THE PREHISTORIC AND HISTORIC MINING DISTRICT IN THE REGION OF KITZBÜHEL (TYROL, AUSTRIA): AN INTERDISCIPLINARY APPROACH TO RECONSTRUCT THE PAST

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Introduction

Bronze Age and modern mining activities played a significant role in shaping the Tyrolean landscape. The well-known mining regions of Kitzbühel and Schwaz had an important impact on the Alpine cultures, economy and environment. The large amount of copper ore in the Kitzbühel area caused many people to immigrate which lead to the development of mining communities. Initially the discovery of silver ore deposits resulted in a flourishing mining industry in the Early Modern Times. Starting from the 17th century AD, the copper production had been the reason for ongoing mining activities.

An interdisciplinary approach encompassing a comprehensive database, obtained from archaeological, historical and palaeological results will allow an integrated view of the mining landscape on Kitzbühel.

Fig. 1: The Bachalm (Kelchalm mining district, ca. 1700 m a.s.l.) takes part of the study area in the mining region Kitzbühel and shows extensive overburden dumps (Photo T. Koch Waldner).

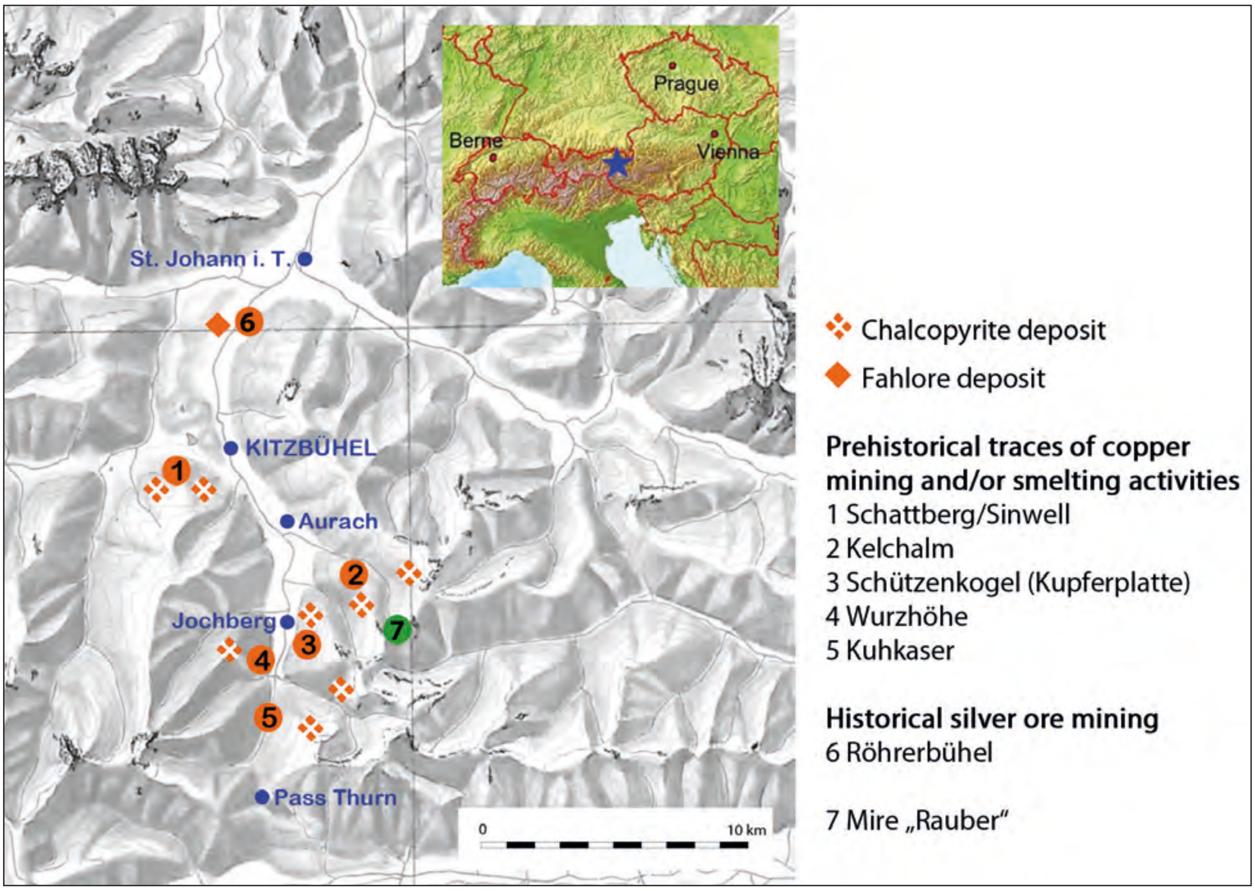

Fig. 2: Study area, the mining district Kitzbühel. Prehistoric and historic ore mining centres and the location of the analysed bog (Graphic modified according to Tirol-Atlas, edited by the Tiroler Landesregierung, Adolf Leidlmair (1982): Tirol-Atlas, D Klima, Reliefgrundkarte. Innsbruck).

This will elucidate crucial objectives of this joint DOC-team research project, which is supported by the Austrian Academy of Science (ÖAW).

One of the main problems to resolve in the archaeological section of this project is the exact dating of the prehistoric mining sites of the Kitzbühel area. Another basic objective is to deal with the question of specialization of the Bronze Age copper production. The duration of the initiation, intensification, and regression phases of the prehistoric mining is discussed together with the palaeoecological part of the project. The historical project part strives for a reconstruction of the supply structures of the mining region of Kitzbühel in Early Modern Times. Since the 16th century AD Tyrol was haunted by crop failures, food shortages and famines, it was essential to establish a functioning system of provision in order to keep smooth mining operations going. To map out the situation then, it is important to understand the interaction between the territorial prince and the commercial companies in their attempt to provide the basic necessities of everyday life ("Pfennwerte") for the miners. The palaeoecological studies aim to evaluate the paleoecological effects of prehistoric mining on the vegetation. This includes the impact of mining on the local vegetation of the study area in terms of devastation of the vegetation cover by ore mining, processing, and smelting as well as woodland exploitation and land use (e.g. tillage, alpine pasture). On a regional scale the impact of mining on the vegetation in terms of deforestation for settlement and agricultural activities to subsist the mining activities will also be discussed. The fourth section of this project deals with databases and GIS. It shows the added value of using ontologies and checks the suitability of the ontology CIDOC CRM for interdisciplinary data. A second aim is to harmonize the different sets of data from archaeology, history, and archaeobotany as well as to link spatial with non-spatial data.

