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Geoarchaeological remote sensing prospection of Miocene limestone quarries in the hinterland of Roman Carnuntum and Vindobona (Vienna Basin, Austria)

Erich DRAGANITS[1]*, Beatrix MOSHAMMER[2], Gabrielle KREMER[3], Michael DONEUS[4]

[1)] Department of Geology, University of Vienna, Althanstrasse 14, 1090 Vienna, Austria; email: Erich.Draganits@univie.ac.at

[2)] Retired from Geological Survey, now GeoSphere Austria, Neulinggasse 38, 1030 Vienna, Austria

[3)] Austrian Archaeological Institute, Austrian Academy of Sciences, Hollandstraße 11–13, 1020 Vienna, Austria; Gabrielle.Kremer@oeaw.ac.at

[4)] Department of Prehistoric and Historical Archaeology, University of Vienna, Franz-Klein-Gasse 1, 1190 Vienna, Austria; Michael.Doneus@univie.ac.at

[*)] Corresponding author, Erich Draganits

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Abstract

We have documented quarries in Miocene limestone in the Vienna Basin (Austria), Hundsheim Mountains, Leitha Mountains and Rust Hills in high-resolution airborne laser scanning data and orthophotos aiming for a diachronic quarry inventory since the Roman period. The study region was divided into 6 quarry regions and the quarries of the whole study area as well as each separate region were analyzed concerning different rock types, mean, minimum and maximum quarry area and development in the different maps. Age information have been sought from historical maps, historical photography and paintings as well as quarry face graffiti. In total, 658 quarries, possible quarries and shallow quarries have been outlined in the detailed digital terrain models, which were compared with 453 quarries indicated in four generations of historical maps between the years 1754 to 1872. The numbers of quarries are generally low in the Walter map (1754–1756), the First Military Survey (1773–1785) and Second Military Survey (1809–1846) but increase tremendously in the maps of the Third Military Survey (1872–1873).

Most old quarries were quarried also in subsequent periods, commonly destroying virtually all pre-existing traces. According to our results two types of quarries represent highly interesting targets for more detailed studies in the search for Roman quarries: (i) areas in historical maps with suspicious uneven terrain, which have never been outlined as quarries and areas that have been mapped as "old quarries" – especially in the Third Military Survey; examples represent areas northwest and west of Pfaffenberg in Bad Deutsch-Altenburg (Lower Austria), "*Gruibert*" in Winden am See (Burgenland) and "*Hoher Berg*" in Stotzing (Burgenland); (ii) Shallow quarries, which neither appear in historical maps nor in the mining archive of the Geological Survey of Austria like the one from the saddle between Pfaffenberg and Hundsheimer Berg.

1. Introduction

All kinds of building and construction materials are very common and important commodities for human society. Due to the high preservation potential of stone material, stone monuments (architecture and sculpture) are especially abundant in the architectural and archaeological record (Pereira et al., 2015). The petrographic investigation of building stones is fundamental to analyze their lithological classification, geotechnical properties, status of weathering, aesthetical esteem, reuse of ancient stones (e.g. Antonelli et al., 2016), reconstruction of former economic history, availability, networks and logistics (Draganits et al., 2008; Κοκκορού-Αλευρά and Πουπάκη, 2010; Russell, 2013a; 2013b; Djurić, 2019). The knowledge about their possible provenance is also absolutely needed for the location of possible replacement material in building restauration (Kieslinger, 1949; Kieslinger, 1972; Rohatsch, 1991; McMillan et al., 1999; Favaretto et al., 2000; Hudson and Cosgrove, 2019). Some building stones have become so important concerning their archaeological, historical and architectonical significance that some

of them are scientifically designated as Global Heritage Stone Resource (GHSR) by the Heritage Stone Subcommission (HSS) of the International Union of Geological Sciences (IUGS) (Kaur et al., 2021).

There is likewise growing interest in using knowledge about building stone lithologies for geo-tourism (e.g. McMillan et al., 1999; Masriera et al., 2005; Dowling and Newsome, 2018; Lezzerini et al., 2019) and/or geoeducation (e.g. Seemann and Summesberger, 1999; Summesberger and Seemann, 2008). Additionally, geoarchaeological investigation of building stones and their provenance provides important results and interpretations of archaeological contexts and infrastructure (e.g. Papageorgakis and Mposkos, 1988; Draganits, 2009; Kerschner and Prochaska, 2011). Finally, stone quarries themselves have come into the focus of research for their values of archaeological/historical monuments on their own right (e.g. Schaaff, 2016; Pearson et al., 2019; Karl, 2021), recognizing their significance as "quarryscapes" (Abu-Jaber et al., 2009) and geoheritage sites (e.g. Pereira et al., 2015; Bonomo et al., 2019). However, studies dedicated mainly to the location and inventory of stone quarries like the Eurolithos research project on European ornamental stone resources (https://www.eurolithos.org) are very rare.

The present study is part of the Austrian Science Fund project P 26368 "Stone monuments and Stone Quarrying in the Carnuntum – Vindobona Area" (CarVin), dedicated to the documentation, interdisciplinary analysis and study of Roman stone monuments and their provenance (e.g. Rohatsch et al., 2016; Kremer et al., 2018; Rohatsch et al., 2018; Kremer et al., 2021).

Generally, stone quarries and even abandoned stone quarries are comparably larger and – because they were cut into solid rock – better preserved and visible, especially in airborne laser scanning (ALS) derived terrain models than many other archaeological features (e.g. Opitz and Cowley, 2013). Additionally, different rock types may show enormous differences concerning their composition, hardness, weathering resistance, natural splitting properties, natural fractures, bedding etc., which not only define their possible use but also maximum block sizes and quarrying techniques. For example, the outline of quarries and quarrying traces are generally different in granite, gneiss, limestone or porous sandstone (e.g. Waelkens et al., 1990; Eppensteiner, 1999; Abu-Jaber et al., 2009).

The main aims of our research are (i) the diachronic and multi-method geoarchaeological remote sensing prospection of stone quarries in Neogene calcareous sandstones, calcarenites/-rudites and limestones in the vicinity of the Roman cities of Carnuntum and Vindobona, (ii) the localization of potential source sites of Roman stone monuments (architecture and sculpture) and (iii) methodological improvement of geoarchaeological prospection of quarries in Central European landscapes, land use and vegetation conditions. Ground truthing of detected quarries, lithological classification, lithological comparison of quarry samples with archaeological stone objects as well as provenance consideration are carried out by another group of the CarVin Project (e.g. Rohatsch et al., 2016; 2018; Moshammer et al., 2018).

2. Study area

This project aims at the quarrying and processing of Neogene (mainly Middle Miocene), relatively porous, calcareous sandstone *sensu lato* from the southern Vienna Basin, Leitha Mountains and Hundsheim Mountains with focus on the Roman period. It concerns study area of ca. 60 km by 60 km in north-south and east-west extension which has been reduced to 950 km^2 by geological preselection (Figs. 1, 2) [Figure numbers of figures in online Supplement A start with the letter "A"]. Based on the evidence of stone cist graves from the Leitha Mountains and Lake Neusiedl area (e.g. Willvonseder, 1938; Berg, 1954; Kaus, 1991), stone quarrying in this area dates back at least to the early Late Bronze Age. An extraordinarily high number of stone monuments from the Roman period (architecture, sculpture, various utensils) have been found in this area (e.g. Kremer, 2012; <lupa.at>). The material used for marble monuments in Carnuntum has already partly been investigated in another study (Kremer et al., 2009; Unterwurzacher et al., 2010; Unterwurzacher and Uhlir, 2012). Consequently, our focus in this project are the building and sculptural stone quarries in the Hinterland of Carnuntum and Vindobona, two important Roman centers at the northern border of the Roman Empire. From the beginning, geological information was integrated into the interpretation of the remote sensing data. Mining sites for different types of rocks, e.g. marble (Unterwurzacher et al., 2010), the radiolarite mining sites in Vienna (Trnka, 2011; Schmitsberger et al., 2019) or potentially interesting small granite quarries in the Hundsheim Mountains have been left aside.

The southern Vienna Basin and surrounding has been selected as key study area because (i) this region shows quarrying activity at least since the Roman presence from the Augustan period onwards, (ii) the study area is the Hinterland of the important Roman legionary fortresses and civil settlements of Carnuntum and Vindobona with a documented high usage of local stone material (Kronberger et al., 2010, Gadermayr et al., 2014; Kremer et al., 2018; Rohatsch et al., 2018), (iii) the area contains various landscapes ranging from flat to hilly and mountainous, covered by different vegetation types from grassland to forests – thus allowing for testing different visualizations and prospection methods (e.g. Doneus and Briese, 2010), (iv) existence of geological maps at 1:50000 scale for the whole area, (v) availability of high-resolution airborne laser scanning data and several generations of aerial photography, (vi) pre-existing studies on building stone lithologies and provenance regions (e.g. Karrer, 1886; Karrer, 1900; Kieslinger, 1949; Kieslinger, 1972; Rohatsch, 1991; Rohatsch, 2005; Pivko, 2012; Gadermayr et al., 2014; Pivko et al., 2017) as well as on the location of quarries (Heinrich et al., 2010; Kronberger et al., 2010;

Figure 1: Overview of the study area with the most important place names (UTM33, WGS86); exactly the same extent as Figures 2 and 5. Satellite imagery, World View, ESRI.

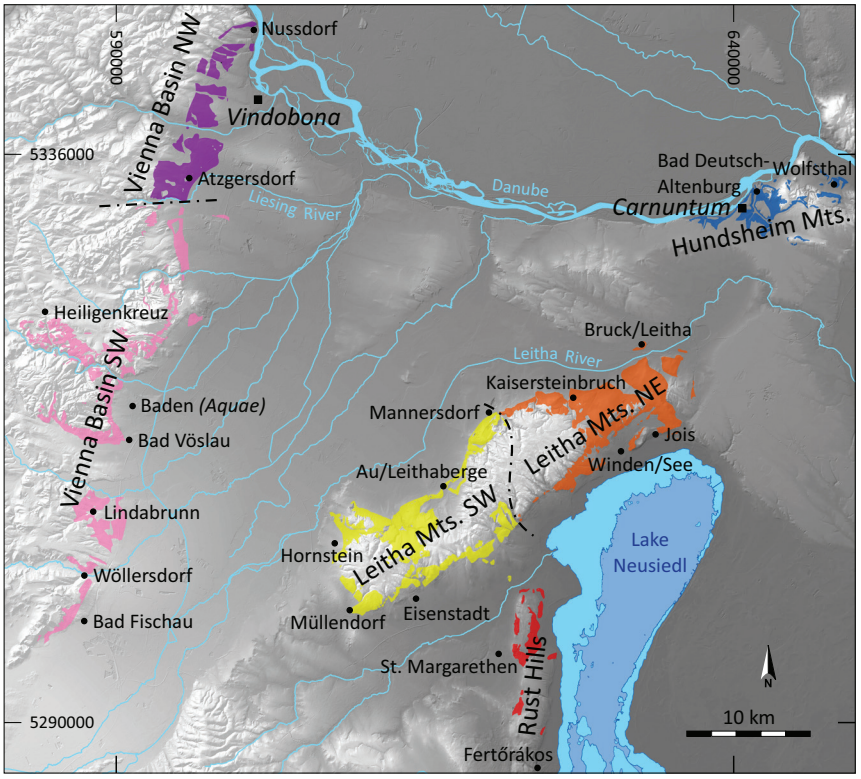


Figure 2: Overview of the study area with the different quarry areas indicated by different colors. 10x10 m DTM in grey shades, 40 % brightness standard deviation stretch, 70 % transparent hillshade azimuth 315° and 45° illumination angle, standard deviation stretch; all statistics calculated from current display extent. Areas in Hungary and Slovakia are visualized with 30x30 m Shuttle Radar Topography Mission (SRTM) data. River network is based on the data of BMLFUW (2014a, 2014b) and shows rivers with > 100 km^2 catchment areas. The Danube course in Vienna is reconstructed from maps for 1529 by Hohensinner et al. (2013).

http://hq.chc.sbg.ac.at). The enormous demand of more such studies is exemplified in the map of major quarries in the western part of the Hungarian Basin by Durić (2019), which is empty in the area between the Roman centers of *Scarabantia* (Sopron), *Sala* (Zalalövő) and *Flavia Solva*.

3. Geological setting

The study area in eastern Austria is located at the geodynamical complex boundary between Eastern Alps, Western Carpathians and Pannonian Basin. This area was and is strongly affected and shaped by the still ongoing collision between Europe, Africa and small micro-continents in between, resulting in crustal thickening (Cavazza et al., 2004; Schuster et al., 2019), modified by late Paleogene and Neogene lateral extrusion (Ratschbacher et al., 1991a; 1991b; Schuster et al., 2019) and extensional deformation connected to the late Paleogene and Neogene formation of the Pannonian Basin (Horváth et al., 2006).

The stone monuments (architecture and sculpture) targeted in the study comprise biogene calcareous to siliciclastic sandstone (in a broad sense) deposited during the Middle to early Late Miocene (Langhian, Serravallian and early Tortonian, i.e. the Badenian, Sarmatian and early Pannonian of the Central Paratethys; broadly between 16 to 10 million years ago) (Piller et al., 2007). Lithostratigraphically, these include, at least partly, the Leitha Formation, Holic Formation, Skalica Formation as well as sandstone of the lower Pannonian (Piller et al., 2004; Harzhauser et al., 2020 and references therein). The Langhian, Serravallian sediments were deposited in a marine environment (Piller and Harzhauser, 2005; Wiedl et al., 2012; 2013; 2014), except the early Tortonian deposits, which were sedimented in a lacustrine environment (e.g. Harzhauser et al., 2003). Hohenegger et al. (2014) divided the Badenian sediments into Early Badenian (16.30–15.03 Ma), Mid Badenian (15.03–13.82 Ma) and Late Badenian (13.82–12.83 Ma).

Leithakalk or Leythakalk was already mentioned by Keferstein (1828) and Partsch (1831), but both included Badenian as well as Sarmatian limestones into this term. These sedimentary rocks represent the coastal rhodalgal foramol and siliciclastic facies deposits of these periods, with fine-grained equivalents in the distal areas (e.g. Siedl et al., 2020). The sediments were deposited onto a tectonically strongly structured surface and were partly deformed during sedimentation and after. Especially, the study area is strongly affected by a combination of sea-level variations (Siedl et al., 2020) with strike-slip deformation related to the lateral extrusion (Ratschbacher et al., 1991a; 1991b), the extension of the Pannonian Basin, resulting in the formation of the pull-apart type Vienna Basin (Royden, 1985; Decker et al., 2005) and deformation structures east of the Leitha Mountains (Zámolyi et al., 2017; Loisl et al., 2018). This background knowledge about the geodynamical situation and sea-level change is needed to understand the patchy occurrence, preservation at different altitudes and the local facies variations of the investigated limestones and sandstones used for the building and decorative stones (Schönlaub, 2000; Wessely, 2006; 2007; Wiedl et al., 2012; 2014; Harzhauser et al., 2014; Berka, 2015; Pivko et al., 2017).

4. Archaeological context

The timing of the first Roman military presence in the Danube area of the Vienna Basin is still in discussion. A plausible date is the year 6 Common Era (CE) related to war preparations by Tiberius against Marbod, mentioned in written sources (Velleius Paterculus II 109.5). However, the oldest datable traces of a permanent Roman legionary fortress (*castrum legionarium*) at Carnuntum, at the eastern boundary of the Vienna Basin, date around 35 – 40 CE (Genser, 2006) or 40/50 CE (Gugl, 2006). The earliest structures were built in earth and timber, and it was only at a later stage that they were rebuilt in stone. The central buildings within the fortress, such as the *principia* or the *praetorium*, were probably already built in stone during the Flavian period, from around 70 CE (Gugl, 2006; Gugl and Kastler, 2007). The gradual change from the earth and timber technique to stone construction has also been observed in the civilian city (e.g. Jobst et al., 1988; Humer et al., 2005; Maschek, 2008; Humer, 2014) and applies to the *canabae legionis* as well (e.g. Gugl, 2015). A recently found building inscription suggests the at least partial rebuilding of the military amphitheater in stone in early Flavian times (Beutler, 2013). On the basis of the oldest funerary stelae from Carnuntum, however, it can be demonstrated that the first local and regional quarries must have been developed long before the first extensive military stone building activities in Carnuntum (Mosser, 2003; Weber-Hiden, 2017; Kremer et al., 2021).

