.035	0	11.767
4840	24	814	MH	tupus mediano	0	0	0	0	0.006	0	0	0.026	0.017	0.014	0	0	2.022	0	0	0.135	76.096	0	0	0.258	0	0	13.207
4840	25	814	MH	tupus mediano	0	0	0	0	0	0	0.005	0.026	0.005	0	0	0	1.1	0	0	0.113	77.662	0	0	0.34	0.121	0	9.613
4840	26	814	MH	tupus grande de cobre	0.124	0.078	0	0	0.007	0	0	0	0.025	0.013	0	0		0	0	0.118	77.543	0	0	0.325	0	0	5.975

PAP-No.	Sub-No.	Site	Age	Description	Sb (%)	Sn (%)	Cd (%)	Ag (%)	Ru (%)	Mo (%)	Nb (%)	Zr (%)	Bi (%)	Pb (%)	Hg (%)	Au (%)	As (%)	Se (%)	W (%)	Zn (%)	Cu (%)	Ni (%)	Co (%)	Fe (%)	V (%)	S (%)	P (%)
Average Error pXRF					0.017	0.036	0.010	0.511	0.002	0.012	0.008	0.005	0.006	0.011	0.070	0.905	0.069	0.027	0.047	0.016	1.222	0.013	0.056	0.087	0.019	0.069	0.343
4840	27	814	MH	aguja grande de cobre	0	0	0	0	0	0.033	0	0	0	0.246	0	0	0.118	0	0	0.17	84.457	0	0	2.898	0	0	9.16
4840	28	814	MH	lamina de cobre	0	0	0	0	0	0.025	0	0	0	0.102	0	0	0.181	0	0	0.162	80.225	0	0	1.843	0	0	14.187
4840		814	MH	lamina de oro	0	0	0	22.235	0	0	0	0	0.173	0	0.229	56.115	0	0.087	0	0	1.865	0	0	2.095	0	0	8.043
4840		814	MH	lamina de cobre	0.133	0.077	0.023	0	0.009	0	0	0	0.064	0.008	0	0		0	0	0.087	70.175	0	0	0.229	0	0	9.394
4842	1	814	MH	discos grandes de	0.035	0.027	0	0	0	0	0	0.012	0.009	0	0	0	0.672	0	0	0.107	66.893	0	0	0.369	0	0	13.49
4842	2	814	MH	discos grandes de	0.037	0	0	0	0	0	0	0.031	0.007	0	0	0	1.244	0	0	0.097	84.766	0	0	0.097	0	0	10.05
4842	3	814	MH	discos grandes de	0	0	0	0	0	0	0	0.013	0.029	0.023	0	0	1.168	0	0	0.133	71.064	0	0	0.333	0	0	14.726
4842	4	814	MH	lamina circular de	0	0	0	0	0	0	0.005	0.027	0.011	0.009	0	0	1.023	0	0	0.102	82.493	0	0	0.113	0	0	14.783
4842	5	814	MH	aguja de cobre	0	0	0	0	0	0	0	0.037	0	0.038	0	0	0.016	0	0	0.115	75.679	0	0	0.209	0	0	18.503
4842	6	814	MH	artifacto de cobre	0	0	0	0	0	0	0	0.013	0.012	0.016	0	0	0.871	0	0	0.129	75.835	0	0	0.309	0	0	18.289
4842	7	814	MH	disco pequeño de	0.106	0.023	0	0	0	0	0	0.013	0	0	0	0	2.203	0	0	0.102	71.265	0.798	0	0.217	0	0	12.638
4842	8	814	MH	disco pequeño de	0.184	0.071	0.022	0	0	0	0	0.016	0	0	0	0	3.02	0	0	0.118	73.131	0.483	0	0.179	0	0	16.99
4842	9	814	MH	disco pequeño de	0.146	0.064	0	0	0	0	0	0.018	0	0.04	0	0	2.385	0	0	0.105	74.242	0.736	0	0.244	0	0	14.861
4842	10	814	MH	disco grandes de	0	0	0	0	0	0	0	0.012	0.01	0.016	0	0	2.296	0	0	0.131	78.297	0	0	0.143	0	0	14.381
4842	11	814	MH	disco grandes de	0	0	0	0	0.008	0.005	0	0.014	0.017	0.019	0	0	2.952	0	0	0.124	77.888	0	0	0.104	0	0	15.622
4842	12	814	MH	lamina circular de	0	0	0	0	0	0	0	0.023	0.015	0.007	0	0	0.848	0	0	0.107	67.996	0	0	0.275	0	0	14.528
4889		814	MH	tupus de cobre	0	0	0	0	0	0.007	0	0.014	0	0.026	0	0	0.026	0	0	0.136	62.911	0	0	2.13	0	0	1.984
4892		814	MH	lamina de cobre	0	0	0	0	0	0	0.004	0.012	0	0	0	0.085	0.049	0	0	0.083	65.412	0	0	0.685	0	0	3.546
4908		814	MH	aguja de cobre	0	0	0	0	0	0.015	0.012	0.012	0	0.095	0	0	0.931	0	0	0.173	47.285	0	0	5.538	0.07	0	4.654
4912		814	MH	placa de cobre	0	0.132	0	0	0	0	0	0.011	0	0	0	0	0.032	0	0	0.102	77.807	0	0	0.534	0.027	0	4.971
4913	1	814	MH	aguja de cobre	0	0	0	0	0	0.023	0	0	0	0.213	0	0	0.46	0	0	0.104	74.405	0	0	2.043	0	0	17.755
4913	2	814	MH	aguja de cobre	0	0	0	0	0	0.267	0.277	0.25	0	0.44	0	0	0	0	0	0.674	60.114	0	0	20.235	0	0	9.248
4914	1	814	MH	tupus de cobre	0	0	0	0	0	0.012	0	0	0	0	0	0	1.085	0	0	0.102	76.454	0	0	0.918	0	0	12.71