Study Area

The mining district Kitzbühel is located in the eastern part of North Tyrol (Austria), between the mining areas Schwaz (Tyrol) and Mitterberg (Salzburg). The study area, a prominent copper and silver mining district in the Eastern Alps since the Bronze Age, stretches from St. Johann in Tirol to the Pass Thurn (Leukental) and belongs geologically to the greywacke zone.

The study area is divided into the following mining activity centres (Fig. 2): Schattberg/Sinwell, Kelchalm, Schützenkogel (Kupferplatte), Wurzhöhe and Kuhkaser where chalcopyrite ores were exploited for the extraction of copper during the Bronze Age. In Early Modern Times, mainly during the 16th century AD, the Röhrerbühel was the silver hot spot of the region. Up to now a peat core from a bog in the immediate vicinity of the Kelchalm was extracted for pollen analysis.

Acknowledgements

These studies are supported by the Austrian Academy of Science (ÖAW) in the course of a DOC-team fellowship (DOC-team 20: 70205, 70206, 70207, 70208). We acknowledge Dr. Eva Maria Wild, University of Vienna, for AMS-dating, Mag. Thomas Pichler, University of Innsbruck, for providing dendrochronological data and Mag. Mathias Mehofer, Vienna Institute for Archaeological Science, for metallurgical analyses.

Characterization of the Bronze Age mining and copper production area in the region of Kitzbühel, Tyrol

Thomas Koch Waldner

Some of the most eminent prehistoric copper mining regions in central Europe are situated in the Eastern Alps, along the greywacke zone. Because of the numerous findings related to the prehistoric copper production, Kitzbühel is one of the largest known prehistoric copper mining districts in the Alps.

Since the beginning of archaeology in Austria, there has been a big interest in the traces of prehistoric mining activities in the region of Kitzbühel. Archaeological records and discoveries were mentioned for the first time in 1879 by Matthäus Much (Much, 1879). The research focused specifically on the ore processing heaps in the Kelchalm region, where Richard Pittioni and Ernst Preuschen performed large excavations in the 1930s until the 1950s (Preuschen and Pittioni, 1937; 1954; Pittioni, 1947). They located more than 50 ore-processing heaps in the Kelchalm district (Fig. 1) near Aurach. The archaeological records and discoveries, like stone and wooden tools, found at the excavations in the Kelchalm district enable a reconstruction of the ore processing operation chain. Hammer and anvil stones were used to crush the mix of rock and ore into finely ground particles. Due to the different specific weight of dead rock and ore, these components were separated with water. Some of the most relevant finds related to these wet processing techniques are two troughs with an original size of about 175 x 80 cm as discovered (Preuschen and Pittioni, 1954, pp.20-22, 69, Fig. 10-13 and 36/1). The troughs were made out of fir trunks with diameters of around 80 cm.

Several underground mining sites were found by modern miners during mining activities in the 19th century (Much, 1879, pp.18-36; Much, 1902, pp.1-31). After the modern mining came to an end, the mining entrances broke down. Today none of the prehistoric mines are accessible anymore. To gain a picture of the Bronze Age mining, we have to combine different sources, such as historic mining reports, mining maps, and sinkholes on the surface which are related to prehistoric mining activities.

Further information can be obtained by few finds related to the underground mining. Handles for bronze picks (Preuschen and Pittioni, 1937, p.61; Pittioni, 1947, pp.62-63) and tapers have been found during the excavations on the Kelchalm. These handles are similar in type to those used in the Bronze Age mining district of Mitterberg in Salzburg (Klose, 1918, p.11, p.19, Fig. 29; Eibner, 1998, p.88). The tapers are also comparable with those found in the Mitterberg district, as well as the tapers from the Middle and Late Bronze Age salt mines in Hallstatt (Klein, 2006, pp.77-86; Koch Waldner, 2010, pp.72-76).

Some of the finds and features related to mining and ore processing show significant technological similarities with the Mitterberg district. This suggests a transfer of knowledge or perhaps even a migration from the Mitterberg area to the region of Kitzbühel. Dendrochronological analysis of wooden findings from the Kelchalm dated the investigated processing heaps into the middle of the 13th century BC (Pichler, et al., 2009).

Beside the mining and the ore processing features on the Kelchalm, about 50 smelting sites have been located in the communal-areas of Kitzbühel, Aurach, and Jochberg in the valley bottom as well as on the mountain sides between the Kitzbühler Horn to the north and the Pass Thurn to the south (Pittioni, 1968). The smelting sites are characterized by different slag types, like fragments of slag blocks, plate slags, and slag sand. Only one of the excavated smelting sites (site: WH/SP 5, Fig. 3) had no evidence of plate slags and processed slags (Koch Waldner, et al., 2013).

To extract copper matte, metallic copper, and ore-residue from the slag, the blocks of slag were

Fig. 3: Smelting furnaces on the site WH/SP 5 near Jochberg (Photo T. Koch Waldner).

processed to slag sand. The archaeological discoveries from the smelting sites with slag sand heaps suggest that the processing of slags was done with a similar technique as with ore.

In the first step, the slag blocks were crushed to finely ground particles by using an anvil and hammer stones. In the second step the copper matte, metallic copper, and ore-residue were extracted from the slag with water. Two gutters situated parallelly were excavated on a smelting site on the Wurzhöhe near Jochberg (Koch Waldner, et al., 2012; Koch Waldner and Goldenberg, 2012). The gutters were slightly sunk into the ground and their sides were reinforced by wooden boards. The archaeological investigation has shown that these constructions were used for the wet processing of slag.

Similar constructions for wet processing of slag sand have been found on two smelting sites in the lower Inn valley. The first one is situated near Radfeld/Brixlegg (Goldenberg and Rieser, 2004) and the other in Buch near Schwaz (Klaunzer and Staudt, 2011). The investigated traces of prehistoric mining and smelting activities in the mining district of Schwaz/Brixlegg were dated into the Late Bronze Age (Goldenberg et al., 2012). Another important copper production hub of the Late Bronze Age is situated in the eastern part of the Trentino in the Southern Alps. The results of the investigations on the smelting site Acqua Fredda showed that slag was also processed to slag sand in this Late Bronze Age smelting site (Cierny, et al., 2004).

