Central Bohemian-Moravian Highlands on the threshold of the High Middle Ages

Archaeology, geochemistry and the analyses of alluvial sediments

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1. Introduction

1.1. Why the Middle Ages, floodplains, archaeobotany and geochemistry

Usual historical questions…

This study sums up the interdisciplinary research into medieval settlement, gold placer mining and ore mining in Central Bohemian-Moravian Highlands in the 12th–13th centuries (Fig. 1 and 2). The foundations of settlement structure can be traced here since the early 12th century (Chapter 1.2. and Fig. 8). From the mid-12th century on, local population became aware of the existence of exogenic gold deposits and began to exploit them as well (Chapter 3.2.). A large part of Europe experienced a boom in production of precious metals since the mid-12th century, which also included the development in the Bohemian-Moravian Highlands. Each monarch tried to enhance his income and solve the circulation of coin (*Žemlička 2002*, 288–314, 318–319). The main precondition was a constant inflow of silver. Until then, the Přemyslids have obtained silver in various ways but they were not able to produce it using their own primary resources. Even though the theoretical, methodological and instrumental aspects of our research involve interdisciplinary approach, the questions treated remain culturally-historical in their essence:

1) Detection, dating and interpretation of changes in landscape induced mainly by agrarian colonisation.
2) Detection, dating and interpretation of changes in landscape induced by mining.
3) Detection, dating and interpretation of changes in landscape induced by the slowdown of mining and metallurgical activities.

…and unusual historical sources

Little-used sources of information about human activities are floodplains (Fig. 7, 11, 17, 20, 21 and 36). Their main attribute is the capability of long-time conservation of ecofacts, such as pollen and macroremains of plants, whose species composition present in given segment of the landscape has changed depending on human-induced alterations of vegetation and woodland (*Čech et al. 2002*, 231–249). The water-bearing anaerobic environment also retains heavy metals which indicate ore processing (Fig. 30 and 31). Changes in landscape induced by agrarian colonisation can be studied using specific methods. The floodplains are mostly of Holocene age and their formation culminates with increased human activity. Among the research methods used are metallometry, analysis of technoliths, pollen and charcoal together with radiocarbon dating (Chapter 2.1.2.). The axis of study is mainly based on four localities which were archaeologically examined in 2007–2012 (Chapter 2.2.–2.5.). Based on their example, we will show which impact had the deforestation, pastoralism and placer mining. We will also show how preparation and smelting of ores is reflected in archaeobotanical and geochemical record (Fig. 29).

1.2. Settlement and human activity impacting the development of watercourses and floodplains in the Bohemian-Moravian Highlands

1.2.1. Settlement until the beginning of silver ore mining

Villages, markets, manorial farms, churches and monasteries

From literary sources we know that systematic colonisation of the Bohemian-Moravian Highlands took place from the very beginning of the 12th century (*Hejhal 2012*). Ecclesiastical institutions and monasteries are predominant, as far as the significance and wealth are concerned. Among regions on the Moravian side, which were colonised since the 12th century at the latest, are the middle reaches of Jihlava and the Třebíč Region (*Měřínský 1986*, 158, 160–169; *1988*, 23–28, 39–40; *Poláček 1993*; *Obšusta 2000*, 191). The colonisation process was assisted here by a Benedictine monastery founded in 1101. Many settlements in the Jihlava Region appear in documents from the years 1233–1240 (Fig. 8: 11, 12, 22). Founding activities of ecclesiastical institutions and monasteries were most intensive in the period before the mid-12th century. In the north we hear from the so-called Libický újezd (village), which was property of the Olomouc Bishopric. The possessions of the diocese were larger, as is indicated by a chronicle entry for the year 1149. This allows us to take into consideration the existence of a manorial farm with a hamlet near Větrný Jeníkov (*Hejhal 2010*). In 1144, a Benedictine monastery was founded at the confluence of Želivka and Trnava (Fig. 8: 13). The Benedictines were superseded by the Premonstratensians in 1149. In 1226, Pope Honorius III issued a charter, in which he confirmed the tenure of villages between Želiv and Jihlava (*Hejhal – Šrámek 2014*). Colonisation before the mid-12th century began to be initiated by the Prague Bishopric as well. The centre of its domain is Červená Řečice. The activity of the Bishopric was concentrated on the upper reaches of Želivka, which is documented by a deed by Bishop Daniel II (1197–1214) for the Church of St. Bartholomew in Rynárec from the year 1203 (*CDB II*, No. 33, p. 31). At the end of the first third of the 13th century, colonisation of the upper reaches of Jihlava was also assisted by the Premonstratensian monastery in Louka, founded in 1190 (*CDB II*, No. 305, pp. 303–304). In the 1230s can also be recorded the founding activity of the Teutonic Order. We can identify them as builders of the Church of St. Nicholas in Humpolec and the Church of St. John the Baptist in Jihlava (*CDB III/1*, No. 48, p. 48). Among the evidence of colonisation from Sázava after the year 1200 we count churches, whose builders are unknown to us. Some of them are possibly related to the Benedictine monastery in Vilémov, some others can be considered manorial foundations.

Absence of contemporaneous archaeological finds or a problem with their identification?

Even though from literary sources we know that the territory under review has been colonised since the mid-12th century at the latest (Fig. 8), we lack any adequate archaeological evidence. From the Želiv Region be named an assemblage of finds from older excavations of a burial ground in the Premonstratensian monastery (Fig. 10) but also from recent archaeological excavations which yielded material from the 12th century (*Hejhal 2012*, 52–53; *Thomová 2014*, 64). In Havlíčkův Brod we can name the find of an imitation of the Friesach pfennig from the end of the 12th century (*Rous 1982*, 39). A glass bead which is dated to the 10th-12th centuries was discovered during survey at the mining site of Buchberg, which flourished after the mid-13th century. From the same place also comes a lead ring (Fig. 11), which corresponds to 11th–12th century finds. In the Jihlava Region we know archaeological finds from excavations of the settlement in Telč (Fig. 8: 19), whose origin can be dated according to coins to the end of the 12th century. From among recent finds we must mention a ceramic assemblage from the excavations in economic hinterland of a settlement with ovens near Kostelec. Pottery in some cases bore toothed wheel decoration, which can be considered a clue in dating the vessels to the first third of the 13th century (Fig. 9).

New pieces in the mosaic of spot samples in floodplains

A source of data equally important as the sparse archaeological finds is represented by archaeo-environmental sampling in floodplains. At the above-mentioned Kostelec (Fig. 8: 9), for example, a fir beam with mortise was discovered in the river floodplain near the area under examination (Fig. 9). According to dendrochronological dating, the fir was felled in the summer of 1206 (*Kyncl 2013*). The sampling was done in 2012 during excavations in Žďár nad Sázavou in the forefield of the well-known 13th century settlement at Staré město (Fig. 8: 10). A buried soil horizon was identified, enriched with charcoal (Fig. 12) with dominant share of spruce. The obtained conventional ^{14}C dates fall within the interval of 949–1222 after calibration (*Světlík 2013b*). New knowledge also resulted from research into the floodplain of the Perlový Stream (Fig. 8: 3, 4). At the base of one of the sections there was an evident increase in charcoal from forest woody plants as well as indicators of forest openings and clearings. This sequence yielded ^{14}C AMS dates calibrated to between 1042–1221 and 1220–1387. Also important is the research into the Březina Stream near Česká Bělá (Chapter 2.3.) where a fir plank was found (Fig. 60). The wood sample yielded ^{14}C (AMS) dates calibrated to between 1016–1155 (Tab. 2 and 3). In Česká Bělá, samples were also taken on the Bělá Stream (Fig. 40: 4 and Fig. 20). From the oldest sedimentary layer rich in organic matter a soil sample was taken and from this sample then driftwood was separated, which was conventionally ^{14}C dated to between 765–1023 after calibration (*Světlík 2013a*).

Floodplain of the Pstružný Stream near Kejžlice as a small example

The Kejžlice site on the Pstružný Stream counts among the small ones (Fig. 8: 8). At the depth of about 1.5 m a relic of a water raceway was found, built of round timber from local woody plants (willow/poplar, alder/birch; Fig. 13 and 14). A round log sample No. 0401 was conventionally ^{14}C dated to between 1037–1297 after calibration (*Světlík 2013a*). Another sample (No. 0402), however, was calibrated after ^{14}C AMS to between 1265–1314 (*Goslar 2014*). Two sections were sampled on the site. The climax woody plants are dominated by fir (*Abies alba*) mixed with spruce (*Picea abies*) and beech (*Fagus sylvatica*). Macroremains come from coniferous stands, which were referred to as black forest (fir and spruce) in medieval times, but they also can represent evidence of wood selection. Also present is alder (*Alnus* sp.). Frequent occurrence was also recorded with species of forest clearings and openings, above all shrubs and sub-shrubs. Among them are common hazel (*Corylus avellana*), common blackberry (*Rubus fruticosus*), raspberry (*Rubus idaeus*), red elderberry (*Sambucus racemosa*) and black elder (*Sambucus nigra*). Red elderberry and raspberry are species which grow into coniferous forest clearings. Species of forest-free areas are represented only sporadically. Among them are species of wet meadows and pastures, such as creeping buttercup (*Ranunculus repens*), ragged robin (*Lychnis flos-cuculi*) and upright bugle (*Ajuga genevensis*). Wetland species are represented by European water-plantain (*Alisma plantago-aquatica*), sedges (*Carex* ssp.), spike-rushes (*Eleocharis* sp.), simplestem burreed (*Sparganium erectum*) and marsh violet (*Viola palustris*). Synanthropic species were represented by rye (*Secale cereale*), ruderal species by white nettle (*Lamium* cf. *album*) and common nettle (*Urtica dioica*). Common beech (*Fagus sylvatica*), as a beech forest species with favourable hydrological regime, was present in the form of both charcoal and wood. Elm wood (*Ulmus* sp.) and maple charcoal (*Acer* sp.) indicate a stand rich in nutrients (Graph 1–4, Tab. 4 and 5).

