

Historical blast furnace in Peklo valley of Ľubietová (Slovakia) and its reconstruction using 3D modelling

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In Slovakia, several ironwork regions were preserved up to these days. Dominant technical structures preserved in these areas are ironworks furnaces of different ages and different shapes. The paper presents the history of an iron blast furnace at the ironworks site in Peklo valley near Ľubietová, one of the Upper Hungary' royal mining towns. The site is being currently studied as a metallurgical location with minimal ironworks relics preserved, considering relics of old metallurgical heaps in particular. Credible history of the site with a focus on the beginning, development and the destruction of the blast furnace technical object was reconstructed based on historical, archival and field research. We pointed out the causes of the end of the blast furnace and mapped the preserved relics of metallurgical production. We have determined the exact position and created a 3D model based on the information about the furnace form from the late 18th century despite the lack of preserved field relics. We have been working with the software AutoCAD 2012 and results were imported into SketchUp Pro Software 2013, from where the model was placed in the GoogleEarth environment.

Keywords: *Ironworks regions, ironworks, blast furnace, historical mining, historical metallurgy, computer reconstruction of historical blast furnace, 3D visualisation, archival research of historical maps, field research of the relief relics*

Introduction

Iron metallurgy has a long and rich tradition reaching to the beginnings of human society in Slovakia. Several ironwork regions were preserved up to these days as specific phenomena of the landscape. Dominant technical structures preserved in these regions are ironworks furnaces of different ages and different shapes, for example, “Františkova” smelter near Podbiel, blast furnace at “Tri vody” site, “Etelka” smelter in Nižná Slaná, smelter in Červeňany near Sirk, blast furnace “Jakubany” near Stará Ľubovňa and others.

Except for many preserved ironwork furnaces of various types, Slovakia is also a territory from which the oldest preserved blast furnace picture comes. This is the case of the picture of “Rožňavská Metercia” dated 1513, which is almost half a century older than pictures from world-famous work of G. Agricola, *De re Metallica* Libri XII., printed in Basle in 1556.

In addition to the preserved blast furnaces in Slovakia, there are also a number of locations without any surface relics preserved where similar furnaces stood in the past. Difficulties with the existence of any credible written or pictorial sources occur often, as in case of the metallurgical site in Peklo valley, formerly known as “Čierne Peklo” (Black Hell) or “Peklo” (Hell), “Schwartyhale”, “Chyrno Peklo”, “Höll“ or “Schwarzer Grund”. The present conventional name for the site - “Trosky” - reflects the presence of old metallurgical heaps in this area (Fig. 1).

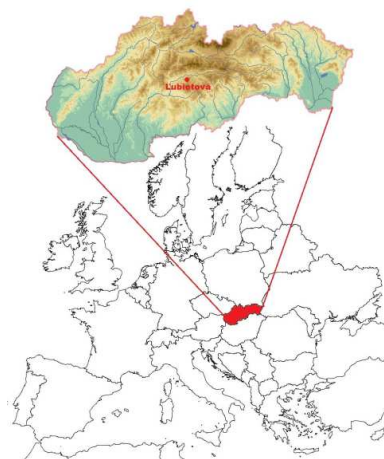


Fig. 1. Location of the studied site.

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The goal of the study and methodology

The goal of the study is to process the relevant text reconstruction of the metallurgical site in the hinterland of an independent royal mining town of Lubietová (Slovakia), based on archival research of written, pictorial and cartographic historical documents. Historical sources are stored in the Central State Archive Mining Banská Štiavnica. The results of the archival research will be supplemented by a detailed on-site field research of the preserved relics (Hronček 2014). The second goal is to create a simple 3D visualisation of the entire site using a schematic map sketch, based upon the critically and properly analysed and processed historical sources. The derived conclusions made it possible to point out that from the 16th until the late 18th century, the functioning blast furnace utilised for processing of iron ore from the nearby mines was the centre of the whole site.

