Der Anschnitt, Beih. 34, S. 11 – 23, 2017, DOI https://doi.org/10.46586/DBM139

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Resources, innovation, technology

Theoretical approaches to abstract concepts and research content

ABSTRACT: *The appropriation of raw materials and their conversion to widely accepted resources was and is an innovation process that is the basis for any further explanation of why a raw material got exploited and traded in the history of mankind. In contrast to natural raw materials, resources are socially produced constructions expressing what people perceive as relevant for their life. Therefore consumption and production are in a special relation to each other: the "charging" of resources with meaning is a complex process that inherits also the information about the innovation that once led to their appropriation and introduction. The evolvement of knowledge is basic as it is tightly connected with human beings and their practice in social and spatial contexts. For archaeologists it is always difficult to reconstruct the gradual process of how knowledge has evolved. To look behind this curtain of evidence requires definitely a theoretical approach to ask the right questions. In this article the reconstruction of techniques and technical development is discussed, one key level of understanding the practices that led to the social construction of raw materials. The evolvement of knowledge and the assertion of a technological concept will be therefore envisaged in tight relation to each other: the article follows this correlation on a broader frame.*

KEYWORDS: RESOURCES, INNOVATION, TECHNOLOGY, MINING ARCHAEOLOGY

Introduction

The appropriation of raw materials and their conversion to widely accepted resources was and is an innovation process that is a basis for any further explanation of why any raw material got exploited and traded in the history of mankind. In contrast to natural raw materials, resources are socially produced constructions expressing what people perceive as relevant for their life, no matter if it is about their physical (food, water) or their social needs (status symbols, religious items)[1]. Resources generally have been differentiated into natural, material and culturally constructed immaterial resources (Storberg, 2002, p.469). Therefore consumption and production are in a special relation to each other: the "charging" of resources with meaning is a complex process that also inherits the information about the innovation that once led to their appropriation and introduction (Bourdieu and Waquant, 1992, p.119; Schlee, 2006). The evolvement of knowledge is basic as it is tightly connected with human beings and their practice in social and spatial contexts. For archaeologists it is always difficult to reconstruct the gradual process of how knowledge has evolved as we often only find settled stages of a concept at one time[2]. To look behind this curtain of evidence requires definitely a theoretical approach to ask the right questions. Reconstruction of techniques and technical development is one key level of investigation that humanities have been walking on since decades with the help of science: The assertion of technological concepts and its implementation to wider cultural and economic spheres is puzzling though. Is it the availability of "resources" such as knowledge and raw materials alone that helped a sustainable and continuous acceptance? The social construction of raw materials, the evolvement of knowledge and the assertion of a technological concept are therefore in tight relation to each other. This relation will be a vocal point within this short note.

The enmeshment of consumers and producers

The enmeshment of consumers and producers is the first key-issue to discuss: any societal view on production and consumption spheres of societies has to pursue the question of the technical complexity, its economic scale and the ideological charging of materials. Gold for instance enables us to explain the evolvement of supra-structures and societal control. Often goods of that kind are qualified as markers of an evolved social inequality and a starting dichotomy between producers and consumers (on this special aspect recently Stöllner, 2016).

The difference between seasonal and permanent mining practice can be used as an explanatory model, as the mining practice itself implies information about the necessity of involvement of labour force and specialist

Fig. 1. Expeditions of the New Guinean tribe of the Kimyal led by Delyat Kiroman to a "tabu site" at the volcano Min Muchabya, where only he was allowed to split and win the basaltic rocks for the adze-production (Laschimke, 2013, 199, Fig. 14-15).

skills. Extensive, informal mining still today is following different rules of practice and productivity than industrial, intensive exploitation (Stöllner, 2008, pp.169-172).

Therefore it is of great importance for our debate to understand production practices as societal enmeshment and activity: the appropriation of materials and objects inherits all the practice that producers and consumers had with them (in a broader sense as affordances within human practices: Gibson, 1977). This for instance becomes clear when regarding tribal societies in the Western Pacific and their specific access to the procurement of raw materials such as prestigious stones, salt or obsidian[3]. It is the societal action that is important and displays a part of the ideological concept that is attributed to the objects: It is important how and as part of which action the raw material had been achieved. Mining experts and leaders are not only those who know about the technical work flow but also about the ritual narratives and necessary action – a second "work flow", that has to be likewise reconsidered (such as the Yeleme "axe-share the hit man". Laschimke (2013, p.196) for instance reports of the axe-maker Delyat Kiroman from the Kimyal tribe who was initiated to split the basalt rocks and prepare the right blades (Fig. 1):

> *"Only me it is allowed to touch the stones. If someone else touches the stones, so the stone flies in pieces, if a sinner tries to prepare adze-blades from them."*

Such a tight ritual interplay between the procurement of materials and the social practice combined with it is hard to evidence by help of archaeological sources: One very interesting example was documented along with the gold mining and productions areas of the 4th to early 3rd millennium complex of Sakdrisi-Dzedzvebi in SE-Georgia (Stöllner, et al., 2014). It was fascinating to learn that nearly all the production practices were once accompanied by ritual practices such as lay-down rituals posterior of the work-process. But also prior-rituals could be evidenced, although more difficult to identify as their spatial and temporal relation are not unambiguous all the time (Stöllner, 2017).