PAP-No.	Sub-No.	Site	Age	Description	Sb (%)	Sn (%)	Cd (%)	Ag (%)	Ru (%)	Mo (%)	Nb (%)	Zr (%)	Bi (%)	Pb (%)	Hg (%)	Au (%)	As (%)	Se (%)	W (%)	Zn (%)	Cu (%)	Ni (%)	Co (%)	Fe (%)	V (%)	S (%)	P (%)
Average Error pXRF					0.017	0.036	0.010	0.511	0.002	0.012	0.008	0.005	0.006	0.011	0.070	0.905	0.069	0.027	0.047	0.016	1.222	0.013	0.056	0.087	0.019	0.069	0.343
4914	2	814	MH	tupus de cobre	0	0	0	0	0	0.005	0	0	0	0	0	0	1.663	0	0	0.125	80.46	0	0	0.028	0	0	16.893
4915	1	814	MH	tupus de cobre	0	0	0	0	0.007	0.007	0	0	0	0.013	0	0	5.422	0	0	0.123	74.592	0	0	0.241	0	0	14.026
4915	2	814	MH	aguja de cobre	0	0	0	0	0	0	0	0.019	0	0	0	0	1.092	0	0	0.146	71.555	0	0	0.184	0	0	19.607
4920		814	MH	tupus de cobre	0	0	0	0	0	0	0.006	0.02	0	0	0	0	0.007	0	0	0.104	67.837	0	0	0.65	0	0	1.013
3815	1	Botigiriayoq	MH-LIP	tupus de cobre	0	0.258	0	0	0	0	0	0	0	0.032	0.089	0	1.076	0	0	0.113	79.253	0	0	0.1	0	0	11.181
3815	2	Botigiriayoq	MH-LIP	tupus de cobre	0	0	0	0	0	0	0.005	0.017	0.013	0.125	0	0	1.539	0	0	0.14	75.754	0	0	0.033	0	0	17.241
3815	3	Botigiriayoq	MH-LIP	tupus de cobre	0	0.859	0	0	0	0	0.007	0.012	0.008	0	0	0	0.072	0	0	0.116	84.298	0.048	0	0.025	0	0	7.723
396		Chillo	LIP	brazalete	0	0	0	87.036	0	0	0	0	0.009	0.104	0	0.144	0	0	0	0.017	7.863	0	0	0.246	0	0	0
2605		Chillo	LIP	artifacto de cobre	0	0	0	0	0	0.019	0	0	0	0	0	0	0.088	0	0	0.118	72.717	0	0	0.982	0	0	0
128				depilador	0	0.087	0	3.589	0	0.007	0	0.019	0.006	0.059	0	0	0.023	0	0	0.129	64.102	0	0	1.378	0	0	0.992
128		128		tumi de metal con madera	0	2.07	0	0	0	0	0	0	0	0.011	0	0	0.019	0	0	0.086	79.098	0	0	0.632	0	0	0.53
780		Mauca Llaqta		lamina	0	0	0	0	0	0	0	0	0	0	0	0	2.469	0	0	0.048	60.843	0.017	0	0.664	0	0	1.629
794		794		cobre	0	0	0	0	0	0	0	0.013	0	0	0	0	0.024	0	0	0.098	83.274	0.06	0	0.105	0	0	0.945
808		808		metal	0.256		0	0	0	0	0	0	0	0.058	0	0	0.02	0	0.109	0.138	60.081	0	0	0.388	0	0	3.262
809		809		metal	0.104	3.908	0	0	0	0	0	0	0	0.059	0	0	2.713	0	0	0.114	62.359	0	0	0.642	0	0	4.676
828		828		tupus de cobre	0	0	0	0	0	0.02	0.018	0.012	0	0	0	0	0	0	0	0.066	83.874	0	0	0.272	0	0	4.374
1938		Jauranga		metal moderna	0	0	0	0	0	0	0	0.022	0.005	0	0	0	0.162	0	0	0	0.099	0	0.218	92.203	0	0.519	0

Table 8: Results of the geochemical element analysis of samples from the 2018 survey in the research area by ICP MS.