A relevant historical visualisation of the blast furnace, as it most probably looked from the second half of the 18th century until its destruction at the beginning of the 19th century, had been modelled using research results presented in the first part of the study. Similar methodological procedures for 3D visualisation of medieval and modern mining locations were used for the Gelnica area in the Eastern Slovakia (Rybár and Hvizdák, 2010). 3D visualisations of water reservoirs around Banská Štiavnica, which is registered in the UNESCO, were also methodologically interesting (Weis and Kubinský 2014). We had also drawn some inspiration from the methodology used for historical mining adits relief relics modelling (Hronček and Weis 2014, Rybár, Hvizdák, Molokáč and Hvizdáková 2010, Hvizdák and Molokáč 2012).

Visualisation of the blast furnace in the form of a 3D model based upon relevant historical documents was drawn using the AutoCAD 2012 and subsequently imported into SketchUp Pro 2013. It was modified in the software to be accurately localised in the Google Earth environment. Creating 3D visualisations of non-existent historical buildings and their subsequent import into Google Earth “landscape” is not seen very often (Hronček and Liga 2014).

Background, goals and computer reconstruction of blast furnace in Peklo valley

Reconstruction of the landscape in the area of ironworks site was enabled through archival and field research. The whole area was dominated by the metallurgical furnace, accompanied by a variety of objects of its economic hinterland. Construction of the furnace took place in the 16th century, and it had been working intermittently until the beginning of the 19th century (Central State Mining Archive Banská Štiavnica 1951a & National Archives of Hungary Budapest). It was processing excavated iron ore from the mining sites “Kolby” and “Peklo”. The mining site “Peklo” was situated in the direct hinterland of the furnace. Three mining galleries, as well as the shaft “Ján”, were identified during the field research (Hronček 2014). Hereditary mining adit opened out directly at the smelter. Water from the currently destructed gallery, which is emerging even today, was used as the third water energy source. The main sources of water in the area were the creeks Peklo and Brzáčka (Práčová). According to the terrain morphology, the water was brought to the site using headwater channels as well as flumes.

The existence of smelter required a sufficient fuel base. The abundance of fuel was ensured by the surrounding beech forests in which charcoal was produced on seasonal charcoal-burning sites. A dense network of seasonal charcoal-burning sites was created in the upper parts of the valleys of Peklo and Brzáčková creeks. These sites were built only in areas with forest roads, which made it possible to transport the charcoal to the smelter using horse waggons. The existence of a permanent charcoal-burning site at the smelter is documented in written form from the 17th century. Wood transported using flumes from the inaccessible parts of side valleys ends was burned here.

In addition to the equipment related to mining and metallurgy, a water powered saw worked in the Peklo area in the 17th century. Other activities including forest crafts – e.g. shingles production, were documented in the area as well. Carpenters and many other labourers worked in the mining industry here. House of the gamekeeper from Lubietová and his family stood near the site on the ridge of Valachová hill in the 17th century. The existence of three houses of a seasonal smelter and adjacent economic background workers is documented from the first half of the 18th century. An old limestone quarry operated for quality limestone required for the blast furnace was located on the right slope of Brusnianka valley near “Čertova Dolinka” value.

We have compiled a reconstruction sketch of the metallurgical site in the Peklo valley in the early 18th century using the results of the historical research (Fig. 2).

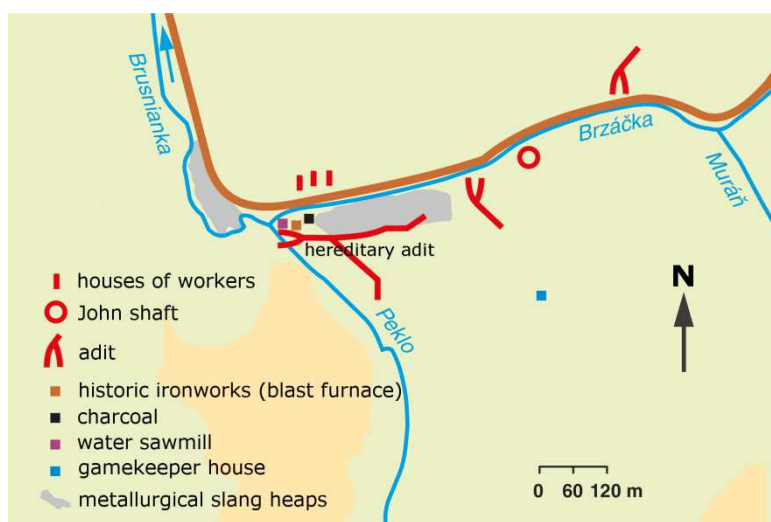


Fig. 2. A schematic illustration of individual objects located within the area of Peklo in the early 18th century.