Relations of this kind may be seen in relation to many early materials and their production-process. Such features provide us also with information about the cultural appropriation of material and its cultural meaning: "Meaning" of all kinds is decisive when discussing access and exchange patterns in a further sense. It is therefore often more appropriate to think about direct access routes for "meaningful" material/objects than about trading patterns in a more modern sense. The example of Alpine Jadeite axes, highlighted in recent years by a broad European network of researchers, can indicate such on broad bases of analyses and technical and typological studies (e.g. Pétrequin, et al., 2012)[4].

Direct access to raw materials is therefore a very important aspect for the appropriation of raw materials and their conversion into resources. I would therefore argue that direct access exploitation and consumption modes are basic modes (in general Renfrew 1993). They have to be considered different from the trading of commodities (e.g. Stjernquist, 1985). The latter required some kind of dichotomy between producers and consumers and therefore led to a more externalized relation to resources. We could call it alienation similar to the commoditization of I. Kopytoff (Kopytoff, 1988, pp. 66-67): Traded commodities like salt, iron or metals had to be weighed and described as well as proven according to their quali-

Fig. 2. (1) Oman, Al-Aqir, black copper ingot with slag-inclusion (photo: Deutsches Bergbau-Museum Bochum, M. Prange, (2) The Ea-nasir-tablet BM 131236, left: obverse part, right: reverse part (reproduced by courtesy of the Trustees of the British Museum).

ties. So it is clear that the appropriation of raw materials to resources underwent various steps: first the usage and practice with things and substances raised experience and knowledge but later also triggered a desire for the things and substances. This is the moment in which resources were not seen any longer purely as daily goods of practice but also as worthy equivalents – this has to be assumed especially for goods and resources that were not in direct practical uses such as food. Metals, specials colourful pigments and sharp stones, especially when practicing with them, acquired values beyond daily consumables – they became commodities stable in worth and value: The change of material practices therefore led to the rise of new "scapes" of acting (scapes in the sense of Appadurai 1996). Such acting of course involves the way of exchange and as such underlies mechanisms of demand and supply. Societal equivalences of worth had to be expressed as a consequence. Social administration evolves for instance along with institutions such as barter-trade (for barter trade in a sociological view: Hildebrandt, 2009). In addition administered trade also opened the doors for cheating. Well known is the evidence of cheating documented at cuneiform tablets from Sumerian southern Mesopotamia in the early 2nd millennium BC: the complaint of tradesman Nanni in Ur is well known. He wrote and complained to Ea-nasir (British Museum Tablet UET 5 81: Oppenheimer, 1967, pp.82-83) (Fig. 2,2):

I will give Gimil-Sin (when he comes) fine quality copper ingots. You left then but you did not do what you promised me. You put ingots which were not good before my messenger (Sit-Sin) and said: "If you want to take them, take them; if you do not want to take them, go away!

What do you take me for, that you treat somebody like me with such contempt? I have sent as messengers gentlemen like ourselves to collect the bag with my money (deposited with you) but you have treated me with contempt by sending them back to me empty-handed several times, and that through enemy territory. Is there anyone among the merchants who trade with Telmun who has treated me in this way? You alone treat my messenger with contempt! On account of that one (trifling) mina of silver which I owe(?) you, you feel free to speak in such a way, while I have given to the palace on your behalf 1,080 pounds of copper, and umi-abum has likewise given 1,080 pounds of copper, apart from what we both have had written on a sealed tablet to be kept in the temple of Samas.

How have you treated me for that copper? You have withheld my money bag from me in enemy territory; it is now up to you to restore (my money) to me in full.

Take cognizance that (from now on) I will not accept here any copper from you that is not of fine quality. I shall (from now on) select and take the ingots individually in my own yard, and I shall exercise against you my right of rejection because you have treated me with contempt."

If we look at Bronze Age ingots from Aqiir and Ra's al Hadd, that manifest a false core consisting of copper matte or even slag, we clearly understand these complaints (Prange, 2002, pp.11-12 Abb. 6) (Fig. 2,1); worth equivalences could be cheated whenever their worth allowed to take benefit from such a practice – for whatever reason. But it can be understood also as an expression of alienation of the product from oneself and the own societal nuclear-group.

Understanding the modes of exploitation

Looking on our archaeological record there are many case-studies that indicate a seasonal mode of winning and a non-permanent access to the desired resources[5] (Fig. 3,1). Seasonal non-permanent production modes