In the region of Kitzbühel three smelting sites with slag sand heaps have been dated to the beginning of the Late Bronze Age (Goldenberg, 2004; the radiocarbon dating results of two sites recently excavated by T. Koch Waldner have not been published yet). The common features of Late Bronze Age smelting sites in different mining districts discreetly raise the assumption that the mentioned slag processing techniques are phenomena of the Late Bronze Age. In this period of enormous demand for copper, the prehistoric smelting workers increased the yield by obtaining ore-residue, copper matte, and metallic copper drops from the slags.

Further investigation will help to reconstruct the duration of the prehistoric mining activities in the region of Kitzbühel.

The only prehistoric cemetery in this mining district is located in the area of Lebenberg in the city of Kitzbühel (Pittioni, 1952; Eibner, et al., 1966; Scheiber, 2011). Few urn graves were excavated from this cemetery. According to the relative chronology based on the spectrum of finds, this cemetery was used at least from the 14th to the end of the 11th century BC (Scheiber, 2011, p.75). Other finds from the area around the mining districts in this region are mainly dated to the middle and Late Bronze Age.

The absolute dating of smelting and mining sites in the 13th / 14th century BC combined with the relative dating of the cemetery Lebenberg as well as stray finds show that human activities increased in this period. This result suggests the assumption that the increase of human activities was related to the beginning of an extensive mining industry in the phase of transition from the Middle to the Late Bronze Age.

References

Cierny, J., Marzatico, F., Perini, R. and Weisgerber, G., 2004. La riduzione del rame in località Acqua Fredda al Passo del Redebus (Trentino) nell' età del Bronzo Recente e Finale. In: G. Weisgerber and G. Goldenberg, eds. 2004. Alpenkupfer – Rame delle Alpi. *Der Anschnitt*, Beiheft 17. Bochum, pp.125-154.

Eibner, C., Plank, L. and Pittioni, R., 1966. Die Urnengräber vom Lebenberg bei Kitzbühel, Tirol. *Archaeologia Austriaca,* 40, pp.215-248.

Eibner, C., 1998. Schaubergwerk Arthurstollen. *Archäologie Österreich,* 9(1), pp.85-89.

Goldenberg, G., 2004. Ein Verhüttungsplatz der mittleren Bronzezeit bei Jochberg (Nordtirol). In: G. Weisgerber and G. Goldenberg, eds. 2004. Alpenkupfer – Rame delle Alpi. *Der Anschnitt*, Beiheft 17. Bochum, pp.165-176.

Goldenberg, G. and Rieser, B., 2004. Die Fahlerzlagerstätten von Schwaz/Brixlegg (Nordtirol) – Ein weiteres Zentrum urgeschichtlicher Kupferproduktion in den österreichischen Alpen. In: G. Weisgerber and G. Goldenberg, eds. 2004. Alpenkupfer – Rame delle Alpi. *Der Anschnitt*, Beiheft 17. Bochum, pp.37-52.

Goldenberg, G., Breitenlechner, E., Deschler-Erb, S., Hanke, K., Hiebel, G., Hüster-Plogmann, H., Hye, S., Klaunzer, M., Kovacs, K., Krismer, M., Lutz, J., Maass, A., Moser, M., Nicolussi, K., Oeggl, K., Pernicka, E., Pichler, T., Pöllath, N., Schibler, J., Staudt, M., Stopp, B., Thurner, A., Töchterle, U., Tomedi, G., Tropper, P., Vavtar, F., Weinold, T., 2012. Prähistorischer Kupfererzbergbau im Maukental bei Radfeld/Brixlegg. In: Goldenberg, G., Töchterle, U., Oeggl, K. and Krenn-Leeb, A. 2012. Forschungsprogramm HiMAt - Neues zur Bergbaugeschichte der Ostalpen. Archäologie Österreichs Spezial 4, Wien 2011, pp.61-110.

Klaunzer, M. and Staudt, M., 2010. Fundchronik Bronzezeit, Tirol, KG Buch, OG Buch bei Jenbach, VB Schwaz. *Fundberichte aus Österreich*, Band 49, p.417.

Klein, A., 2006. *Bronzezeitliche Holznutzung in Hallstatt.* Diplomarbeit. Institut für Holzforschung, Universität für Bodenkultur Wien.

Klose, O., 1918. Die prähistorischen Funde vom Mitterberge bei Bischofshofen im städtischen Museum Carolino-Augusteum zu Salzburg und zwei prähistorische Schmelzöfen auf dem Mitterberge. In: Kunsthistorisches Institut der k. k. Zentral-Kommission für Denkmalpflege ed. *Urgeschichte des Kronlandes Salzburg. Österreichische Kunsttopographie*, 17, Beitrag II, Wien.

Koch Waldner, T., 2010. *Bronzezeitliche Funde aus dem Hallstätter Salzbergwerk – Christian von Tusch-Werk, Alter Grubenoffen, Westvortrieb, Grabungsjahre 1996-1999. Unter besonderer Berücksichtigung der Holzfunde.* Diplomarbeit. Institut für Ur- und Frühgeschichte, Universität Wien (unpublished).

Koch Waldner, T., Staudt, M. and Goldenberg, G., 2011. Fundchronik Bronzezeit, Tirol, KG Jochberg, OG Jochberg, VB Kitzbühel. *Fundberichte aus Österreich,* Band 50, pp.414-416.

Koch Waldner, T. and Goldenberg, G., 2012. Charakterisierung der bronzezeitlichen Bergbaulandschaft in der Region Kitzbühel – Ergebnisse und Ausblick. In: K. Oeggl and V. Schaffer, eds. 2012. *Die Geschichte des Bergbaus in Tirol und seinen angrenzenden Gebieten, Proceedings zum 6. Milestone-Meeting des SFB HiMAT vom 3.-5.11.2011 in Klausen Südtirol.* Innsbruck, pp.126-133.