When the first furnace for iron ore smelting was built in the Peklo valley in the 16th century, it was most likely similar to the technical device described by G. Agricola in his work (Agricola 1556). Similar smelters worked not only in the region of Pohronie (Central Slovakia), with 11 smelters in the mid-16th century but also in the Eastern Slovakia. A unique historical work from 1513, which very credibly depicts one type of blast furnace, comes from the eastern part of Slovakia. It is an altar panel painting, called “Metercia” in Latin writing, located in the Episcopal cathedral in Rožňava. In the background of the main character of St. Ann are realistic mining and ironworks scenes from Rožňava. The left edge of the painting is the most important in relation to our study, showing a working melting furnace. We can reconstruct the original construction of the furnace in Peklo valley according to the “Metercia” painting and the work of G. Agricola. The smelter depicted on the “Metercia” painting has almost an identical position in the terrain as the blast furnace in Peklo valley (Fig. 3). Under the roof, there is a body of the two pit-type furnaces. From the left, an integral part of the device was attached – a water wheel with an upper flow, which powered the devices forcing air into the furnaces. A waste water canal led from the water wheel. The body of the furnace was usually about 2.5 m high. A 25 cm wide and 50 cm high clay-walled opening with a little tap hole was at the bottom of the front part.

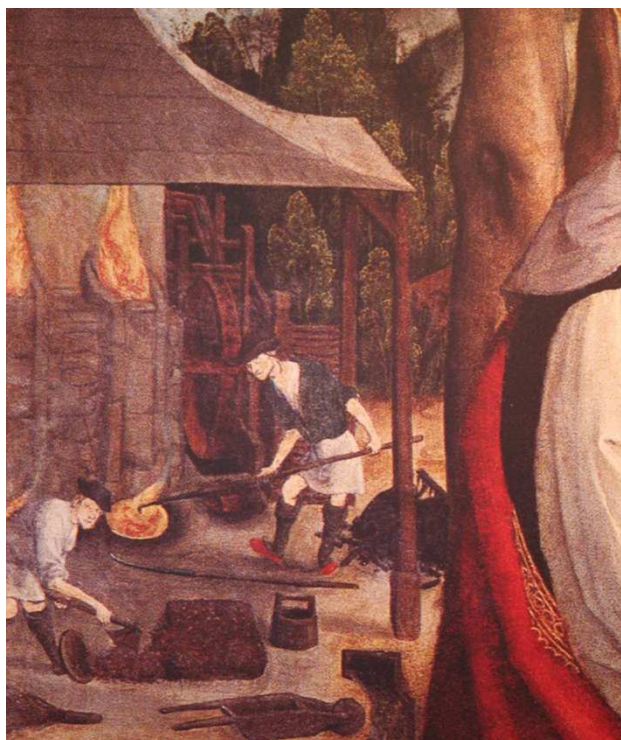


Fig. 3. Picture of the smelter on the altarpiece “Metercia” in the cathedral church in Rožňava from 1513.

There is no doubt that the furnace in Peklo valley was rebuilt, modified and enlarged several times. Furnaces from this geographical area were often enlarged because it was cheaper than a construction of more robust and more modern furnaces. As the blowing devices improved, the volume of the furnace shaft could become larger. This was many times done only by extending the inner cylinder shafts upwards and by thickening of the furnace stone shell. Bigger air supply permitted higher combustion of the charcoal column, and a more robust shell withstands higher temperatures.