In the last decade of the 1st century CE, related to the *bellum Suebicum* of Domitian, a further military base was built at the western boundary of the Vienna Basin, south of the Danube, some 42 km upstream of Carnuntum, at the location of the center of modern Vienna (Kronberger and Mosser, 2015). The construction of the 22 hectare large legionary fortress of Vindobona initiated necessary infrastructure including roads, quarries and clay pits for bricks. From the beginning in 98 CE, the fortification wall as well as the most important buildings inside the fortress were built in stone (Mosser et al., 2010; Kronberger and Mosser, 2015). In the *canabae legionis* and in the civilian town, it is likely that the early building phases in timber construction were partly replaced by masonry structures during the 2nd century CE (Kronberger, 2005; Müller et al., 2011). The settlement areas of Vindobona reached their maximum extent in the reign of Septimus Severus and were gradually abandoned from the 2nd third of the 3rd century CE onwards (Kronberger, 2005; Kronberger and Mosser, 2015). Minor building actions during the first third of the 5th century CE were of short duration and the legionary fortress was abandoned shortly after (Mosser et al., 2010; Kronberger and Mosser, 2015). It is also true

for Vindobona that the earliest funerary stelae testify the development of local and regional quarries already some time before the permanent stationing of the legionary garrison.

Both centers, Carnuntum and Vindobona depended on supply from the surrounding. The reconstruction of possible transportation routes and least-cost path are promising, but one must be aware that present-day topography, roads and transportation may be very different to those in the past. For example, Willvonseder (1938, p. 110) refers to Alphons Barb about the discovery of an Urn Field period grave in Illmitz in 1932, that according to one workman at that time stone was commonly brought from St. Margarethen (Fig. 1) across the frozen Lake Neusiedl on carriages, which hardly would be possible at present climate conditions.

5. Data and methods

Quarries and abandoned quarries are commonly larger and better visible than most other archaeological features usually documented by archaeological prospection (e.g. Opitz and Cowley, 2013). Consequently, the applied prospection methods have been optimized for their detection, but also concerning the availability of data and the more than 950 km^2 geologically defined significant study area. All available data sets have been integrated, analyzed and interpreted in a geographical information system (GIS) using ArcGis 10.6.1 by ESRI and WGS 84 and UTM 33N as coordinate system (Figs. 3, 4). Based on regional distribution and geological properties of the investigated Miocene sediments, six different quarry regions have been differentiated within the study area (Insulander et al., 2018; Kremer et al., 2021) (Fig. 2): (1) *Leitha Mountains Northeast* (LM-NE): Upper Badenian Leithakalk, Lower Sarmatian and Lower Pannonian reworked Corallinaceae and detrital limestones; (2) *Leitha Mountains Southwest* (LM-SW): Middle Badenian Leithakalk, Lower Sarmatian fine grained bioclastic limestones; (3) *Rust Hills* (RH): Middle and Upper Badenian Leithakalk; (4) *Hundsheim Mountains* (HM): Upper Badenian lithoclastic Leithakalk, Upper Sarmatian coquinas

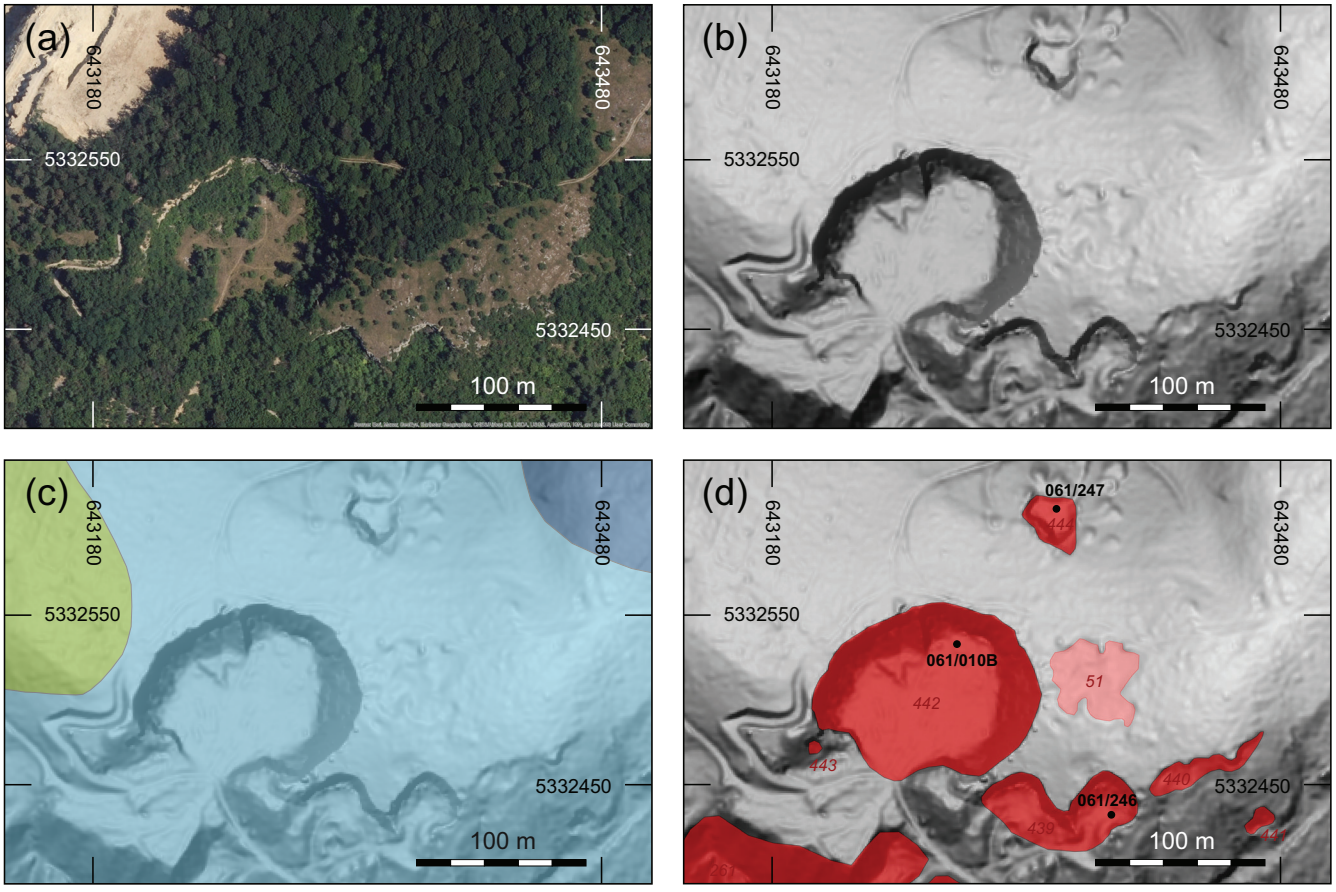


Figure 3: Example of quarry and shallow quarry representations in the ALS data, Quarry Region HM, saddle between Pfaffenberg and Hundsheimer Berg, **(a):** Satellite image, World Imagery, ESRI. The modern quarry in the northwestern corner of the image is younger than the ALS data (2006 – 2010), **(b):** Visualization of 1x1 m ALS data as combination of (i) DTM in gray shades, percent clip stretch, (ii) 50 % transparent hillshade, azimuth 315° and 45° illumination angle, minimum-maximum stretch and (iii) 50 % transparent slope map with inverted standard deviation stretch, **(c):** Visualization of 1x1 m ALS data with geological information from Fuchs et al. (1985), blue: Middle Triassic calcitic/dolomitic marble; light blue: Badenian Leithakalk; green: Sarmatian sediments, **(d):** Interpretation of the ALS visualization; red: quarry (ALS data), very light red: shallow quarry (ALS data). Numbers in italics are abbreviated ID_1 numbers of the shape files attribute tables in the respective colors and bold numbers are points of the mining archive of the Geological Survey of Austria.

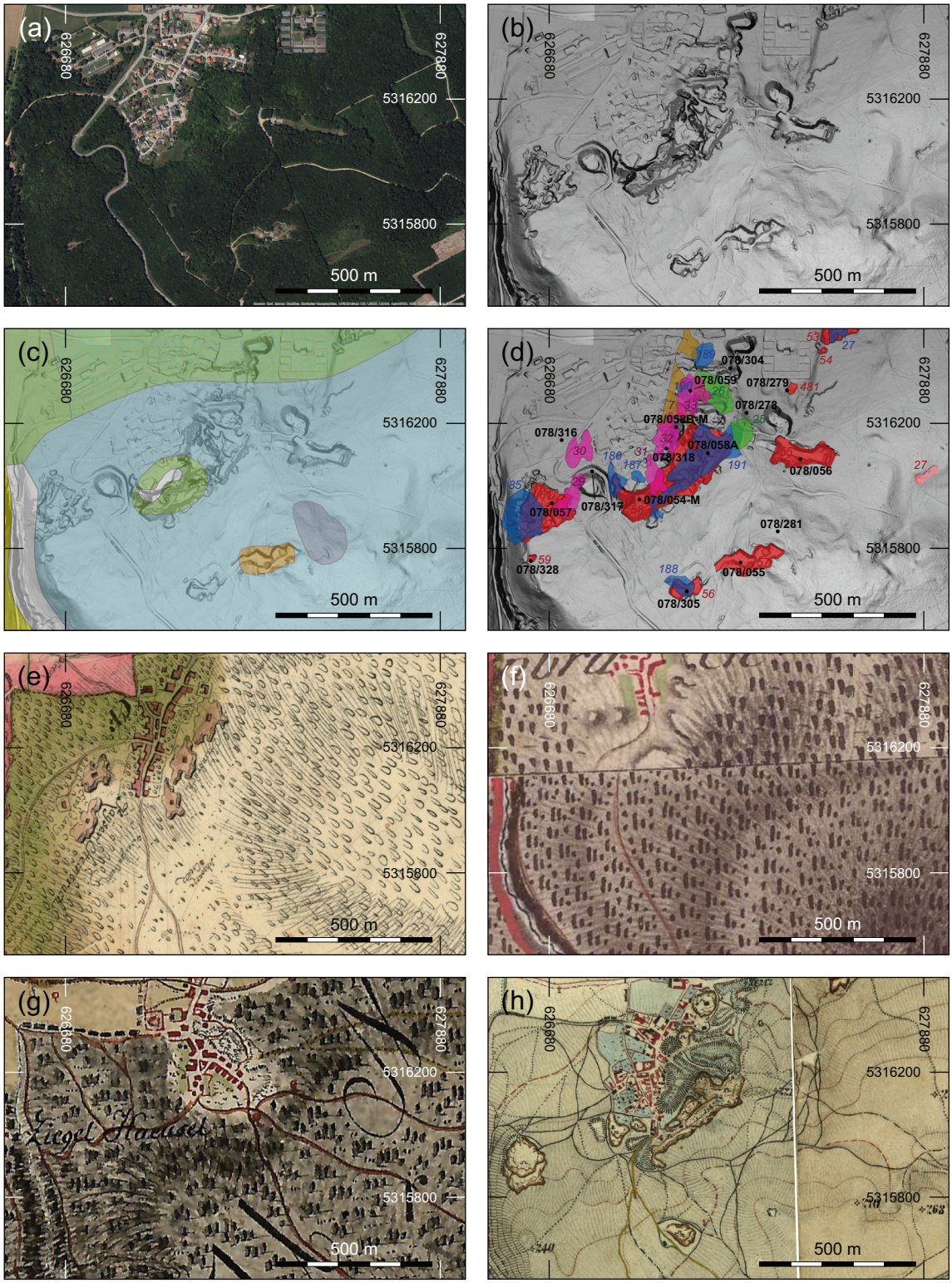


Figure 4: Example of the historically very important quarry scape at Kaisersteinbruch in the Quarry Region LM-NE, **(a):** Satellite image, World Imagery, ESRI. Most quarries are hidden in forests, **(b):** Visualization of 1x1 m ALS data as combination of (i) DTM in gray shades, standard deviation stretch, (ii) 50 % transparent hillshade, azimuth 315° and 45° illumination angle, standard deviation stretch and (iii) 50 % transparent slope map with inverted standard deviation stretch, **(c)** Visualization of 1x1 m ALS data with geological information from Hermann et al. (1993), blue: Middle Triassic dolomitic marble; light blue: Badenian Leithakalk; green: Sarmatian sediments in general; green with blue dots: Sarmatian sandstone; light brown: Pannonian sediments; yellow: Pleistocene loess; white: Quaternary sediments, **(d):** Interpretation of the ALS visualization and historical maps: pink: quarries (Walter map); brown: quarries (First Military Survey); green: quarries (Second Military Survey); blue: quarries (Third Military Survey); red: quarries (ALS data); light red: shallow quarry (ALS data). Numbers in italics are abbreviated ID_1 numbers of the shape files attribute tables in the respective colors and bold numbers are points of the mining archive of the Geological Survey of Austria, **(e):** The Walter Map (1754–1756) shows 5 active quarries in this area, **(f):** The First Military Survey (1784) is less detailed compared with the Walter Map and does not show clear indications of active quarries. Also note the map sheet boundary effects, **(g):** The quarries in the Second Military Survey (1845–1846) are not outlined very clear, but many maps of this survey are drawn with not much detail, **(h):** Maps of the Third Military Survey (1872–1873), especially those at 1:12 500 scale are very detailed.

and oolites; (5) *Vienna Basin Northwest* (VB-NW; north of Liesing River, Neogene sediments deposited mainly on top of the Flysch tectonic unit): Middle Badenian Leithakalk, Lower Sarmatian calcareous quartz sandstones, Upper Sarmatian "Atzgersdorf Sandstone" and (6) *Vienna Basin Southwest* (VB-SW; south of Liesing River, Neogene sediments deposited on top of the Northern Calcareous Alps): basal conglomerates/breccias and Middle Badenian Leithakalk, Upper Sarmatian "Atzgersdorf Sandstone".

5.1 Geological data and quarry data bases

Geological maps at scales at 10000, 25000 and 50000 have been scanned and georeferenced in ArcGis 10.6.1. or were accessed from the web map service (WMS) of the Geological Survey of Austria (GBA) at https://gisgba.geologie.ac.at/arcgis/services/image/AT_GBA_GK50/ImageServer/WMSServer?request=GetCapabilities& for scale of 1:50000 and at https://gisgba.geologie.ac.at/arcgis/services/image/AT_GBA_GK100_200/ImageServer/WMSServer? for geological maps at scales of 1:100000 and 1:200000. Geological map information was supplemented by existing geological literature about the Neogene sediments (e.g. Toula, 1906; Wessely, 1961; Sohs, 1963; Schmid, 1968; Schönlaub, 2000; Plöchinger and Karanitsch, 2002; Harzhauser and Piller, 2004; Piller et al., 2004; Rohatsch, 2005; Wessely, 2006; Häusler, 2010; Wiedl et al., 2012; 2014; Häusler, 2019 and references cited therein), which also contain information about quarries. The geological data were crucial for the preselection of areas with relatively porous, calcareous sandstone *sensu lato*, deposited during the Middle to early Late Miocene (Langhian, Serravallian and early Tortonian, i.e. the Badenian, Sarmatian and early Pannonian). Areas comprising metamorphic rocks and middle Pannonian to Quaternary unconsolidated clastic sediments were excluded from detailed prospection. Interpretation of remote sensing data was cross-checked with literature about quarries in the research area (e.g. Čžjžek, 1852; Roth, 1883; Schmid, 1894; Hanisch and Schmid, 1901; Schafarzik, 1909; Schmölzer, 1933; Rohatsch, 2017). The historic quarries data base at the University of Salzburg (http://hq.chc.sbg.ac.at) provides information of several quarries and the location of stone use. The extensive and detailed GIS point data base of building stone quarries of the mining archive (e.g. Malecki and Heinrich, 1999), provided by our project partner Geological Survey of Austria (containing map sheet number, municipality, coordinates, lithology and activity status) proofed extremely helpful in separating newly discovered from already known quarries. Quarries documented in the ALS data were associated with data points of the mining archive, if they were closer than 100 m.

5.2 Airborne laser scanning (ALS), aerial photography and Google Earth

Airborne laser scanning (ALS) digital terrain models (DTM) at 1x1 m resolution and < 10 cm vertical accuracy have been used in the whole > 950 km^2 study area. ALS data from Lower Austria were acquired in 2006 – 2010 and kindly provided by the Amt der Niederösterreichischen Landesregierung, Abteilung Hydrologie und Geoinformation. ALS data from Burgenland were acquired by Energie Burgenland AG, 3D Laser Scanning in April 2010 and kindly provided by the Amt der Burgenländischen Landesregierung, Servicestelle Geodaten. 10x10 m DTM data of the Austrian Inspire initiative (https://www.data.gv.at/katalog/dataset/d88a1246-9684-480b-a480-ff63286b35b7) have been used for overview figures (Figs. 2, 5, A1–A7).