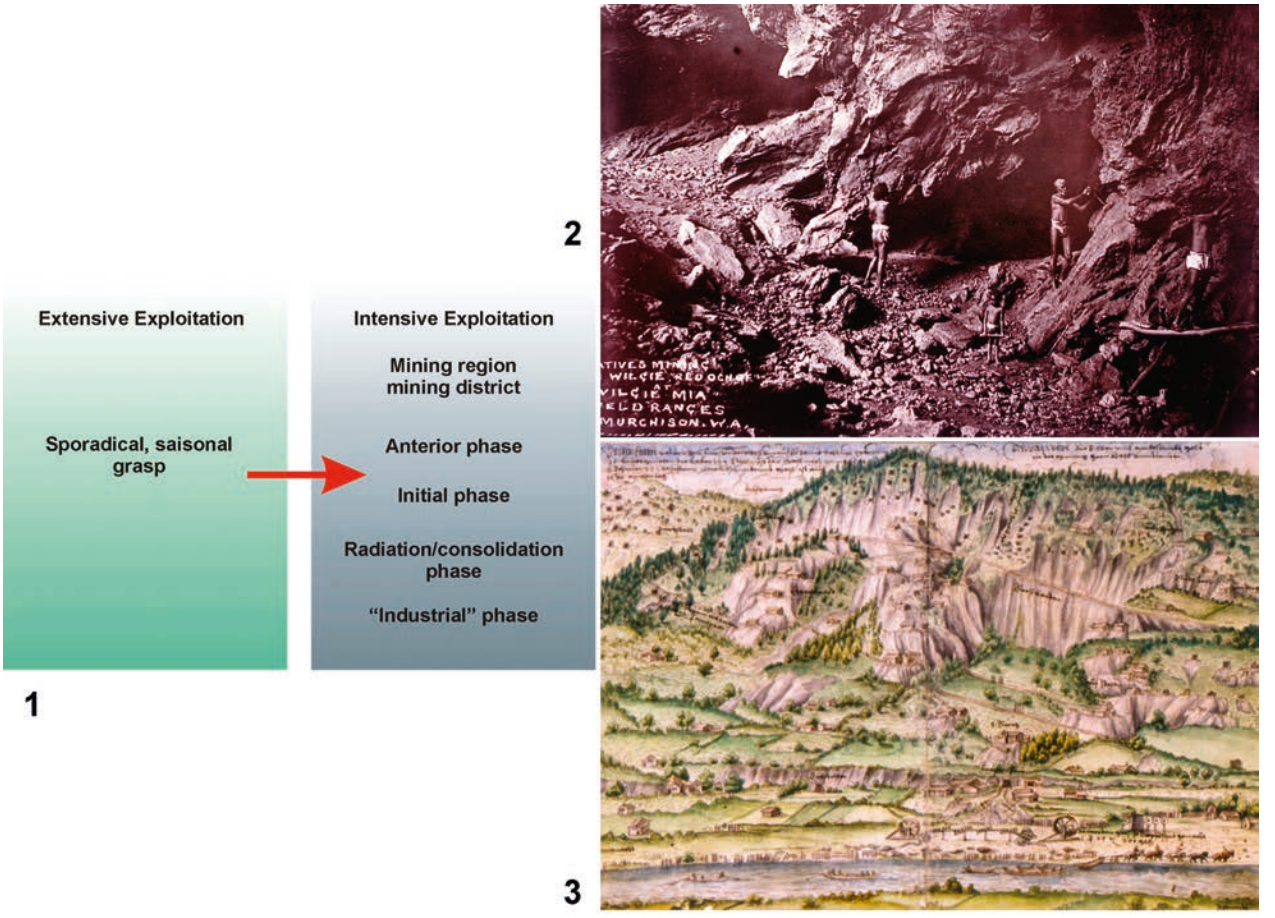


Fig. 3. (1) Production modes and their relation to imprinting processes (intensive exploitation) in mining regions (after Stöllner, 2008b, 77, fig. 5); (2) Wilgie Mia, West Australia, ocre mining of an Aboriginal community, after W.H. Kretchmar (R. Woodburn, Wilgie Mia – an ancient red centre. Australian Geographic 31, 1993, 24-25); (3) Schwaz, Falkenstein district as an example for intensive mining exploitation, after C. Bartels, A. Bingener, R. Slotta (eds.), Das Schwazer Bergbuch, vol. 1. Der Bochumer Entwurf von 1554 – Faksimile. Veröff. Deutsches Bergbau-Museum, 2006, p. 922 Fig.).

generally dominate most of the older prehistoric periods. Small scale, extensive workings, the lack of settlements and infrastructure as well as the near-surface working can be characteristic for this sort or winning-mode (Fig. 3,2). In opposition there are intensively and permanently worked deposits with accompanying settlements and the concentration of most of the productive steps (Fig. 3,3): they develop over a certain time and have by their larger production a higher quantitative impact to the societies involved. The oldest pigment mines at Thasos (Tzines) were already exploited sporadically or within a seasonal mode presumably alongside with the hunt of Saiga antelopes (Weisgerber, et al. 2008). Many of the Neolithic cases in Central Europe can be classified as such, for instance the silex/chert-mining (e.g. Arnhofen recently Roth, 2008; Rind, 2009); but the same is true for many of the Egyptian raw material acquisitions that followed the mode of seasonal expeditions (e.g. Weisgerber, 1991). Bronze Age metal ore mining often provides ample evidence of transitional modes which ranged between semi-permanency and seasonality, something that seems typical for the steppe-mining such as the Bronze Age tin mines in Central Asia (Garner, 2013; for the site of Sičkonči: Parzinger and Boroffka, 2003)[6]. Single examples of permanent infrastructures in the surroundings of mining enterprises are already known from the late 4th millennium on, but they seem still the exception[7]. During the later 2nd millennium B.C.E. and the Iron Age it seems that the degree of permanency increased, especially in the large area of the Mediterranean and its neighbouring landscapes (e.g. Iron Age Fenan: Levy, et al., 2014; Cyprus: e.g. Given and Knapp, 2003; the Alpine copper mining: Goldenberg, et al., 2012). During the 1st millennium and the Roman Empire permanency seems more the rule (e.g. in general Domergue, 2008). But one should never forget that informal mining practice may still have existed besides the more regulated and permanent ones[8].

Time and quantity of production are therefore important parameters to not only understand the societal but also the economic impact that an exploitation once had. A large mining field such as in prehistoric chert-flint production can look like a large production but was worked on an informal, non-permanent mode, although over a long time-span of course (e.g. the discussion of Abensberg-Arnhofen in Roth, 2008). To balance these arguments it is necessary to understand technical complexity

and the production-size in various aspects – either as social activity but also as production-system that is enmeshed with landscapes, the quality of the deposits and other factors.