			% Na2O	% MnO	% P2O5	% SO2	% CaO	% TiO2	% ZnO	% BaO	% MgO	% Al2O3	% SiO2	% Fe2O3	% Cu	% K2O	% Sum	ppm Sr	ppm Ag	ppm Sn	ppm Sb	ppm Te	ppm Pb	ppm Bi	ppm U	ppm V	ppm Cr	ppm Co	ppm Ni	ppm As	ppm Se
3980_18	Qz / Cu	P18017	0.03	0.003	0.004	0.03	0.06	0.00	0.001	0.004	<0.001	0.81	97.6	0.08	0.39	<0.002	99.0	2.8	<1	<1	5.9	<1.5	8.8	1.1	<0.5	1.8	10	35	<2	10	<10
3981_18	Cu ore	P18018	0.06	0.02	0.004	1.44	0.18	0.00	0.14	0.004	<0.001	0.96	27.5	25.3	33.1	<0.002	88.7	15	780	25	35	6.5	20	25	6.5	<0.3	5.3	140	40	300	15
3982_18	Qz / Cu Au	P18020	0.02	0.01	0.02	0.04	0.24	0.07	0.006	0.002	0.04	0.74	87.0	4.90	4.21	0.18	97.5	5.8	1.4	1.1	30	3.7	15	1900	6	170	15	2.5	4.2	95	9.8
3983_18	Qz / Cu	P18022	0.04	0.01	0.02	0.07	0.26	0.11	0.01	0.004	0.05	2.64	80.1	5.86	5.68	<0.002	94.9	8.4	1.4	2.3	25	<1.5	15	2.6	45	170	5.0	20	25	80	<10
3984_18	Qz / Au?	P18023	3.35	0.01	0.08	0.20	0.87	0.33	0.005	0.06	0.54	14.0	66.6	5.23	0.01	4.06	95.3	110	2.5	3.8	6.8	3.6	20	140	5.2	80	80	5.6	55	55	3.6
3985_18	Cu ore	P18024	0.12	2.51	0.05	0.36	1.39	0.12	0.01	0.01	0.18	1.78	38.5	36.4	10.9	0.21	92.5	85	8.2	10	30	2.8	65	1300	160	190	15	170	75	2400	20
3986_18	Qz	P18025	0.04	1.64	0.02	0.40	28.1	0.02	0.002	0.02	0.24	0.30	40.6	5.62	0.01	0.06	77.1	180	<1	<1	10	3.7	6.7	75	11	45	8.3	15	<2	20	9.3
3987_18	Cu ore	P18026	0.08	0.22	0.01	0.06	9.58	0.00	0.004	0.004	0.06	0.87	52.8	16.4	12.8	<0.002	92.9	30	2.9	1.1	6.9	<1.5	3.3	3.1	170	250	3.0	6.4	15	45	<10
3988_18	Cu ore	P18027	0.06	0.02	0.03	2.75	0.50	0.00	0.08	0.004	0.05	2.90	26.8	28.1	30.9	<0.002	92.1	20	530	20	50	6.7	20	20	110	1100	45	75	95	500	15
3989_18	Cu ore	P18028	5.54	0.14	0.19	0.02	1.15	0.75	0.02	0.01	6.43	13.0	51.6	12.8	3.60	0.31	95.5	35	2.4	1.6	10	<1.5	15	0.8	2.1	350	230	50	50	15	<10
3990_18	Cu ore	P18030	0.04	0.15	0.04	0.06	0.59	0.04	0.01	0.01	0.06	3.09	38.3	23.9	25.5	0.04	91.9	20	4.0	3.5	45	2.7	10	5.7	130	1200	2.7	30	60	630	10
3991_18	Qz / Au	P18032	0.01	0.01	0.01	0.06	0.20	0.01	0.008	0.002	<0.01	<0.03	96.8	2.12	0.26	<0.03	99.5	4.4	110	<1	5.1	5.0	55		5.7	35	6.5	1.7	<2	45	<3
3992_18	Qz / Au	P18033	0.01		0.003	0.02	0.14	0.01	0.001	0.001	<0.01	<0.03	96.5	1.53	0.02	<0.03	98.2	1.8	4.0	<1	4.7	3.7	6.1	540	<0.5	10	8.9	0.8	<2	20	<3
3993_18	Cu ore	P18034	0.62	0.45	0.03	0.01	1.84	0.06	0.36	0.02	0.73	5.93	64.5	3.53	14.4	0.35	92.9	35	20	1.1	30	<1.5	40	8.4	15	85	15	150	15	260	<10
3994_18	Qz / Au	P18035	0.08	0.01	0.10	0.05	0.20	0.43	0.02	0.03	0.21	6.72	83.7	3.44	0.01	2.20	97.2	40	5.7	2.1	7.5	3.7	510	90	2.4	65	320	7.6	170	95	<3
3995_18	Qz / Cu	P18036_1	0.04	0.02	0.01	0.67	7.14	0.01	0.02	0.003	0.03	4.45	68.5	7.43	7.02	0.11	95.4	10	40	2.7	85	25	5400	2100	4.3	15	4.4	55	45	270	<10
3996_18	Qz	P18036_2	0.03	0.002	0.03	0.28	0.20	0.06	0.002	0.01	0.04	1.04	85.1	2.60	0.003	0.32	89.8	20	5.0	<1	3.8	3.6	300	340	<0.5	15	15	1.0	<2	75	<3
3997_18	FeOx / Au	P18037	0.11	0.13	0.02	0.67	0.56	0.02	0.23	0.003	0.13	0.25	6.84	89.9	0.15	<0.03	99.0	20	3.9	4.3	20	4.2	4800		3.7	160	4.7	160	210	5000	15
3998_18	Qz / Au	P18038	0.07	0.01	0.02	0.05	0.21	0.38	0.002	0.05	0.61	7.01	86.5	2.95	0.01	1.86	99.7	35	1.5	1.3	9.8	4.3	7.5	230	1.6	40	25	3.7	6.6	25	5.4
3999_18	Qz / Au	P18048	0.03	0.03	0.03	0.01	0.17	0.31	0.002	0.002	0.62	1.09	94.8	2.05	0.001	<0.03	99.1	5.4	1.8	<1	3.5	3.7	5.4	45	1.4	10	25	2.9	3.0	10	4.5
4000_18	FeOx / Au	P18056	0.06	0.01	0.01	0.03	0.16	0.08	0.003	0.005	0.69	1.82	91.5	4.29	0.02	0.14	98.8	20	1.9	<1	4.6	3.6	120	540	0.6	20	8.6	20	15	70	<3