Koch Waldner, T., Skomorowski, R. and Grutsch, C., (in print). Fundchronik Bronzezeit, Tirol, KG Jochberg, OG Jochberg, VB Kitzbühel. *Fundberichte aus Österreich*, Band 51.

Much, M., 1879. Das vorgeschichtliche Kupferbergwerk auf dem Mitterberge (Salzburg). *Mitteilungen der k.k. Central-Commission,* Neue Folge 5, pp.18-36.

Much, M., 1902. Prähistorischer Bergbau in den Alpen. *Zeitschrift des Deutschen und österreichischen Alpenvereins*, 33, pp.1-31.

Pichler, T., Nicolussi, K., Goldenberg, G. and Klaunzer, M., 2009. Die Hölzer des bronzezeitlichen Bergbaus auf der Kelchalm bei Kitzbühel. Dokumentation und erste Ergebnisse dendrochronologischer Analysen. *Archäologisches Korrespondenzblatt*, 39, pp.59-75.

Pittioni, R., 1947. *Untersuchungen im Bergbaugebiete Kelchalpe bei Kitzbühel, Tirol* (2. Bericht). Mitteilungen der prähistorischen Kommission der Akademie der Wissenschaften 5, Wien.

Pittioni, R., 1952. Das Brandgrab vom Lebenberg bei Kitzbühel, Tirol. *Archaeologia Austriaca*, 10, pp.53–59.

Pittioni, R., 1968. Der urzeitliche Kupfererzbergbau im Gebiete um Kitzbühel. In: E. Widmoser, ed. 1968. *Stadtbuch Kitzbühel*, Band 2. Kitzbühel, pp.32-102.

Preuschen, E. and Pittioni, R., 1937. *Untersuchungen im Bergbaugebiete Kelchalpe bei Kitzbühel,* Tirol. Mitteilungen der prähistorischen Kommission der Akademie der Wissenschaften 3, Wien.

Preuschen, E. and Pittioni, R., 1954. Untersuchungen im Bergbaugebiet Kelchalm bei Kitzbühel, Tirol. 3. Bericht über die Arbeiten 1946-53 zur Urgeschichte des Kupferbergwesens in Tirol. *Archaeologia Austriaca*, 15.

Scheiber, E.-M., 2011. *Das spätbronzezeitliche Gräberfeld am Lebenberg bei Kitzbühel, Tirol.* Diplomarbeit. Institut für Archäologien der Universität Innsbruck (unpublished).

The Trade in Cereals in the Mining Region of Kitzbühel

Anita Feichter-Haid

In this essay I will focus on the trade in cereals intended to supply the early modern mining district around the small city of Kitzbühel which is located in the east of northern Tyrol (Austria) close to the border to Germany.

With the boom of silver-mining in the district of Kitzbühel, mainly on the Röhrerbühel, in the second half of the 16th century AD, the demand for cereals increased dramatically due to the great numbers of mine workers. We know of 1200-1500 workers in the mines of the Röhrerbühel alone (Mutschlechner, 1968). In addition there existed several other smaller mines located closer to the city of Kitzbühel, e.g. on the Jufen or in the region of Sinwell (Fig. 2).

Some companies which owned mines in this district tried to supply their workers sufficiently to guarantee smooth mining operations. Hence they formed several trading companies, for instance the „Gesellschaft und Verwandte des Kössentalerischen Schmelzhandels", short „Kössent(h)aler" (Rupert, 1976).

During the entire 16th century Tyrol was never self-sufficient in the production of cereals, maybe also due to the large population within the mining districts of Schwaz, Kitzbühel, Sterzing etc. Wheat and rye were mostly imported from Bavaria and other parts of Germany, Salzburg, Bohemia, Upper Austria and occasionally from Italy (Spranger, 2006).

The situation worsened in the second half of the 16th century when Tyrol was haunted by crop failures. The situation was especially bad in the years from 1550 to 1552, in the turn of the year 1566 to 1567 and in the years from 1569 to 1572 (Fischer, 1919).

In years of poor harvests free trade was replaced by a system of allowances. Therefore the trading companies and even the Tyrolean prince Ferdinand II had to ask the respective lord for an allowance to buy a certain amount of cereals within his territory (Spranger, 2006). Even if it was intended only to transport the cereals through the respective territory, the landlord had to give his permission. To add to the already complicated situation, logistic problems had to be tackled. In any case there were customs and excise dues to be paid. Another obstacle was the fact, that the river Inn was more or less unnavigable from May on. In the years of crisis the situation even worsened. Due to the lack of cereals there was a lack of fodder (oats). Therefore it was harder to find pack animals, like horses and higher transport prices had to be paid. In several regions which were not as much affected by the bad harvests there were other reasons for the rise of transportation costs, in parts of Italy, for instance, the transport system was already overloaded by the dispositions for the war with the Turks etc. (Fischer, 1919).

To give a better understanding of the complex and difficult situation I will now examine a specific correspondence between the archbishop of Salzburg, Johann Jakob von Kuen-Belasy, the "Kössenthaler"-company and the duke Albrecht V. of Bavaria.

The whole correspondence deals with the trade in grain of Mühldorf, a small city (today in Germany, about 70 km north from Salzburg), where from 1571 on the archbishop resided, since Salzburg was haunted by the pest. This city seems to have been a regional centre of the trade in cereals.

In November 1570 the "Kössenthaler"-company wrote to the Archbishop of Salzburg. They appealed to Johann Jakob to intervene on their behalf, since although they possessed allowances to buy grain in Mühldorf they were not allowed to transport it away.

From June on they had ordered and in most cases already paid certain amounts of cereal, but due to some difficulties they had not been able to ship it in time. Some sellers now refused to deliver with the argument: "das abermallen ain furstlich bevelch solle an euch ausgegangen sein, welcher mit bringt, das ir nichts verkauffen oder wegkh fiern lassen soldet" (SLA Geheimes Archiv, XXVIIII, 12; 16. November 1570) ("that again a princely command has been given, which claims that nothing shall be sold nor carried away").

We do not know the reaction of the archbishop in that case, but we do know his actions in another: One month later the same company appealed to the archbishop again. This time they had bought cereals and intended to buy even more in the Duchy of Bavaria and planned to ship the grain on the Inn to Tyrol. Now their request was to make sure that they were allowed to bring the cereals through Mühldorf without being pressed to unload and offer it. Again there seemed to be no reaction of the archbishop.