DTMs were imported into ArcGis as GeoTIFF files and various visualizations were calculated. For an overview and best practice of DTM visualizations and their combinations used in archaeological prospection see Grammer et al. (2017), Kokalj and Hesse (2017) and Kokalj and Somrak (2019). In our study, combinations of elevation with hillshade and elevation with slope were the preferred visualizations during prospection. In some areas with low relief combinations of elevation with slope and local relief model as well as elevation with openness visualizations (Doneus, 2013) allowed for further details. Along with the DTM data and visualizations aerial ortho-photos were used, which had a resolution of 0.2 m and were acquired between 2010 to 2013 for Burgenland and Lower Austria. Where useful, prospection was complemented with Google Earth in 2D and 3D as well as historic imagery. Probable and possible quarries were mapped by their outline, allowing for additional information and quantification compared with solely point information of previous existing databases.

5.3 Hydrological data

Hydrological data used for the figures were derived from digital data provided by BMLFUW (2014a; 2014b), which were calculated based on DTM data with 25 m resolution; figures show rivers with > 100 km^2 catchment areas.

5.4 Historical maps

In the study area, historical maps at scales potentially useful for our subject date back to about the 16th century CE (Dörflinger et al., 1977). However, it took about 200 years for the oldest map showing quarries, which is from Walter (1754–1756), surveyed at a scale of 1:14000 and final drawing at 1:28000 (Ulbrich, 1952), which is also the first map with comparable useful accuracy and detail. This map is not only very important because it is to the best of our knowledge the oldest showing quarries, but it additionally noted some names of the quarry owners at that time. Unfortunately, the Walter maps cov-

er just the Hundsheim Mountains, the Leitha Mountains and the northern part of the Rust Hills without the area around Fertőrákos. Principally, we have used available and accessible maps from many different sources, which include the Map Department of the Austrian National Library (https://www.onb.ac.at/bibliothek/sammlungen/karten), the Esterhazy Archive in Burg Forchtenstein (https://esterhazy.at/burg-forchtenstein/die-burg-forchtenstein/das-archiv-der-burg), the State Archives of Burgenland (https://www.burgenland.at/themen/wissenschaft/landesarchiv) and Lower Austria (http://www.noe.gv.at/noe/Landesarchiv/findbuch.html).

The backbones of our quarry prospection concerning historical maps are the three military surveys of the Austrian-Hungarian Monarchy, which cover the entire empire of this time. In the First Military Survey, maps at a scale of 1:28 800 were produced; Lower Austria was surveyed in 1773–1781, Hungary in 1782–1785 (northern Burgenland in 1784, except sheet IV/2 Breitenbrunn, which was mapped in 1785). The maps of the Second Military Survey were also drawn at a scale of 1:28 800; Lower Austria was surveyed in 1809–1818, Hungary in 1819–1869 (parts of northern Burgenland in 1845–1846). The Third Military Survey mapped the empire at the scale of 1:25000 (in our study area in 1872–1873, except sheet Mattersburg, which was done in 1880). In the surrounding of Vienna 47 map sheets were produced even at 1:12 500. These detailed maps were surveyed in 1872–1873 and cover the whole study area at the western side of the Vienna Basin, to the north of the Piesting Valley and the Leitha Mountains north of the village Hornstein.

The maps for the First and Second Military Survey are kept in the Austrian State Archives (https://www.state-archives.gv.at), the Third Military Survey is housed in the Federal Office of Metrology and Surveying (http://www.bev.gv.at). Access to maps is extremely facilitated by Arcanum Adatbázis Kiadó in Budapest https://www.arcanum.hu/en/about), which scanned thousands of historical maps, published many of them on DVDs and provides online access via the websites MAPIRE (https://mapire.eu/en) and HUNGARICANA (https://hungaricana.hu/en). Depending on the rectification methods, the maps of the First Military Survey may have errors up to 500 to 2000 m (Timár et al., 2010). Using improved georeferencing methods, errors can be reduced to 100 – 200 m (Molnár et al., 2014). The maps of the Second Military Survey and especially the Third Military Survey can be georeferenced with much smaller errors (Timár et al., 2006). Most of the maps used in this study originate from the scans of Arcanum Adatbázis Kiadó. They were originally scanned at 600 dots per inch (dpi) as lossless tagged image file format (tiff). Unfortunately, maps are made available only at lower resolution and a compressed format (Timár and Biszak, 2010).

All available historical maps, including the large-scale maps by Brequin de Demenge (1755), Streffleur (ca. 1840), Burgerstein (1882) and Groller (1900), have been evaluated for information concerning quarries. However, only the quarries outlined in the Walter Map, First Military Survey, Second Military Survey and Third Military Survey have been used for comparison with the ALS prospection, because they are the only ones, which cover the whole project area. Additionally, the Walter Map was used, which covers the Hundsheim Mountains, Leitha Mountains and Rust Hills. Concerning the Walter Map, an "-" field entry means that this area is outside of the map and "no" means that no quarry is indicated in the map. The evaluation of quarries in the Walter Map and the military surveys is summarized in Tables 1–5 and Tables B1–B4. Quarries in historical maps were not connected with GBA GIS data points, because of the coordinate uncertainties of pre-Third Military Survey maps.

5.5 Historic pictures and photos

Historic photos, paintings and drawings were used to supplement the information of historical maps. Many of them were found in the picture archive (http://www.bildarchivaustria.at), the postcard archive (https://akon.onb.ac.at) of the Austrian National Library and by chance finds in museums, literature and the world wide web. Many photos and pictures from Bad Deutsch-Altenburg and surroundings are collected in the books by Lachmayer (1999), Farka (2000) and Geng-Sesztak et al. (2000). Specific pictures and photos will be discussed later.

5.6 Comparison of the area and numbers of the documented quarries

Arithmetic mean, variance and standard deviation was calculated for the area of the quarries interpreted from the (i) high resolution ALS data (2006 – 2010), (ii) maps of the First Military Suryey (1773–1781, 1784, 1785), (iii) maps of the Second Military Suryey (1809–1818, 1845–1846) and (iv) Third Military Survey (1872–1873, 1880). The detailed Walter Map (1754–1756) covers only the Hundsheim Mountains, Leitha Mountains and the northern part of the Rust Hills, therefore this map and other – detailed but local – maps have not been used for the analysis (Tab. 4). The arithmetic mean was calculated from the sum of the quarry areas divided by their number.

6. Results

For space reasons, we kept the number of figures and tables to an absolute minimum and included additional data into online supplements: Supplement A – Additional figures (Figs. A1 to A7), Supplement B – Additional tables (Tabs. B1 to B4) and Supplement C – ArcGis shape files (including all GIS data of this geoarchaeological survey). In total, 1109 quarries, possible quarries, shallow quarries and inactive quarries have been mapped in the ALS data and the historical maps by Walter (1754–56) and the three military surveys (Tabs. 1–4, B1–B4, Figs. 3–5, A1–A6). Additionally, 134 possible burial mounds have been documented in the ALS data and maps. Additional 21 quarries

have been mapped in large-scale maps by Brequin de Demenge (1755), Streffleur (ca. 1840), Burgerstein (1882) and Groller (1900). The large number of quarries, the ca. 60 km by 60 km large study area as well as limitation of paper size and number of figures makes the presentation of the results challenging. Figure 5 shows an overview of all quarries in the entire study area; Figure A1 to Figure A6 show quarries of the six different quarry regions. These map representations are supplemented by the content of Tables 1–5 and Tables B1–B4. Figures 3 and 4 show two selected areas in more detail.

To ease access to the data, we used a consistent color scheme throughout the GIS data set, figures and tables: ALS quarries: red, ALS possible quarries: light red, ALS shallow quarries: very light red, Third Military Survey quarries: blue, Third Military Survey inactive quarries: blue with red outline, Second Military Survey quarries: green, Second Military Survey inactive quarries: light green with red outline, Streffleur: turquoise, First Military Survey quarries: brown, Walter Map quarries: pink, Walter Map inactive quarries: light pink with red outline (for more detailed color information see the online Supplement C). In figures showing different generations of quarries, they are usually drawn from older to younger, to increase visual clarity (e.g. Figs 4d, 5, A6f). Abbreviations of the ID_1 field are used from the shape file attribute tables (see online Supplement C) for different types of quarries in the historical maps and the ALS data: WMQ- quarries of the Walter Maps, WMIQ- inactive quarries of the Walter maps, 1MSQ- quarries of the First Military Survey, 2MSQ- quarries of the Second Military Survey, 2MSIQ- inactive quarries of the Second Military Survey, 3MSQ- quarries of the Third Military Survey, 3MSIQ- inactive quarries of the Third Military Survey, ALSQ- quarries in ALS data, ALSPQ- possible quarries in ALS data and ALSSQ- shallow quarries in ALS data.

6.1 Quarries documented in ALS data

In the whole study area (Figs. 1, 5), 479 *quarries*, 108 *possible quarries* and 71 *shallow quarries* (in total 658) have been recorded in Miocene sedimentary rocks using ALS and ortho photo data (Tabs. 1–5). The three different types of quarries have been distinguished based on the insight and experience gained during data interpretation: (i) *Quarries* are excavated depressions in exposed rock, > 4 m deep and with at least one steep quarry face. (ii) *Possible quarries* are similar to quarries, but with less certainty. Finally, (iii) *shallow quarries* are < 4 m deep, usually with quite irregular shapes and boundaries (Figs. 3b, d, 4b, d). *Inactive quarries* are a type of quarries that has been interpreted only from historical maps, in which they are sometimes explicitly labeled "old". These three types of quarries are also characterized by different sizes, especially concerning their mean areas, 10 175 m^2, 1 887 m^2 and 1 584 m^2, respectively (Tab. 5).

Table 1 shows that of the 479 quarries 198 (41 %) are not recorded in the quarry data base of the Geological Survey of Austria, most of them in the western Vienna Basin. Of the 108 possible quarries, 89 (83 %) are not documented in the quarry data base (Tab. 2). Furthermore, of the 71 shallow quarries, 56 (79 %) are not listed in the quarry data base (Tab. 3). Finally, 30 probable burial mounds have been interpreted in the ALS data.

Of the 479 quarries documented in the ALS data, 295 (62 %) are not indicated in any of the historical maps, or they are at least 100 m away of any of them. Of the 108 possible quarries outlined in the ALS data, 92 (87 %) are not shown in any of the historical maps, or they are at least 100 m away of any of them and finally, of the 71 shallow quarries documented in the ALS, 71 (100 %) are not indicated in any of the historical maps, or they are at least 100 m away of any of them. Figures A1f, A2f, A3f, A4f, A5d and A6e show the location of the three different quarry types in the six quarry regions (Fig. 2) and Table 4 summarizes their respective numbers, as well as their minimum, maximum, mean and total areas for each quarry region (Fig. 2).

6.2 Quarries documented in the Walter Map (1754–1756)

In the whole study area (Figs. 1, 5), 34 quarries and one inactive quarry ("alter Steinbruch") have been recorded in Miocene sedimentary rocks using the Walter Map (1754–1756) (Tabs. 4, 5, B1). Figure 4d shows some of these quarries in context with quarries from other historic maps and the ALS data. Additionally, 6 probable burial mounds were documented. Figures A1b, A2b, A3b and A4b show the location of the quarries and inactive quarry; Table 4 summarizes their respective numbers, as well as their minimum, maximum, mean and total areas for each quarry regions (Fig. 2).

6.3 Quarries documented in the First Military Survey (1773–1785)

In the whole study area (Figs. 1, 5), 23 quarries are indicated in the First Military Survey (1773–1785) (Tabs. 4, 5, B2). Figure 4d gives an example of these quarries in context with quarries from other historic maps and the ALS data. Additionally, 61 probable burial mounds were documented. Figures A1c, A2c, A3c, A4c and A6b show the location of the quarries and Table 4 summarizes their respective numbers, as well as their minimum, maximum, mean and total areas for each quarry regions (Fig. 2).

TABLE 1 – Quarries located in the ALS terrain models

Quarry Region Leitha Mountains Northeast (LM-NE)

ID_1	GBA_ID	Lithology	Age	Wal-ter	1st Surv.	2nd Surv.	3rd Surv.	Area (m²)	x-coord.	y-coord.
ALSQ-0	060/187	Leithakalk	Badenian	yes	yes?	no	yes	7927	635356	5319672
ALSQ-1	060/185, 060/213	Leithakalk	Badenian	no	no	no	yes	5001	634647	5319627
ALSQ-2	060/186	Leithakalk	Badenian	no	no	no	yes	5127	634860	5319565
ALSQ-3		Leithakalk	Badenian	no	no	no	no	2095	632932	5319402
ALSQ-4	060/212	Leithakalk	Badenian	no	no	no	yes	10896	633020	5319409
ALSQ-5	060/177B	Leithakalk	Badenian	no	no	no	yes	995	632831	5319255
ALSQ-6	060/177B (12 m)	Leithakalk	Badenian	no	no	no	yes	2713	632861	5319252
ALSQ-7		Leithakalk	Badenian	no	no	no	yes	1004	632909	5319298
ALSQ-8		Leithakalk	Badenian	no	no	no	yes	461	632856	5319318
ALSQ-9		Leithakalk	Badenian	no	no	no	no	287	632866	5319357
ALSQ-10		Leithakalk	Badenian	no	no	no	no	489	632887	5319329
ALSQ-11	060/177A	Leithakalk	Badenian	yes	?	?	yes	28491	632573	5319084
ALSQ-12	078/159	Sandstone	Sarmatian	yes	?	yes	yes	19701	635212	5314193
ALSQ-13	078/330	Leithakalk	Badenian	no	no	no	yes	1470	631025	5314041
ALSQ-14		Leithakalk	Badenian	no	no	no	yes	299	630978	5314079
ALSQ-15		Leithakalk	Badenian	no	no	no	no	341	630839	5314094
ALSQ-16	060/182B	Leithakalk	Badenian	no	no	no	yes	6675	631546	5318158
ALSQ-17	060/183	Leithakalk	Badenian	yes	no	?	yes	73344	631900	5317897
ALSQ-18	078/288 (9 m)	Leithakalk	Badenian	no	no	no	yes	9805	631157	5317736
ALSQ-19	078/288	Leithakalk	Badenian	no	no	no	yes	7914	631159	5317636
ALSQ-20		Leithakalk	Badenian	no	no	no	yes	13587	631124	5317421
ALSQ-21	078/288	Leithakalk	Badenian	no	no	no	yes	1461	631137	5317545
ALSQ-22	078/283	Leithakalk	Badenian	no	yes	no	yes	27598	630065	5317022
ALSQ-23		Leithakalk	Badenian	no	no	no	yes	4934	629795	5316929
ALSQ-24		Leithakalk	Badenian	no	no	no	no	1897	629827	5317038
ALSQ-25		Leithakalk	Badenian	no	no	no	no	1838	629869	5317066
ALSQ-26	078/283	Leithakalk	Badenian	no	no	no	yes	3266	629911	5316959
ALSQ-27	078/284	Leithakalk	Badenian	no	no	no	no	2141	628994	5315970
ALSQ-28	078/082	Leithakalk	Badenian	no	no	no	no	9847	628577	5316375
ALSQ-29	078/331	Calcareous sandstone	Sarmatian	no	no	no	no	2920	634390	5315225
ALSQ-30		Sandstone	Sarmatian	no	no	no	no	271	633837	5315698
ALSQ-31		Sandstone	Sarmatian	no	no	no	no	108	633887	5315692
ALSQ-32		Sandstone	Sarmatian	no	no	no	no	463	633902	5315643
ALSQ-33		Sandstone	Sarmatian	no	no	no	no	421	633953	5315651
ALSQ-34		Sandstone	Sarmatian	no	no	no	no	265	633722	5315583
ALSQ-35		Sandstone	Sarmatian	no	no	no	no	96	633774	5315629
ALSQ-36		Sandstone	Sarmatian	no	no	no	no	110	633758	5315634
ALSQ-37		Sandstone	Sarmatian	no	no	no	no	374	633867	5315653
ALSQ-38	078/295 (28 m)	Calcareous sandstone	Sarmatian	yes?	no	no	yes	3315	634030	5315739
ALSQ-39	078/052A,052B,052C	Leithakalk	Badenian	no	no	no	yes	50992	633336	5316538
ALSQ-40	078/292	Calcareous sandstone	Sarmatian	no	no	no	yes	4666	632934	5315947
ALSQ-41	078/334	Leithakalk	Badenian	no	no	no	yes	3530	630604	5314881
ALSQ-42	078/333	Leithakalk	Badenian	no	no	no	yes	3620	630659	5315059