			% Na2O	% MnO	% P2O5	% SO2	% CaO	% TiO2	% ZnO	% BaO	% MgO	% Al2O3	% SiO2	% Fe2O3	% Cu	% K2O	% Sum	ppm Sr	ppm Ag	ppm Sn	ppm Sb	ppm Te	ppm Pb	ppm Bi	ppm U	ppm V	ppm Cr	ppm Co	ppm Ni	ppm As	ppm Se
4001_18	Cu Ore	P18060	0.71	1.96	0.06	0.10	1.12	0.27	0.19	0.04	0.67	6.03	23.3	16.9	35.6	1.51	88.5	40	10	3.6	110	<1.5	15	10	35	210	10	940	390	820	<10
4002_18	Qz / Au	P18061	0.05	0.01	0.01	0.20	0.18	0.01	0.001	0.001	0.01	0.27	94.4	3.18	0.01	<0.03	98.4	7.7	1.4	<1	4.7	3.6	6.9	300	<0.5	15	15	15	10	50	3.8
4003_18	FeOx / Au	P18069	0.19	0.15	0.12	0.48	0.62	0.26	0.004	0.02	2.35	10.4	42.7	38.6	0.59	2.48	99.0	110	1.3	85	15	1.9	2.0	1.3	1.6	160	20	170	15	110	<10
4004_18	Qz / FeOx	P18070	0.62	0.08	0.11	0.02	0.23	0.48	0.01	0.02	3.04	14.5	59.2	9.70	0.46	4.09	92.6	10	1.1	3.8	5.1	<1.5	1.3	0.7	2.0	80	1100	75	1300	20	<10
4005_18	Qz / Au	P18071	0.04	0.003	0.01	0.15	0.19	0.04	0.001	0.003	<0.01	0.08	96.6b	1.93	0.001	<0.03	99.1	6.6	1.0	<1	3.5	4.6	2.4	130	<0.5	10	8.2	2.6	<2	<10	<3
4006_18	Qz / Au	P18072	0.05	0.02	0.02	0.15	0.27	0.19	0.001	0.003	0.02	0.28	94.3	4.67	0.01	0.03	100.0	8.0	1.1	1.6	4.0	3.8	2.8	80	0.8	45	7.0	10	<2	35	3.6

Tab. 9: Gold Content of the samples from the survey campaign 2018.

DBM Lab.-Nr.	Survey Ref.-Nr.	Ru102(LR)	Rh103(LR)	Pd106(LR)	Re185(LR)	Os192(LR)	Ir193(LR)	Pt195(LR)	Au197(LR)	Ag	Ru102(MR)	Rh103(MR)
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
3980_18	P18017	0.510732	0.212112	0.12582	0.017496	0.005508	0.007992	0.017496	0.04	<1	0.482112	0.168372
3981_18	P18018	0.741151	21.930162	0.233125	0.060053	0.01492	0.027229	0.057069	14.679788	780	0.705343	21.106578
3982_18	P18020	1.302375	2.4905	1.094	0.028875	0.00525	0.01075	0.023125	5.397375	1.3556	1.108875	2.292375
3983_18	P18022	0.5508	3.11496	0.31464	0.02244	0.00564	0.00912	0.05208	0.17	1.357	0.47388	2.91336
3984_18	P18023	0.908432	0.321104	2.106272	0.019152	0.0056	0.013104	0.028448	0.05	2.5224	0.84616	0.253232
3985_18	P18024	0.730975	6.791575	0.72345	0.032375	0.00805	0.0133	0.032725	3.43735	8.22382	0.782425	6.034
3986_18	P18025	0.1678	0.094	0.236	0.0173	0.0044	0.0072	0.0159	0.02	<1	0.1274	0.0259
3987_18	P18026	0.509852	5.688853	0.350419	0.029051	0.006672	0.010703	0.024186	18.780568	2.9081	0.458283	4.682493
3988_18	P18027	0.857592	16.120098	0.863526	0.04386	0.010836	0.019092	0.04257	7.10016	530	0.782514	15.42711
3989_18	P18028	0.6426	2.2268	0.9582	0.0171	0.0051	0.0091	0.0228	0.05	2.4458	0.5758	1.3715
3990_18	P18030	0.828387	14.788872	0.486108	0.036666	0.008316	0.013986	0.035154	0.23	4.00223	0.671895	13.503483
3991_18	P18032	0.588125	0.368375	0.137625	0.01975	0.004875	0.00925	0.019125	7.01975	110	0.562125	0.3255
3992_18	P18033	0.525028	0.195279	0.128401	0.018921	0.00476	0.008568	0.018564	0.09	3.9812	0.508249	0.163387
3993_18	P18034	0.581148	7.746732	1.633824	0.018576	0.004644	0.007776	0.017064	0.06	20	0.425844	5.308524
3994_18	P18035	0.411546	0.153228	2.791891	0.021244	0.00565	0.0113	0.028137	0.590425	5.7056	0.330977	0.102378
3995_18	P18036_1	1.307025	3.243753	0.225441	0.017094	0.00444	0.008214	0.018093	0.640026	40	1.269285	2.270727
3996_18	P18036_2	0.232554	0.094581	0.629071	0.01921	0.005085	0.009379	0.01921	0.03	5.0101	0.204756	0.068139
3997_18	P18037	0.438892	0.299337	0.805916	0.019775	0.004633	0.008475	0.018419	5.506377	3.9174	0.372335	0.195603
3998_18	P18038	0.3592	0.1271	2.1485	0.0157	0.0048	0.0105	0.0235	0.15	1.5089	0.3294	0.0795
3999_18	P18048	0.3174	0.0982	7.1378	0.0156	0.0072	0.0178	0.0414	0.01	1.8169	0.2782	0.0901
4000_18	P18056	0.302049	0.107915	0.96389	0.01921	0.004859	0.009379	0.020001	0.02	1.9138	0.264646	0.082829
4001_18	P18060	0.7302	19.3769	2.1864	0.0217	0.0057	0.0102	0.023	0.04	10.4773	0.5959	17.4542
4002_18	P18061	0.2811	0.0865	0.1452	0.0159	0.0037	0.0074	0.0155	0.02	1.3546	0.2625	0.0714
4003_18	P18069	0.526926	0.196524	2.51962	0.027984	0.005406	0.011342	0.026394	0.04	1.2751	0.416474	0.160484
4004_18	P18070	0.1393	0.0825	3.5141	0.0374	0.0064	0.0136	0.0286	0.013	1.0867	0.1098	0.0567
4005_18	P18071	0.2413	0.071	0.1184	0.0154	0.004	0.0074	0.0156	0.13	1.0297	0.2252	0.053
4006_18	P18072	0.2149	0.0683	0.9745	0.0182	0.0043	0.0085	0.0191	0.104	1.0597	0.2052	0.0669