1.2.2. Secondary gold deposits and their exploitation

Pelhřimov and Humpolec Regions

Gold deposits represent a phenomenon which has been studied over a long time, but the knowledge of placer mines is still very poor (*Kořan 1974; Morávek et al. 1992; Litochleb – Pavlíček 1989; Litochleb – Sejkora 2004; Litochleb – Sztacho 1977; Waldhauser 1987*). An increase in placer mining activities did not occur until the 12th century (e.g. *Žemlička 2002*, 301–303). Among the most interesting regions are those in the neighbourhood of Humpolec and Želiv. We can find here two gold catchment areas. The larger one extends southwest of Humpolec (Trucbába), the smaller one northeast of Humpolec (Fig. 19). Gold flakes from the neighbourhood of Trucbába have the dimensions of 0.01–0.50 mm. Southwest of Humpolec 775 relics of open-pit mining and 589 tailing piles were documented (Fig. 15 and 19; *Losertová et al. 2011*; *2012*, *Losertová 2013*). Down the river Želivka, a placer is preserved near the Vřesník reservoir (Fig. 16 and 17, Fig. 19: 2). The best known locality is the Zlátenka settlement in the vicinity of Pacov. Placer mines were situated between Leskovice and Zlátenka (Fig. 2). South of Zlátenka there was a placer in a spring, which was referred to as *Na sejpech* ("on tailings"). The toponym *Na štůlkách* ("on small adits") was known north of Zlátenka (*Gabriel 1989*, 47). Mining is documented in connection with activities of Heinrich of Ziegelheim in 1366 (*Kratochvíl 1955–64,* Vol. I., 215, Vol. IV., 37, 306, Vol. VII., 261; *Litochleb – Sejkora 2004,* 170–171). A placer mine of medieval age was examined north of the village of Eš on the right bank of the Ešský Stream in the 1990s. This place is associated with the toponym *Zlaté písky* ("golden sands") (*Gabriel 1989; Simota 1992a-b; Kratochvíl 1955–64,* Vol. II., 89). On the rivulet Trnava, a placer 30–170 m wide was identified in the river floodplain near the villages of Bratřice, Zhořec and Roučkovice (*Simota 1992a-b*).

Havlíčkův Brod Region and Česká Bělá

In the Havlíčkův Brod Region it is necessary to mention palaeoplacers along the Perlový Stream and in the neighbourhood of Česká Bělá. Gold-bearing sediments are also registered south of Havlíčkův Brod. A verified gold deposit is situated near Koječín (*Morávek et al.*, No. 272). The incidence of gold flakes in sediments was recently evidenced near Česká Bělá at tailings in the Bělá Stream (Fig. 18 and 40: 6).

1.2.3. The end of colonisation and beginning of silver ore mining

Much was already written about the 13th century silver mining

The earliest evidence of exploitation of exogenic gold deposits in the Přemyslid domain occurred in the Jeseník Region (Chapter 3.3.1.) at the end of the first third of the 13th century. At the same time we also can suppose the early phase of mining activities focused on silver production in the Jihlava Region. The aim of this study is not to describe the political and historical boom of our silver ore mining in the 13th century. Our interpretation will target at the onset, conjuncture and decline of mining mainly from the viewpoint of archaeology. The contexts and finds under review reflect the whole technological sequence from ore mining up to metallurgy. This can be associated with terms such as workplace and compound. This all provides a base for setting up a theoretical model of infrastructure of mining areas (Fig. 93). Another category of study is the modelling of economic-distributional relations between mining areas and towns or villages (*Hrubý 2012*, 99–108; 2013, 263).

Something little about the metallogeny of silver ore deposits

Sulphide deposits and ores (so-called *k-pol association*) are developed in the Havlíčkův Brod, partly Jihlava and Pelhřimov mining districts. The ore bodies occur in the form of lodes or mineralised dislocation zones, in extreme cases dozens of metres thick and hundreds of metres long. Among typical ore minerals are black sphalerite, pyrite, galenite, arsenopyrite and pyrrhotite; less frequent are chalcopyrite, stannine, pyrargyrite, cassiterite, bismuth minerals and other silver sulphosalts (Fig. 22). The Upper Variscan polymetallic ore deposits (so-called *pol-association*) can be identified in a part of the Jihlava and Štěpánov mining districts and in some isolated ore deposits. The ore bodies occur in the form of lodes dozens of centimetres thick and at most a few hundreds of metres long. An exception is represented by the Staré Hory dislocation zone (Fig. 72 and 73). Metasomatic ore bodies are found only sporadically. Among typical ore minerals are sphalerite, galenite, sometimes chalcopyrite and pyrite; rarely occurring minerals are pyrargyrite, tetrahedrite, freibergite, antimonite, boulangerite, bournonite and other sulphosalts, and argentite.

Havlíčkův Brod Region and ore mining near Česká Bělá

Polymetallic mineralisations are classed with the so-called k-pol association or the so-called Lower Permian Fe-Zn-Pb-Ag vein mineralisation. Among the minerals identified are arsenopyrite, galenite, chalcopyrite, feather ores, pyrite, sphalerite, graphite; gangue is reportedly composed of quartz with chlorite and dolomitic carbonate. The total length of mineralised structures can be estimated to about 3400 m and the dominant orientations are NW-SE and NNW-SSE. Pyrargyrite and tetrahedrite were identified as silver-bearing minerals (inclusions in galenite up to 30 micrometres). Most terrain relics of mining activities have the form of pits (Fig. 23 and 43; *Malý 2001*; *Koutek 1960*). The silver mines near Česká Bělá were first mentioned in a charter issued by Smil of Lichtenburg in 1257 (*CDB V/1*, No. 138, p. 223).

Jihlava ore district and Staré Hory dislocation in the 13th century

Mineralised structures of the Upper Variscan age are concentrated in larger units in the vicinity of so-called dislocation zones. One of the most important structures is the Staré Hory dislocation zone (Fig. 72, 73 and 76; *Vosáhlo 1988*, 56–58). Gangue minerals are represented by several generations of quartz accompanied by barite. Among ore minerals occur sphalerite, galenite, less frequently chalcopyrite, arsenopyrite, pyrite and tetrahedrite (*Pluskal – Vosáhlo 1998*). The most recently discovered indicator of mining activities in the Staré Hory dislocation zone are worked pieces of wood, probably relics of an ore washing facility, directly within the mineralisation zone. The wood was felled in the winter of 1238/1239 (*Kyncl 2012*). This find is associated with a pfennig of the Moravian Margrave Vladislaus III who reigned in 1246–1247 (Fig. 26). To the Bohemian-Moravian Highlands probably refers an entry in the chronicle of the Colmar town (Chronicon Colmariense), which in 1249 mentions an increase in number of German miners in Bohemia (*Post hec multiplicati sunt in Bohemia Theutonici; per hos rex ingentes divicias collegit ex auri et argenti fodinis*; *MGH SS XVII*, 245). A deed from October 23, 1272 is the oldest record of tenancy of mines in the Jihlava Region (*RBM II*, No. 799, p. 322). In the earliest mention in sources to Staré Hory from the year 1315, the locality is named *antiquus mons* (*Laštovička et al. 2001*, 39–40; *Vosáhlo 1999*; *2001*; *2005*).

Pelhřimov Region

A narrower spatial concept comprises verified deposits of lead, silver, zinc and iron ores east of Pelhřimov (Fig. 2, 4, 5 and 90; *Kratochvíl 1955–64,* Vol. V, 488; *Litochleb 1996*, 10–12; *Luna – Zimola 2007*; *Hrubý et al. 2012*, 345, 347–348). Mineralisation is mostly associated with quartz veins of some dozens of centimetres in thickness. Among ore minerals are pyrite, pyrrhotite, arsenopyrite, sphalerite, galenite (Fig. 22), tetrahedrite and chalcopyrite. The main silver-bearing ore mineral is galenite (PbS). The uppermost subsurface parts can also contain acanthite (*Litochleb 1996*). Problematic is the silence of literary sources. A text which may be related to mining in the Pelhřimov Region is a charter by Přemysl Ottokar II from January 3, 1272. It is a privilege which grants Jihlava one hide in each surveyed mine near Ústí. The charter also grants rights of leasing and surveying mining plots in mountains, which were and will be discovered between Jihlava and Ústí. It is mostly thought that the town mentioned in the charter is Ústí of the Vítkovci family, 65 km to the west of Jihlava (*CDB V*, 650, 278; *Šmahel et al.* 1988). Herewith it would concern the Pelhřimov Region, where Jihlava had the right to lease and survey mines and this territory would thus fall completely within the mining rights of Jihlava.

2. Case sites

2.1. Methods used

2.1.1. Archaeological area excavations and examination of sections in stream floodplains

Archaeological area excavations were carried out using standard research methods (*Hrubý 2011*, 43–46; *Hrubý et al. 2012*, 348–350). Excavation areas at the Jihlava – Staré Hory, Česká Bělá and Cvilínek sites were divided into a 5 x 5 m grid for the purpose of sampling for metallometric analysis (Fig. 38, 45 and 93). Soil sections of the Perlový Stream near Květinov were documented and sampled using a manually dug trench (Fig. 35). Soil sections near Česká Bělá were prepared on selected erosion edges of the bed of the Březina Stream (Fig. 33). On the Koželužský Stream, two pillar holes of a bridge over the stream valley were used (Fig. 36 and 85).

2.1.2. Geochemistry

On-site sampling and sample processing for soil metallometry

Samples were taken for the purpose of analyses of non-ferrous metals and separation of technoliths comprising ore and gangue which underwent preparation, metallurgical and smithy slags, and drops of non-ferrous metals. Soil samples from extensively examined archaeological situations at the Česká Bělá, Jihlava – Staré Hory and Cvilínek sites were taken for the purpose of metallometric analyses in a 5 x 5 m grid, always at the corner stake of the basic research orthogonal grid. Samples for metallometric analyses in a locally condensed 1 x 1 m grid were taken from layers in the operational area in immediate neighbourhood of ovens (Fig. 50–52, 103–105).

Washing of the operational sediments from relics of preparation plants, and alluvial deposits

Samples from relics of preparation facilities were analysed for non-ferrous metals and subsequently washed. At the Česká Bělá and Květinov sites, samples were taken from ovens or hearths. Washing at the Cvilínek site was targeted at sediments from basins of the ore washing facility (Fig. 39 and 96). Examined was the phase- and chemical composition of heavy fraction

(Tab. 15–16). The washing of deposits for separation of gold flakes from alluvial sediments of the Perlový Stream was a little different. On-site washing has been done using a large pan, and subsequent washing in laboratory conditions was completed with a small pan (Fig. 39).

Geochemical soil analyses and analyses of technoliths

The spectrum of analysed metals and metalloids at individual localities was varied and not always the same. Also diverse was the spectrum of sampling conditions: 1) samples taken from the whole area in a 5 x 5 m grid, 2) samples taken from partial segments in a 1 x 1 m grid in the operational area around the ovens and primary preparation places, 3) samples from the infills of ovens or hearths, 4) samples from tailing piles, 5) samples from sediments in basins of the ore washing facilities, 6) samples from floodplains. The analysed spectrum of elements at one and the same locality was not identical with regard to archaeometallurgical finds, either (Graph 5–7, 19). Mineralogical assessment was carried out using a binocular microscope. The AAS method was applied to detect Pb, Ag, Cu, Zn, Sb, As in technogenic deposits. Mineralogical assessment of ores or technoliths was also done on thin sections using an Olympus BX-40 microscope. For the determination of phases and their chemistry the JEOL JSM-6490LV electron microscope with EDX analyser was used (*Malý 2004*; *2005*; *2006*; *2008*).