ALSQ-43	078/238_M	Leithakalk	Badenian	no	no	no	yes	5013	630765	5315082
ALSQ-44	078/287	Leithakalk	Badenian	no	no	no	yes	7030	630753	5315193
ALSQ-45	078/287	Leithakalk	Badenian	no	no	no	yes	787	630812	5315262
ALSQ-46	078/332	Leithakalk	Badenian	no	no	no	yes	1386	630802	5315378
ALSQ-47	078/286	Leithakalk	Badenian	no	no	no	yes	5050	630735	5315544
ALSQ-48	078/053	Leithakalk	Badenian	no	no	no	yes	2287	630189	5313376
ALSQ-49	078/289C	Leithakalk	Badenian	no	no	no	yes	36693	631187	5316093
ALSQ-50	078/289B (11 m)	Leithakalk	Badenian	no	no	no	near	618	631376	5316041
ALSQ-51	078/053 (19 m)	Leithakalk	Badenian	no	no	no	near	1077	631227	5315867
ALSQ-52	078/053 (16 m)	Leithakalk	Badenian	no	no	no	yes	4597	631025	5316007
ALSQ-53	078/280	Leithakalk	Badenian	no	no	no	yes	7836	627622	5316505
ALSQ-54	078/280 (9 m)	Leithakalk	Badenian	no	no	no	near	370	627557	5316432
ALSQ-55	078/056	Leithakalk	Badenian	no	no	no	no	13025	627490	5316101
ALSQ-56	078/305	Leithakalk	Badenian	no	no	no	yes	4845	627118	5315674
ALSQ-57	078/055	Leithakalk	Badenian	no	no	no	no	12282	627325	5315765
ALSQ-58	078/054-M,058A,318	Leithakalk, calcareous sandst.	Badenian, Sarmatian	yes	no	yes	yes	48388	627096	5316044
ALSQ-59	078/328	Leithakalk	Badenian	no	no	no	no	523	626629	5315771
ALSQ-60	078/306	Leithakalk	Badenian	no	no	no	no	2002	626457	5315894
ALSQ-61	078/057	Leithakalk	Badenian	yes	no	no	yes	20695	626666	5315919
ALSQ-62	078/341A	Leithakalk	Badenian	no	no	no	yes	2175	629092	5313364
ALSQ-63	078/341B	Leithakalk	Badenian	no	no	no	yes	1848	629155	5313314
ALSQ-64	078/351	Leithakalk	Badenian	no	no	no	yes	1226	629419	5313014
ALSQ-65	078/201-M	Leithakalk	Badenian	no	no	no	yes	17435	629405	5313175
ALSQ-66	078/285	Leithakalk	Badenian	no	no	no	yes	101059	629846	5313477
ALSQ-67	078/352 (28 m)	Leithakalk	Badenian	no	no	no	yes	1748	629123	5312995
ALSQ-68	078/352	Leithakalk	Badenian	no	no	no	yes	2191	629182	5312976
ALSQ-69	078/353	Leithakalk	Badenian	no	no	no	yes	2448	629089	5312809
ALSQ-70	078/353 (99 m)	Leithakalk	Badenian	no	no	no	yes	417	629007	5312744
ALSQ-71	078/025 (59 m)	Leithakalk	Badenian	yes	no	no	near	4166	628698	5312627
ALSQ-72	078/025,025B,025C	Leithakalk	Badenian	near	no	no	yes	38643	628844	5312564
ALSQ-73	078/114	Calcareous sandstone	?	no	no	no	no	923	626112	5309199
ALSQ-74	078/113 (67 m)	Leithakalk	Badenian	no	no	no	no	4439	626118	5309585
ALSQ-75	078/113 (25 m)	Leithakalk	Badenian	no	no	no	no	809	626156	5309536
ALSQ-76	078/113	Leithakalk	Badenian	no	no	no	no	1256	626155	5309483
ALSQ-77		Calcareous sandstone	?	no	no	no	no	797	626283	5309467
ALSQ-78		Sandstone	Sarmatian	no	no	no	near	2319	635726	5314291
ALSQ-79		Sandstone	Sarmatian	no	no	no	near	10959	634687	5314101
ALSQ-80	078/122	Sandstone	?	no	no	no	no	4448	628249	5310877
ALSQ-81	078/122 (84 m)	Sandstone	?	no	no	no	no	709	628329	5310832
ALSQ-82	078/218-M (59 m)	Calcareous sandstone	?	no	no	no	yes	14689	628287	5311323
ALSQ-83		?	?	no	no	no	no	130	627834	5311148
ALSQ-84	078/302	Leithakalk	Badenian	no	no	no	yes	6552	622690	5306429
ALSQ-97	060/177B	Leithakalk	Badenian	no	no	no	yes	1037	632905	5319232
ALSQ-98	060/177B	Leithakalk	Badenian	no	no	no	yes	140	632925	5319274
ALSQ-99	078/329	Leithakalk	Badenian	no	no	no	no	1002	628279	5316323
ALSQ-100		?	?	no	no	no	yes	2042	628282	5311181
ALSQ-157	078/040	Leithakalk	Badenian	no	no	no	yes	2838	621504	5315259

ALSQ-158	078/079-M	Sandstone	?	no	no	no	yes	37916	621737	5315545
ALSQ-159	078/080-M	Sandstone	?	no	no	no	no	2332	622044	5315608
ALSQ-160	078/324	Calcareous sandstone	Sarmatian	no	no	no	no	988	622077	5315543
ALSQ-161	078/273	Sandstone	Sarmatian	no	no	no	yes	1114	622355	5315377
ALSQ-162	078/273	Sandstone	Sarmatian	no	no	no	no	287	622305	5315359
ALSQ-163	078/273 (31 m)	Sandstone	Sarmatian	no	no	no	no	1733	622251	5315322
ALSQ-164		Calcareous sandstone	Sarmatian	no	no	no	no	195	623479	5315452
ALSQ-165		Calcareous sandstone	Sarmatian	no	no	no	no	732	623496	5315472
ALSQ-166	078/325A	Sandstone	Sarmatian	no	no	no	no	6480	623250	5315771
ALSQ-167	078/325B	Sandstone	Sarmatian	no	no	no	no	1573	623218	5315880
ALSQ-168	078/325B	Sandstone	Sarmatian	no	no	no	no	1199	623197	5315934
ALSQ-169		Sandstone	Sarmatian	no	no	no	no	492	623163	5316000
ALSQ-170	078/081A, 078/081B	Calcareous sandstone	Sarmatian	no	no	no	no	2140	622757	5315879
ALSQ-171	078/081	Calcareous sandstone	Sarmatian	yes	no	no	yes	4963	622833	5315800
ALSQ-172	078/081A 26 m)	Calcareous sandstone	Sarmatian	no	no	no	yes	2337	622730	5315823
ALSQ-173		Calcareous sandstone	Sarmatian	no	no	no	no	731	622713	5315763
ALSQ-174	078/037	Calcareous sandstone	Sarmatian	no	no	no	yes	2805	623267	5316034
ALSQ-175	078/037 (36 m)	Calcareous sandstone	Sarmatian	no	no	no	yes	6625	623347	5316076
ALSQ-176	078/038	Calcareous sandstone	Sarmatian	no	no	no	yes	10425	623484	5316118
ALSQ-177	078/039	Calcareous sandstone	Sarmatian	yes	no	yes	yes	11946	623817	5316172
ALSQ-178		?	?	no	no	no	no	1037	623892	5316029
ALSQ-179	078/327	Leithakalk	Badenian	no	no	no	yes	1986	624312	5316162
ALSQ-180	078/327	Leithakalk	Badenian	no	no	no	no	669	624382	5316178
ALSQ-181	078/326A	Calcareous sandstone	Sarmatian	no	no	no	near	5511	624475	5316393
ALSQ-182	078/326B (58 m)	Calcareous sandstone	Sarmatian	no	no	no	near	535	624596	5316398
ALSQ-183	078/326B	Calcareous sandstone	Sarmatian	no	no	no	no	7098	624658	5316431
ALSQ-184	078/326C	Calcareous sandstone	Sarmatian	no	no	no	no	3167	624859	5316544
ALSQ-185		Calcareous sandstone	Sarmatian	no	no	no	no	3575	624715	5316513
ALSQ-186		Calcareous sandstone	Sarmatian	no	no	no	no	878	624596	5316515
ALSQ-187	078/277	Sandstone	?	no	no	no	near	2338	625312	5316692
ALSQ-188	078/232	Conglomerate	Sarmatian/Panno-nian	no	no	no	yes	7714	624864	5316646
ALSQ-189	078/110	Leithakalk	Badenian	no	no	no	no	575	625208	5316594
ALSQ-190		Leithakalk	Badenian	no	no	no	no	191	624925	5316105
ALSQ-191		Leithakalk	Badenian	no	no	no	no	262	625057	5316192
ALSQ-192	078/200 (64 m)	Calcareous sandstone	Badenian/Sarmatian	no	no	no	yes	1379	625797	5316666
ALSQ-193	078/200	Calcareous sandstone	Badenian/Sarmatian	no	no	no	yes	8334	625899	5316614
ALSQ-429	078/052B (59 m)	Calcareous sandstone	Sarmatian	no	no	no	no	1730	633383	5316830
ALSQ-430		Sandstone	Sarmatian	no	no	no	no	822	632295	5316461
ALSQ-432		?	Sarmatian	no	no	no	no	3908	628816	5312174

ALSQ-449		Sandstone	Sarmatian	no	no	no	no	853	634705	5314508
ALSQ-450		Leithakalk	Badenian	no	no	no	no	225	624839	5308713
ALSQ-451	078/320 (46 m)	Leithakalk	Badenian	no	no	no	yes	879	630879	5314105
ALSQ-452	078/320 (28 m)	Leithakalk	Badenian	no	no	no	no	361	630917	5314105
ALSQ-481	078/279	Leithakalk	Badenian	no	no	no	no	896	627460	5316312

Quarry Region Leitha Mountains Southwest (LM-SW)

ID_1	GBA_ID	Lithology	Age	Wal-ter	1st Surv.	2nd Surv.	3rd Surv.	Area (m²)	x-coord.	y-coord.
ALSQ-85	078/028A-C/M	Leithakalk	Badenian	no	no	no	no	1358	621670	5305183
ALSQ-86	078/349	Leithakalk	Badenian	no	no	no	no	4138	620941	5304862
ALSQ-87	078/347	Calcareous sandstone	Sarmatian	no	no	no	no	3546	619601	5303928
ALSQ-88	078/348	Calcareous sandstone	Sarmatian	yes	no	no	no	5674	619747	5304043
ALSQ-89		?	Sarmatian?	no	no	no	no	723	618513	5303280
ALSQ-90		?	Sarmatian?	no	no	no	no	361	618537	5303266
ALSQ-91		Calcareous sandstone?	Badenian	no	no	no	no	962	618393	5303411
ALSQ-92	077/240A	Leithakalk	Badenian	no	no	no	no	4551	616069	5302565
ALSQ-93	077/051, 077/240B	Calcareous sandstone	?	no	no	no	no	15705	616215	5302420
ALSQ-94	077/240C	Calcareous sandstone	?	no	no	no	no	2214	616423	5302355
ALSQ-95		Calcareous sandstone	?	no	no	no	no	394	616363	5302279
ALSQ-96	077/051 (67 m)	Calcareous sandstone	?	no	no	no	no	986	616309	5302329
ALSQ-101	078/088	Calcareous sandstone	Sarmatian	no	no	no	no	3892	619802	5303661
ALSQ-102	078/088 (57 m)	Calcareous sandstone	Sarmatian	no	no	no	no	1005	619871	5303600
ALSQ-127	077/105A-M (24 m)	Calcareous sandstone	?	no	no	no	no	1598	617640	5303203
ALSQ-128	078/086	Leithakalk	Badenian	no	yes	no	yes	3197	618231	5311060
ALSQ-129	078/086 (25 m)	Leithakalk	Badenian	no	no	no	near	1412	618236	5310968
ALSQ-130	078/075-M (81 m)	Leithakalk	Badenian	no	no	yes	yes	6003	618388	5312098
ALSQ-131	078/075-M (78 m)	Leithakalk	Badenian	no	no	yes	near	1250	618411	5311918
ALSQ-132	078/342	Leithakalk	Badenian	no	no	no	no	1606	618534	5312307
ALSQ-133		Leithakalk	Badenian	no	no	no	yes	960	618661	5312632
ALSQ-134		Leithakalk	Badenian	no	no	no	no	160	618572	5312579
ALSQ-135	078/261	Leithakalk	Badenian	no	no	no	no	689	618808	5312584
ALSQ-136	078/029	Leithakalk	Badenian	no	no	no	yes	3269	618728	5312803
ALSQ-137	078/335, 078/350	Leithakalk	Badenian	no	no	no	no	12318	618593	5312899
ALSQ-138		Leithakalk	Badenian	no	no	no	no	5967	618572	5312801
ALSQ-139	078/336	Leithakalk	Badenian	no	no	no	no	2821	618798	5312906
ALSQ-140	078/337	Leithakalk	Badenian	no	no	no	yes	693	618883	5312954
ALSQ-141	078/339	Leithakalk	Badenian	no	no	no	yes	806	619099	5312764
ALSQ-142	078/076E	Leithakalk	Badenian	no	no	no	yes	28172	619486	5312863
ALSQ-143	078/338	Leithakalk	Badenian	no	no	no	yes	7793	619104	5312915
ALSQ-144	078/010	Leithakalk	Badenian	no	no	no	yes	13455	619264	5313330
ALSQ-145	078/011,/076A-M,076B	Leithakalk	Badenian	no	no	no	yes	76531	619321	5313089
ALSQ-146	078/001	Leithakalk	Badenian	no	no	no	no	45953	619039	5313339
ALSQ-147	078/076D	Leithakalk	Badenian	no	no	no	no	3078	618908	5313201

ALSQ-148		Leithakalk	Badenian	no	no	no	no	277	618858	5313045
ALSQ-149		Leithakalk	Badenian	no	no	no	yes	7722	619193	5313436
ALSQ-150	078/001A	Leithakalk	Badenian	no	no	no	yes	2992	619423	5313612
ALSQ-151	078/014,033-035,262-263,265,267–270	Leithakalk	Badenian	yes	no	no	yes	790552	620143	5313761
ALSQ-152	078/266	Leithakalk	Badenian	yes	no	no	yes	15447	619882	5314113
ALSQ-153	078/264	Leithakalk	Badenian	no	no	no	yes	4286	620173	5314315
ALSQ-154	078/076F (76 m)	Leithakalk	Badenian	no	no	no	no	2669	619989	5312904
ALSQ-155	078/076F	Leithakalk	Badenian	no	no	no	no	393	619908	5312839
ALSQ-156	078/078-M	Leithakalk	Badenian	no	no	no	no	10261	621040	5314802
ALSQ-194	077/020	Leithakalk	Badenian	no	no	yes	yes	6504	613054	5303579
ALSQ-195	077/104	Calcareous sandstone	Badenian	no	no	no	no	2841	613614	5302215
ALSQ-196	077/239	Calcareous sandstone	Badenian	no	no	no	yes	1126	613757	5302164
ALSQ-197	077/236	Leithakalk	Badenian	no	no	no	no	2679	614322	5302034
ALSQ-198	077/237	Leithakalk	Badenian	no	no	no	no	12383	614317	5301909
ALSQ-199	977/235	Limestone	Badenian	no	no	no	no	4878	614866	5302330
ALSQ-200	077/052-M	Sandstone	Badenian	yes	no	no	yes	21158	615161	5301720
ALSQ-201		Sandstone	Badenian	no	no	no	yes	3655	614231	5302003
ALSQ-202		Leithakalk	Badenian	no	no	no	yes	2192	613365	5301613
ALSQ-203	077/214	Sandstone	Badenian	no	no	no	no	6090	614177	5301427
ALSQ-204	077/224	Leithakalk	Badenian	no	no	no	no	4177	614975	5301568
ALSQ-205	077/241	Leithakalk	Badenian	no	no	no	yes	1613	612848	5300826
ALSQ-206		Leithakalk	Badenian	no	no	no	no	30212	612794	5300500
ALSQ-207	077/053	Leithakalk	Badenian	no	no	no	no	3371	612034	5300216
ALSQ-208	077/243	Leithakalk	Badenian	no	no	no	no	3569	611837	5300095
ALSQ-209		Leithakalk	Badenian	no	no	no	no	916	611026	5300577
ALSQ-210		Leithakalk	Badenian	no	no	no	no	1879	610617	5300304
ALSQ-211	077/005	Leithakalk	Badenian	no	no	no	no	51530	610432	5300205
ALSQ-212	077/056	Leithakalk	Badenian	yes	no	yes	yes	18060	611504	5299542
ALSQ-213	077/027 (38 m)	Leithakalk	Badenian	no	no	no	no	20642	610778	5299343
ALSQ-214	077/242	Leithakalk	Badenian	no	no	no	no	7004	609844	5299693
ALSQ-215	077/202-M	Leithakalk	Badenian	no	no	no	no	4768	610191	5299667
ALSQ-216	077/006-M (55 m)	Leithakalk	Badenian	no	no	no	no	5899	610210	5299892
ALSQ-217	077/071-M	Sandstone	Pannonian	no	no	no	no	32984	608902	5296579
ALSQ-218	077/071-M	Sandstone	Pannonian	no	no	no	no	57560	608848	5296793
ALSQ-219	077/021	Leithakalk	Badenian	no	no	no	yes	14889	608183	5301619
ALSQ-220	077/022-024	Leithakalk	Badenian	no	no	no	no	218574	608640	5301510
ALSQ-221	077/060B-M	Calcareous sandstone	Sarmatian	no	no	no	no	9121	607367	5301727
ALSQ-222	077/081A	Calcareous sandstone	Sarmatian	no	no	yes	yes	6063	608020	5306132
ALSQ-223	077/081A (91 m)	Calcareous sandstone	Sarmatian	no	no	no	yes	720	607925	5306134
ALSQ-224	077/230	Sandstone	Sarmatian	no	no	no	no	11222	609718	5307340
ALSQ-225	077/044B	Sandstone	Sarmatian	no	no	no	no	4430	613232	5306452
ALSQ-226	077/044A	Sandstone	Sarmatian	yes	no	no	yes	8930	613339	5306354
ALSQ-227	077/044C	Sandstone	Sarmatian	no	no	no	no	1300	613408	5306233
ALSQ-228	077/044C (54 m)	Sandstone	Sarmatian	no	no	no	no	761	613462	5306245
ALSQ-229	077/044C (38 m)	Sandstone	Sarmatian	no	no	no	no	1633	613449	5306186
ALSQ-230	077/044C (42 m)	Sandstone	Sarmatian	no	no	no	no	1543	613351	5306183