Table 10: Results of the geochemical element analysis of samples from the 2009 survey in the research area by ICP MS.

Number	Samples	SiO2 (%)	TiO2 (%)	Al2O3 (%)	Fe2O3 (%)	MnO (%)	MgO (%)	CaO (%)	Na2O (%)	K2O (%)	P2O5 (%)	Cu (%)	Pb (%)	Zn (%)	S (%)	Ba (%)
PA 12	4338-09	80.241	0.0008531	1.3413	8.1536846	0.0052	0.0536	0.312	0.1657	0.05	0.015	3.9651452	< 0.0001	0.0008	0.1	0.01
PC 01	4339-09	67.935	0.1091817	2.7667	12.966336	0.0839	0.3588	5.072	0.0647	0.6	0.025	3.501901	0.000473	0.0009	0	< 0.0003
PD 17	4345-09	9.8722	0.0133086	2.2329	75.451529	0.032	0.1358	1.207	0.1085	0.08	0.083	1.5429521	0.039876	0.0599	0.3	0.01
Number	**Sr (%)**	**Ni (%)**	**Y (%)**	**Zr (%)**	**As (%)**	**Se (%)**	**Sb (%)**	**Bi (%)**	**Sn (%)**	**Cr (%)**	**V (%)**	**Co (%)**	**Ag (%)**	**Au (%)**	**Nb (%)**	**Mo (%)**
PA 12	0.0018554	0.0053	0.0004161	0.0126	0.0032969	0.0066	0.0002	7E-05	0.0001	0	0.006	0.0001338	0.000193	0.0101	< 0.0003	0
PC 01	0.0011593	0.012	0.0011705	0.0164	0.0040548	0.0066	0.0004	1E-04	0.0002	0	0.02	0.0013939	0.000189	0.0149	< 0.0003	0
PD 17	0.0028684	0.2076	0.0036207	0.0132	0.0227076	0.0079	0.0103	0.002	0.0013	0	0.087	0.004343	5.62E-05	0.0148	0	0.01
Number	**Cd (%)**	**Te (%)**	**Cs (%)**	**La (%)**	**Ce (%)**	**Nd (%)**	**Yb (%)**	**W (%)**	**Th (%)**	**U (%)**	**Sc (%)**	**Ga (%)**	**Tb (%)**	**Sum**	**LOI (%) 1050°C**	**Sum**
PA 12	0.0000737	< 0.0001	0.0001017	3E-05	0.0000367	7E-05	4E-05	8E-04	3E-06	0	2E-04	0.0000616	< 0.0000005	94.396	2.5	96.9
PC 01	0.0000069	0.0004	0.000328	0.0004	0.0006154	0.0006	7E-05	8E-04	4E-05	0	3E-04	0.0002686	< 0.0000005	93.508	6.4	99.9
PD 17	0.000581	0.0019	0.0000364	0.0015	0.0030354	0.0027	0.0004	0.008	0.0001	0	0.001	0.012938	5.09E-05	91.199	9.1	100

Tab. 11: ***In-situ*** *chemical analyses of gold samples from the research area using a field-emission electron microprobe "SXFiveFE".*