2.1.3. Archaeobotany, dendrochronology and radiometry

On-site soil sampling for the analyses of charred and uncharred macroremains

Soil sampling for the analysis of macroremains has been carried out according to particular conditions. At the Staré Hory site, only the deposits in relics of sunken-featured buildings (Fig. 83) were sampled. At the Cvilínek site, samples were taken from a) infills of sunken archaeological features, b) alluvial sediments induced by medieval mining activity in archaeological feature 0615 (Fig. 37) and c) water sedimentary environment of the floodplain prior to emergence of medieval mining areas. For the analysis of macroremains, wet soil samples were taken from the Česká Bělá – Březina Stream and Květinov – Perlový Stream sections. Macroremains also were flotated from a wet soil sample on the Pstružný Stream. The sections were dissected into pieces sized about 5 cm (Fig. 13 and 14). The analysis of charred macroremains was done with a sample from Žďár nad Sázavou (Fig. 8: 10, Fig. 12, Tab. 3).

On-site soil sampling for pollen analyses

For pollen analysis, columns were taken from sections into tin boxes sized 10 x 10 x 50 cm (Fig. 59 and 60, Fig. 87). At the Cvilínek site, three sections in the neighbourhood of local stream were sampled for pollen analyses. Analysed was Section 3 from archaeological feature 0615 (Fig. 37).

Analysis of plant macroremains

Samples were first soaked in water, then flotated through graduated sieves with mesh size as necessary (0.25–0.4 mm), and dried. Separated charred and uncharred plant remains were picked and sorted under a stereoscopic microscope. The material was analysed in an amount which is necessary to obtain a statistically representative assemblage of plant macroremains (*Anderberg 1991*; *Berggren 1969*; *1981*; *Bertsch 1941*; *Katz et al. 1965*; *Beijerinck 1947*; *Schermann 1967*; *Körber-Grohne 1964*; *Klán 1947*).

Pollen analyses

The column taken from Section 1 on the Březina Stream was divided into 37 samples where the bottom part of the section was dissected by 5 cm mechanical layers, and the upper part by 10 cm layers. Section 2 was divided into 25 mechanical layers and Section 3 was taken in a length of 195 cm and divided into 29 samples. The 150 cm long column taken from Section 1 on the Perlový Stream was dissected in laboratory into 28 samples. Samples were prepared using a standard acetylation method (*Faegri – Iversen 1989*; *Moore et al. 1991*). Pollen diagrams and numerical analyses were done in the POLPAL programme (*Nalepka – Walanus 1999*).

Analysis of wood and charcoal

Charcoal pieces were separated from soil samples after flotation. At Cvilínek, charcoal pieces were mainly studied as fuel remnants in three main find contexts: a) infills of ovens and features in their neighbourhood; b) accumulations of charcoal in the operational area around ovens and slag dumps; c) charcoal included in slags, which is an authentic evidence of fuel. Fragments of wood and charcoal were picked under a stereoscopic microscope. After having made some fresh fracture surfaces and cuts with a razor blade (transversal, radial and tangential fracture), they were examined using a light microscope with 50x, 100x and 200x magnification. Fragments were recorded with 0.001 g precision. The samples were determined as exactly as to the level of genus (Graph 24, Fig. 108).

Analyses and dating of wet constructional wood and wooden ecofacts

With regard to hydrological conditions, it is an assortment of finds typical of Cvilínek. During both of the excavation campaigns, samples were taken from constructional wood for the purpose of typological and dendrochronological analysis (*Rybníček 2010*). Wood samples from Kostelec and from the Staré Hory dislocation also were dated by dendrochronology. Wood from Kejžlice, on the other hand, could not be dated by this method due to an insufficient number of tree rings (*Kyncl 2012*; *2013*; *Kyncl 2014*; cf. Tab. 1).

Radiocarbon dating and calibrated ^{14}C dates

The Česká Bělá – Březina Stream and Perlový Stream sections were dated using the ^{14}C method. Dating was made with the AMS method in the Center for Applied Isotope Studies, University of Georgia, USA. Calibration was made with confidence interval between 89 % and 95.4 %. Samples from the Koželužský Stream and one of the samples from Kejžlice were dated by AMS method in the Poznań laboratory. Calibration was made with confidence interval between 68 % and 95 %. Radiocarbon dates were measured by conventional method in the laboratory of the Nuclear Physics Institute of the Academy of Sciences of the Czech Republic. Samples from a section of the Bělá Stream in the built-up area of Česká Bělá (Fig. 20 and 40: 4) were processed for dating. Round logs from the floodplain of the Pstružný Stream also were conventionally dated. Another sample was represented by charred spruce branches from Žďár nad Sázavou (Fig. 8: 10, Tab. 2).

2.2. Česká Bělá: medieval mining areas and the Březina Stream

2.2.1. Landscape context and settlement history of the Česká Bělá micro-region

The micro-region is defined by watercourses, which run into the Borovský Stream, a right-bank tributary of the Sázava River. The township of Bělá is situated on the upper reaches of the eponymous Bělá Stream. Bělá in its upper reaches forms only a shallow valley with marshes (meadows). South of the township it already sinks deeper into the landscape relief (Fig. 40–42).

2.2.2. Medieval mining area

Archaeology of the mining area

The locality is situated 800 m northeast of the town at the height of 540–560 m ASL. Among the evidence of prospecting and extraction of ores are mouths of mining shafts (Fig. 45). Ore preparation was evidenced by two accumulations of crushed material. At the site several hearths were found, probably remnants of ore roasting (Fig. 50–52). Among them are a hearth within square C13 or two hearths at the very edge of the excavation area in squares I1 and I2. They were mostly oval in plan, bowl-shaped in cross-section, and contained charcoal pieces, ashes and a red- through to black-burned bottom. These hearths can be situated at the foot of former tailing pile, which makes an impression of sorting and roasting facility immediately at the spoil heap. Exceptional was an interior heating device approximately square in plan, sized 3.1 x 3.1 m. Postholes were identified in the middle of two opposite sides. Soil metallometry identified increased content of Cu, Pb and Zn; in the infill of the feature also Ag, As, Cd. At the site also an underground basement of an aboveground building was found (Fig. 48 and 49). The majority of archaeological movable finds are represented by pottery which forms a chronologically homogeneous assemblage (Fig. 54). Based on this material we can date the area to the second half of the 13th century or to the beginning of the 14th century respectively.

Geochemistry of the mining area

Area assessment shows non-accidental local concentrations of metals, which is a result of mining and preparation activity in medieval times. Ores were manually sorted and crushed near the base of the tailing piles at mining pits. Hearths and ore dumps are found in relation to places with higher contents of Pb, Zn and Cd, which can be considered relics of a sorting and roasting facility (Fig. 46 and 47). An exception is represented by a local increase in concentration of copper, which is placed elsewhere than the other elements (Fig. 47 on the right). Hypothetically seen, it might be an evidence that copper ores, which demand more complicated preparation procedures (*Vaněk – Velebil 2007*), were sorted and separated elsewhere than the other ores. Interesting results were obtained from an analysis in the neighbourhood of mining pits within a condensed 0.5 x 1 m grid (Fig. 50 and 51). Two hearths with fuel residues were found at a distance of about 50 cm from each other. Both of them were situated in the vicinity of an ore dump. The ore dump location showed higher concentrations of lead and silver (even though absolute values are not high). Local concentrations of metals are most distinctive with arsenic and cadmium in the operational area around the hearths. Similar is the correlation of enrichment with zinc and cadmium in the operational area around hearths at the north-eastern edge of the area (Fig. 52).

2.2.3. Březina Stream and its floodplain

The Březina Stream (Fig. 40: 3, Fig. 42 and 56: 2) was chosen for floodplain research due to its closeness to a mining area. The total length is 3.65 km. Three sections were examined here until as deep as 2 m below the present ground surface (Fig. 55–60).

Geochemistry of sections

Only with As and Sb in Section P1, with regard to behaviour of elements in supergenic environment, it can be supposed that the maximums detected are of anthropogenic origin. The Au maximum at the depth of 160 cm can, but not necessarily, be associated with gold extraction (Fig. 57, Graph 5). An increase in Pb, As, Sb, Cu, Zn, Ag, Cd and Au at the depth of 100–80 cm was detected in Section P2 (Fig. 58, Graph 6). Section P3, similar to Section P1, exhibits an increased Au content at its base (Fig. 59, Graph 7). The detected contents of metals and metalloids most probably resulted from mining, preparatory and metallurgical activity. Interesting is the correlation between elements related to polymetallic ore veins (Ag, Pb, Zn, Cu, Sb, As) and gold: this also may be an indicator of joint extraction of these metals.

Pollen analysis of Section 2

Sections P2 and P3 were analysed (Graph 8–9). Samples from the depths of 137, 128 and 124 cm (**LPZ ČB – 2A** zone) exhibit a high share of woody plants (over 80 %). Dominant wood is spruce

(*Picea* – up to 60 %). Pine (*Pinus*), birch (*Betula*) and lime (*Tilia*) are represented by about 10 % each. The other woody plants such as fir (*Abies*), beech (*Fagus*), oak (*Quercus*), hazel (*Corylus*) and alder (*Alnus*) are rare. The most frequent herbaceous plants are grasses (about 10 %), and cereals (less than 5 %) as anthropogenic indicators. Ruderal and synanthropic species are found only sporadically, among them mainly mugwort (*Artemisia*) and field sorrel (*Rumex acetosella*). The next **LPZ ČB – 2B** zone is represented by samples from the depth of 91 to 71 cm. The pollen of woody plants shows the lowest value of 30 %. Spruce (*Picea*) recedes, and the representation of the other woody plants remains unchanged. Slightly prevailing are pine (*Pinus*) and birch (*Betula*), less frequent are fir (*Abies*), beech (*Fagus*), spruce (*Picea*), oak (*Quercus*), hazel (*Corylus*) and alder (*Alnus*). Grasses reach almost 30 %. A significant share was recorded with cereals and weeds (30 %). Among ruderal plants are mugwort (*Artemisia*), field sorrel (*Rumex acetosella*) and nettle (*Urtica*). This zone shows the widest diversity of species and reflects the strongest human impact. The last **LPZ ČB – 2C** zone is represented by two samples from the depths of 51 and 44 cm. The pollen of woody plants reaches 50 %, with dominant alder (*Alnus* – up to 30 %). Cereals and ruderal plants are less frequent. This zone exhibits a smaller variety of species.