ALSQ-231		Sandstone	Badenian/Sarmatian	no	no	yes	yes	625	613712	5306084
ALSQ-232	077/068-M	Sandstone	Badenian/Sarmatian	no	no	yes	yes	2222	613691	5305987
ALSQ-233		?	Badenian/Sarmatian	no	no	no	no	289	613658	5305756
ALSQ-234	077/042	Calcareous sandstone	Badenian/Sarmatian	no	yes	yes	yes	20795	613191	5305979
ALSQ-235		Calcareous sandstone	Badenian/Sarmatian	no	no	no	no	869	613635	5305689
ALSQ-236	077/233	Leithakalk	Badenian	no	no	no	yes	4698	614321	5305904
ALSQ-237	077/050	Leithakalk	Badenian	no	no	no	no	5022	615055	5306663
ALSQ-238	077/017	Calcareous sandstone	Badenian/Sarmatian	no	no	no	no	31531	613649	5307154
ALSQ-239	077/018-M	Calcareous sandstone	Badenian/Sarmatian	no	no	no	yes	8187	613854	5307779
ALSQ-240	077/018-M	Calcareous sandstone	Badenian/Sarmatian	no	no	no	no	5651	613946	5307771
ALSQ-241	077/066-M	Calcareous sandstone	Badenian/Sarmatian	no	no	no	yes	3361	614195	5307933
ALSQ-242	077/066-M (39 m)	Calcareous sandstone	Badenian/Sarmatian	no	no	no	no	2985	614298	5307948
ALSQ-243	077/049-M	Calcareous sandstone	Badenian/Sarmatian	yes	yes	yes	yes	72978	614833	5308011
ALSQ-244	077/065-M	Calcareous sandstone	Badenian/Sarmatian	no	no	yes	yes	17395	615484	5308364
ALSQ-245		Calcareous sandstone	Badenian/Sarmatian	no	no	no	yes	912	615616	5308323
ALSQ-246	077/064-M	Calcareous sandstone	Badenian/Sarmatian	no	no	no	yes	3263	616224	5308461
ALSQ-247	078/356	Leithakalk	Badenian	no	no	no	no	1199	619377	5312176
ALSQ-431		Sandstone	Pannonian	no	yes	no	yes	4103	609380	5297292
ALSQ-455		Leithakalk	Badenian	no	no	no	no	176	618773	5312461

Quarry Region Rust Hills (RH)

ID_1	GBA_ID	Lithology	Age	Wal-ter	1st Surv.	2nd Surv.	3rd Surv.	Area (m^2)	x-coord.	y-coord.
ALSQ-103		?	Badenian	no	no	no	no	1155	622839	5299864
ALSQ-104		?	Badenian	no	no	no	no	101	622878	5299825
ALSQ-105	078/065-M (32 m)	?	Badenian	no	no	no	yes	2768	624482	5300631
ALSQ-106	078/065-M (68 m)	?	Badenian	no	no	no	near	179	624498	5300499
ALSQ-107		Leithakalk	Badenian	no	no	no	yes	4510	622338	5298714
ALSQ-108	078/067	Leithakalk	Badenian	no	no	no	no	11190	622468	5298077
ALSQ-109	078/067 (84 m)	Leithakalk	Badenian	no	no	no	no	2306	622390	5298044
ALSQ-110	078/067	Leithakalk	Badenian	no	no	no	no	483	622425	5297996
ALSQ-111	078/048A	Leithakalk	Badenian	no	no	no	yes	954	622489	5297558
ALSQ-112		Leithakalk	Badenian	no	no	no	yes	590	622335	5297513
ALSQ-113	078/048	Leithakalk	Badenian	no	no	no	yes	13995	622426	5297578
ALSQ-114	078/229-M	Leithakalk	Badenian	no	no	no	no	3141	623809	5297203
ALSQ-115	078/068	Leithakalk	Badenian	no	no	no	no	16117	623801	5297007
ALSQ-116	078/068 (50 m)	Leithakalk	Badenian	no	no	no	no	262	623779	5296899
ALSQ-117	078/003B	Leithakalk	Badenian	no	no	yes	yes	15072	622478	5295938
ALSQ-118	078/003	Leithakalk	Badenian	yes	yes	yes	yes	77444	622285	5295721
ALSQ-119	078/063	Leithakalk	Badenian	yes	no	no	yes	27393	622282	5295429
ALSQ-120		Leithakalk	Badenian	no	no	no	no	428	622164	5295987
ALSQ-121	078/003A-M (16 m)	Leithakalk	Badenian	no	no	no	no	440	623078	5295587
ALSQ-122	078/044-M (20 m)	Leithakalk	Badenian	no	no	no	no	2242	622917	5294737

ALSQ-123	078/202	Leithakalk	Badenian	no	no	no	no	6132	624214	5296181
ALSQ-124		Leithakalk	Badenian	near	no	no	no	328	622454	5295409
ALSQ-125		Leithakalk	Badenian	near	no	no	no	425	622537	5295330
ALSQ-126		Leithakalk	Badenian	near	no	no	no	134	622653	5295312
ALSQ-456		Leithakalk	Badenian	-	yes	yes	yes	12071	623222	5287154

Quarry Region Hundsheim Mountains (HM)

ID_1	GBA_ID	Lithology	Age	Wal-ter	1st Surv.	2nd Surv.	3rd Surv.	Area (m²)	x-coord.	y-coord.
ALSQ-248		?	Badenian	no	no	no	no	204	648873	5333954
ALSQ-249		?	Badenian	no	no	no	no	200	648804	5333999
ALSQ-250	061/259	Limestone	Sarmatian	no	no	no	no	570	646694	5331728
ALSQ-251	061/004	Limestone, oolite, lumach.	Sarmatian	yes	no	no	no	10931	648215	5332650
ALSQ-252	061/173	Calcareous sand-stone	Sarmatian	no	no	no	no	2005	648496	5332221
ALSQ-253	061/185 (69 m)	Limestone	Sarmatian	no	no	no	no	5157	645392	5329203
ALSQ-254	061/185	Limestone	Sarmatian	no	no	no	no	9788	645505	5329111
ALSQ-255	061/186	Limestone	Sarmatian	no	no	no	no	9008	645603	5329025
ALSQ-256	061/251	Limestone, lumach., congl.	Sarmatian	no	no	no	yes	3639	645120	5332267
ALSQ-257	061/172	Calcareous sandstone	Sarmatian	no	no	no	no	1136	645680	5332585
ALSQ-258	061/020	Limestone	Badenian	no	no	no	no	4444	644569	5333779
ALSQ-259	061/001	Dolomit, calcareous sandst.	Mesozoic, Badenian	no	no	no	no	572869	642584	5332869
ALSQ-260	061/010A	Leithakalk	Badenian	no	no	yes	no	15198	643036	5332420
ALSQ-261		Leithakalk	Badenian	no	no	yes	no	5998	643188	5332397
ALSQ-262		Leithakalk	Badenian	no	no	yes	no	1024	643281	5332377
ALSQ-263		Calcareous sandstone	Sarmatian	no	no	no	no	719	643849	5332274
ALSQ-264		Calcareous sandstone	Sarmatian	no	no	no	no	328	643831	5332249
ALSQ-265		Limestone	Badenian	no	no	no	no	558	642600	5333490
ALSQ-266		Limestone	Badenian	no	no	no	no	1794	642980	5333380
ALSQ-267		Limestone	Badenian	no	no	no	no	9985	642168	5333607
ALSQ-268		?	Sarmatian	no	no	no	no	15330	641936	5332904
ALSQ-269	061/168	Limestone	Badenian	no	no	no	yes	2482	641822	5333131
ALSQ-270	061/167	Limestone	Badenian	no	no	no	yes	2152	641793	5333182
ALSQ-271	061/016B	Sandstone, limestone	Pannonian	no	no	no	yes	8742	647361	5328796
ALSQ-272	061/017	Quartz sandstone	Pannonian	no	no	no	yes	6459	647333	5328624
ALSQ-421	061/008B	Calcareous sandstone	Badenian	no	near	no	near	24996	643627	5332387
ALSQ-422	061/008	Calcareous sandstone	Badenian	no	yes	no	yes	14229	643662	5332516
ALSQ-423		Calcareous sandstone	Badenian	no	no	no	no	339	643741	5332416
ALSQ-424		Calcareous sandstone	Badenian	no	no	no	no	365	643785	5332244
ALSQ-425	061/250	Limestone	Sarmatian	no	no	no	yes	887	642799	5332175
ALSQ-426		Leithakalk	Badenian	no	no	no	yes	3916	643257	5332316
ALSQ-428	061/158	Calcareous sandst., dolo. marble	Badenian, Triassic?	no	no	no	yes	9759	641752	5333348
ALSQ-433		?	Badenian	no	no	no	no	1807	643175	5333917

ALSQ-434		Calcareous sandstone	Badenian	no	no	no	no	3254	643793	5332299
ALSQ-435		Calcareous sandst., dolo. marble	Badenian, Triassic?	no	no	no	no	18524	641985	5333165
ALSQ-436		Calcareous sandstone	Badenian	no	no	no	no	17205	642031	5333025
ALSQ-437	061/170	Calcareous sandstone	Badenian/Sarmatian	no	no	no	yes	12319	643181	5332220
ALSQ-438		Calcareous sandstone	Badenian	no	no	no	yes	3078	643171	5332328
ALSQ-439	061/246	Leithakalk	Badenian	no	no	no	yes	2761	643352	5332434
ALSQ-440	061/246 (22 m)	Leithakalk	Badenian	no	no	no	no	731	643433	5332459
ALSQ-441		Leithakalk	Badenian	no	no	no	no	160	643468	5332429
ALSQ-442	061/010B	Leithakalk	Badenian	no	no	no	yes	10257	643275	5332505
ALSQ-443		Leithakalk	Badenian	no	no	yes	no	49	643206	5332472
ALSQ-444	061/247	Leithakalk	Badenian	no	yes	no	no	769	643347	5332605
ALSQ-445	061/248	Leithakalk	Badenian	no	no	no	no	1430	643244	5332876
ALSQ-446	061/167 (39 m)	Leithakalk	Badenian	no	no	no	yes	741	641765	5333227
ALSQ-447	061/158 (20 m)	Leithakalk	Badenian	no	no	no	yes	4201	641737	5333447
ALSQ-454	061/005	Limestone	Sarmatian	no	no	no	no	3403	647883	5332606

Quarry Region Vienna Basin Northwest (VB-NW) (Danube to Atzgersdorf)

ID_1	GBA_ID	Lithology	Age	Wal-ter	1st Surv.	2nd Surv.	3rd Surv.	Area (m^2)	x-coord.	y-coord.
ALSQ-317	058/437	Dolomite breccia	Badenian	-	no	no	no	870	593185	5332407
ALSQ-318	058/012B	Breccia, conglomerate	Badenian	-	no	no	no	1131	593277	5332546
ALSQ-457	058/313B	Atzgersdorf Calcareous Sandst.	Sarmatian	-	no	yes	yes	26779	595653	5333568
ALSQ-458	058/410	Atzgersdorf Calcareous Sandst.	Sarmatian	-	no	yes	yes	15067	595461	5333702
ALSQ-459	058/409 (52 m)	Atzgersdorf Calcareous Sandst.	Sarmatian	-	no	yes	yes	10460	595319	5333683
ALSQ-460	058/413 (33 m)	Atzgersdorf Calcareous Sandst.	Sarmatian	-	no	no	yes	11939	595618	5333400
ALSQ-461		Atzgersdorf Calcareous Sandst.	Sarmatian	-	no	no	no	4334	595457	5333306
ALSQ-462		Atzgersdorf Calcareous Sandst.	Sarmatian	-	no	no	no	6808	595426	5333184
ALSQ-463	058/313C (54 m)	Atzgersdorf Calcareous Sandst.	Sarmatian	-	no	no	no	2780	595469	5332790
ALSQ-464	058/313C	Atzgersdorf Calcareous Sandst.	Sarmatian	-	no	no	no	2540	595435	5332727
ALSQ-465	058/313C (51 m)	Atzgersdorf Calcareous Sandst.	Sarmatian	-	no	no	no	2336	595376	5332815
ALSQ-466	058/411, 058/412	Atzgersdorf Calcareous Sandst.	Sarmatian	-	no	no	yes	6237	595191	5333301
ALSQ-467	058/313A-M (63 m)	Atzgersdorf Calcareous Sandst.	Sarmatian	-	no	no	yes	779	595313	5333201
ALSQ-468	058/313A-M (85 m)	Atzgersdorf Calcareous Sandst.	Sarmatian	-	no	no	yes	548	595347	5333183
ALSQ-469	058/415	Atzgersdorf Calcareous Sandst.	Sarmatian	-	no	no	yes	2056	595441	5332401
ALSQ-470		Atzgersdorf Calcareous Sandst.?	Sarmatian?	-	no	no	no	1153	595496	5332544
ALSQ-471	058/436	Breccia	Badenian	-	no	no	no	176	592771	5332460
ALSQ-472		Breccia	Badenian	-	no	no	no	1304	592804	5332470
ALSQ-473		Breccia	Badenian	-	no	no	no	1363	592840	5332518
ALSQ-474		Breccia	Badenian	-	no	no	no	875	592944	5332516

ALSQ-475		Breccia	Badenian	-	no	no	no	1274	592902	5332528
ALSQ-476	058/437	Breccia	Badenian	-	no	no	no	4389	593243	5332417
ALSQ-477		Breccia	Badenian	-	no	no	no	4163	593355	5332636

Quarry Region Vienna Basin Southwest (VB-SW) (Perchtoldsdorf to Bad Fischau)