	Weight (%)										Det.Lim ppm(A)									StdDev wt (%)													
Comment	S	Fe	Ni	Cu	Pd	Ag	Te	Pt	Au	Total	S	Fe	Ni	Cu	Pd	Ag	Te	Pt	Au	S	Fe	Ni	Cu	Pd	**Ag**	**Te**	**Pt**	**Au**	**X**	**Y**	**Z**	**Distance (μ)**	**Date**
PA12-1	0.04	0.08	0.00	0.22	0.00	14.07	0.08	0.00	80.53	95.03	44	126	112	149	144	314	149	458	1513	0.012	0.0244	-0.0001	0.0238	0	0.3678	0.0481	0	1.3338	11701	11237	-584		May 28. 2019
PA12-2	0.03	0.16	0.01	0.59	0.00	5.48	0.00	0.00	83.01	89.27	76	130	122	155	128	278	306	475	1548	0.0188	0.0262	0.0199	0.027	0	0.1945	0	0	1.3625	11636	10912	-592		May 28. 2019
PA12-3	0.00	2.63	0.02	0.83	0.09	2.21	0.06	0.00	81.53	87.38	74	134	120	161	107	297	312	478	1557	0	0.056	0.0199	0.0295	0.0382	0.1338	0.0724	0	1.3537	11628	11011	-576		May 28. 2019
PA12-4	0.32	6.91	0.00	14.40	0.00	1.06	0.00	0.00	22.14	44.83	55	102	78	133	105	224	255	350	1114	0.0234	0.0939	-0.0001	0.1125	0	0.0871	0	0	0.6795	12063	11012	-532		May 28. 2019
PD17-1	0.03	0.17	0.02	0.04	0.00	19.35	0.00	0.00	76.06	95.67	24	128	107	139	144	335	84	431	1521	0.0077	0.0263	0.018	0.0213	0	0.4736	0.0187	0	1.2868	-11259	11123	-405		May 28. 2019
PD17-2	0.02	0.15	0.03	0.01	0.00	18.88	0.17	0.00	54.65	73.90	79	120	115	146	121	302	295	430	1440	0.0182	0.0249	0.0197	0.0223	0	0.4625	0.0945	0	1.0548	-11084	10701	-373		May 28. 2019
PD17-3	0.28	23.08	0.02	0.58	0.00	11.57	0.00	0.21	49.64	85.36	34	121	97	126	112	303	115	409	1356	0.0194	0.2244	0.0179	0.0258	0	0.3111	-0.0001	0.0927	1.018	-10573	10402	-369		May 28. 2019
PD17-4	0.00	0.03	0.01	0.01	0.00	23.54	0.00	0.00	74.27	97.86	57	127	114	150	146	338	181	460	1593	0.0129	0.0241	0.0191	0.0228	0	0.5571	0	0	1.2723	-11286	11128	-405		May 28. 2019
PC01-1	0.04	0.10	0.00	0.47	0.00	19.90	0.00	0.00	68.45	88.97	57	130	112	147	146	334	199	468	1529	0.0145	0.0258	0	0.0259	0	0.4846	0	0	1.2084	-11713	-4269	-313		May 28. 2019
PC01-2	0.00	0.11	0.01	0.06	0.00	24.67	0.01	0.00	72.75	97.60	76	129	122	155	138	332	306	474	1522	0.0169	0.0259	0.0206	0.024	0	0.5793	0.0678	0	1.2527	-11763	-4295	-313		May 28. 2019
PC01-3	0.04	0.31	0.02	0.87	0.00	12.82	0.01	0.00	72.68	86.75	72	131	115	154	145	324	298	478	1577	0.018	0.0289	0.0192	0.0292	0	0.3436	0.0657	0	1.2561	-11342	-3900	-313		May 28. 2019
PC01-4	0.03	0.29	0.07	0.19	0.00	26.52	0.00	0.00	75.27	102.37	25	127	117	151	140	323	101	454	1492	0.008	0.0284	0.0204	0.0245	0	0.6159	0	0	1.279	-11155	-2419	-300		May 28. 2019
PD01-1	0.06	3.18	0.00	1.28	0.00	0.10	0.00	0.59	92.88	98.09	42	112	90	92	142	281	181	404	1546	0.0131	0.0598	0	0.026	0	0.0907	0	0.0867	1.4664	-11485	11421	-505		May 28. 2019
PD01-2	0.03	0.13	0.00	0.19	0.00	0.09	0.03	0.00	93.89	94.36	37	132	76	102	149	302	137	344	1561	0.0108	0.0258	0	0.0167	0	0.0983	0.0329	0	1.4784	-11601	11072	-505		May 28. 2019
PD01-3	0.00	0.13	0.00	0.14	0.00	0.11	0.00	0.00	92.22	92.60	73	131	123	161	143	297	317	506	1597	0	0.0255	0	0.0243	0	0.0969	0	0	1.4631	-11950	11166	-505		May 28. 2019
PD01-4	0.00	2.50	0.00	1.57	0.00	0.09	0.00	0.00	95.29	99.44	70	135	124	161	144	298	280	494	1600	0.0169	0.0546	0	0.0341	0	0.0962	0	0	1.4935	-11857	10319	-502		May 28. 2019
P18026-1	0.16	1.46	0.00	2.46	0.00	1.77	0.00	0.00	11.39	17.25	50	85	77	104	83	191	242	284	893	0.0181	0.0398	0	0.0369	0	0.1003	0	0	0.4823	-12431	-1403	-456		May 28. 2019
P18026-2	0.65	1.15	0.00	0.73	0.00	2.62	0.00	0.07	13.17	18.39	41	60	39	56	93	208	181	184	819	0.0294	0.0343	0.0068	0.0189	0	0.124	0	0.0405	0.5013	-12325	-1395	-486		May 28. 2019
P18026-3	0.00	0.09	0.01	0.07	0.00	13.00	0.00	0.00	87.56	100.73	65	132	117	149	146	326	279	470	1558	0.0151	0.0256	0.0193	0.0226	0	0.3477	-0.0004	0	1.4091	-11709	-1686	-451		May 28. 2019