Pollen analysis of Section 3

The **LPZ ČB – 3A** pollen zone includes layers from the depth of 193 to 181 cm. The pollen of woody plants decreases to 10 %. Among them are spruce (*Picea* – 5 to 25 %), pine (*Pinus*), birch (*Betula*), fir (*Abies*), lime (*Tilia*), less frequently beech (*Fagus*), alder (*Alnus*), hazel (*Corylus*), oak (*Quercus*) and hornbeam (*Carpinus*). The spectrum of herbaceous plants is dominated by grasses (over 20 %), and a significant share is shown by the aster family (*Asteraceae*) and buttercup family (*Ranunculaceae*). Anthropogenic indicators are represented by pollen of cereals (20 to 40 %), weeds such as cornflower (*Centaurea cyanus*) and corn-cockle (*Agrostemma*). Frequent occurrence was recorded with ruderal plants, such as mugwort (*Artemisia*), field sorrel (*Rumex acetosella*), nettle (*Urtica*), narrow-leaf plantain (*Plantago lanceolata*), broad-leaf plantain (*Plantago major*), the goosefoot family (*Chenopodiaceae*) and common knotgrass (*Polygonum aviculare*). The next **LPZ ČB – 3B** zone (depth of 173 to 115 cm) exhibits a deviation in the incidence of spruce (*Picea*), decrease in fir (*Abies*) and beech (*Fagus*). The share of cereals and some ruderal plants slightly decreases. Frequent occurrence was recorded with spores of eagle fern (*Pteridium aquilinum*) and pollen of the buttercup family (*Ranunculaceae*). At the end of the zone increases the share of sedge pollen (*Carex*). The changes in diversity of the pollen spectrum are very small (Graph 9).

Analysis of plant macroremains from Section 1

CB P1 I zone *Abies alba* – *Montia fontana*, 170–200 cm: It is characterised by indicators of primary woodland cover (fir and spruce forests) and, on the local level, by indicators of spring areas. The vegetation is very sporadic and consists exclusively of the water-blinks species (*Montia fontana*). In the surroundings there was probably the primary forest with fir (*Abies alba*).

CB P1 II zone *Scirpus silvaticus* – *Sambucus nigra* – *Linum catharticum*, 170–120 cm: It is characterised by indicators of human activities. Among the plants recorded are utility species (flax, hazel), indicators of deforestation, species of forest clearings and shrubland species, ruderal plants and segetal weeds. Species of mown meadows and pastures also are present. On the local level there is a water reservoir with riparian tall grasses.

CB P1 III zone, hiatus around 100–120 cm: We can observe a hiatus which is induced by sedimentation of coarse gravel (extraction activities, flood?).

CB P1 IV zone *Alchemilla* sp. – *Chenopodium album*, 100–0 cm: This zone encompasses the period of emergence of loamed floodplain with ruderal species. The floodplain is overgrown with alluvial grassland species (Graph 10).

Analysis of plant macroremains from Section 2

From the base of the section up there are evident indicators of human activity. The section is characterised by only sporadic indicators of woodland. Among them, if recorded, are species of spruce forests or secondary forest openings (birch). Indicators of human activities also occur: utility species (rye, flax), deforestation (secondary forests, clearings and openings), sporadically ruderal sites and field cultures (weeds, ruderal species), meadows and pastures (species of secondary grassland ecosystems).

CB P2 I zone *Sambucus nigra* – *Rubus idaeus*, 150–110 cm: This zone includes indicators of forest openings or clearings and collapsed river banks (gravel terraces and sandy tongues) and other mineral substrates (*Scleranthus annuus*, *Stachys annuus/arvensis*).

CB P2 II zone *Scirpus silvaticus* – *Alisma plantago-aquatica*, 110–0 cm: At the site we can locally observe a succession of wetland ecosystems from initial stages up to wet meadow communities (Graph 11).

Analysis of plant macroremains from Section 3

CB P3 I zone *Spergula maxima* – *Polygonum aviculare*, 195–160 cm: This zone includes utility species (flax), ruderal plants (*Chenopodium album*, *Sambucus nigra*, *Urtica dioica*), cereal and flax weeds (*Centaurea cyanus, Spergula arvensis ssp. arvensis* and *ssp. maxima, Viola arvensis*), species of trampled soils (*Polygonum aviculare, Carex ovalis*), indicators of meadows and pastures (*Leucanthemum vulgare, Ranunculus acris, Hypericum perforatum*). Synanthropic character is evidenced by charcoal. Directly on site there is a wetland fed with nutrients (*Alisma plantago-aquatica*, *Bidens tripartitus*, *Persicaria hydropiper*).

CB P3 II zone, hiatus ca. 160–150 cm: A hiatus in palaeoecological record (only species with most resistant seeds and fruits, for example *Chenopodium album*). Interesting find of a charred oat grain (*Avena* sp.) indicates continuous and intensive human activities.

CB P3 III zone *Scirpus silvaticus, Carex* ssp., 150–80 cm: The existence of wetland on the local level. Short and intensive sedimentation of peat (*Scirpus silvaticus*, *Carex* ssp., *Viola palustris*).

CB P3 IV zone *Ajuga genevensis – Chenopodium album*, 80–0 cm: Loamed floodplain affected by eutrophication (ruderal species *Chenopodium album*, *Urtica dioica*). Detected were indicators of meadows and pastures (*Ajuga genevensis*; Graph 12).

2.3. Květinov: shores and floodplain of the Perlový Stream

2.3.1. Landscape context and settlement history of the Perlový Stream

Perlový Stream is part of the catchment area of the river Sázava. Its total length is 20 km (Fig. 61). The sedimentary infill of the stream floodplain (Fig. 63) is formed in the basal part by dislocated fragments of weathered granitoid rocks with Pleistocene alluvial gravel/sand sediments, and by plastic sedimentary layers alternating with gravel/sand layers. The upper part of the stratigraphy consists of Holocene and historical (medieval, modern) sediments, which are partly organogenic and contain, probably in several flood horizons, driftwood and other organic matter. The total depth of sediments in the valley down to the base varies between 8–11 m in the place of archaeological excavations.

2.3.2. The area with a wooden building, ovens and a millstone from a hand-operated gold mill

Archaeology of the extensively excavated area

The locality was situated near the village of Květinov (Fig. 2: 3 and 4, Fig. 61). Archaeological excavation identified here a relic of an aboveground building, which was probably partly open (Fig. 64). Three pit ovens were unearthed in the shelter (Fig. 65). Another two ovens of a different type were discovered outside the building (Fig. 67 and 68). In the collapsed structure of one of these ovens a part of a rotary stone mill was discovered, which is very well preserved, except a secondary damage caused by fire (Fig. 68 and 70). With regard to dimensions we can interpret it as an evidence of a gold mill. The assemblage of pottery found on site dates the area to the 13th century (Fig. 69).

Geochemistry of the extensively excavated area

The determination of metal contents is summarised on Fig. 66. The Zn contents are between 99 and 6 ppm (with average value of 31 ppm); these values can be considered a natural "background" at the site. The Pb contents vary between 79 ppm and the limit of detection; average values (9 ppm) can be considered natural, but the highest detected lead contents are already unusual with given environment. Lead is slightly concentrated around the ovens. Increased values of copper contents were detected around and inside, the ovens 1 and 2.

2.3.3. On-site archaeobotanical profile of the production area for the first time

A sediment sample was taken from the burnt layer in the area with building relic. It contained charred grains of cereal rye (*Secale cereale*) and common wheat (*Triticum aestivum*), fragment of a cereal culm (*Cerealia*) and several species of segetal weeds or ruderal plants (*Fallopia convolvulus*, *Galium aparine*). The spectrum of charcoal was similar to that in the stream floodplain. Dominant species here is fir (*Abies*, 51 %), followed by beech (*Fagus*, 23 %), lime (*Tilia*, 18 %) and maple (*Acer*, 8 %).

2.3.4. Perlový Stream and its floodplain

On-site situation with soil sections 1 and 2

A trench was laid out in the floodplain of the stream, on its eastern bank (Fig. 35 and 62). Section 1 was documented at a length of 150 cm (Fig. 71). Geological subsoil was not reached in the sampling place. Section 2 was documented at a length of 50 cm.

Analysis of plant macroremains from Section 1

The analysis of plant macroremains informs us about changes of vegetation cover and thereby also about changes of human activities. The analysis helped to distinguish three biostratigraphic zones (Graph 13 and 14).

PP I zone *Abies alba* – *Populus* l. 0210 and 0211, depth 100–150 cm: We can observe isolated macroremains of forest vegetation. Charcoal indicates human presence.

PP II zone *Rubus idaeus* – *Sambucus nigra* base l. 0206, 0207, 0208 and 0209, depth 52–100 cm: We can observe an increase in macroremains of forest openings and clearings, i.e. an abrupt increase in indicators of human activity: raspberry (*Rubus idaeus*) and common blackberry (*Rubus fruticosus*), as well as species of ruderalised areas, e.g. black elder (*Sambucus nigra*), creeping buttercup (*Ranunculus repens*), white goosefoot (*Chenopodium *album*), common nettle (*Urtica dioica*). Woody plants are represented by silver fir (*Abies alba*).

PP III zone *Polygonum aviculare – Centaurea cyanus* l. 0124, 0126, 0201–0206, depth 0–52 cm: In the latest period we can observe here indicators of meadows, such as creeping bent-grass (*Agrostis* cf. *stolonifera*), blue bugle (*Ajuga reptans*), lady's mantle (*Alchemilla* sp.), cinquefoil (*Potentilla* sp.) and dandelion (*Taraxacum* sect. *Ruderalia*). Permanent human presence is indicated by ruderal species such as white goosefoot (*Chenopodium album*) and common nettle (*Urtica dioica*).

Analysis of plant macroremains from Section 2

It is a segment approximately corresponding to PP II zone of Section 1. We can observe here the incidence of indicators of forest openings, such as black elder (*Sambucus nigra*), raspberry (*Rubus idaeus*), and indicators of ruderalisation – dandelion (*Taraxacum* sect. *Ruderalia*), white goosefoot (*Chenopodium album*). Interesting is the occurrence of a kernel of grape vine (*Vitis vinifera*), which only hardly could be cultivated at the site. From forest vegetation only a single needle of silver fir (*Abies alba*) was found in the upper part of the section.

Wood and charcoal

The amount of charcoal in sediments fluctuates and reflects changes of woody vegetation and human activities (Graph 15). Section 1 enabled to divide the local development into three anthracotomic zones corresponding to general division based on plant macroremains.

PP I zone l. 0210 and 0211, depth 100–150 cm: In the earliest period we can observe isolated fragments of wood and charcoal of fir (*Abies*), beech (*Fagus*) and indeterminable conifers (*Conifera* ind.). This period yielded only a limited volume of anthracotomic data; detected were indicators of climax forest communities (fir-beech and beech forests). Charcoal fragments indicate human presence.