A few days later the duke of Bavaria (who owned a certain amount of shares of the "Kössenthaler"-company) intervened on their behalf. He wrote a letter to Johann Jakob to ask for permission to transport the rest (!) of the grain that the company had bought and paid for. His letter allows us an even deeper insight into the whole situation. It seems that the company had not only bought cereals in Bavaria but also around the city of Mühldorf and even from the townsmen with an allowance granted by the duke. But Johann Jakob did not seem to take offence in that. The archbishop's reaction this time was swift. On the next day he wrote a letter to the bailiff of the city court, mayor and council of Mühldorf explaining that he had received the request in question from the duke of Bavaria and ordered them to release the cereals. His main argument was that it was neither wise nor an option at all to stop this freight, since otherwise it might be possible that no cereals from Bavaria would reach Mühldorf anymore (SLA Geheimes Archiv, XXVVIIII, 12; 20. Dezember 1570).

Finally I want to pick up the question how the territorial prince Ferdinand II. dealt with these supply crises, since he must have had a twofold interest in keeping the situation stable. On the one hand, to prevent hunger meant preventing riots; on the other hand he made enormous profit out of the mines and therefore it must have been his utmost concern to keep the workers in the mines (and working) and that meant to guarantee them a living without hunger.

So what did the Tyrolean sovereign do? First, in order to keep the cereals in the country in the years of crisis he passed a ban on exports and established a system of allowances as did the other lords in the adjacent areas. Second, he allowed a free price formation in order to motivate the traders to come into the country, which lead to sudden price explosion (comp. Schmelzer, 1972).

Moreover, he tried to get allowances to buy cereals and transport them to Tyrol. A huge correspondence with the sovereigns of Bavaria, Salzburg, Bohemia etc. testifies his efforts (Fischer, 1919). Often also the different mining companies appealed to the sovereign to act in their interest, which he obviously tried to do. A letter (sent to the archbishop of Salzburg) in October 1570 shows that Ferdinand (or his chamber) had been successful in obtaining allowances to buy and ship cereals for several companies, such as the "Yenpacher"-company and Hans Dreyling, both providing the mining region of Schwaz, to buy and transport grain. But – as the letter goes on – although Heinrich Ruedl who was the purchasing agent of the "Yenpacher"-company held an allowance, the amount of cereals he had bought in Mühldorf and which was already being shipped was stopped by the officials of the city. Now the sovereign intervened in the interest of this company and asked to give the cereals free (SLA Geheimes Archiv, XXVIIII, 12; 22. Oktober 1570). So even though allowances were granted they did not always guarantee a successful and in-time supply.

The examples given were intended to shed some light on the sometimes wearisome and risky venture of trade in cereals during that time. It stands as a showcase for all the difficulties which trading (mining) companies had to face while importing material and supplying the mines in Tyrol.

References

Salzburger Landesarchiv (SLA), Geheimes Archiv, XXVIIII, 12.

Fischer, J., 1919. *Tirols Getreidepolitik von 1527 bis 1601*. Innsbruck.

Mutschlechner, G., 1968. Das Kitzbüheler Bergbaugebiet. In: E. Widmoser, ed. 1968. *Stadtbuch Kitzbühel,* Band 2. Kitzbühel, pp.10-30.

Rupert, M., 1976. Vom Aufkommen des Rerobichl-Bergbaus (1540) bis zum Ende der bei der Stadt Kitzbühle gelegenen Schmelzhütten im 17. Jahrhundert. *Archaeologia Austriaca,* 59/60, pp.273-437.

Schmelzer, M., 1972. *Geschichte der Preise und Löhne in Rattenberg*. Innsbruck.

Spranger, C., 2006. *Der Metall und Versorgungshandel der Fugger in Schwaz in Tirol 1560-1575 zwischen Krisen und Konflikten*. Augsburg.

Mining-related land use changes since the Neolithic in the region of Kitzbühel (Tyrol)

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Introduction

All operations around ancient mining and smelting affected both the surrounding vegetation and environment on a local as well as on a regional scale. The trees from the surrounding woodlands were used for constructions, tools and commodity items of settlements in the vicinity of mines. Additionally, wood and charcoal were the main energy sources for several metallurgical activities (fire-setting, smelting, metal working) in ancient times (Stöllner, 2003). Moreover, the production of raw materials has always been accompanied by the reclamation and the cultivation of land, which resulted in clearings of woodland. This is also expected for the area of Kitzbühel (Tyrol), a prominent eastern Alpine mining region during the Bronze Age and Early Modern Times.

The area under investigation is the prehistoric mining district "Kelchalm" located on the Laubkogel, a 5 km long mountain ridge of the Kitzbühel Alps (Fig. 2). The analysed 1 ha sized mire is called "Rauber", which is situated on 1762 m a.s.l. and about 1.5 km south of the Kelchalm, in the immediate vicinity of the mine. A 1.6 m thick peat core was extracted for pollen analysis from the centre of this mire. By palynological analyses of this peat core we aim to evaluate the paleoecological impact of prehistoric and historic mining on the vegetation in the region of Kitzbühel.

Methods

Peat archives pollen and by these means becomes a source of vegetation history. Thus former changes in the vegetation and land use are able to be reconstructed by pollen analysis. Settlement activities of prehistoric humans and related land use changes are pollen-analytically recorded by changes in the arboreal (AP) and non-arboreal pollen (NAP) values connected with the appearance of anthropogenic indicators (Iversen, 1973; Behre, 1981).

The radiocarbon dating of ten peat samples has been conducted at the VERA-Laboratory of the Isotope Research on the Faculty of Physics, University of Vienna. The sidereal age was generated with the INTCAL09 calibration curve (Reimer, et al., 2009) and the calibration program OxCal (Bronk Remsey, 1995).

Results and Discussion

The oldest pollen strata in the pollen profile were deposited during Mesolithic Times, more than 7500 years ago. The prevailing vegetation was a sparse spruce forest (163-138 cm) with a lot of herb taxa in the understory; e.g. true grasses (Poaceae), pink family (Caryophyllaceae), bellflower family (Campanulaceae), yarrow (*Achillea*), mugwort (*Artemisia*) or spike moss (*Selaginella*) in the two lowermost samples. Fir (*Abies*) and beech (*Fagus*) have already immigrated to the investigation area and expand in lower altitudes.