Based on the research, we can conclude that century the furnace was already rebuilt in the form of the so-called Slovak iron furnace – “Dúchačka” (Ger. Blauföfen) in the mid-18th century. The furnace was 225 cm high, but could be a meter higher in some cases. The frustum furnace shaft was 74 cm wide at the base. The top was approximately 31 cm wide. The shaft could be filled with approximately 370 kg of iron ore. The furnace was filled with charcoal from the top and heated and the ore mixture had been added later. Melting usually took 4-8 hours depending on the amount and the quality of the iron ore. The result was a mass of melt charcoal pig iron, which was further refined. The weight of a raw - fungal lump of smelted iron was around 80-110 kg (Paulinyi 1966). Pig iron was transported down Peklo creek (Brusnianka) and valleys of the river Hron into the hammer mill in the area of Banská Bystrica for further processing. This situation is shown on the map of the first military mapping in 1783. A German writing meaning “iron smelter” appears on the map in addition to the buildings (Anonymus 2004) (Fig. 4).

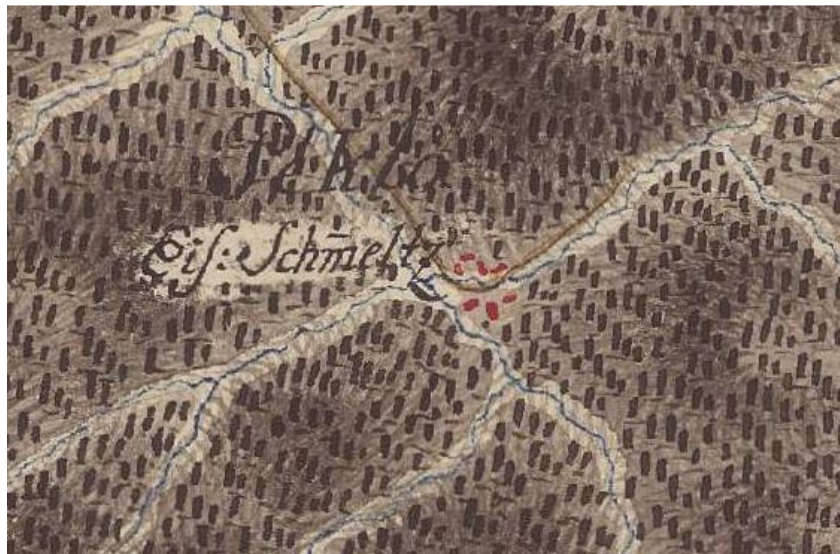


Fig. 4. Location of the smelter - map of the 1st military mapping (1783) (Anonymus, 2004).

The furnace was reconstructed and possibly enlarged in the second half of the 18th century. Its height reached up to 4 m, as it was common for the Slovak furnaces constructed in the Eastern Slovakia. It was used only for a short time after this reconstruction and definitively ceased to exist in the early 19th century (Central State Mining Archive Banská Štiavnica 1951b). Due to the approaching decline, we do not expect it was rebuilt in such a massive form as implemented in the case of the neighbouring Hronec, or Ľubietová, where the square furnace base was about 8 m wide, 6 meters wide at the top and its height reached 8 m. The walls of the furnace were almost 2 m thick. Similar, but slightly larger dimensions were achieved by the first “modern” high blast furnace in the former Hungary, built at Tri Vody (then part of royal mining town Ľubietová) in 1795.

In the second half of the 18th century, production of 100 kg of iron consumed from 390 to 817 kg of charcoal including the refining process. The yield of smelting in the “Slovak” furnace was around 20 %, and it was gradually declining. The production required large quantities of water to drive the water wheel. Maximum 5 person staff worked in two 12 h shifts by smelting, which used to be continuous. The first shift was usually operated by a master with an assistant and the second one by an assistant and apprentices (Vozár 1983). Due to high water consumption per wheel drive and lack of water reservoir (called “tajch”) in the Peklo valley, the smelter could work only during major water levels, especially in the spring and early summer.

We created a historical reconstruction of the blast furnace in the Peklo valley using 3D modelling based upon the historical documents obtained by archival and field research. We captured the state of the furnace at the end of the 18th century, in the final stage of its operation and its largest size (Fig. 5 and 6).