PP II zone base l. 0206, 0207, 0208 and 0209, depth 52–100 cm: We can observe an abrupt increase in quantity, mainly with charcoal. Detected were above all fir (*Abies*), beech (*Fagus*), indeterminable conifers (*Conifera* ind.), fir/spruce (*Abies/Picea*) and spruce (*Picea*, wood fragment). Photophilous woody plants (hazel and poplar/willow) were detected in the upper part of the zone. In the floodplain an environmental change has taken place, accompanied by an increase in indicators of deforestation (charcoal).

PP III zone l. 0124, 0126, 0201, 0202, 0203, 0204, 0205, 0206, depth 0–52 cm: In the latest period we can identify photophilous woody plants poplar/willow (*Populus/Salix*), pine (*Pinus*) and birch (*Betula*). Charcoal of fir (*Abies*), fir/spruce (*Abies/Picea*) and beech (*Fagus*) occurred sporadically. In this period we can suppose the emergence of substitutional vegetation with birch, aspen and pine; the original fir-beech and beech forests survive on a limited scale. Anthracotomic analysis reflects the emergence of cultural landscape with a mosaic of altered as well as semi-natural forests.

Analysis of washed sediments from manual sampling and from core drills in the floodplain

Washing of sediments of the Perlový Stream confirmed the presence of gold flakes. This gold may originate from gold-bearing sediments but also from a deposit in the polymetallic vein mineralisation near Koječín (*Morávek et al. 1992*, No. 272). The origin of this gold may also be associated with primary deposits at the Humpolec – Štůlny sites. Most of the minerals in heavy fraction come from rocks in the neighbourhood of the site. The placer mining does not necessarily leave geochemical traces, particularly if it was carried out on a small scale. Tailing piles and other surface features of placer mines are often destroyed by later cultivation of floodplains. Gold metallurgy does not necessarily leave any evident traces, either, because it has been performed on a small scale and with focus laid on minimisation of losses. It can only be speculated that gold in sediments in the neighbourhood of settlements most probably did not escape the notice of medieval people.

2.4. Jihlava and Antiquus mons: prominent mining and metallurgical centre at the land frontier

2.4.1. Landscape context of the western forefield of Jihlava and Koželužský Stream

The most important watercourse in the region is the river Jihlava, which to a high degree co-forms its relief (Fig. 72). In the first third of the 13th century, the river was defined as a boundary between the oldest documented holdings in this area, and in the place where one of the trade routes has crossed the river Jihlava by a ford, an eponymous settlement emerged (Fig. 8). Mills were built on the river, at the time of existence of local mining enterprises also ore mills, and along with them also washing facilities, stamp-mills and smelteries (Fig. 72: 3 and 73: 3). In the following text, however, we will rather focus on tributaries of Jihlava. Even the smallest watercourses in the vicinity of mining, preparatory and metallurgical plants were namely intensively used (Fig. 29 and 30).

2.4.2. Historical development of pre-urban settlement in Jihlava

An evidence of settlement on the territory of present-day Jihlava still before the beginning of mining activities is represented by the Church of St. John the Baptist. It is situated about 1.3 km north of the town centre of Jihlava. In the Middle Ages, the church was part of the pre-urban agglomeration, which is mentioned in the year 1307 as *Iglavia Antiqua*. The church has verifiably existed in 1233, when the Želiv Premonstratensians purchased the patronage together with several villages from the Teutonic Order (*CDB IV/1*, No. 13, pp. 74–75).

2.4.3. Medieval mining agglomeration at the Staré Hory dislocation

Archaeology of mining areas on a large scale

Extensively excavated medieval mining areas at the NW and W edge of Jihlava are referred to as Staré Hory I-III (Fig. 8: 5, Fig. 72: 2, Fig. 73 and 76). Archaeological excavations in 2002–2006 were instigated by building activities (*Hrubý 2011*, 42, 50–52). Dendrochronological measurements of fir planks from a place about 250 m away from the medieval areas yielded a date of 1238/1239 (*Kyncl 2012*; Fig. 73: 4). After this followed chronologically an unstratified find of a pfennig of the Moravian Margrave Vladislaus III (1246–1247; Fig. 24–26). Within this context falls the measurement of one of the burnt round logs from the construction of a sunken-featured wood-and-earth building in the northern part of the dislocation (Fig. 73: 5, Tab. 1). The wood was felled in 1247/1248 (*Kyncl 2014*). 88 mouths of shafts were identified on this site. In several cases these pits were arranged in groups, mostly by three. Mining pits are larger in diameter. At the Staré Hory I site, ore washing facilities were found, whose axis was formed by a canal running out of one of the mining pits (Fig. 77: 1). The whole system was connected with a small stream. At the Staré Hory III site, the area of the washing facility was connected with mining pits (Fig. 79: 1 and Fig. 80). The main canals were trapezoid in cross-section. One of the canals ran directly out of a defunct shaft. The canals were linked with basins, in which the ore-bearing silt has sedimented and in the final stage of washing then pure ore concentrate. Ovens or forges, or flat hearths respectively, show evidence of operational heat. Their daubed walls and bottoms are fired, in one case stone walls with daubing are preserved. Evidence of settlement activities is represented by relics of more than twenty sunken-featured buildings (Fig. 77, 79 and 83). They are the main source of archaeological finds and archaeobotanical data (cf. Fig. 84).

Soil metallometry in the ore washing facility at the Staré Hory III site

The whole area is contaminated with non-ferrous metals in values several times as high as the normal background (Fig. 82). Enrichment is evident in the place of the washing facility, which may be associated with deposition of washed ore concentrate. Slightly increased values can be observed with As at the subsoil level, but in a relatively non-contrasting and full-area distribution. Higher concentrations of arsenic are supposed with roasting or washing. Also non-contrasting is the Ba content where barite is the dominant vein material. A connection to the washing facility can be observed with Cd and Zn, which exhibit a similar "behaviour" from the viewpoint of geochemistry.

Metallometry of tailings

All analysed sediments in basins which are classified as tailings exhibit increased contents of non-ferrous metals and all of them included both technogenic particles (slags) and particles originating from ore lodes (barite, or quartz crystals). However, based only on the content of the above metals it is very difficult to decide whether these sediments are truly "operational", or only secondary (Tab. 7–9).

2.4.4. On-site archaeobotanical profile of the production area for the second time

Plant macroremains

The assemblage of charred macroremains from the period of existence of the mining settlement is mainly dominated by cereals. Weeds, ruderal plants and grasses are represented by species with wide ecological amplitude. Charred wild species mainly occur in segetal communities. Uncharred macroremains, on the other hand, can be an indicator of decline of the agglomeration or its parts. Dominant is here the genus *Rubus* ssp. Among utility plants are barley (*Hordeum vulgare*), common wheat (*Triticum aestivum/compactum*), rye (*Secale cereale*). Exceptionally the waste from cleaning of cereals was found. Legumes are represented by pea/vetch (*Pisum/Vicia*) and lentil (*Lens esculenta*). The find of lentil indicates import from southerly situated regions. The highest share of utility species was recorded with gathered fruit such as raspberry (*Rubus idaeus*) and common blackberry (*Rubus fruticosus*). Potherbs were represented by dill (*Anethum graveolens*). Wild species indicate segetal communities in crop plants (*Galium* cf. *spurium*), nitrophilous ruderal communities (*Rumex* sect. *Rumex*, *Galium* cf. *aparine*) and communities of disturbed soils fed with nutrients (*Chenopodium polyspermum*, *Galium* cf. *aparine*; Tab. 10–12; Graph 16–18).

Wood and charcoal

Woody plants were detected – fir, spruce, beech, pine, poplar, poplar or willow, yew, lime and elm. The main economic woody plants were spruce, fir and beech, dominant in all of the contexts analysed. Interesting is a find of charcoal from lime and yew. Also detected were riparian woody species – poplar (*Populus*) and poplar/willow (*Populus/Salix*; Graph 18).

2.4.5. Koželužský Stream and its floodplain in contact with the Staré Hory fault

On-site situation with soil sections 1 and 2

The locality is situated in the floodplain of the Koželužský Stream 2300 m W/WSW of the Church of St. James the Greater in Jihlava. The elevation above sea level is 521–522 m. It is a flat floodplain valley approximately in W-E direction. The slopes on the southern bank of the stream are a little steeper than the moderate slopes on the northern bank (Fig. 8: 6, Fig. 72: 7 and Fig. 85).

Geochemistry of the Koželužský stream Section 2

Section 2 exhibits an increased concentration of metals in the lower part (Fig. 87 and 88, Graph 19, Tab. 13). Sediments 0130–0134 are anomalously enriched with heavy metals (Pb, Zn, Cu, Ag, As) and barium, which are metals typical of the Staré Hory mineralisation. Anomalies in barite concentration on the Koželužský Stream were also detected by previous panning surveys. This might be associated with continuation of the Staré Hory dislocation towards the south, where this mineral may have appeared in the form of weathered inclusions.

Incidence of technoliths in sediments of Section 2

Coarse-fissile barite can be observed macroscopically in layer 0131. The size of its fragments is variable of up to 5 cm. In a sample of 0.268 kg in weight, more than 30 slag fragments weighing 0.164 g and sized up to ca. 5 mm were separated under a binocular microscope. The layer 0132 contains a negligible amount of barite and isolated pieces of charcoal. On the other hand, barite is frequent with layer 0133, whose sediment contains charcoal as well. The sample also contained isolated fragments of glassy slag sized up to 0.5 mm.

Pollen analysis of Section 2

Pollen is best preserved in bog layers containing a minimum of siliceous sand. Crucial proved to be the Section 2 (Graph 20), which enabled to distinguish three local palynological zones (LPZ).

K-1 zone, depth 117 to 141 cm, layers 0127 and 0134: Pollen of woody plants (AP) shows a maximum of 75 % at the base, and decreases to 30 % at the end of the zone. Prevalent species is fir (*Abies* – up to 25 %), less frequent are spruce (*Picea* – up to 15 %) and pine (*Pinus* – up to 10 %). Similar development also was recorded with beech (*Fagus*), which exhibits 5 % and then vanishes almost completely. A different development is shown by alder (*Alnus*), lime (*Tilia*) and birch (*Betula*). Their share of less than 5 % remains unchanged. The oak (*Quercus*), hazel (*Corylus*) and hornbeam (*Carpinus*) curves, on the other hand, are variable. Cereals reach as much as 20 % at the end of LPZ. Analogical development was detected with anthropogenic indicators, such as nettle (*Urtica*), the goosefoot family (*Chenopodiaceae*) and common knotgrass (*Polygonum aviculare*). Crop plants are represented by buckwheat (*Fagopyrum*).