With the onset of peat accumulation in the Neolithic (138-110 cm) fir (*Abies*) expanded and a spruce-fir forest (Piceeto-Abietetum) evolved in the surroundings of the mire, which persisted until Medieval Times (750 AD). In the Late Neolithic (2500 BC, 126 cm) there are possible first indications for human impact, by decreasing values of spruce (*Picea*) and fir (*Abies*) and increasing values of grasses (Poaceae) and herbs (Asteraceae, Cichoriaceae, Ranunculaceae, *Artemisia*, *Senecio* type) as well as charcoals (*Particulae carbonae* 50-100 µm), in the wider vicinity of the mire but that has to be verified by a second peat core from the valley floor.

At the beginning of the Bronze Age (2200 BC, 113 cm) a first clearance of the forest appears and takes ca. 200 years (Fig. 4). This is reflected in a decline of spruce (*Picea*) and fir (*Abies*) pollen. Towards the end of this clearing phase the values of charcoals (*Particulae carbonae* 50-100 µm) are getting higher because of enhanced fire activities and are validating human impact together with the increasing values of pasture and settlement indicators. Additionally a secondary succession starts with birch (*Betula*) and hazel (*Corylus*). In the next 150 years the spruce-fir forest regenerates. The following three more forest clearing and regeneration cycles until ca. 900 BC (80 cm) – like described above – are also visible in the pollen diagram. Additionally the settlement indicators (sorrel – *Rumex acetosella*, *R. acetosa* type, goosefoot family – Chenopodiaceae type) as well as the charcoal particles (*Particulae carbonae* 50-100 µm) achieve synchronously higher values. Since the Late Bronze Age additional crop plants like cereals (Cerealia) indicate human presence and agricultural activities in the valley bottoms. In the Late Bronze Age (80 cm) a maximum of grasses (Poaceae) and herbs (*Plantago lanceolata-type*) becomes obvious and the charcoal particles (*Particulae carbonae* 50-100 µm) are increasing in the pollen diagram. These effects can be lead back on fire events.

In the Late Iron Age (100-0 BC; 72-70 cm) the pollen diagram shows a decline of spruce (*Picea*) in combination with a rise of grasses (Poaceae) accompanied by increasing values of settlement indicators and crops again reflecting a phase of intense human impact, also during Roman Times.

Afterwards a regeneration of the spruce forest (*Picea*) is visible and also the fir (*Abies*) reclaims indicating declining anthropogenic influence in higher altitudes.

During Medieval and Modern Times an increasing of the pasture and settlement indicators (e.g. *Rumex acetosella*, *Plantago lanceolata*-type, *Urtica*) as well as crop plants reflects an intensification of settlement activities. The values of grasses are increasing significantly since the Early Middle Ages (700 AD; 60 cm), as well as the curves of pasture and settlement indicators, crop plants and charcoal particles. This pattern suggests fire clearing in the vicinity of the mire to obtain pastures. During the High Middle Ages (1050-1250 AD; 52-42 cm) the pollen diagram shows a slight reduction of human impact which is increasing again in the Late Middle Ages (1250-1492 AD; 42-28 cm) and consists until current times.

Conclusion

The pollen analysis from the peat sequence near the mining area Kelchalm yields human activities since