Archival and field research

Two preserved historical maps from the second half of the 18th century are also the proof of many years of iron production in the area under the study. Maps show border disputes among free royal town Lúbeťová and Lúbeťianska castle estate, namely the municipality Brusno. Both, historical map (1773) (Fig.7) and historical map (1775) (Fig.8), display and denominate localities of the study area. Both historical documents - artistically and in content are of very high quality. Name of the place of study blast furnace is in the same and in the Slovak language: „Na Starí hutti“ ("On the Old Smeltery"). Consistently, it is named according to the valley in which the blast furnace was situated: „Dolina do Starej Hutti“ ("Walley towards the Old Smeltery"). Other facts that confirm the old iron metallurgical production are local names of places, were large-scale metallurgical dumps were presented: „Na Starí hutti“, which now is called "Slag", what is the older name of metallurgy scrap.

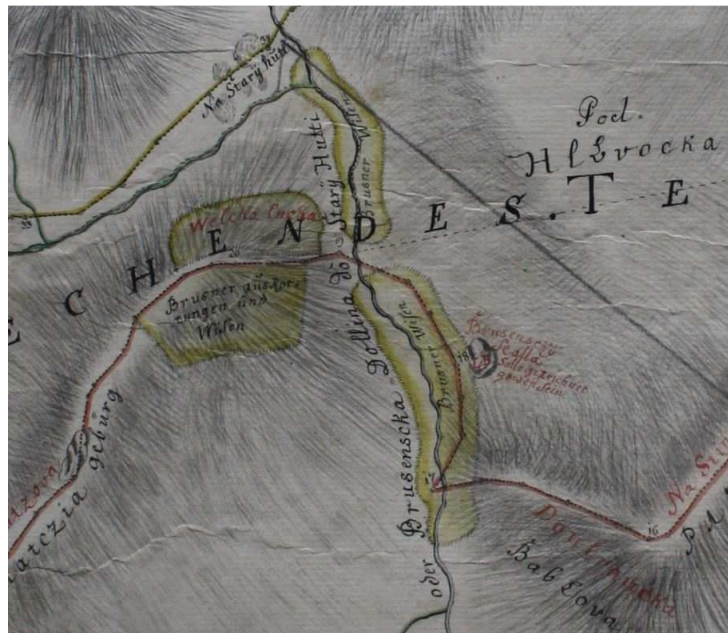


Fig. 7. Historical map with Slovak local names of the studied sites (Historical map 1773).

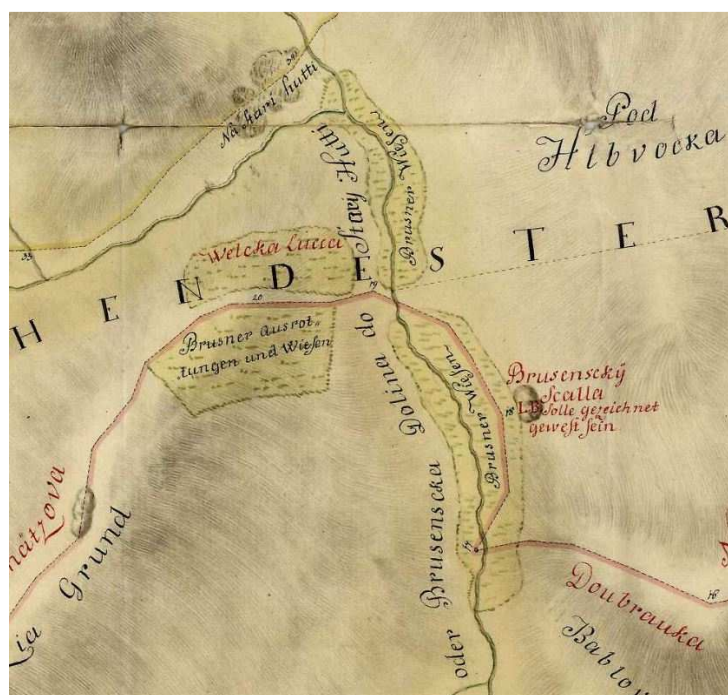


Fig. 8. Historical map with Slovak local names of the studied sites (Historical map 1775).