What is most interesting for the discussion raised here is this: It is worth thinking how the mining practice and its socio-economic embedding does interrelate with the consumption and social practice of these products. And how this relation gradually changed from seasonal, small scale production to permanent winning in larger scale, and how this again changed also the social complexity of a society must also be considered. It is of importance for our question when the joint role of consuming and producing was separated and divided: when producers started to work for consumers and their consumption practices such as rituals in burials and sanctuaries.

Innovation and knowledge

Innovation and knowledge are certainly very important terms when describing the change of societies and economies, though there is a wide span of theories about how to explain them, their influences on societal change or to the simple question what and how to explain innovation: Which processes did a new invention help to be established in a societal system? Joseph Schumpeter (1883-1950) (1911, pp.17-23) was one of the first who pinpointed the fact that not the technical invention makes an innovation but the economic application to a successful "production" process[9]. Schumpeter thought solely on the economic sphere and their entrepreneurs, but nowadays innovation research has a far wider perspective (e.g. Sauer and Lang, 1999; Hof and Wengenroth, 2010)[10]. Is it the inclusion of a common application to societal practice either in the sense of production or in the sense of any other relational habit that produces meaning and remembrance? However, if we look to the appropriation of raw materials as resources it is clear that once a society has accepted a substance as a resource it has undergone an innovation process[11]. The societal practice has decided upon its application; but what has directed such societal decisions – this question had puzzled generations of theorists in sociology and economics. Was it only the rational decision about supply and demand according to prices, as it was already summarized on the basis of older writings by Adam Smith in the late 18th century and later by the classical national economists?[12]

In the frame of ancient cultures we often observe striking cases when decisions seem not to be driven by rational decisions only[13]. One could take for instance the introduction of basic materials such as metals. How we may explain the adherence to concepts of form-function and materials when a new material such as metal was introduced? We may discuss this simply as an adherence to a perhaps better, or seemingly better, base material or "technology" but we cannot earn much from such explanations.

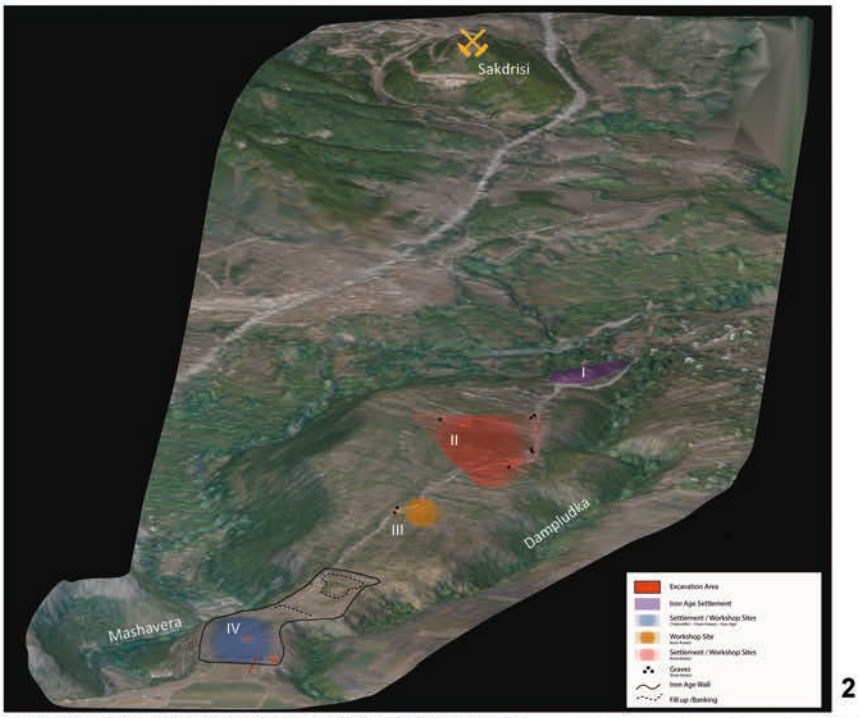
The Nobel Prize winner Douglass Cecil North (2005, 87-102) did argue in favor of "path dependencies" of certain processes and did question mark the traditional arguments of a balance or stable equilibrium of economic processes ("homo economicus")[14]. In the centre there is the assumption that developments and their history strongly influence or limit future possibilities and directions of innovation developments and their application. "Path dependencies" may be observed in many aspects of innovations during the history of ancient cultures; and they may be detected even easier if we observed them during a longer period of time. Already Schumpeter was one of the first who did prefer to talk about long-wave-cycles which he understood as a never ending development (Schumpeter 1911, pp. 463-473)[15].

Let us take the question of the invention of metallurgy as a case example: since Gordon Childe's epochal writings (e.g. Childe, 1928; 1944) we have seen many theories about how metallurgy has been applied to different regions and spheres in the world (recently Roberts et al. 2009). Some have described it as a process of a long-lasting diffusion of ideas, techniques and societal innovation; others stressed autochthonous elements during this development. But it is obviously not only a question of diffusionism or autochthonism, as this is our mental construction[16].

First, it is really hard to decide upon the single processes that led to the application of metallurgical techniques in various regions and cultural settings[17]; second, we are only able to understand these processes from a bird's-eye view in a global perspective (e.g. Roberts, et al., 2009; recently the commend: Pearce, 2015, pp.45-47; Rosenstock, et al., 2016, p.83). What is needed is a perspective that includes further regional arguments such as the societal backgrounds and "path dependencies". How else we can explain why there was such a long time span between the appropriation of green pigments and native copper to the application of pyrotechnics and the casting of objects suddenly during the early 5th millennium? How do we estimate interesting anomalies of very early tin-bronzes found in metallurgical remnants in Serbia already at the beginning of pyrotechnics there (Radivojević, et al., 2010; Radivojević, et al., 2013)? Were they inventions that of course led to no consequences as to an innovation stream?