K-2 zone, depth 109 to 85 cm, layers 0128 and 0147: The AP/NAP ratio is stable between 30 to 40 %. Among woody plants, the pine (*Pinus*) curve increases to as much as 20 %. Fir (*Abies*) decreases below 10 % and a similar development also shows spruce (*Picea*). Lime (*Tilia*) vanishes at the beginning of the zone, beech (*Fagus*) exhibits an increase and subsequent decrease. Alder (*Alnus*), birch (*Betula*) and oak (*Quercus*) remain unchanged. Sporadically also hornbeam (*Carpinus*) is detected. Dominant herbaceous plants are grasses, whose occurrence increases to as much as 40 % at the end of the zone. Anthropogenic indicators are dominated by cereals (up to 20 %). Local vegetation is mainly represented by the pollen of sedges (*Carex*), whose share increases from 15 % to as much as 40 % at the end of the zone. The pollen curve of nettle (*Urtica*), on the other hand, remains unchanged at around 5 %. Wetland vegetation is represented by bulrush (*Typha*), the genus *Filipendula*, pondweed (*Potamogeton*) and watermilfoil (*Myriophyllum*).

K-3 zone, depth 77 to 5 cm, layers 0145, 0140, 0142, 0125, 0135, 0136, 0148 and 0143: The ratio of woody to herbaceous plants varies between 20 and 40 %. Woody plants are dominated by pine (*Pinus* – 10 to 20 %), whereas spruce (*Picea*) and fir (*Abies*) are on decrease. Small changes (between 5 and 10 %) are recorded with birch (*Betula*) and alder (*Alnus*). Less frequent is oak (*Quercus*); beech (*Fagus*), hornbeam (*Carpinus*), hazel (*Corylus*) and elm (*Ulmus*) are only sporadic. Anthropogenic indicators are represented by cereals (about 20 %). Less frequent are common knotgrass (*Polygonum aviculare*), field sorrel (*Rumex acetosella*) and the goosefoot family (*Chenopodiaceae*). Sporadic occurrence was recorded with narrow-leaf plantain (*Plantago lanceolata*), broad-leaf plantain (*Plantago major*), cornflower (*Centaurea cyanus*) and corn-cockle (*Agrostemma*). The spectrum of local swampland vegetation is dominated by sedges (*Carex* – about 20 %). Much less frequent is nettle (*Urtica* – under 5 %) and also taxa such as bulrush (*Typha*) or the genus *Filipendula* were detected rarely in comparison to the preceding zone.

Plant macroremains in sediments of Section 2

Botanical taxa detected represent various communities and it was possible to divide them into sixteen ecological groups: aquatic plants, species of spring areas, reed beds, tall sedge grass stands, wet ruderal sites, aerated sites (rubble), the other ruderal sites, cereal weeds, crop plants, species of trampled sites, peat meadows, short grassland, regularly mown meadows, species of forest clearings, woodland and shrubland species, and species of alder forests. Diasporas of species of trampled sites and mineral substrates were frequent with places newly opened to vegetation succession. Direct indicators of human activities were detected only sporadically. Indirect indicators, on the other hand, were very frequent. Among them are weeds: ball mustard (*Neslia paniculata*), cornflower (*Centaurea cyanus*), wild radish (*Raphanus raphanistrum*), field parsley-piert (*Aphanes arvensis*), red pimpernel (*Anagallis arvensis*). A significant component was represented by grassland species. Detected were also species of short grassland and heaths. Very abundant were species of regularly mown wet meadows. Also frequent were woodland and shrubland remnants – European spruce (*Picea abies*), silver fir (*Abies alba*), common beech (*Fagus sylvatica*), lime (*Tilia* sp.), common hazel (*Corylus avellana*), blackthorn (*Prunus spinosa*), three-nerved sandwort (*Moehringia trinervia*), wood sedge (*Carex sylvatica*), goldilocks buttercup (*Ranunculus auricomus* agg.). Specific is the evidence of alder forests (*Alnus* sp.). The analysis enabled to divide the section into several biostratigraphic zones (Graph 21; Fig. 89).

KP I zone *Rubus idaeus* – *Abies alba*, d. 114–140 cm, layers 0134, 0127: In the earliest studied period we can observe a concentration of woodland species and indicators of forest clearings or secondary shrubland. These species are supplemented to a lesser extent with indicators of human activity. Conspicuous is the absence of indicators of agriculture, weeds and crop plants.

KP II zone *Phragmites australis* – *Potamogeton* ssp. – *Polygonum hydropiper*, d. 74–114 cm, layers 0128, 0147: We can observe an increase in macroremains of aquatic and riparian vegetation. A significant change of the floodplain management occurred, which is reflected in an increased supply of nutrients (*Polygonum hydropiper*), invasion of aquatic vegetation and fauna, and secondary alder forest (*Alnus* sp.).

KP III zone *Polygonum aviculare* – *Centaurea cyanus*, d. 57–74 cm, layers 0145, 0140: Newly we can observe a retreat of indicators of wet ruderal sites (*Bidentetea*).

KP IV zone *Lychnis flos-cuculi* – *Carex echinata*, d. 0–57 cm, layers 0142, 0143: In the last biostratigraphic zone we can document the development of meadow communities in the floodplain of the Koželužský Stream. Indicators of short grassland, pastures and regularly mown mesophilic meadows are on the rise. At the same time also we can observe a spread of alder forests.

Wood and charcoal

Charcoal from Section 2 was analysed and the amount in individual sediments is varied (Graph 22). The section thus can be divided into two periods, which differ from each other not only in quantity by the content of burnt wood, but also in quality by the share of wood genera. In the anthracotomic horizon 1, d. 114–140 cm we can observe a dominance of woody plants of fir-beech forests – fir (*Abies*, ca. 56 %), beech (*Fagus*, 37 %) with admixture of spruce (*Picea*, under 1 %), lime (*Tilia*, 4 %) and the genus *Prunus* (ca. 0.5 %). In the anthracotomic horizon 2, d. 0–114 cm we identify a change of conditions. Dominant taxa become alder (*Alnus*, ca. 57 %) and pine (*Pinus*, 16 %) along with indeterminable conifers (*Conifera* ind., 19 %). A share of more than 1 % was still recorded with poplar (*Populus*) and poplar/willow (*Populus/Salix*). The other woody plants – maple (*Acer*), hazel (*Corylus*), spruce (*Picea*) and *Prunus* – are represented only marginally, showing a concentration of less than 1 %. The assemblage of uncharred wood exhibits similar shares of woody plants as with charcoal. In Horizon 1 we observe the dominance of fir (*Abies*, ca. 40 %), beech (*Fagus*, 7 %), spruce (*Picea*, 2 %), pine (*Pinus*, under 1 %) and indeterminable conifers (*Conifera* ind., 50 %). Dominant taxa in Horizon 2 become alder (*Alnus*, ca. 67 %), poplar (*Populus*) and poplar/willow (*Populus/Salix*, ca. 7 % in total), pine (*Pinus*, 2 %) and spruce (*Picea*, 1 %) along with indeterminable conifers (*Conifera* ind., 8 %). The results indicate a radical change of woodland communities in the neighbourhood. At the time of sedimentation of layers 0134, 0127 and 0129 we can observe destruction of fir-beech forests. Charcoal in these layers can be interpreted as a result of exploitation of beech, fir and spruce. High consumption of wood leads to changes of conditions. Metallurgical activity subsequently declines and the spectrum of woody plants in Horizon 2 corresponds to alder forests and willow stands growing on released areas.

2.5. Cvilínek: a mining and metallurgical complex on the European watershed

2.5.1. Landscape context and settlement history of the south-eastern part of the Pelhřimov Region

The last locality is situated in the south-eastern part of the Pelhřimov Region, prevailingly in the monotonous Moldanubian group composed of Precambrian or Palaeozoic biotite and sillimanite-biotite gneiss with cordierite (Fig. 4 and 5, Fig. 90: 3). With regard to this peripheral part of the Pelhřimov Region we know only of a few indications of settlement from the 12th or at least from the beginning of the 13th century (Fig. 8: 7, 17, 18). In the Early Middle Ages, the territory under review was part of the frontier area of the Duchy of Bohemia, which fulfilled, among others, also military and defensive functions. One of the most complicated periods after the mid-13th century was represented by the episcopacy of Tobias of Bechyně (1278–1296).

2.5.2. Mines, ore preparation plants, washing facilities, smelteries and settlement

Archaeology of mining areas

Cvilínek is situated about 3.4 km NNW of Horní Cerekev on the upper reaches of the Kamenička Stream (Fig. 2: 7, Fig. 8: 7, Fig. 90: 3 and Fig. 92). Mining relics are located ca. 630 m from the excavated areas (Fig. 90, 92 and 93). In the north-eastern part of the area, relics of workplaces were found where the extracted ore was sorted in multiple phases and crushed (Fig. 93 and 95). The distance to the ore washing facility and to the settlement was 20 m. The most common minerals here are pyrite and arsenopyrite. Galenite is rare (Fig. 22). It contains almost 1.4 % Ag. Fragments of granite millstones were found, which give evidence of ore mills (Fig. 112: 8–11). The next area was an ore washing facility (Fig. 93: B) where utility ore was separated by gravity from gangue (Fig. 88: 4). Thanks to specific conditions of this site, wooden components survived (Fig. 94; 115). Another assemblage is composed of relics of ovens, forges and hearths accompanied by metallurgical waste (Fig. 102–108). During excavations, individual fragments of slag were found as well as some slag dumps with various types of slags, which are indicators of smelteries and smithies (Fig. 31). The complex also comprises relics of sunken-featured buildings, indicating a mining and metallurgical settlement, and a ditch enclosing a small area (Fig. 93: D). The ditch emerged in the later phase.

Soil metallometry in the ore washing facility and in the operational area around the relics of ovens

The measurement shows increased contents of Pb, Ag, Zn, Cu and As (Fig. 97–101). In soils they are bound as mechanical admixtures in phases (so-called clastic admixture). Besides this, metals can be adsorbed to the surface of clay minerals or the organic part of soils, or to oxides and hydroxides of iron and manganese, respectively. Metallometry in a 1 x 1 m grid yielded interesting results with ovens 0900 and 0576 (Fig. 103–105).

Metallometry of tailings

The analysed infills from basins of the ore washing facility (Fig. 96, Tab. 15 and 16) can be classified as operational sediments. They are composed of sharp-edged grains or automorphic crystals (pyrite, arsenopyrite). A statistically significant correlation was detected between Ag and Cu and between Ag and Sb in schlich (correlation coeficient 0.871 and 0.875). Statistically significant, however, is also the correlation coeficient between Ag and Pb. The value of –0.843 indicates that Ag is not bound to galenite but probably to minerals Ag-Cu-Sb. Ground or stamped and washed pulp was deposited besides the basins. The major part consisted of vein-impregnated gneiss, the minor part of quartz (Fig. 88: 4).