ID_1	GBA_ID	Lithology	Age	Wal-ter	1st Surv.	2nd Surv.	3rd Surv.	Area (m²)	x-coord.	y-coord.
ALSQ-273	076/012C	(Gainfarn-) Dolomite breccia	Badenian	-	no	no	yes	18123	589338	5315663
ALSQ-274		(Vöslau-) Conglomerate	Badenian	-	no	no	no	9389	589418	5315991
ALSQ-275		(Vöslau-) Conglomerate	Badenian	-	no	no	no	1333	589545	5315995
ALSQ-276		(Vöslau-) Conglomerate	Badenian	-	no	no	no	8518	589552	5315907
ALSQ-277	076/009A	(Vöslau-) Conglomerate	Badenian	-	no	no	no	18814	589421	5316861
ALSQ-278	076/009B	(Vöslau-) Conglomerate	Badenian	-	no	no	no	12949	589701	5316881
ALSQ-279		(Vöslau-) Conglomerate	Badenian	-	no	no	no	5752	589739	5316545
ALSQ-280	058/075B	Breccia	Badenian	-	no	no	no	4864	589892	5317160
ALSQ-281		Breccia	Badenian	-	no	no	no	499	587754	5320149
ALSQ-282		Breccia	Badenian	-	no	no	no	6812	587799	5320436
ALSQ-283	058/088	Leithakalk	Badenian	-	no	no	no	3121	586294	5321604
ALSQ-284	058/220	Breccia	Badenian	-	no	no	no	963	585880	5321595
ALSQ-285	058/223	Breccia	Badenian	-	no	no	no	2178	582235	5322305
ALSQ-286		Conglomerate	Badenian	-	no	no	no	270	587487	5321632
ALSQ-287		Conglomerate	Badenian	-	no	no	no	868	587519	5321649
ALSQ-288		Breccia	Badenian	-	no	no	no	725	589326	5320537
ALSQ-289		Breccia	Badenian	-	no	no	no	615	589281	5320475
ALSQ-290		Breccia	Badenian	-	no	no	no	1679	589408	5320371
ALSQ-291		Breccia	Badenian	-	no	no	no	6156	589140	5320414
ALSQ-292		Breccia	Badenian	-	no	no	yes	6199	590690	5318650
ALSQ-293		Breccia	Badenian	-	no	no	yes	2769	590656	5318475
ALSQ-294		Breccia	Badenian	-	no	no	yes	3926	590868	5318460
ALSQ-295		Breccia	Badenian	-	no	no	yes	1472	590445	5318354
ALSQ-296		Breccia	Badenian	-	no	no	yes	7205	590446	5318241
ALSQ-297		Breccia	Badenian	-	no	no	yes	4803	590553	5318234
ALSQ-298		Breccia	Badenian	-	no	no	no	2279	590596	5318493
ALSQ-299		?	?	-	no	no	no	877	585781	5322408
ALSQ-300		Breccia	Badenian	-	no	no	no	172	585679	5321664
ALSQ-301		Breccia	Badenian	-	no	no	no	189	585724	5321684
ALSQ-302		Breccia	Badenian	-	no	no	no	199	593617	5325354
ALSQ-303		Breccia	Badenian	-	no	no	yes	7355	593515	5320783
ALSQ-304		Conglomerate	Badenian	-	no	no	yes	1871	594633	5321931
ALSQ-305	058/321	Calcareous sandstone, congl.	Badenian	-	no	no	no	4393	595281	5322876
ALSQ-306	058/318B	Conglomerate	Badenian	-	no	no	yes	5096	595313	5323484
ALSQ-307		Leithakalk	Badenian	-	no	yes	near	3062	594962	5328249
ALSQ-308		Leithakalk	Badenian	-	no	yes	no	3739	595105	5328112
ALSQ-309		Leithakalk	Badenian	-	no	no	no	2442	594879	5328808

ALSQ-310	058/320	Calcareous sandst., oolite, lumach.	Badenian	-	no	no	no	10686	594919	5329109
ALSQ-311	058/017	Dolomite breccia	Badenian	-	no	no	yes	3873	593046	5330530
ALSQ-312	058/430 (33 m)	Dolomite breccia	Badenian	-	no	no	no	4798	592691	5330420
ALSQ-313		Dolomite breccia	Badenian	-	no	no	yes	3245	593018	5330460
ALSQ-314		Dolomite breccia	Badenian	-	no	no	no	1264	593097	5330587
ALSQ-315		Dolomite breccia	Badenian	-	no	no	no	630	592970	5330653
ALSQ-316		Dolomite breccia	Badenian	-	no	no	no	377	592780	5330878
ALSQ-319		(Vöslau-) Conglomerate	Badenian	-	no	no	no	1076	590031	5314109
ALSQ-320		(Vöslau-) Conglomerate	Badenian	-	no	no	no	2219	589932	5314175
ALSQ-321		(Vöslau-) Conglomerate	Badenian	-	no	no	no	4714	590070	5313983
ALSQ-322		(Vöslau-) Conglomerate	Badenian	-	no	no	no	2193	590080	5313679
ALSQ-323		(Vöslau-) Conglomerate	Badenian	-	no	no	no	36487	590393	5313313
ALSQ-324		(Vöslau-) Conglomerate	Badenian	-	no	no	no	9145	589877	5313386
ALSQ-325	076/251	Breccia	Badenian	-	no	no	yes	4906	589239	5313347
ALSQ-326		(Vöslau-) Conglomerate	Badenian	-	no	no	no	1025	589746	5313454
ALSQ-327	076/133	Breccia	Badenian	-	no	no	yes	11927	589280	5313650
ALSQ-328		Breccia	Badenian	-	no	no	yes	289	589041	5313412
ALSQ-329		Breccia	Badenian	-	no	no	no	851	589150	5313327
ALSQ-330		Breccia	Badenian	-	no	no	no	1108	589010	5313171
ALSQ-331	076/013C	Breccia	Badenian	-	no	no	no	8579	588703	5313141
ALSQ-332	076/013B	Breccia	Badenian	-	no	no	no	5067	588587	5313177
ALSQ-333	076/013A	Breccia	Badenian	-	no	no	no	1810	588503	5313265
ALSQ-334		Breccia	Badenian	-	no	no	yes	20845	588281	5313109
ALSQ-335		Breccia	Badenian	-	no	no	no	10750	589873	5313057
ALSQ-336		Breccia	Badenian	-	no	no	no	1713	585143	5314677
ALSQ-337		Breccia?	Badenian?	-	no	no	no	1099	584078	5315906
ALSQ-338		Breccia	Badenian	-	no	no	no	340	585464	5314274
ALSQ-339		Breccia	Badenian	-	no	no	no	743	585328	5314229
ALSQ-340		Conglomerate	Pannonian	-	no	no	no	1434	581351	5315053
ALSQ-341		Conglomerate	Pannonian	-	no	no	no	398	581450	5315361
ALSQ-342		Conglomerate	Pannonian	-	no	no	no	354	581480	5315335
ALSQ-343		Conglomerate	Pannonian	-	no	no	no	2661	587465	5308928
ALSQ-344		Conglomerate	Pannonian	-	no	no	near	3064	587377	5308676
ALSQ-345		Conglomerate	Pannonian	-	no	no	no	985	587322	5308623
ALSQ-346		Conglomerate	Pannonian	-	no	no	no	2040	587373	5308537
ALSQ-347		Conglomerate	Pannonian	-	no	no	no	1378	585895	5307778
ALSQ-348		Conglomerate	Pannonian	-	no	no	no	794	585723	5307946
ALSQ-349		Conglomerate	Pannonian	-	no	no	no	258	585672	5307905
ALSQ-350		Lindabrunn-) Conglomerate	Badenian	-	no	no	no	504	586653	5307344
ALSQ-351		Lindabrunn-) Conglomerate	Badenian	-	no	no	no	903	586801	5307376
ALSQ-352		Lindabrunn-) Conglomerate	Badenian	-	no	no	no	1458	586774	5307406
ALSQ-353	076/005	Lindabrunn-) Conglomerate	Badenian	-	no	no	yes	34286	586729	5307529
ALSQ-354	076/005C	Lindabrunn-) Conglomerate	Badenian	-	no	no	no	6683	587128	5307551

ALSQ-355		Lindabrunn-) Conglomerate	Badenian	-	no	no	yes	14754	587079	5307355
ALSQ-356	076/005A	Lindabrunn-) Conglomerate	Badenian	-	no	no	yes	2123	587344	5307473
ALSQ-357	076/005A	Lindabrunn-) Conglomerate	Badenian	-	no	no	yes	19166	587224	5307449
ALSQ-358		Lindabrunn-) Conglomerate	Badenian	-	no	no	yes	11812	587381	5307768
ALSQ-359		Conglomerate	Badenian/Pannonian	-	no	no	no	2187	587339	5308297
ALSQ-360		Conglomerate	Badenian/Pannonian	-	no	no	no	342	587393	5308311
ALSQ-361		Conglomerate	Badenian/Pannonian	-	no	no	no	3645	587406	5308371
ALSQ-362		Lindabrunn-) Conglomerate	Badenian	-	no	no	no	676	587743	5307374
ALSQ-363	076/006B	Lindabrunn-) Conglomerate	Badenian	-	no	no	no	1012	587079	5307170
ALSQ-364	076/006A-M	Lindabrunn-) Conglomerate	Badenian	-	no	no	no	3378	587308	5307037
ALSQ-365		Lindabrunn-) Conglomerate	Badenian	-	no	no	yes	5361	587738	5306872
ALSQ-366		Sndstein, conglomerate	Sarmatian	-	no	no	no	1780	588253	5306683
ALSQ-367		Lindabrunn-) Conglomerate	Badenian	-	no	no	yes	9013	588152	5306286
ALSQ-368		Lindabrunn-) Conglomerate	Badenian	-	no	no	no	499	588206	5306151
ALSQ-369	076/281	Sandstone, conglomerate	Badenian/Sarmatian	-	no	yes	yes	8152	589168	5305400
ALSQ-370		Conglomerate	Pannonian	-	no	no	no	1936	589456	5303535
ALSQ-371	076/022A	Leithakalk	Badenian	-	yes	yes	yes	30353	587767	5302291
ALSQ-372	076/033	Leithakalk	Badenian	-	no	no	yes	17638	586833	5302939
ALSQ-373		Leithakalk	Badenian	-	no	no	no	2215	586356	5303185
ALSQ-374	076/266	Conglomerate	Pannonian	-	no	no	no	4476	583440	5303116
ALSQ-375		Conglomerate	Pannonian	-	no	no	yes	2874	588814	5303836
ALSQ-376		Conglomerate	Pannonian	-	no	no	no	2130	585373	5305963
ALSQ-377	076/022B (78 m)	(Vöslau-) Conglomerate	Badenian	-	no	no	no	19410	587470	5301524
ALSQ-378	076/022B-C,023A,023D	(Vöslau-) Conglomerate	Badenian	-	no	yes	yes	123941	587562	5301258
ALSQ-379		(Vöslau-) Conglomerate	Badenian	-	no	no	no	482	587475	5301402
ALSQ-380		(Vöslau-) Conglomerate	Badenian	-	no	no	no	681	587273	5301124
ALSQ-381		(Vöslau-) Conglomerate	Badenian	-	no	no	no	418	587249	5301070
ALSQ-382		(Vöslau-) Conglomerate	Badenian	-	no	no	no	5487	587245	5300968
ALSQ-383		(Vöslau-) Conglomerate	Badenian	-	no	no	no	371	587359	5300791
ALSQ-384	076/023E	(Vöslau-) Conglomerate	Badenian	-	no	no	no	5953	587379	5300381
ALSQ-385	076/023B	(Vöslau-) Conglomerate	Badenian	-	no	no	no	4652	587510	5300886
ALSQ-386	076/023C	(Vöslau-) Conglomerate	Badenian	-	no	no	no	5758	587684	5300885
ALSQ-387		(Vöslau-) Conglomerate	Badenian	-	no	no	no	2033	587572	5300931
ALSQ-388		(Vöslau-) Conglomerate	Badenian	-	no	no	no	1434	587484	5300679
ALSQ-389		(Vöslau-) Conglomerate	Badenian	-	no	no	no	449	587470	5300516
ALSQ-390		Conglomerate	Pannonian	-	no	no	no	766	587865	5300808
ALSQ-391		(Vöslau-) Conglomerate	Badenian	-	no	no	no	751	587093	5299632

ALSQ-392		(Vöslau-) Conglomerate	Badenian	-	no	no	no	197	586816	5299577
ALSQ-393		(Vöslau-) Conglomerate	Badenian	-	no	no	no	1239	586832	5299506
ALSQ-394	076/020	(Vöslau-) Conglomerate	Badenian	-	no	no	yes	10038	585872	5299106
ALSQ-395	076/021	(Vöslau-) Conglomerate	Badenian	-	no	no	yes	10602	586164	5298977
ALSQ-396		(Vöslau-) Conglomerate	Badenian	-	no	no	no	3958	585842	5298565
ALSQ-397		(Vöslau-) Conglomerate	Badenian	-	no	no	no	1119	585732	5298377
ALSQ-398	076/018	Conglomerate	Badenian/Sarmatian	-	no	no	no	5650	586012	5298378
ALSQ-399	076/016B	Conglomerate	Badenian/Sarmatian	-	no	no	no	3946	585889	5298052
ALSQ-400	076/016A	Conglomerate	Sarmatian	-	no	no	yes	16209	585981	5297918
ALSQ-401		Conglomerate	Sarmatian	-	no	no	no	19890	586204	5298159
ALSQ-402		Conglomerate	Sarmatian	-	no	no	no	3283	586241	5298312
ALSQ-403	076/031	Conglomerate	Sarmatian	-	no	no	near	4107	586360	5298610
ALSQ-404		Conglomerate	Sarmatian	-	no	no	near	6425	586422	5298399
ALSQ-405	076/17	Conglomerate	Pannonian	-	no	no	yes	19323	587068	5298630
ALSQ-406		Conglomerate	Pannonian	-	no	no	no	2193	587167	5298361
ALSQ-407		(Vöslau-) Conglomerate	Badenian	-	no	no	no	5379	586286	5298946
ALSQ-408		Conglomerate	Sarmatian	-	no	no	no	995	586320	5298865
ALSQ-409		Conglomerate	Sarmatian	-	no	no	no	1148	586288	5298818
ALSQ-410		Conglomerate	Sarmatian	-	no	no	no	1620	586440	5298920
ALSQ-411		Conglomerate	Sarmatian	-	no	no	no	320	586542	5298939
ALSQ-412		Conglomerate	Sarmatian	-	no	no	no	1331	586232	5298737
ALSQ-413		(Vöslau-) Conglomerate	Badenian	-	no	no	yes	2688	585294	5297595
ALSQ-414		(Vöslau-) Conglomerate	Badenian	-	no	no	no	672	585337	5297653
ALSQ-415	076/019 (48 m)	Limestone, breccia	Triassic, Badenian	-	no	no	yes	10836	585549	5298219
ALSQ-416	076/019	Breccia	Badenian	-	no	no	yes	1974	585578	5298098
ALSQ-417		Breccia	Badenian	-	no	no	yes	2667	585655	5298159
ALSQ-418		(Vöslau-) Conglomerate	Badenian	-	no	no	no	10870	584327	5297115
ALSQ-419		(Vöslau-) Conglomerate	Badenian	-	no	no	no	4508	584404	5297230
ALSQ-420		(Vöslau-) Conglomerate	Badenian	-	no	no	no	1356	584492	5297257
ALSQ-427	076/001	Dolomite breccia	Badenian	-	no	no	yes	73733	588903	5313572
ALSQ-448		Conglomerate	Sarmatian, Pannonian	-	no	no	yes	42650	586524	5298415
ALSQ-453		Leithakalk	Badenian	-	no	yes	no	4318	595086	5327996

Table 1: Quarries interpreted from the ALS data (2006 – 2010), arranged into the six quarry regions. Quarries not exactly marked with GBA mining archive points, but within 100 m have been connected with those and the distance is written next to the GBA number. Lithologies and stratigraphic age have been taken from the geological map as well as GBA mining archive and the ages from the geological map. Uncertain entries are marked with a question mark. In some cases, quarries cover more than one lithology or age. While the 1:12 500 maps of the Third military survey are very accurate, the coordinate uncertainties increase with higher ages, therefore in some cases the connection of quarries mapped in the DTM visualization with quarries in the historic maps is not always straight forwards. To increase clarity, quarries mapped in the DTM, which have been mapped in historical maps are colored in the same colors also used in the GIS project. Concerning the Walter Map, "-" field entry means that this area is outside of the map and "no" means that no quarry is indicated in the map. The coordinates in the last two columns represent the location of the shape´s centroid in UTM 33N and WGS 84 coordinate system.