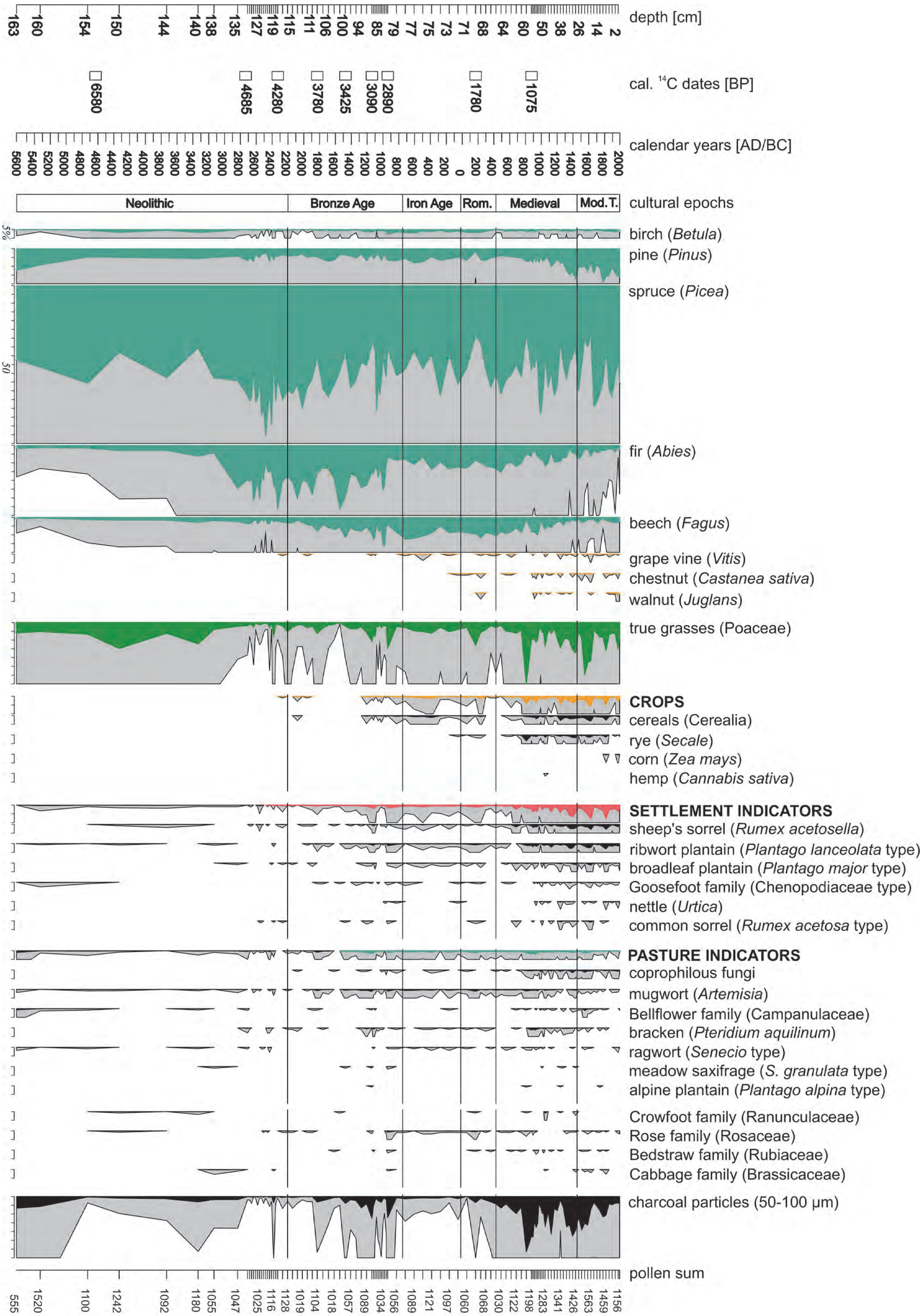

Fig. 4: Relative Pollen diagram (selected species) of the mire "Rauber" near the Kelchalm. Silhouette curves with black or coloured background correspond to percentage values (%), the solid line with gray background is a 10x exaggeration (‰), scale: each pitch line represents 5% (Graphic B. Viehweider).

2500 BC, visible in openings of the landscape combined with the appearance of anthropogenic indicator plants. These interventions can be locked through recurring patterns proven in changes of the vegetation and the changes of the ratio of AP and NAP. First actions are forest clearings combined with fire activity (increasing charcoals). Following a secondary succession starts and indicator plants for settlement and pasture as well as crops are increasing.

In the Early and Middle Bronze Age first two forest clearings (2000-1500 BC) are displayed by the occurrence of pasture and settlement indicators as well as a decline of spruce (*Picea*) and fir (*Abies*). During the Middle and Late Bronze Age another forest clearing (1400-1100 BC) occurs. This human impact is contemporaneous to mining activities which is confirmed by dendrochronological datings (Pichler, et al., 2009; 2010) as well as archaeological wooden finds and findings (Preuschen and Pittioni, 1954; Klaunzer, et al., 2009) which date to that time. In the Late Bronze Age there is one more forest clearing (1100-900 BC). Then the human impact diminished until the Late Roman and Early Medieval Times (500 AD). Here the pollen diagram reflects settlement and agriculture activities sustained by forest clearings, pasture and settlement indicators and also crops. From that moment the area is incessantly influenced by men. From the Early Modern Times we know by historical sources about a second mining phase (15^{th}-16^{th} century AD). This is also reflected in the pollen diagram by a forest clearing 1250-1500 AD and additional following clearings.

References

Behre, K.-E., 1981. The interpretation of anthropogenic indicators in pollen diagrams. *Pollen et Spores,* 23, pp.225-245.

Bronk Ramsey, C., 1995. Radiocarbon Calibration and Analysis of Stratigraphy: The OxCal Program. *Radiocarbon,* 37(2), pp.425-430.

Iversen, J., 1973. The development of Denmark's Nature since the Last Glacial. Geology of Denmark III. *Geological Survey of Denmark,* V. Series, 7-C, pp.126.

Klaunzer, M., Goldenberg, G. and Staudt, M., 2009. Fundchronik Bronzezeit, Tirol, KG Aurach, OG Aurach, VB Kitzbühel. *Fundberichte aus Österreich*, Band 48, pp.389-390.

Pichler, T., Nicolussi, K., Goldenberg, G. and Klaunzer, M., 2009. Die Hölzer des bronzezeitlichen Bergbaus auf der Kelchalm bei Kitzbühel. Dokumentation und erste Ergebnisse dendrochronologischer Analysen. *Archäologisches Korrespondenzblatt,* 39, pp.59-75.

Pichler, T., Nicolussi, K., Klaunzer, M. and Goldenberg, G., 2010. Dendrochronological Analysis and Dating of Wooden Artefacts from the Prehistoric Copper Mine Kelchalm/Kitzbühel (Austria). In: P. Anreiter, G. Goldenberg, K. Hanke, R. Krause, W. Leitner, F. Mathis, K. Nicolussi, K. Oeggl, E. Pernicka, M. Prast, J. Schibler, I. Schneider, H. Stadler, T. Stöllner, G. Tomedi and P. Tropper, eds. 2010. *Mining in European History and its Impact on Environment and Human Societies* – Proceedings for the 1st Mining in European History-Conference of the SFB HiMAT, 12.-15. November 2009. Innsbruck University Press, pp.227-231.

Preuschen, E. and Pittioni, R., 1954. Untersuchungen im Bergbaugebiet Kelchalm bei Kitzbühel, Tirol. 3. Bericht über die Arbeiten 1946-53 zur Urgeschichte des Kupferbergwesens in Tirol. *Archaeologia Austriaca,* 15, pp.3-97.

Reimer, P.J., Baillie, M. G. L., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C., Buck, C. E., Burr, G. S., Edwards, R. L., Friedrich, M., Grootes, P. M., Guilderson, T. P., Hajdas, I., Heaton, T. J., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., McCormac, F. G., Manning, S. W., Reimer, R. W., Richards, D. A., Southon, J. R., Talamo, S., Turney, C. S. M., van der Plicht, J. and Weyhenmeyer, C. E., 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0-50,000 years cal BP. *Radiocarbon,* 51(4), pp.1111-1150.

Stöllner, T., 2003. Mining and Economy – A Discussion of Spatial Organisations and Structures of Early Raw Material Exploitation. In: T. Stöllner, G. Körlin, G. Steffens and J. Cierny, eds. 2003. Man and Mining – Mensch und Bergbau. *Der Anschnitt*, Beiheft 16. Bochum, pp.415-446.

Ontologies in the field of archaeology – potential and challenges

Anja Masur

The field of archaeology relies like no other on the support of other scientific disciplines. The effective and efficient integration as well as the exchange of data is a fundamental requirement for successful collaboration. Semantic technologies, such as CIDOC CRM, offer the opportunity to enable cross thematic communication and data integration by closing the semantic gap.

This article shall introduce CIDOC CRM as a suitable tool to integrate heterogeneous data from distributed sources into a cultural heritage data environment. Furthermore this article aims at identifying benefits of using CIDOC CRM for the archaeological work as well as highlighting the still remaining limits and problems of archaeological data exchange.