However, let us look to "path dependencies" either in a historical perspective but also in a geographical sense: In a historical sense it would mean that societies and people followed social interrelations and perspectives over a certain time-span. While social institutions may have changed more rapidly, the perspective to foreignness enhances practices of cultural memory: It is the vision of consumers to lands of wealth and wellbeing, to lands full of raw material and sources. Such visions were encountered with lands like Punt in the Egyptian tradition (e.g. Fattovich, 1999; Meeks, 2003), the Biblical Tarshish (2. book of Chronicle, 21; 1st book of kings 10,22; Jeremia 10,9; Jesaja 60,9)[18] and the kingdom of Alashya within the


Gold-winning around BC 3000
Sakdrissi: Mining
Ore production
Ore beneficiation Above ground
Testing the ores
Balitschi Dzedzwebi: Settlement
Milling of gold ores
Wet beneficiation near the river
Crucible smelting
1


Sakdrisi
I
II
III
IV
Dampludka
Mashavera
2

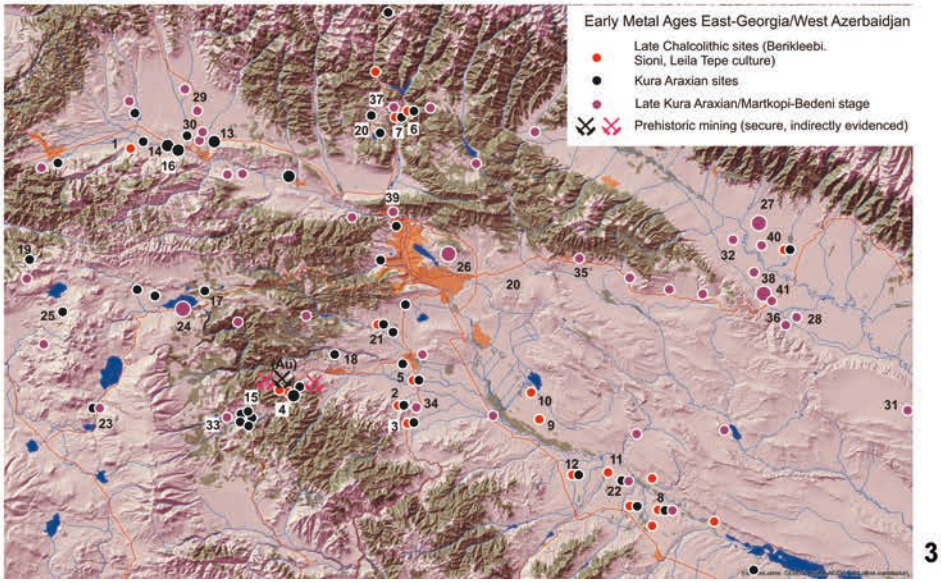

Early Metal Ages East-Georgia/West Azerbaidjan
Late Chalcolithic sites (Berikleebi. Sioni, Leila Tepe culture)
Kura Araxian sites
Late Kura Araxian/Martkopi-Bedeni stage
Prehistoric mining (secure, indirectly evidenced)
3

Fig. 4. (1) Simplified chaîne opératoire of the Early Bronze Age gold winning in south-east Georgia, after Stöllner, et al., 2014 (graphics/photos: Th. Stöllner, K. Stange, Deutsches Bergbau-Museum Bochum; (2) The plateau of Balitchi-Dzedzvebi and their Kura-Araxes-settlements, workshops and graves in relation to the gold mining site at the Kachagiani hillock/Sakdrisi (graphics: F. Klein, Deutsches Bergbau-Museum Bochum); (3) Archaeological sites of the 4th and 3rd millennium in East Georgia and the Kura Valley in Azerbaijan (after Stöllner, 2016, p. 224 Fig. 10).

Antiquity[19]. This also includes a geographical vision, as these lands are remote and distant: The East Iranian land of Aratta is a good example, as it was in memory of Sumerian and Elamite kings and elites as a vision from where materials had to be acquired (Madjidzadeh, 1976, pp.105-113; Hansman, 1978; see recently Potts, 2004): To build up tight social relations to their kings and elites was one important practice to establish this flow of materials and most likely also of knowledge along certain routes. But we learn such routes are manifold: they are paths both of social and of spatial practice, more like mental maps that may not be realistic[20]. In the visions of the Elamite king Enmerkar he was advised by the goddess Inanna to send a messenger via the mountains and further on to Aratta (Kramer, 1952): It is a vision of a way that is described rather than a detailed description of the track the messenger had to follow. I mean it is cultural memory that obviously was inherited over generations that told people where (far away!) and how to acquire raw materials and goods. The same is perhaps true also for pathways of innovations in acquiring goods, ideas and knowledgeable persons: It is often a social construction that binds certain experiences to groups and their geographical setting: we ourselves know this quite well if we talk about the *French savoir vivre* and the *German punctuality*. It meets our cultural expectations no matter if they are correct or not. The point I want to make is that these "cultural path dependencies" direct the way in which people and goods and the ideas inherited to them travelled. Transfer walks on the pathways of cultural memory, one could argue.