	Weight (%)									Det.Lim ppm(A)									StdDev wt (%)														
Comment	S	Fe	Ni	Cu	Pd	Ag	Te	Pt	Au	Total	S	Fe	Ni	Cu	Pd	Ag	Te	Pt	Au	S	Fe	Ni	Cu	Pd	**Ag**	**Te**	**Pt**	**Au**	**X**	**Y**	**Z**	**Distance (µ)**	**Date**
P18026-4	0.01	0.06	0.01	0.06	0.00	12.61	0.00	0.00	90.69	103.43	66	136	123	159	147	322	274	489	1629	0.0158	0.0257	0.0204	0.0239	0	0.3396	0	0	1.4435	-11495	-1823	-502		May 28. 2019
P18026-5	0.01	1.44	0.00	1.49	0.00	13.94	0.05	0.00	83.31	100.24	51	133	116	149	152	339	220	465	1592	0.0122	0.0437	0.0194	0.0331	0	0.3667	0.0534	0	1.369	-11836	-1984	-461		May 28. 2019
P18026-6	0.00	8.46	0.00	0.88	0.00	10.04	0.00	0.00	36.05	55.44	16	126	32	48	131	312	70	143	1317	0.004	0.1086	0	0.0203	0	0.284	0.0153	0.0311	0.8533	-11936	-1986	-429		May 28. 2019
PE01-1	1.53	35.56	0.00	1.33	0.00	0.18	0.00	0.00	6.87	45.48	58	105	71	97	89	285	255	290	912	0.0431	0.3219	0	0.0321	0	0.0738	0	0	0.414	11219	-2581	-525		May 28. 2019
PE01-2	0.28	14.10	0.00	0.51	0.00	19.56	0.04	0.00	43.40	77.89	67	119	103	134	130	337	291	402	1359	0.0229	0.1545	0	0.0261	0	0.4733	0.065	0	0.9393	11215	-2565	-525		May 28. 2019
PE01-3	0.62	32.29	0.00	1.22	0.00	7.57	0.00	0.00	18.92	60.61	49	121	83	113	117	317	197	339	1097	0.0283	0.2962	0	0.0315	0	0.2259	0	0	0.63	11223	-2569	-525		May 28. 2019
PE01-4	0.06	4.81	0.01	0.22	0.00	20.30	0.01	0.03	66.78	92.20	72	122	112	143	127	317	297	444	1424	0.018	0.0767	0.0192	0.0238	0	0.4904	0.0651	0.0935	1.1895	11213	-2564	-525		May 28. 2019

Table 12: Chemical composition results of the SEM measurements from the samples taken in the laboratories of the Deutsches Bergbau-Museum Bochum (DBM).

Weight %

	C	N	O	Al	Mn	Fe	Cu	Ag	Ta	Au
PE01(3)_pt1	2.52	2.04	14.27	0.49	0.74	3.87	0.47	12.88	0.00	62.72

Weight % Error (+/- 2 Sigma)

	C	N	O	Al	Mn	Fe	Cu	Ag	Ta	Au
PE01(3)_pt1	+/-0.09	+/-0.66	+/-0.56	+/-0.05	+/-0.14	+/-0.18	+/-0.17	+/-0.49	+/-0.60	+/-0.64

Weight %

	C	N	O	Al	Ag	Ta	Au
PD17(1)_pt1	7.05	3.04	5.24	0.18	15.14	1.72	67.63

Weight % Error (+/- 2 Sigma)

	C	N	O	Al	Ag	Ta	Au
PD17(1)_pt1	+/-0.28	+/-0.81	+/-0.75	+/-0.08	+/-0.91	+/-1.07	+/-0.81

Weight %

	C	N	O	F	Al	Si	Ca	Fe	Cu	Ag	Sb	Te	Ta	Au
PD17(2)_pt1	3.52	2.59	8.19	0.23	0.23			0.61	0.27	19.24	0.18		0.00	64.94
PD17(2)_pt2	2.49	2.03	9.31		0.13			2.51	0.16	23.96		0.08	0.36	58.98
PD17(2)_pt3	3.05	2.24	4.46					0.50	0.15	28.25		0.04	0.69	60.62
PD17(2)_pt4	5.58		38.26		0.40	0.98	0.11	54.46		0.09				0.12

Weight % Error (+/- 2 Sigma)

	C	N	O	F	Al	Si	Ca	Fe	Cu	Ag	Sb	Te	Ta	Au
PD17(2)_pt1	+/-0.12	+/-0.37	+/-0.36	+/-0.38	+/-0.09			+/-0.14	+/-0.16	+/-0.54	+/-0.18		+/-0.00	+/-0.65
PD17(2)_pt2	+/-0.11	+/-0.55	+/-0.55		+/-0.05			+/-0.30	+/-0.17	+/-0.58		+/-0.17	+/-0.57	+/-0.54
PD17(2)_pt3	+/-0.09	+/-0.37	+/-0.54					+/-0.15	+/-0.19	+/-0.66		+/-0.19	+/-0.65	+/-0.66
PD17(2)_pt4	+/-0.21		+/-0.48		+/-0.09	+/-0.08	+/-0.04	+/-0.57		+/-0.12				+/-0.12

Weight %

	C	N	O	F	Al	Ca	Fe	Cu	Ag	Te	Ta	Au
PD17(3)_pt1	3.43	2.07	6.96		0.27	0.46	0.81	0.20	21.40		0.17	64.24
PD17(3)_pt2	3.90	2.44	6.39	0.12	0.25		0.82	0.27	21.29	0.12	0.31	64.09

Weight % Error (+/- 2 Sigma)