TABLE 2 – Possible quarries located in the ALS terrain models

Quarry Region Leitha Mountains Northeast (LM-NE)

ID_1	GBA_ID	Lithology	Age	Walter	1st Surv.	2nd Surv.	3rd Surv.	Area (m²)	x-coord.	y-coord.
ALSPQ-0		Leithakalk	Badenian	no	no	no	yes	3230	631767	5312925
ALSPQ-1		Leithakalk	Badenian	no	no	no	no	5077	628371	5313876
ALSPQ-2		?	?	no	no	yes	no	756	630362	5315080
ALSPQ-3		?	Badenian	no	no	no	no	130	626135	5309285
ALSPQ-4		?	Badenian?	no	no	no	yes	1013	630182	5313375
ALSPQ-5		?	?	no	no	no	no	124	628617	5312777
ALSPQ-6		?	?	no	no	no	no	108	628624	5312748
ALSPQ-7		?	Badenian	no	no	no	no	128	628535	5312626
ALSPQ-8		?	Badenian	no	no	no	no	187	628517	5312646
ALSPQ-9		Leithakalk	Badenian	no	no	no	no	196	626832	5315414
ALSPQ-85		Sandstone?	Sarmatian	no	no	no	no	5650	631611	5316055
ALSPQ-86		?	?	no	no	no	no	78	625409	5308897
ALSPQ-91		?	?	no	no	no	no	576	625383	5308967
ALSPQ-92		?	Sarmatian	no	no	no	no	134	625613	5308945
ALSPQ-93		?	Sarmatian	no	no	no	no	226	625592	5308961
ALSPQ-94		Leithakalk	Badenian	no	no	no	yes	765	632469	5313546
ALSPQ-95	078/084-M	Leithakalk	Badenian	no	no	no	yes	1269	632385	5313477
ALSPQ-96		Leithakalk	Badenian	no	no	no	yes	3939	632119	5313321

Quarry Region Leitha Mountains Southwest (LM-SW)

ID_1	GBA_ID	Lithology	Age	Walter	1st Surv.	2nd Surv.	3rd Surv.	Area (m²)	x-coord.	y-coord.
ALSPQ-10		Leithakalk	Badenian	no	no	no	no	783	620908	5305031
ALSPQ-11		Calcareous sandstone	Sarmatian	no	no	no	no	165	620125	5304330
ALSPQ-12		?	Sarmatian	no	no	no	no	541	619893	5304219
ALSPQ-13		?	Sarmatian	no	no	no	no	166	619893	5304307
ALSPQ-14		?	?	no	no	no	no	538	620741	5304930
ALSPQ-33		?	Badenian/ Sarmatian	no	no	no	no	524	617543	5303437
ALSPQ-34		?	Badenian	no	no	no	no	9815	617279	5309424
ALSPQ-35		Leithakalk	Badenian	no	no	no	no	224	617529	5309791
ALSPQ-36		?	Badenian	no	no	no	no	329	618305	5310855
ALSPQ-37		?	Badenian	no	no	no	no	282	618387	5310734
ALSPQ-38		?	Badenian?	no	no	no	no	1944	620361	5313020
ALSPQ-39		?	Badenian	no	no	no	no	5428	611375	5299263
ALSPQ-40		?	Badenian	no	no	no	no	4221	610810	5299181
ALSPQ-41	077/063-M (39 m)	Calcareous sandstone	Badenian/ Sarmatian	no	no	no	yes	6516	616777	5309329
ALSPQ-42		?	Badenian?	no	no	no	no	3652	617055	5309342
ALSPQ-87		Leithakalk	Badenian	no	no	no	no	116	619056	5312706
ALSPQ-88		Leithakalk	Badenian	no	no	no	no	48	619065	5312698
ALSPQ-89		Leithakalk	Badenian	no	no	no	no	571	619112	5312681
ALSPQ-90		Leithakalk	Badenian	no	no	no	no	126	619155	5312674

Quarry Region Rust Hills (RH)

ID_1	GBA_ID	Lithology	Age	Walter	1st Surv.	2nd Surv.	3rd Surv.	Area (m²)	x-coord.	y-coord.
ALSPQ-15	078/065A	Leithakalk	Badenian	no	no	no	yes	1324	623746	5300665
ALSPQ-16	078/065-M (48 m)	?	Badenian	no	no	no	no	50	624492	5300518
ALSPQ-17		Leithakalk	Badenian	no	no	no	no	2876	624186	5298952
ALSPQ-18		?	?	no	no	no	no	3271	624088	5298950
ALSPQ-19		?	?	no	no	no	no	1107	624053	5298797
ALSPQ-20		?	Badenian	no	no	no	no	449	623454	5298041
ALSPQ-21		Leithakalk	Badenian	no	no	no	no	9749	622298	5297943
ALSPQ-22		Leithakalk	Badenian	no	no	no	no	401	622170	5296030
ALSPQ-23		Leithakalk	Badenian	yes	no	no	no	10912	622742	5295625
ALSPQ-24	078/004-M (41 m)	Leithakalk	Badenian	no	no	no	no	509	622862	5294743
ALSPQ-25		Leithakalk	Badenian	no	no	no	no	673	622558	5291648
ALSPQ-26		Leithakalk	Badenian	no	no	no	no	737	622587	5291606
ALSPQ-27		Leithakalk	Badenian	no	no	no	no	343	622674	5292072
ALSPQ-28		Leithakalk	Badenian	no	no	no	no	122	622614	5292014
ALSPQ-29		Leithakalk	Badenian	no	no	no	no	50	622223	5296158
ALSPQ-30		Leithakalk	Badenian	no	no	no	no	117	622242	5296152
ALSPQ-31		Leithakalk	Badenian	no	no	no	no	65	622258	5296135
ALSPQ-32		Leithakalk	Badenian	no	no	no	no	102	622268	5296127

Quarry Region Hundsheim Mountains (HM)

ID_1	GBA_ID	Lithology	Age	Walter	1st Surv.	2nd Surv.	3rd Surv.	Area (m²)	x-coord.	y-coord.
ALSPQ-43		?	Badenian	no	no	no	no	2092	646587	5335079
ALSPQ-44	061/136	?	Badenian?	no	no	no	no	2224	647015	5334509
ALSPQ-45	061/138-M	?	Badenian?	no	no	no	no	12802	647337	5334320
ALSPQ-46	061/178-M (50 m)	?	Badenian?	no	no	no	no	673	647511	5334226
ALSPQ-47	061/080	?	Badenian?	no	no	no	no	2765	648285	5334045
ALSPQ-48		?	Sarmatian	no	no	no	no	420	647539	5332828
ALSPQ-49		?	Sarmatian	no	no	no	no	262	647580	5332824
ALSPQ-50		Calcareous sandstone	Sarmatian	no	no	no	no	1965	648354	5332582
ALSPQ-51		Calcareous sandstone	Sarmatian	no	no	no	no	1182	648412	5332603
ALSPQ-52		Calcareous sandstone	Sarmatian	no	no	no	no	759	648350	5332657
ALSPQ-53		Calcareous sandstone	Sarmatian	no	no	no	no	915	648432	5332639
ALSPQ-54		Calcareous sandstone	Sarmatian	no	no	no	no	110	648537	5332613
ALSPQ-55		Calcareous sandstone	Sarmatian	no	no	no	no	224	648453	5332474
ALSPQ-56	061/176	Limestone	Sarmatian	no	no	no	no	163	644857	5332259
ALSPQ-57		Limestone	Badenian	no	no	no	no	607	643180	5333022

Quarry Region Vienna Basin Northwest (VB-NW) (Danube to Atzgersdorf)

ID_1	GBA_ID	Lithology	Age	Walter	1st Surv.	2nd Surv.	3rd Surv.	Area (m²)	x-coord.	y-coord.
ALSPQ-97	058/337	Sandstone?	Sarmatian	no	no	no	near	3138	598633	5343344
ALSPQ-98		Sandstone?	Sarmatian	no	no	yes	yes	10101	599246	5343821
ALSPQ-99	059/525	Sandstone?	Sarmatian	no	no	yes	yes	5168	599122	5343793

ALSPQ-100	058/328 (43 m)	Sandstone?	Sarmatian	no	no	no	inac-tive	2872	598495	5343885
ALSPQ-101	058/341 (34 m)	Sandstone?	Sarmatian	no	no	no	near	7603	598804	5342895
ALSPQ-102	059/525	Sandstone?	Sarmatian	no	no	no	no	4593	599038	5343767
ALSPQ-103	058/332	Sandstone?	Sarmatian	no	no	no	no	20994	598666	5343463
ALSPQ-104		Sandstone?	Sarmatian	no	no	no	no	2639	598915	5342782
ALSPQ-105	058/335	Sandstone?	Sarmatian	no	no	no	yes	967	598530	5343383
ALSPQ-106	041/276	Leithakalk	Badenian	no	no	no	yes	2504	600181	5346269
ALSPQ-107		Leithakalk	Badenian	no	no	no	no	1883	599881	5346380

Quarry Region Vienna Basin Southwest (VB-SW) (Perchtoldsdorf to Bad Fischau)

ID_1	GBA_ID	Lithology	Age	Walter	1st Surv.	2nd Surv.	3rd Surv.	Area (m^2)	x-coord.	y-coord.
ALSPQ-58		Dolomite breccia	Badenian	no	no	no	no	392	589196	5315641
ALSPQ-59		Breccia	Badenian	no	no	no	yes	1014	589270	5315535
ALSPQ-60		Breccia	Badenian	no	no	no	no	247	589225	5315533
ALSPQ-61		Breccia	Badenian	no	no	no	no	161	589199	5315510
ALSPQ-62		Breccia	Badenian	no	no	no	no	841	589939	5317080
ALSPQ-63		Breccia	Badenian	no	no	no	no	91	588148	5319203
ALSPQ-64		Breccia	Badenian	no	no	no	no	172	588155	5319181
ALSPQ-65		Breccia	Badenian	no	no	no	no	1460	585748	5321641
ALSPQ-66		Conglomerate	Badenian	no	no	no	no	1597	593586	5320562
ALSPQ-67		Conglomerate	Badenian	no	no	no	no	403	594689	5322033
ALSPQ-68		Conglomerate	Badenian	no	no	no	no	1330	595396	5323061
ALSPQ-69		Conglomerate	Badenian	no	no	no	no	307	595182	5323707
ALSPQ-70		Conglomerate	Badenian	no	no	no	no	181	595263	5323764
ALSPQ-71		Breccia	Badenian	no	no	no	no	1902	595153	5327341
ALSPQ-72		Breccia	Badenian	no	no	no	no	116	592720	5331040
ALSPQ-73		Breccia	Badenian	no	no	no	no	138	592751	5330989
ALSPQ-74		Breccia	Badenian	no	no	no	no	3418	589034	5312956
ALSPQ-75		Vöslau Conglomerate	Badenian	no	no	no	no	2497	590736	5312943
ALSPQ-76		Breccia	Badenian	no	no	no	yes	358	588001	5313173
ALSPQ-77		Breccia	Badenian	no	no	no	no	431	587946	5313190
ALSPQ-78		Breccia	Badenian	no	no	no	yes	169	588035	5313132
ALSPQ-79		Breccia	Badenian	no	no	no	no	133	587929	5313137
ALSPQ-80		Breccia	Badenian	no	no	no	no	3353	586434	5313796
ALSPQ-81		Breccia	Badenian	no	no	no	no	562	584596	5314946
ALSPQ-82		?	?	no	no	no	no	736	584386	5314892
ALSPQ-83		?	?	no	no	no	no	223	584487	5314817
ALSPQ-84		?	?	no	no	no	no	128	584468	5314786

Table 2: Possible quarries interpreted from the ALS data (2006 – 2010), arranged into the six quarry regions. Quarries not exactly marked with GBA mining archive points, but within 100 m have been connected with those and the distance is written next to the GBA number. Lithologies and stratigraphic age have been taken from the geological map as well as GBA mining archive and the ages from the geological map. Uncertain entries are marked with a question mark. In some cases, quarries cover more than one lithology or age. While the 1:12 500 maps of the Third military survey are very accurate, the coordinate uncertainties increase with higher ages, therefore in some cases the connection of quarries mapped in the DTM visualization with quarries in the historic maps is not always straight forwards. To increase clarity, quarries mapped in the DTM, which have been mapped in historical maps are colored in the same colors also used in the GIS project. The coordinates in the last two columns represent the location of the shape´s centroid in UTM 33N and WGS 84 coordinate system.

TABLE 3 – Shallow quarries located in the ALS terrain models

Quarry Region Leitha Mountains Northeast (LM-NE)

ID_1	GBA_ID	Lithology	Age	Walter	1st Surv.	2nd Surv.	3rd Surv.	Area (m²)	x-coord.	y-coord.
ALSSQ-0	078/294	Leithakalk	Badenian	no	no	no	no	3527	633760	5317728
ALSSQ-1	078/294 (57 m)	Leithakalk	Badenian	no	no	no	no	73	633737	5317686
ALSSQ-2	078/294(65 m)	Leithakalk	Badenian	no	no	no	no	980	633758	5317672
ALSSQ-3	078/294 (49 m)	Leithakalk	Badenian	no	no	no	no	179	633778	5317796
ALSSQ-4	078/322 (32 m)	Leithakalk	Badenian	no	no	no	no	842	633466	5317572
ALSSQ-5		Leithakalk	Badenian	no	no	no	no	433	633304	5317632
ALSSQ-6	078/322	Leithakalk	Badenian	no	no	no	no	25810	633378	5317563
ALSSQ-7		Leithakalk	Badenian	no	no	no	no	1190	633700	5317314
ALSSQ-8		Leithakalk	Badenian	no	no	no	no	1243	633970	5317432
ALSSQ-9		Leithakalk	Badenian	no	no	no	no	107	633345	5317870
ALSSQ-10		Leithakalk	Badenian	no	no	no	no	2378	633374	5317878
ALSSQ-11		Leithakalk	Badenian	no	no	no	no	37	633416	5317889
ALSSQ-12		Leithakalk	Badenian	no	no	no	no	118	633422	5317884
ALSSQ-13		Leithakalk	Badenian	no	no	no	no	135	633436	5317911
ALSSQ-14		Leithakalk	Badenian	no	no	no	no	270	633454	5317914
ALSSQ-15	060/184 (57 m)	Leithakalk	Badenian	no	no	no	no	1556	633498	5317878
ALSSQ-16	060/184 (57 m)	Leithakalk	Badenian	no	no	no	no	1490	633517	5317910
ALSSQ-17	060/184 (11 m)	Leithakalk	Badenian	no	no	no	no	1409	633577	5317887
ALSSQ-18	060/184 (31 m)	Leithakalk	Badenian	no	no	no	no	294	633579	5317854
ALSSQ-19	060/184 (89 m)	Leithakalk	Badenian	no	no	no	no	712	633476	5317949
ALSSQ-20		Leithakalk	Badenian	no	no	no	no	1366	633511	5317989
ALSSQ-21	060/184 (37 m)	Leithakalk	Badenian	no	no	no	no	5359	633574	5317973
ALSSQ-22		Leithakalk	Badenian	no	near	no	near	110	629581	5316911
ALSSQ-23		Leithakalk	Badenian	no	near	no	near	440	629644	5316927
ALSSQ-24		Leithakalk	Badenian	no	near	no	no	960	629651	5316914
ALSSQ-25		Leithakalk	Badenian	no	near	no	no	518	629678	5316923
ALSSQ-26		Leithakalk	Badenian	no	near	no	no	2325	629696	5316907
ALSSQ-27		Leithakalk	Badenian	no	no	no	no	1890	627886	5316035
ALSSQ-53		?	Badenian	no	no	no	no	2667	633452	5317995
ALSSQ-54		Leithakalk	Badenian	no	no	no	no	744	633189	5317570
ALSSQ-55		Leithakalk	Badenian	no	no	no	no	1283	633229	5317541
ALSSQ-56		?	Badenian	no	no	no	no	2078	633307	5317976
ALSSQ-57		?	Badenian	no	no	no	no	1253	633350	5318113
ALSSQ-58		?	Badenian	no	no	no	no	3154	633454	5318131
ALSSQ-59		?	Badenian	no	no	no	no	151	633392	5318098
ALSSQ-69	060/184	Leithakalk	Badenian	no	no	no	no	3765	633498	5317825
ALSSQ-70		Leithakalk	Badenian	no	no	no	no	339	633993	5317476

Quarry Region Leitha Mountains Southwest (LM-SW)

ID_1	GBA_ID	Lithology	Age	Walter	1st Surv.	2nd Surv.	3rd Surv.	Area (m²)	x-coord.	y-coord.
ALSSQ-28		?	Sarmatian	no	no	no	no	694	619786	5303516
ALSSQ-29		?	Sarmatian	no	no	no	no	181	619727	5303543
ALSSQ-30		?	Sarmatian	no	no	no	no	318	619738	5303517

ALSSQ-31	?	Sarmatian	no	no	no	no	100	619700	5303503
ALSSQ-32	?	Sarmatian	no	no	no	no	86	619753	5303500
ALSSQ-33	?	Sarmatian	no	no	no	no	149	619773	5303486
ALSSQ-34	?	Sarmatian	no	no	no	no	152	619470	5303738
ALSSQ-35	?	Sarmatian	no	no	no	no	86	619495	5303736
ALSSQ-36	?	Sarmatian	no	no	no	no	254	619729	5303451
ALSSQ-44	?	Sarmatian	no	no	no	no	263	619622	5303733
ALSSQ-45	Leithakalk	Badenian	no	no	no	no	290	613034	5304826
ALSSQ-46	Leithakalk	Badenian	no	no	no	no	103	613062	5304820
ALSSQ-47	Leithakalk	Badenian	no	no	no	no	97	613012	5304875
ALSSQ-60	?	Sarmatian	no	no	no	no	52	619748	5303484
ALSSQ-61	?	Sarmatian	no	no	no	no	299	619712	5303469
ALSSQ-62	?	Sarmatian	no	no	no	no	243	619701	5303520
ALSSQ-63	?	Sarmatian	no	no	no	no	36	619719	5303526
ALSSQ-64	?	Sarmatian	no	no	no	no	159	619758	5303476
ALSSQ-65	?	Sarmatian	no	no	no	no	141	619800	5303495
ALSSQ-66	?	Sarmatian	no	no	no	no	440	619716	5303495
ALSSQ-67	Limestone	Sarmatian	no	no	no	no	1083	620156	5304536
ALSSQ-68	Limestone	Sarmatian	no	no	no	no	278	620201	5304622