It is easy to find examples if we follow the appropriation of raw materials over time and space: So let us take the gold mining at the central Mashavera-valley (Bolnisi zone) in Georgia, an example we are dealing with in a longer lasting project (e.g. Stöllner, et al., 2014). The gold mine that surprisingly is well developed already in the late 4th millennium raises the general question if the highly complex technical and societal structure had been evolved gradually or suddenly (Fig. 4,1-2). But gold was already a materialized part of late-chalcolithic social innovation before the Sakdrisi mine evolved – and so was metallurgy in that area (Courcier, 2014; Stöllner, 2016, pp.213-214, fig. 4, pp.223-226, fig. 10). These techniques were accompanied by technical innovations already in the late chalcolithic – a flow of ideas has reached the Mashavera-valley, presumably from the Kura-valley and its tributaries, already before the mining in Sakdrisi started to be a large and well-organized enterprise (Fig. 4,3). But even then the regional framework continued to the north-eastern valley to which the Sakdrisi-gold was transported even later: It is a kind of "path-dependency" that did not only frame the consumption of goods in the valleys northwards but did obviously also include the transfer of knowledge. The recently discovered late chalcolithic crucible and mould fits best, therefore, to a series of metallurgical innovations that resemble metallurgical workshop traditions from the eastern Caucasian and North-West-Iranian background (Gambashidze and Stöllner 2016, pp.106-111; the general connections within the metallurgical knowledge: Helwing, 2012; Ivanova, 2012).

The growth of technical knowledge

But do the spatial and social aspects of so called "path dependencies" explain the third point of our consideration, the growth of technical knowledge? In Sakdrisi it seems that the appropriation to a raw material basically was accompanied by the experience of daily practice: to handle the rock, to understand the grade of gold and to develop techniques to concentrate and smelt it. Such observations we find also in other mining and metallurgical foci. There certainly were preconditions of knowledge already existing but many experiences depended on the trial and errors of the persons and societies involved.

Claude Leroi-Gourhan developed the idea of the chaîne opératoire for any productive practice (Leroi-Gourhan, 1964; 1988). Essentially this means that we study each step of a particular productive process and look for social and cultural influence within each step (e.g. Sellet, 1993; Edmonds, 1990; Schlanger, 1994; Dobres, 1999; Martinón-Torres, 2002). We are used nowadays to the term and sort our observations about techniques according to a rather mechanical concept: I will not comment on that as others have done it with more background on learning and practice[21].

Let us for instance take the Mitterberg-process in the Eastern Alps: the mining of sulphidic copper ores involves the extraction, the pre-processing (beneficiation and/or roasting), and the smelting of such ores, and finally the fabrication of black copper as a raw product (in general Zschocke and Preuschen, 1932; Eibner, 1982) (Fig. 5). Given a specific level of technical experience, one can propose a several-step process that one may describe within a chaîne opératoire[22]. This proposed model logically depends upon the complexity of technics and procedural steps being involved to complex production process.

But what is interesting is the different angle with which consumers and producers looked on the complexity of techniques and the question of resources: For the mining person this certainly was different as for the casting metal-worker or even the consumer of an implement made of this metal. The single procedural steps that have