	C	N	O	F	Al	Ca	Fe	Cu	Ag	Te	Ta	Au
PD17(3)_pt1	+/-0.09	+/-0.56	+/-0.33		+/-0.05	+/-0.07	+/-0.14	+/-0.17	+/-0.56		+/-0.57	+/-0.65
PD17(3)_pt2	+/-0.15	+/-0.47	+/-0.62	+/-0.41	+/-0.05		+/-0.18	+/-0.22	+/-0.66	+/-0.20	+/-0.76	+/-0.71

Weight %

	C	N	O	Al	Ca	Mn	Fe	Cu	Ag	Sb	W	Au	Th
PA12(2)_pt1	7.21		13.51	0.52			2.60	1.21			0.08	72.58	2.29
PA12(2)_pt2	3.54	2.72	19.22	0.23	0.18	0.25	3.51	0.45	1.97	0.00	0.00	67.94	

Weight % Error (+/- 2 Sigma)

	C	N	O	Al	Ca	Mn	Fe	Cu	Ag	Sb	W	Au	Th
PA12(2)_pt1	+/-0.16		+/-0.52	+/-0.10			+/-0.22	+/-0.25			+/-0.98	+/-0.80	+/-0.58
PA12(2)_pt2	+/-0.12	+/-0.38	+/-0.52	+/-0.07	+/-0.05	+/-0.11	+/-0.25	+/-0.13	+/-0.17	+/-0.00	+/-0.00	+/-0.62	

Weight %

	C	N	O	Al	Fe	Cu	Rb	Ag	Au
PA12(3)_pt1	7.89	2.68	8.21	0.15	0.57	1.08	1.63	3.01	74.78

Weight % Error (+/- 2 Sigma)

	C	N	O	Al	Fe	Cu	Rb	Ag	Au
PA12(3)_pt1	+/-0.23	+/-0.57	+/-0.53	+/-0.06	+/-0.14	+/-0.18	+/-0.27	+/-0.21	+/-0.73

Weight %

	C	N	O	F	Al	Fe	Cu	Ag	Ta	Au	Th
PD01(1)_pt1	6.85	2.92	4.82		0.28	0.12	0.61	0.38		83.14	0.87
PD01(1)_pt2	5.38	3.32	4.74	0.54	0.12	0.39	0.40	1.01	0.36	83.21	0.53

Weight % Error (+/- 2 Sigma)

	C	N	O	F	Al	Fe	Cu	Ag	Ta	Au	Th
PD01(1)_pt1	+/-0.24	+/-0.96	+/-0.60		+/-0.09	+/-0.16	+/-0.20	+/-0.51		+/-0.82	+/-0.78
PD01(1)_pt2	+/-0.21	+/-0.48	+/-0.49	+/-0.33	+/-0.05	+/-0.12	+/-0.14	+/-0.43	+/-0.50	+/-0.74	+/-0.64

Weight %

	C	N	O	F	Al	Fe	Cu	Ag	Ta	Au
PD01(2)_pt1	4.56	2.70	6.03	0.44	0.17	0.52	0.82		0.62	84.14
PD01(2)_pt2	5.93	3.23	8.92		0.25	1.00	1.61	0.01	0.13	78.92

Weight % Error (+/- 2 Sigma)

	C	N	O	F	Al	Fe	Cu	Ag	Ta	Au
PD01(2)_pt1	+/-0.14	+/-0.72	+/-0.54	+/-0.42	+/-0.05	+/-0.13	+/-0.17		+/-0.57	+/-0.77
PD01(2)_pt2	+/-0.21	+/-0.61	+/-0.61		+/-0.06	+/-0.18	+/-0.25	+/-0.22	+/-0.86	+/-0.82

Weight %

	C	N	O	Na	Al	Ca	Cu	Ta	Au
PD01(3)_pt1	4.87	2.40	3.84	0.30	0.25	0.16	0.41	0.14	87.62

Weight % Error (+/- 2 Sigma)

	C	N	O	Na	Al	Ca	Cu	Ta	Au
PD01(3)_pt1	+/-0.15	+/-0.67	+/-0.37	+/-0.08	+/-0.05	+/-0.06	+/-0.18	+/-0.61	+/-0.80

Weight %

	C	N	O	F	Al	K	Fe	Cu	Pd	Ag	Ta	Au
PD01(4)_pt1	2.28	3.13	5.49	0.25	0.34		1.65	0.75	0.13	0.00		85.99
PD01(4)_pt2	4.37	2.62	3.87		0.08	0.06	0.23	0.42			0.08	88.27
PD01(4)_pt3	6.89	3.86	6.22	0.48	0.24		0.30	0.63			0.46	80.92

Weight % Error (+/- 2 Sigma)

	C	N	O	F	Al	K	Fe	Cu	Pd	Ag	Ta	Au
PD01(4)_pt1	+/-0.08	+/-0.35	+/-0.29	+/-0.34	+/-0.08		+/-0.17	+/-0.19	+/-0.21	+/-0.00		+/-0.80
PD01(4)_pt2	+/-0.14	+/-0.66	+/-0.45		+/-0.05	+/-0.06	+/-0.12	+/-0.15			+/-0.50	+/-0.77
PD01(4)_pt3	+/-0.14	+/-0.56	+/-0.54	+/-0.26	+/-0.05		+/-0.16	+/-0.20			+/-0.70	+/-0.78

Palpa. Dr. Guntram Gassmann, Prof. Dr. Thomas Stöllner and the author relaxing on the porch of the Casa Blanca after a day in the field during the survey campaign in 2009 (photo: DBM, B. Gräfingholt).