Based on archival research sources and knowledge of the history of the neighbouring ironwork sites in Ľubietová and Hronec, we can assume the causes of blast furnace destruction and the definitive end of the ironworks at the site. The main reason was the poor quality of iron ore and exhaustion of the surrounding mines. Another reason, which the smelter could never overcome even after the change of ownership, had been the construction of a new high blast furnace in the neighbouring valley near the royal town of Ľubietová in 1692, which started to process iron ore from the valleys of Hutná and Peklo. To fulfil the needs of a new furnace, water was transferred from Peklo creek to Hutná valley via headwater channels, which still appear on the maps of the second military mapping from the mid-19th century (Anonymus 2005). The critical state of the smelter, respectively, its temporary shutdown at the beginning of the second half of the 18th century, is depicted on the map from 1773 stored in the Central State Mining Archive Banská Štiavnica in the main mining-chamber office map fund. A further operation of the smelter was cut off by the unrealized construction of steel mills in the nearby Lučatín in 1788 (State Central Mining Archive Banská Štiavnica). Based on the conducted research, we can conclude that the increased difficulty of production is proved by the fact that no evidence of beater mills and calciners for ore treatment before smelting was found near the smelter, which greatly increased the severity of the process.

Field research of the relief relics can be used to locate the precise position of the blast furnace. Its exact position was 48 ° 45' 21.159" N, 19 ° 24' 22.592" E. Because there are not any direct surface relics of the furnace construction, it is possible to conclude that the limestone from the furnace was used to build houses in the nearby Brusno during the 19th century. Localisation refers to some other relics. We have identified the remains of flumes which led to the furnace to drive the water wheel bags. Since the main flow of Peklo creek was transferred to the neighbouring valley of royal mining town Ľubietová, the actual site was in an acute shortage of water energy. Therefore, all available resources had to be used for energetic purposes. Brzáčka creek, residual water in Peklo creek, but also mine water flowing from the drainage adit. The exact position of the original furnace can be obtained by combining gravitational water supply options of all three sources, terrain characteristics and historical rules of objects arrangement in the surrounding of metallurgical smelting locations.

At the present, the direct evidence of historical ironworks furnace is represented by the relics of slag-heaps, with a typical slag as the waste after iron production. Heaps existed at the site until the mid-20th century, when they were excavated and used for reinforcement of forest roads in Peklo valley (Fig. 9). Their original surface can be reconstructed in the field using relics of their edges and using historical map from 1907, stored in the Central State Mining Archive Banská Štiavnica in the main mining-chamber office map fund. It is a topographic map depicting heaps which cover a total area of 7241 m². On-site terrain mapping confirmed that the slag-heap was divided into two locations - on the left bank of Brzáčka creek it covered an area of about 350 x 50 m. A smaller area of about 80 x 20 m was found on the right side of Brusnianka creek, just below the confluence of Brzáčka and Peklo creeks (Fig.10 and 11).



Fig. 9. reinforcement of forest roads in Peklo valley by material from slag-heaps.



Fig. 10. Slopes of slag-heap on the right side of Brusnianka creek.



Fig. 11. Detail of metallurgical slag preserved on the slopes of the slag-heap.

We have identified a trough depression – a still leaking sink after the hereditary adit – direct evidence of the past mining at the site south-east from the original furnaces. The original adit entrance lied at an altitude of 570 m a. s. l. on the right bank of Peklo creek.

During the first field research trips conducted in the 90s of the 20th century, our local contacts who were currently working as forest workers in Brusnianka valley (Peklo), pointed out that it was possible to find massive rotten wooden bridge construction in the narrow part of the valley even in the early decades of the 20th century. This wooden construction served as the only possible communication road for the export of pig iron produced at the smelter.

Conclusion

In this paper, we have identified until now published knowledge on the occurrence of the blast furnace in the Peklo Valley in the cadastre of royal mining town Lúbietová, based on the results of study archival maps and research in situ. 3D reconstruction visualises the research results and gives both experts and amateurs possibility going a few centuries back in time, to know a high technical level of miners and metallurgists in the Central Slovakia mining region. The blast furnace computer reconstruction can be included among the objects of mining tourism in Slovakia. It is a document of technical maturity of the people of past centuries, proof, that the region

belongs among areas with advanced metallurgy, where mined iron ore was processed. We have shown that the archival and field research can document historical technical equipment, of which there are only slight traces.

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