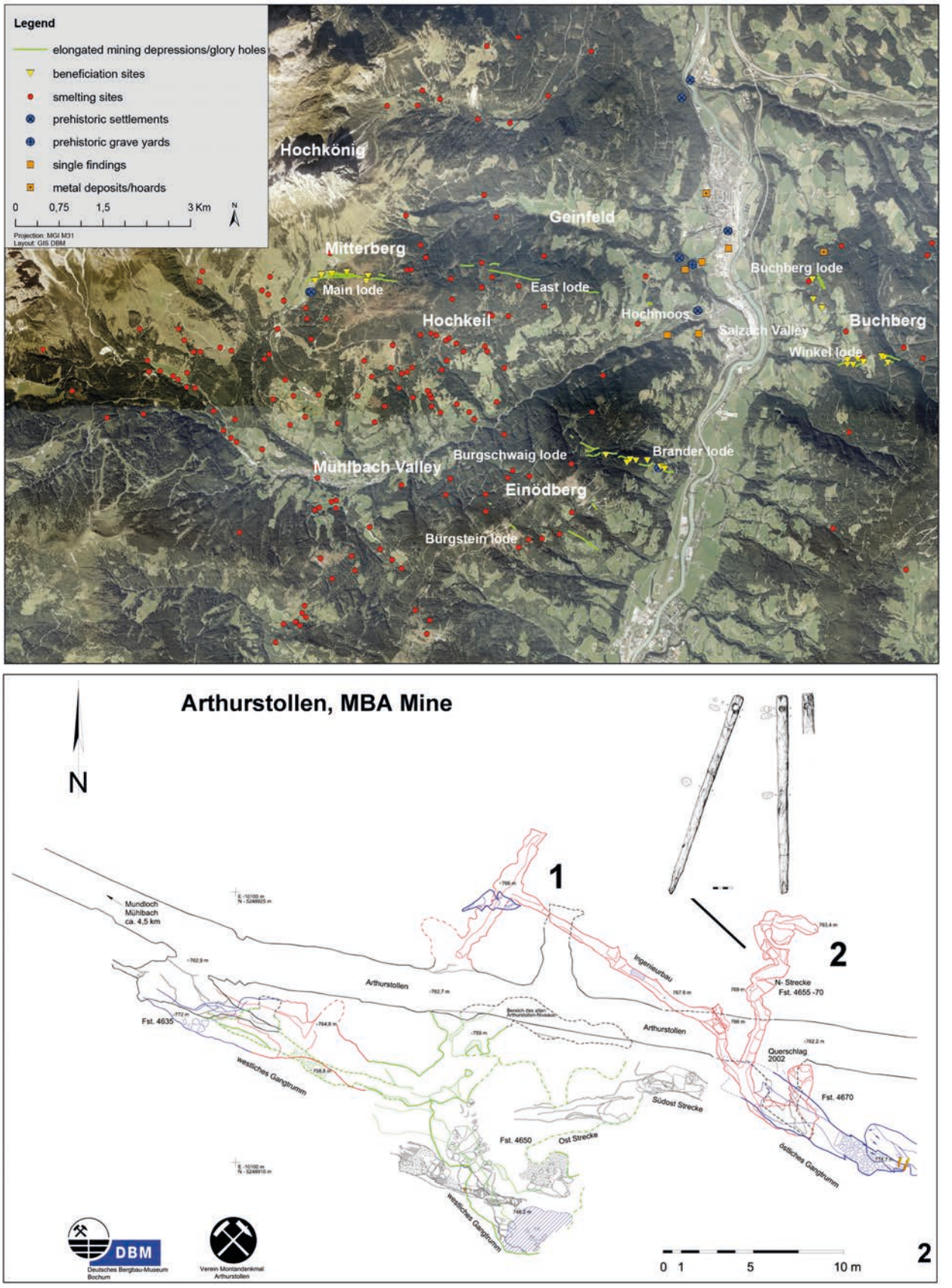


Fig. 5. (1) The "Mitterberg" mining district (the mining field of Mühlbach-Bischofshofen) at the centre of the Salzach-Pongau region as displayed by mining lodes (and their surface depressions), beneficiation and smelting sites as well as settlements, single finds and graves; (2) Arthurstollen-gallery, detail of the base map, 1: Middle-Bronze Age deep mine with interconnecting "engineers" gallery and 2: the compasses found in a small shaft in the North-gallery (map and graphic: Deutsches Bergbau-Museum Bochum/Ruhr-University Bochum, Mitterberg project).

to be learned and practiced were probably not envisaged by all being included. This has consequences, as the growth of knowledge in a single technical environment had to be balanced with others. Joseph Schumpeter (1911) regarded labour-division as a major aspect of the entrepreneurial source of success and income; but regarding a prehistoric mining community, for instance, the value of common knowledge about all the procedural steps is nonetheless most important for the cooperative work task, like in mining regions like the Bronze Age Mitterberg[23] (Fig. 5,1). Such common shared knowledge traditions may have served for all the people of the communities within the mining region as something like a "mental map" that indirectly framed their daily practices (in general Downs and Stea, 1973, pp.8-23).

Nonetheless techniques as part of humans' lifeworlds incorporate many inventions and their application: they provide us information about innovation processes and their appropriation to societies. It is the other side of the coin we have already looked on. Everyday practices in producing and consuming certainly directed the way that innovations turned into wider used techniques and even to externalized technologies. Let us take Bronze Age mining practice as an example: As with any the other techniques the miner also had to solve problems for which he/she had first of all a bundle of practical experiences and knowledge. When extraordinary problems occurred the pressure to change already existing concepts increased dramatically: Such a case we observe in the Bronze Age Arthurstollen, the deepest mine in the 2nd millennium BC world-wide (Fig. 5,2)[24]. The miners did lose the copper-bearing ores eventually: what they did first was to search for it by driving several small scale galleries; they learned that this was wrong as they were working in the hanging roof that had been slid northwards for some meters by tectonic events. Eventually they understood this when they came deeper and found the tectonic rift. Following that rift in the opposite direction finally was successful: they rediscovered the underlying bed together with the ore-body. But as this did cause anew problems with air-circulation they finally reorganized the mine and reinstalled, by help of surveying techniques, a second air-circulation gallery which was interconnected from both sides (for the surveying techniques: Thomas 2016). This example does show the growth of knowledge of course but also the inclusion of knowledge to the bundle of techniques they could use.

Such as the appropriation of raw materials to resources is a multifaceted process of knowledge-growth, it is also with the growth of technical abilities: Both are innovative processes that are following social requirements and constraints by help of individual or communal satisfaction of curiosity and the wishes to change. Availability of knowledge and the socio-economic usage of helped technical solution even whole technologies to be installed.

In this article I followed the basic question of how the conversion from unspecified raw materials to well-known resources was accompanied by social and technical innovations, the growth of knowledge and the vision of transfer and the cultural memory of it. These are all resources that enabled development and transformation: The relation of all those resources to each other still will raise many more questions and sometimes also answer about the complexity of change and movement of the cultural and social developments of mankind. Although such processes must be discussed certainly on a broader perspective, I fear that it can be understood best by archaeologists particularly on the empirical level of their studies. But it was human beings that set all that into action – it was their curiosity and their entanglement to environments of all kinds that drove this forward[25].

Notes

1 The discussion of the term "resource" is manifold and used in various disciplines in a different way: in economics and sociology a broad definition is discussed in most cases, for instance within a resource based view, a theory that underlines the competitive abilities of enterprises and companies (e.g. Pfeffer and Salancik, 1978). A definition cannot given here, some definitions allow a broader approach to various concepts: (e.g. Giddens, 1984; Müller-Christ, 2011, pp.167-170; Mohldaschl, 2007; Bourdieu and Waquant, 1992). An Special Research Area (SFB 1070) in Tübingen now tries to outline a comprehensive definition: https://www.uni-tuebingen.de/forschung/forschungsschwerpunkte/sonderforschungsbereiche/sfb-1070.html

2 When looking to discussion within the archaeological field the discussion often is bound to material or natural resources, which often leads to pessimistic assessments concerning how complex ideological and immaterial processes shall be described, typical for instance: Urban 2002. I myself regarded the methodological approach for an economic archaeology as functional in a first step in order to describe structural patterns (Stöllner, 2002, p.79), a statement that obviously did not exclude further interpretative levels; today the approach had been widened particularly as archaeology itself had been forged links to other disciplines on a higher degree; for mining resources for instance Stöllner 2015.