2.5.3. On-site archaeobotanical profile of the production area for the third time

Wood and tree stumps

For the reconstruction of forest vegetation in the time before the emergence of local ore preparation plants we have an assemblage of uncharred wood from 35 tree stumps. Dominant species were spruce (71 %), alder (14 %), poplar and willow (9 %). Also recorded was juniper, and maybe also birch (Tab. 14). The assemblage of tree stumps showed evident marks of scorching (37 %), chopping or felling (9 %). Also detected was a situation where a tree stump was dug out so that it was possible to insert wooden constructions associated with ore washing (Fig. 109). This composition corresponds to spruce-alder forests (*Piceo-Alnetum*) in spring areas, submontane alder forests (*Alnetum incanae*) along streams, and waterlogged spruce forests.

Wood and charcoal from Section 1

Reconstruction of forest vegetation was enabled by charcoal and uncharred wood from water sedimentary layers in Section 1 (Fig. 93). Dominant species among wood remnants were spruce, poplar and willow. Among charcoal it was beech together with fir and spruce mixed with photophilous woody plants such as birch, juniper and poplar/willow. The last component before the emergence of mining areas were demanding woody plants such as lime, ash and maple. Even though their occurrence was only sporadic, they indicate exploitation of slope and scree forests in the hinterland. Charcoal from the stratigraphically oldest sediments indicates exploitation of submontane forests higher upstream (Graph 23–25).

Wood and charcoal from Sections 2 and 3 in Feature 0615

Charred and uncharred diasporas, needles, charcoal, wood and pollen are preserved here due to permanently anaerobic conditions. Dominant species among uncharred wood were spruce and poplar/willow. There is an evident selection of coniferous wood for constructional purposes (Fig. 110). The assemblage of charcoal, on the other hand, contained a higher share of birch and beech, which were used as fuel because of their calorific value. Macroremains are dominated by fir and spruce. Minor representation was recorded with European aspen, common juniper, beech and elder (Graph 27).

Pollen from Sections 2 and 3 in Feature 0615

The plain spectrum is dominated by spruce (*Picea*, ca. 50 %), pine (*Pinus*), beech (*Fagus*) and fir (*Abies*, ca. 10 %). Other woody plants exhibit a share of less than 5 %: birch (*Betula*), alder (*Alnus*), oak (*Quercus*) and willow (*Salix*), sporadically hornbeam (*Carpinus*), lime (*Tilia*), elm (*Ulmus*) or ash (*Fraxinus*). Evident is a component of surrounding woodland communities, e.g. acidophilous oak forests with pine and oak, oak-hornbeam forests, scree forests with demanding deciduous species such as ash, elm and lime, brushland communities with hazel or secondary forests with birch (Graph 28).

Plant macroremains

Cereals were represented by the undemanding oat (*Avena* sp.) and barley (*Hordeum vulgare*) with admixture of rye (*Secale cereale*) and millet (*Panicum miliaceum*). From the other species common flax (*Linum usitatissimum*) was recorded. Weeds are dominated by species associated with nutrient poor acidic soils (*Scleranthus annuus*, *Rumex acetosella*, *Mentha arvensis*, *Viola arvensis*, *Stachys arvensis/annua*, *Galeopsis ladanum*). The only species which today rather occurs with base-rich lowland soils (brown earth, chernozem) is ball mustard (*Neslia paniculata*), accompanying the millet cultures in the past. Cultivated and gathered species do not go beyond the plain and local character of production. The last group is represented by grasses and herbs. Among them are species typical of short grassland, such as blue bugle (*Ajuga reptans*), lady's mantle (*Alchemilla* sp.), wild basil (*Clinopodium vulgare*), wild strawberry (*Fragaria vesca*), cinquefoil (*Potentilla* sp.), self-heal (*Prunella vulgaris*) and bladder campion (*Silene vulgaris*). Typical plants of wet stands are rushes (*Juncus* sp.). Places affected by pasture are indicated by curly dock (*Rumex crispus*). Tall mown grassland is indicated by meadow buttercup (*Ranunculus acris*) or grassleaf starwort (*Stellaria graminea*). Neglected meadows were overgrown with cabbage thistle (*Cirsium* cf. *oleraceum*), marsh violet (*Viola palustris*), wood club-rush (*Scirpus sylvaticus*) and meadowsweet (*Filipendula ulmaria*). Wet meadows then pass into wetland communities with sedges (*Carex* sp. div.), common spike-rush (*Eleocharis palustris* agg.), water mannagrass (*Glyceria fluitans*), gypsywort (*Lycopus europaeus*), lesser spearwort (*Ranunculus flammula*), bittersweet (*Solanum dulcamara*) and simplestem bur-reed (*Sparganium erectum*). On the passage to wet ruderal sites grows water pepper (*Persicaria hydropiper*; Graph 29).

3. Discussion and conclusions

3.1. Environmental methods of floodplain research: advantages, disadvantages and problems

3.1.1. What floodplains can say us and what not

The floodplain research helped to discover a unique archive of historical activities and natural environment. From a methodical point of view it is an analysis supplementing the parallel extensive archaeological research into adjacent areas. In the case of settlement and production areas, the floodplain research is a source of information on the impact of these areas on the surrounding environment. Many data obtained in floodplains, on the other hand, can be interpreted because the most functions of mining areas are known to us from area excavations.

3.1.2. Anthracotomic analyses: results and perspective

The analyses of charcoal showed that the anthracotomic record is present at all localities off-site in a representative condition. On each section always only a single maximum was recorded, mostly in the deep and old part. These maximums were ^{14}C dated, which yielded a consistent sum of dates from the time of changes of the Bohemian-Moravian Highlands in the 12th and 13th centuries. Charcoal from the on-site contexts represents a varied mix and gives us a general information on fuel wood. The species composition may or may not correspond to the composition of surrounding woodland. It also may or may not give evidence of intentional selection of fuel wood. Only the assemblages of charcoal from operational infills of ovens and forges and charcoal included in slags represent a specific source of information about the selection of fuel in varied and multi-phase processes of thermal treatment of ore.

3.1.3. The problem of pollen record in a floodplain

Palynological record in sediments with dominant mineral fraction is incomplete, including gaps at the time of sedimentation of sandy and gravel layers. Another limitation springs from the fact that sections at one and the same site, which were placed only some hundreds of meters from each other, could not be biostratigraphically correlated due to different age of individual records and specific development of vegetation on micro-localities. Despite the above problems, at the

Česká Bělá and Koželužský Stream localities we can observe a similar sequence of environmental changes, which were induced by mining activities. It was verified that at the time of colonisation, the area under review was covered with fir-beech forests with spruce, which may have been bound to inverse or wet valley locations (*Jankovská 1990*, *Rybníčková 1974*).

3.1.4. Plant macroremains in alluvial sediments

Valuable from a botanical point of view is the record from the Koželužský Stream. The sediments included charred diasporas of cereals (rye, oat) and other crop plants (hazel, Persian walnut, common grape vine). Very specific are the direct remnants of forest stands at Cvilínek including woodchips, branches, cones and tree stumps (Fig. 109–110). Analogous situation is known from the locality of Johanneser Kurhaus near Clausthal-Zellerfeld in the Harz Mountains dated to the 10th-13th/14th centuries (*Alper 2003*, 55, Abb. 12, 83–85, Abb. 37–39, 374, Abb. 170). The tree stumps at Cvilínek showed evidence of human impact, which enabled to make a chronological correlation with archaeological contexts. This makes the whole situation more conclusive than the previous evidence of old forest vegetation, which is known from other ponds or alluvial sediments.

3.2. Specific evidence of ^{14}C radiometry, geochemistry and analysis of technoliths in alluvial sediments

3.2.1. Gold placer mining and ore preparation on the Březina Stream near Česká Bělá

On the territory of the Březina Stream in the 13th–14th centuries, ore has been prepared and in the time before the beginning of ore mining also gold has been extracted from a placer. An evidence thereof is given by the analysis of the oldest detected sediments in Section 3, where a split wooden plank was deposited (Fig. 60). In given context, the plank can be considered evidence of a facility for gold extraction or, in extreme case, for ore washing. Metallometric analysis has shown that the sediment contains a high amount of gold. Calibrated AMS radiocarbon dates obtained from a wood sample vary between the years 1016–1155. Evidence of ore washing is also given by sediments at the depth of 170–200 cm in Section 1. Radiocarbon AMS dates from macroremains at the detected base of the section vary within the interval of 1274–1388 after calibration.

3.2.2. Washing facilities and placer mines on the Pstružný Stream near Kejžlice and Perlový Stream near Květinov

Pstružný Stream counts among gold-bearing areas with gold deposits in fluvial sediments. Their origin can be sought in primary deposits at Trucbába and Orlík – Štůlny. The stream bed reinforced with wood can with some caution be interpreted as a medieval device for regulated water inflow. Even though gold was not attested geochemically in sedimentary infills, this site may be part of a placer. In the Perlový Stream near Květinov we can observe enrichment with lead in the area of ovens 1 and 2 and in place of three ovens below the collapsed building. Placer mining is indicated here by a millstone from a gold mill.

3.2.3. Preparation plants and smelteries on the Koželužský Stream in the hinterland of Staré Hory mines near Jihlava

All indications of ore preparation in sections are associated with mining in the Staré Hory dislocation. Because the sampled section lacks any artefacts, it is evident that these facilities were situated some dozens of metres or more from the place under examination. In the vicinity of the sampling spot there most probably was an ore crushing facility with a stamp-mill, and an ore mill where slag was ground and used as admixture with further smelting. Considering the nearby watercourse and the contaminations with metal elements we can also suppose here ore washing facilities. The presence of crushed slag in sediments is an indicator of nearby smelteries. The possibilities of dating the deposits are limited (Tab. 2).

3.2.4. Cvilínek and Staré Hory: an ideal picture of infrastructure of well-developed mining areas

Mining works and settlements near Jihlava overlapped spatially with the so-called Staré Hory dislocation, which is the most extensive ore deposit in the Bohemian-Moravian Highlands (Fig. 72, 73 and 76). At the time of conjuncture, this condition resulted in emergence of a true mining centre. The period of its existence was long in comparison to small plants bound to small ore deposits: its origins reach back to the end of the 1230s and the activities still continued after 1300. The Cvilínek site is the right opposite in this regard. The development of mining works at Cvilínek in the second half of the 1260s, however, was very sophisticated as far as the organisation is concerned. Unanswered remain the questions of population quantity, production tempo, or the question of whether it was an all-year or only a seasonal enterprise.