The idea of a Semantic Web goes back to Berners-Lee (1998). In his vision a web of data can be seen "in some ways like a global database". One benefit of his idea was that data should not only be readable by human beings but should also be understood by machines respectively computers or so called 'agents' in a distributed information network. This is enabled by the fact that data are structured and processed in a way that computers can understand the meaning behind the data. Therefore we are speaking not only of technical but rather of semantic interoperability. Data are not mere data, data effectively connected become information.

A tool that could be one solution to implement these visions and aims are ontologies. They are models that represent simplifications and reflections of reality by limiting these phenomena to classes and their relations. Each ontology is an individual view of reality in accordance of its needs and purpose. As such they display a network of hierarchically structured concepts resp.their mutual relations (see an example in the section below). Furthermore ontologies in the context of this research are a technology used to bridge semantic gaps (such as between different data models, methodologies, and approaches) and to enable exchange of data resp.information between distributed and heterogeneous parts of the information system.

For the field of archaeology and cultural heritage in general CIDOC CRM is the most frequently used ontology. CIDOC CRM has been an ISO Standard (21127) since 2006 and was developed by experts from different disciplines like computer science, archaeology, philosophy, history and many more since 1998 (Doerr, 2009, p.468). It is "intended to facilitate the integration, mediation and interchange of heterogeneous cultural heritage information" (Doerr, 2009, p.468). CIDOC CRM uses general concepts that are currently aggregated in 80 classes and 132 properties resp.relations. By integrating data into CIDOC CRM every table and field of a database corresponds to a class according to its description. An archaeological find, e.g. an axe, would be referred to the class "E22 Man-made Object" as it is a "physical object[s] purposely created by human activity" (Crofts, et al., 2011). Additionally all classes are connected by properties which goes beyond the function of a database. Thus it is a network of information results.

Despite the named and explained use cases the actual implementation of ontologies in the context of archaeological data exchange is lagging behind its large potential. While in other fields of data exchange semantic technologies became an indispensable part of large information systems (e.g. INSPIRE, GEOSS using semantic technologies such as ontologies and thesauri) the whole development of shared information systems as such is underdeveloped in the field of archaeology.

CIDOC CRM marks an example for successful long-term development of an ontology which considers and meets the requirements of sharing cultural heritage data. While CIDOC CRM became an essential part of several information systems in museums, archives, and libraries (dealing with cultural heritage data but not with archaeological data in specific) such developments in the specific field of archaeology are widely missing even if there are some positive exceptions as e.g. represented by the HiMAT project (Hiebel, et al., 2010).

The main reason for the missing implementation of semantic technologies (which includes ontologies) in the field of archaeologies can by identified by the very general fact that the practice of archaeological data sharing doesn't meet its potential. The number of reasons is manifold and analysing them goes far beyond the scope of this article. But the main reason can be surely identified as the absence of the intention to share data. This results in a vicious circle, which concludes that without the intention to share data and the awareness for the related benefits there is no need for semantic tools like ontologies which actually enable the effective sharing of data.

However, implementing data in ontologies would offer many advantages:

1. ontologies offer a controlled vocabulary
2. ontologies provide a common structure and understanding of complex environments
3. ontologies link different data bases and enable effective integration of heterogeneous and distributed parts of information system

One problem every discipline can notice (especially when working in interdisciplinary and international frameworks) is that technical terms often are used in an inconsistent manner. An example from the field of archaeology is the use of terms such as 'Bronze Age' which implies different time ranges depending on the region and cultural background. By providing a controlled vocabulary (in connection with thesauri) ontologies enable those terms to be used in a harmonized understanding and a standardized way without losing their level of detail and original wording.

By the clearly defined concepts and their recording in classes and relations ontologies furthermore provide a structure, a model of the reality they are representing. But that does not implicate that ontologies also dictate the structure of the data bases of one discipline. Ontologies are designed to act as bridging elements between legacy systems. Legacy databases adjusted to the special demands of a discipline can be maintained and can be linked with other databases after being implemented in an ontology. One obvious advantage can be seen in the fact that a loss of meaning is excluded. Beyond that ontologies - and that applies also for CIDOC CRM - make sure that most of the data occurring in the field of archaeology can be associated with the data model.

Despite these many advantages ontologies and in this context CIDOC CRM, are not free of challenges concerning the handling of ontologies in practice. Using ontologies always requires at least a certain knowhow in IT and specific knowledge regarding the content of the ontology. This may be realizable for bigger interdisciplinary projects (e.g. EU funded projects with different partners providing different background and experience) but the limited budget of smaller institutions and projects often determines clear borders if it comes to IT implementations despite all benefits.

Furthermore it can be stated that the development of tools facilitating the integration of data lags behind the conceptual development and extension of the ontologies, esp.CIDOC CRM.

Additionally for most of the archaeologists the general topic of ontologies is a domain that appears to be too abstract and without a practical orientation.

As shown above there are still many challenges concerning the facilitation with these new technologies. Developing strategies for the acceptance and distributed usage of ontologies in the field of archaeology therefore represents one intention of the fourth PhD project of the DOC-team. A similar approach including targets going beyond this work is also pursued by the EU funded "Ariadne" project (www.ariadne-infrastructure.eu/).

References

Berners-Lee, T., 1998. Semantic Web Road map.[online] Available at: <www.w3.org/DesignIssues/Semantic.html> [Accessed 29 April 2013].

Crofts, N., Doerr, M., Gill, T., Stead, S. and Stiff, M. eds., 2011. Definition of the CIDOC Conceptual Reference Model, Version 5.04, 12. [online] Available at: <www.cidoc-crm.org/docs/cidoc_crm_version_5.0.4.pdf > [Accessed 29 April 2013].

Doerr, M., 2009. Ontologies for Cultural Heritage. In: S. Staab and R. Studer, eds. 2009. *Handbook on Ontologies*, pp.463-486.

Hiebel, G., Hanke, K. and Hayek, I., 2010. Methodology for CIDOC CRM based data integration with spatial data. [online] Available at: <www.uibk.ac.at/himat/sfb-himat/publications/publications-2010/hiebel_hanke_hayek_caa_2010.pdf> [Accessed 29 April 2013].

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