3 Burton, 1984; Harrer, 1976; Laschimke, 2013; Pétrequin and Pétrequin, 1993; 2012.

4 The Spondylus-exchange between the Aegean and the Danubian regions of Central and East-Europe recently discussed by Windler (2015) esp. pp. 95-102; 229-231.

5 Often we lack a thorough study of such mining exploitation modes, in principle defined and discussed by Stöllner (2003, esp. pp. 432-433; 2008b, esp. pp.68-70.

6 The dwelling modes of the mining population obviously was dependent of various aspects, such as the subsistence and herding strategies of the rather small scaled populations: While the climatic conditions of arid zones of the southern part of Central Asia forced the herding population to follow water and better grazing conditions in summer (what indicates a higher mobility), the case seems different in the temperate north where grazing and herding was carried out around the settlements that were used in a more permanent way. The 2nd millennium tin mining complex of Askaraly II provided a good example for such living conditions: Stöllner, et al., 2011. In the meantime it became clear that the settlement of Mastau Baj was reused also in younger chronological phases (Naumann, 2016), which at least allows arguing for some stability in using a favourable dwelling ground (access to water; protection by a hill-ridge against the weather gear etc.).

7 One of the oldest examples is known from the gold mining enterprises near Sakdrisi in Southern Georgia: e.g. Stöllner, et al., 2014, but they got more frequent during the third millennium, as for instance evidenced by the settlement of La Chapitelle-du-Broum in the area of Cabrières in South France: Ambert, et al., 2005; Ambert, et al., 2014, esp. pp.61-63; but there is also no doubt that mining districts like the Silex mining of Spiennes produced permanency in social practice during the exploitation and manufacturing processes over a longer time periods that led to a general appropriation of the area by various communities of the surrounding: e.g. Collet, et al., 2006.

8 The evidence for non-permanent mining activities during that time is more difficult to achieve. So one can take the Roman mining evidence in Cabrières as example: The small scale Roman mining evidence resembles most likely a non-permanent sporadical after-mining grasp to the deposit: e.g. Ambert, 1995.

9 Schumpeter (1911) did not use the term innovation but of technical improvement ("Neuerung") and discussed the importance of the social value system (ibd., 85-86). See also the recent review: Croitoru, 2012.

10 Childe (1944, pp.7-24) already used the term innovation to explain the technical change; Innovation and technology were topics of the DAI research clusters between 2006 and 2016, for the specifically archaeological concept see: https://www.dainst.org/forschung/netzwerke/forschungscluster/cluster-2/konzept.

11 Discussed in principle by C.v.Rüden and Th. Stöllner in: Stöllner, 2015, pp.63-66.

12 Smith, 1776 (1981), pp.616-617; exchange market theory: Ricardo, 1821; on the discussion and critics: Schumpeter, 1965/2009, pp.240-242; Rothbart, 1995, pp.448-457.

13 This is a point that especially is in the centre of the critics of Rothbart, 1995, pp.448-457.

14 The „homo oeconomicus" is the model of the classical-neoliberal economic theory: It is based on an ideal human being, whose economic decisions are basically rational and are driven to maximize the economic welfare; this basic model recently came into serious criticism: e.g. Rost, 2008

15 The observations and discussion of Schumpeter were used a great deal within long-wave theories for instance: Kondratiev, 1984.

16 Juxtaposition recently has been promoted by Rosenstock, et al., 2016. See also for a new diffusionism: Pearce, 2015, pp.46-47.

17 This was one basic argument of Renfrew (1969); recently supported under a Serbian perspective by Radivojevic (et al., 2010).

18 Connection to the realm of "Tartessos" and the Southwest Spain: Koch, 1984; Alvar-Ezquerra, 2000.

19 There is only little doubt not to identify the kingdom of Alashya with Cyprus, the island of copper in which case the main product of island became synonymous for the name of the Island itself. In discussion of the Amarna-correspondence: Knudtzon, 1915; Artzky, et al., 1976; Knapp, 1996, pp. 16-60.

20 Such arguments are highlighted by D. Potts (2004) in regard of the many arguments to localize the land of Aratta.

21 The question of implicit learning and practices can be regarded as most relevant for this discussion, as recently shown in various investigations: Marchand, 2007; Von Rüden, 2015, pp.35-50 esp. pp.36-37.

22 In recent years comprehensive studies have been carried out about the Mitterberg Mining region within the Special Research Area HiMAT coordinated at the University of Innsbruck (Goldenberg, et al., 2012); the research also involved studies about the mining, the beneficiation and the smelting processes as well: a current overview about our teams work: Stöllner in press (esp. chapter 6: The Mitterberg process).

23 There is no indication for a harsh social hierarchy that controlled the work steps within the mining region, see for this discussion e.g. Stöllner, in press (chapter 7.4). For other aspects see also Stöllner, et al., 2016.

24 Stöllner et al. 2009; in general an overview with a commend on the most recent results: Stöllner, in press (chapter 4.2 and chapter 6.2).

25 The Entanglement of human beings and things has been recently discussed by archaeologists controversely: Hodder, 2012; Pollock, et al., 2014.

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