3.2.5. Still uncertain with metallurgy

Which metallurgical processes took place in the ovens, whose relics we find and whose geochemical trail we follow after about seven hundred years? We know that in the early modern practice, silver sulphides and sulphosalts have been roasted twice, and lead ores at least three times. During the first roasting, ore was freed from sulphur as well as from gaseous and liquid inclusions. The second roasting has released volatile compounds of undesirable admixtures (As, Zn, Sb, Hg). The product of this process was the so-called calcined ore, which was subsequently reduced (*Holub – Malý 2012*). The lowering of losses in reductive smelting was achieved by purity of smelted concentrates. The viscosity of melt during reduction has gradually decreased by addition of ferrous slags or iron ore. The smelting product was silver-rich lead. This sank to the hearth of the oven and from there it flowed through an outlet into a pit in the forehearth where it mingled with weak lead which was maintained here in molten state. This lead from the forehearth was loaded into a cupel furnace for slagging, that is transformation into oxides (*Holub – Malý 2012*).

3.3. Bolder outline of the history of Central Bohemian-Moravian Highlands in the 12th-13th centuries?

3.3.1. Development of cultural landscape prior to AD 1200, and gold placer mining

Forest clearing, slash-and-burn, open landscape

Higher-located regions of the Bohemian-Moravian Highlands in the early historic period may have had the character of the so-called oscillating periphery or prehistoric wilderness (*Pokorný 2011*, 251–253). However, the 13th century woodlands were no longer deep virgin forests. Woodland and brushland communities are stable components in the floodplain of the Pstružný Stream, whereas the indicators of forest-free areas are only sporadic. Plant communities indicate non-agricultural activities leading to development of a small forest-free enclave. Our attention also deserves the Cvilínek site at the height of about 640–650 m ASL. Primary forest would be the most probable plant community which we would suppose here at the beginning of the 13th century. This is, however, not the case. Section 1 included charcoal fragments, which in and of itself indicate human impact. Charcoal was dominated by beech together with fir and spruce. The last component represented woody plants such as lime, ash and maple. They indicate exploitation of slope and scree forests. Among uncharred wood from Section 1, spruce was dominant. Spruce, however, was also identified among charcoal from Žďár nad Sázavou and in sediments of the Pstružný and Koželužský Streams. It is also present at Staré Hory (Fig. 110, Tab. 3, 11–13, Graph 1, 2, 18, 23, 24, 27–28).

Wood pasture

The knowledge obtained at Cvilínek is interesting with regard to the utilisation of woodland in Central Bohemian-Moravian Highlands at the time of culminating medieval colonisation. Among the clear-felled woody species, which had to make place to an ore preparation plant (Tab. 1) after the year 1266, was juniper (*Juniperus communis*) as well. This species can naturally occur with some types of extreme stands with less competitive woody plants. However, being inedible to livestock, it is considered an indicator of drove roads or directly of the so-called wood pasture. This type of pasture was widely used on our territory since prehistoric times already (*Nožička 1957*, 198; *Žemlička 1997*, 166).

Gold placer mining around AD 1200

Gold extraction has changed the natural regime of floodplains. Huge amount of soil and rock was relocated in places of extraction. At the same places a mass of gravel/sand was deposited after washing of the gold-bearing material. The volume of fine fraction washed away down the streams has increased enormously, which in some places resulted in hyper-sedimentation. An indication from the area of placer mines in the Bohemian-Moravian Highlands is brought by the research into the Hory – Předín – Želetava region (Fig. 2). Test trenching in tailings on the upper reaches of the Horský Stream yielded a fir trunk, whose felling is dated dendrochronologically to the year 1209 (*Vokáč et al. 2007*, 33, obr. 3B, 49). In this context can also be assessed the finds from the neighbourhood of Česká Bělá, on the Pstružný and Perlový Streams. Interesting is that the gold placer mining did not decline with the beginning of extraction of silver-bearing polymetallic ores in the area of the Bohemian-Moravian Highlands, which was unique by the extent of confrontation between both these mining branches. They coexisted over the whole 13th century, even though the economic significance of the two metals was different.

3.3.2. Ore mining and its impact on formation and appearance of the high medieval landscape

Towns, villages, mines, preparation plants and smelteries

Founding of settlements and temporary production areas (woodcutters, charcoal and tar burners), mining and metallurgical plants, transformation of forest into pasture and agricultural land, or exploitation of constructional and fuel wood, all this caused changes in the composition of woodland. Ore deposits were immediately linked with mining areas and areas of primary ore preparation, which also may have included settlement functions (Fig. 77, 83 and 93). Smelteries were situated in the neighbourhood. All these units and plants had to be supplied with wood, tar and charcoal. A connection with production of precious metals in the LPZ K-1 period is documented on the Březina and Koželužský Streams.

How miners have deforested the shores of Kamenička

The crucial context was Section 1 in the neighbourhood of a preparation plant and a stump field (Graph 24–26, Tab. 14). These sediments preceded the mining activities. Charcoal from woody plants testifies to a more varied species composition than that offered by charcoal from contexts from the period of existence of preparation plants. Dominant wood species here was beech together with fir and spruce, even though with admixture of photophilous woody plants such as birch, juniper and poplar/willow. The latter are indicators of impact of pasture and exploitation of wood in the secondary forest with openings and clearings becoming overgrown with vegetation. This was the appearance of local woodland at the time preceding the emergence of preparation plants, smelteries and a settlement in the 1260s. Then came a moment when the area was colonised by miners and the forest had to retreat. Clearing of the forest is documented by an informationally valuable segment of the clear-felled medieval forest stand on a smaller area north of the ore washing facility. The species composition of tree stumps in the place where subsequently arose a preparation plant reflects, similar to Section 1, ecological conditions immediately before the beginning of mining settlement. Dominant woody plants among the tree stumps were spruce (71 %), alder (14 %), poplar and willow (9 %). The tree stumps exhibited evident marks of scorching and felling with an axe. A tree stump was dug out so that it was possible to insert wooden constructions associated with ore washing at the site (Fig. 109).

Significant change of the Jihlava Region according to off-site data on the Koželužský Stream

The changes in composition of woody plants in the hinterland of the town and mines in the 13th century can be illustrated on the example of "off-site" data from sections on the Koželužský Stream. In the first period we can observe indicators of metallurgical and mining activity. At that time, the context studied had the character of a reservoir. This period ends at the level of layer 0128 (pollen K1, macroremains KPI, xylotomic horizon 1). The macroremain and pollen records in the next period (K2, KP II and III) indicate eutrophication of the sediment, retreat of fir-beech forests in favour of indicators of agriculture and secondary forests (beginning of xylotomic horizon 2). The reservoir during this period becomes overgrown with aquatic and wetland vegetation. We can also observe an optimum of indicators of human activity at local level, which may be associated with an increase in settlement in the immediate neighbourhood; indicators of metallurgical activity, however, were not detected.

Wood for constructional and technical purposes

The direct evidence of constructional wood clearly shows the preference for fir. In the Staré Hory settlement, which flourished most after the mid-13th century, we find evidence of using fir and spruce for constructional elements in pit houses (Fig. 113). At Cvilínek in the area of the preparation plant, which is dated by dendrochronology after 1266/1267, these conifers are dominant materials with boards, planks and deals (Fig. 115). Interesting is the find of charcoal from lime and yew in archaeobotanical material from Staré Hory in Jihlava (Chapter 2.4.4.). The yew wood with excellent flexibility, hardness and resilience was traditionally used for, for example, bows and crossbows, and it also may have been used for some components of mining machines. Lime softwood is suitable for woodcarving and turning.

3.3.3. Mining and metallurgical areas, and water sources

In accordance with trends in other European regions since the early 13th century, ore processing plants in the Bohemian-Moravian Highlands also were situated at watercourses, which were used for flotation treatment of ore, drive of ore mills and maybe also furnace blasts. They were built in places where the distance between the mining area and the watercourse is minimal (Fig. 72: 3, 4, 7; Fig. 90: 3 and 5). The washing facility at Cvilínek was located within a zone of permanent stagnation of water at the stream. Unsolved remains the question of how the watercourses have been used for propulsion of moving devices. Ore mills may have been driven manually, by animals, or by a water wheel respectively. Similar problem also exists with propulsion of furnace blasts. The use of watercourses has undoubtedly caused not only local pollution but also devastation of streams with toxic sediments (Pb, As).

3.3.4. The question of necessary non-agrarian production and settlement infrastructure in the hinterland of mines, preparation plants and smelteries

Mining went hand in hand with increased requirements for smithery, metallurgy, but also carpentry, coopery and joinery. Besides this, we must also take into account crafts, whose products were inevitable for mines, smelteries and smithies (charcoal, tar). Any spectacular evidence of charcoal production is still missing in the Bohemian-Moravian Highlands. An interesting knowledge was obtained from charcoal at Cvilínek. The spectrum of species in slags differs from charcoal in ovens (Fig. 108). Slags contained only charcoal from beech and birch. Charcoal from ovens, on the other hand, exhibits a balanced ratio of conifers (fir, spruce, fir/spruce) to deciduous woody plants (beech, birch, alder, poplar/willow) with admixture of maple and elm. Many procedures (roasting, heating of ovens) did not demand high calorific value and specific type of fuel (Graph 23).

3.3.5. The question of agrarian areas in the hinterland of mining and metallurgical centres versus normal agrarian production

The quantity and species diversity of macroremains from Cvilínek indicate plain crop growing. Among the plants detected were undemanding species such as oat, common barley and marginally rye or millet. The other crop plants were represented by common flax. In the area of the mining agglomeration near Jihlava, on the other hand, we can find oat, millet, rye and common wheat. The processing of cereals (threshing, cleaning) was carried out here only on a limited scale, as is supposed on the basis of sparse presence of waste from cereal cleaning. Corn was already imported as a cleaned commodity. In the surroundings of Jihlava, which is located about 500 m ASL, the share of demanding wheat among bread cereals (rye + wheat) shows high values (52 %). Such a high percentage cannot be observed with any other town in medieval Bohemia and Czech Silesia. The value rather corresponds to the conditions in Moravia where, for example in Brno, this share is 59 % and in Olomouc even 79 %. From all this we can infer that corn was imported from fertile regions such as, for example, the Třebíč Region (Fig. 8). The assemblages of horseshoes at Cvilínek give evidence of the presence of animals (Fig. 116). Moreover, cereals (oat and barley) were used as fodder for horses and pack animals, which were often used in mining (Graph 29).

3.3.6. When the mines went silent

Mining areas bear witness of the little known non-agrarian layer of the historical landscape of the Bohemian-Moravian Highlands, even though their life was short. After this "rush" has died away, many of these localities were abandoned, but some others underwent various forms of transformation. After the decrease in mining activity in the Koželužský Stream Section 2 (period K2, KP II and III) we can observe a retreat of agricultural activity in favour of meadows and live-stock pasture. Forest communities remained at the same level as in the previous period. During the next period (LPZ K-2), the share of pine increases as a result of human economic activities. The subsequent development (LPZ K-3) in the Late Middle Ages and the Modern Times does not show any significant changes. A dead arm of the stream became filled with fen and alluvial sediments. Deforestation of the catchment area of the stream has influenced the change of water regime of the stream and the amount of material carried away.