Quarry Region Rust Hills (RH)

ID_1	GBA_ID	Lithology	Age	Walter	1st Surv.	2nd Surv.	3rd Surv.	Area (m^2)	x-coord.	y-coord.
ALSSQ-37		Leithakalk	Badenian	no	near	no	no	3691	622313	5295980
ALSSQ-38		Leithakalk	Badenian	no	near	no	no	94	622237	5295949
ALSSQ-39		Leithakalk	Badenian	no	near	no	no	115	622248	5295934
ALSSQ-40		Leithakalk	Badenian	no	no	no	no	112	622373	5296020
ALSSQ-41		Leithakalk	Badenian	no	near	no	no	1353	622260	5295992
ALSSQ-42		Leithakalk	Badenian	no	no	no	no	641	622413	5296053
ALSSQ-43		Leithakalk	Badenian	no	no	no	no	188	622450	5296094

Quarry Region Hundsheim Mountains (HM)

ID_1	GBA_ID	Lithology	Age	Walter	1st Surv.	2nd Surv.	3rd Surv.	Area (m^2)	x-coord.	y-coord.
ALSSQ-51		Leithakalk	Badenium	no	near	no	no	1812	643372	5332512
ALSSQ-52	061/008 (62 m)	Leithakalk	Badenium	no	near	no	near	472	643578	5332511

Quarry Region Vienna Basin Southwest (VB-SW) (Perchtoldsdorf to Bad Fischau)

ID_1	GBA_ID	Lithology	Age	Walter	1st Surv.	2nd Surv.	3rd Surv.	Area (m^2)	x-coord.	y-coord.
ALSSQ-48		Leithakalk	Badenian	no	no	no	no	11657	586332,5	5321429,2
ALSSQ-49		Leithakalk	Badenian	no	no	no	no	586	586327,3	5321564,1
ALSSQ-50		Conglomerate	Badenian	no	no	no	no	15065	588532,7	5302882,5

Table 3: Shallow quarries interpreted from the ALS data (2006–2010), arranged into the six quarry regions. Quarries not exactly marked with GBA mining archive points, but within 100 m have been connected with those and the distance is written next to the GBA number. Lithologies and stratigraphic age have been taken from the geological map as well as GBA mining archive and the ages from the geological map. Uncertain entries are marked with a question mark. In some cases, quarries cover more than one lithology or age. While the 1:12 500 maps of the Third military survey are very accurate, the inaccuracies increase with higher ages, therefore in some cases the connection of quarries mapped in the DTM visualization with quarries in the historic maps is not always straight forwards. To increase clarity, quarries mapped in the DTM, which have been mapped in historical maps are colored in the same colors also used in the GIS project. The coordinates in the last two columns represent the location of the shape´s centroid in UTM 33N and WGS 84 coordinate system.

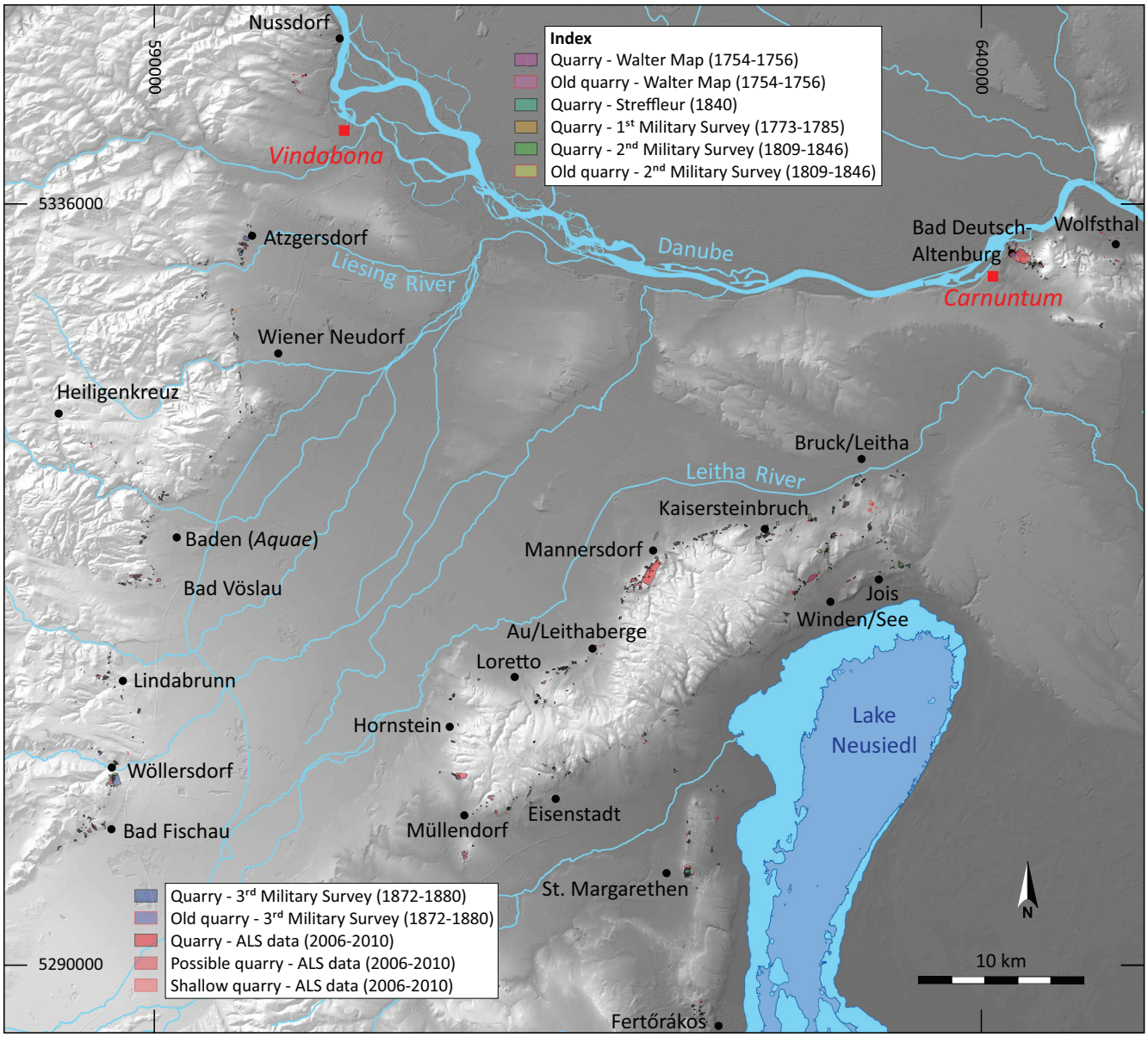


Figure 5: Overview of the study area with all 1109 documented quarries. 10x10 m DTM in grey shades, 40 % brightness standard deviation stretch, 70 % transparent hillshade azimuth 315° and 45° illumination angle, standard deviation stretch; all statistics calculated from current display extent. Areas in Hungary and Slovakia without ALS data were filled with 30x30 m Shuttle Radar Topography Mission (SRTM) data. The Danube course in Vienna is reconstructed from maps for 1529 by Hohensinner et al. (2013).

6.4 Quarries documented in the Second Military Survey (1809–1846)

In the whole study area (Figs. 1, 5), 54 quarries and one inactive quarry are indicated in the Second Military Survey (1809–1846) (Tabs. 4, 5, B3). Figure 4d gives an example of these quarries in context with quarries from other historic maps and the ALS data. Additionally, 18 probable burial mounds were documented. Figures A1d, A2d, A3d, A4d, A5b and A6c show the location of the quarries and inactive quarry; Table 4 summarizes their respective numbers, as well as their minimum, maximum, mean and total areas for each quarry regions (Fig. 2).

6.5 Quarries documented in the Third Military Survey (1872–1880)

The maps of the Third Military Survey show a huge increase in the number of quarries compared with maps of the previous periods (Tab. 4, Figs. 6, 7). In the whole study area (Figs. 1, 5), 327 quarries (of which 12 are located in the southern part of the Rust Mountains near Fertőrákos in Hungary) and 13 inactive quarries (of which 2 are located near Fertőrákos in Hungary) are indicated in the Third Military Survey (1872–1880) (Tabs. 4, 5, B4). Figure 4d gives an example of these quarries in context with quarries from other historic maps and the ALS data. Additionally, 19 probable burial mounds were documented. Figures A1e, A2e, A3e, A4e, A5c and A6d show the loca-

TABLE 4 – Numbers and sizes of quarries

Period	Data	Quarry Region	Number	Type	Minimum area	Maximum area	Mean area	Sum of all areas
2006–2010	**ALS**	**Whole study area**	**479**	**Quarries**	**49**	**790.552**	**10.155**	**4.847.724**
2006–2010	ALS	LM-NE	134	Quarries	96	101.059	6.550	877.640
2006–2010	ALS	LM-SW	100	Quarries	160	790.552	18.710	1.870.976
2006–2010	ALS	RH	25	Quarries	101	77.444	7.994	199.860
2006–2010	ALS	HM	48	Quarries	49	572.869	17.206	825.900
2006–2010	ALS	VB-NW	23	Quarries	176	26.779	4.755	109.361
2006–2010	ALS	VB-SW	149	Quarries	172	123.941	6.470	963.987
2006–2010	**ALS**	**Whole study area**	**106**	**Possible quarries**	**48**	**20.994**	**1.887**	**200.030**
2006–2010	ALS	LM-NE	18	Possible quarries	78	5.650	1.310	23.586
2006–2010	ALS	LM-SW	19	Possible quarries	48	9.815	1.894	35.989
2006–2010	ALS	RH	18	Possible quarries	50	10.912	1.825	32.857
2006–2010	ALS	HM	15	Possible quarries	110	12.802	1.811	27.163
2006–2010	ALS	VB-NW	11	Possible quarries	967	20.994	6.453	58.075
2006–2010	ALS	VB-SW	27	Possible quarries	91	3.418	828	22.360
2006–2010	**ALS**	**Whole study area**	**71**	**Shallow quarries**	**36**	**25.810**	**1.584**	**112.475**
2006–2010	ALS	LM-NE	37	Shallow quarries	37	25.810	1.924	71.185
2006–2010	ALS	LM-SW	22	Shallow quarries	36	1.083	250	5.504
2006–2010	ALS	RH	7	Shallow quarries	94	3.691	885	6.194
2006–2010	ALS	HM	2	Shallow quarries	472	1.812	1.142	2.284
2006–2010	ALS	VB-NW	-	-	-	-	-	-
2006–2010	ALS	VB-SW	3	Shallow quarries	586	15.065	9.103	27.308
Walter Map	**Maps**	**Whole study area**	**32**	**Quarries**	**4.268**	**19.154**	**9.423**	**301.537**
Walter Map	Maps	LM-NE	13	Quarries	4.279	15.368	8.909	115.814
Walter Map	Maps	LM-SW	10	Quarries	6.523	19.154	12.574	125.741
Walter Map	Maps	RH	6	Quarries	4.268	9.573	6.669	40.013
Walter Map	Maps	HM	3	Quarries	5.206	9.461	6.656	19.969
Walter Map	Maps	VB-NW	-	-	-	-	-	-
Walter Map	Maps	VB-SW	-	-	-	-	-	-
1st Military Survey	**Maps**	**Whole study area**	**23**	**Quarries**	**1.418**	**48.843**	**12.073**	**277.681**
1st Military Survey	Maps	LM-NE	9	Quarries	1.418	48.843	17.970	161.731
1st Military Survey	Maps	LM-SW	5	Quarries	3.219	19.876	8.421	42.103
1st Military Survey	Maps	RH	3	Quarries	2.161	10.593	5.404	16.212
1st Military Survey	Maps	HM	2	Quarries	11.727	24.647	18.187	36.374
1st Military Survey	Maps	VB-NW	-	-	-	-	-	-
1st Military Survey	Maps	VB-SW	4	Quarries	1.631	11.922	5.315	21.261
2nd Military Survey	**Maps**	**Whole study area**	**54**	**Quarries**	**553**	**102.005**	**9.828**	**530.714**
2nd Military Survey	Maps	LM-NE	7	Quarries	913	76.256	20.475	143.326
2nd Military Survey	Maps	LM-SW	14	Quarries	998	22.865	8.113	113.578
2nd Military Survey	Maps	RH	9	Quarries	553	102.005	15.267	137.399
2nd Military Survey	Maps	HM	1	Quarries	38.810	38.810	38.810	38.810
2nd Military Survey	Maps	VB-NW	2	Quarries	650	2.099	1.375	2.749
2nd Military Survey	Maps	VB-SW	21	Quarries	686	32.315	4.517	94.852
3rd Military Survey	**Maps**	**Whole study area**	**327**	**Quarries**	**99**	**264.896**	**5.974**	**1.950.914**
3rd Military Survey	Maps	LM-NE	87	Quarries	304	48.705	5.952	517.794
3rd Military Survey	Maps	LM-SW	83	Quarries	131	60.016	4.511	374.396
3rd Military Survey	Maps	RH	21	Quarries	609	101.651	8.581	180.199
3rd Military Survey	Maps	HM	34	Quarries	99	8.908	1.829	62.196
3rd Military Survey	Maps	VB-NW	22	Quarries	279	70.422	7.769	170.919
3rd Military Survey	Maps	VB-SW	77	Quarries	138	264.896	8.382	645.410

tion of the quarries and inactive quarries; Table 4 summarizes their respective numbers, as well as their minimum, maximum, mean and total areas for each quarry regions (Fig. 2).

7. Discussion

In a broad sense, quarry areas can be compared with palimpsests of textual studies, because in both cases older remains are erased or partly erased by younger stone extraction (e.g. Fig. 4d). In the case of quarries, older quarries commonly have been enlarged partly or completely by younger ones. Quarries outlined in historical maps offer a snapshot on the existence of quarries at the time of mapping. The significance of maps concerning quarries strongly depends on various factors, including the scale, accuracy and specific aim of the different maps, as well as the skills, time and motivation of the map maker (Figs. 4d-h). It seems that historical maps – with a few (potentially very interesting) exceptions – show active quarries. This is a big difference to the geoarchaeological prospection of quarries in ALS data visualizations, because there, any (preserved) unnatural, quarry-like surface depression in the targeted rock types was mapped as potential quarry and therefore they include a much larger time range than quarries recorded in historical maps.

7.1 Visibility of quarries in airborne laser scanning data and aerial photography

Clearly, size matters for the recognition of any structure in remote sensing data. No minimum quarry area was defined at the beginning of our geoarchaeological remote sensing prospection. Interestingly, the minimum areas documented 49 m^2, 48 m^2 and 36 m^2, for quarries, possible quarries and shallow quarries, respectively, is surprisingly similar. Probably, these sizes are a reasonable minimum detection limit, considering the resolution of the ALS data (1x1 m), these areas represent about 6x6 to 7x7 pixels and it is difficult to recognize smaller structures as quarries. Probably, smaller quarries can be recognized in a targeted survey of smaller study areas, complemented by feedback loops between remote sensing interpretation and outcrop studies.

The specific challenge of remote sensing studies of quarries is, that – for practical reasons – younger quarries commonly extend older ones and thus erase them partly or completely. Additionally, inactive quarries are frequently used as dumping areas and thus may become hardly visible in ALS data or aerial imagery. The same is true for underground quarries, which are just detectable, if their entrance area is large enough and/or indicated by spoil heaps. Many former quarries in solid rock leave irregular terrain with abundant rock fragments and therefore these areas usually are not useful for agriculture and become overgrown by vegetation. As a result, virtually all inactive quarries that were outlined using ALS data are situated in forested areas (Figs 1, A1), where these data are extremely useful (see also Doneus et al., 2008; Doneus and Briese, 2010; Doneus and Kühtreiber, 2013). During ALS interpretation, the ALS data were mainly visualized in a combination of elevation, overlain by hillshade (50 % transparency) and slope (50 % transparency), all in grey shades (Figs. 3b, 4b).

Aerial photography was used to a lesser extent. For example, no high-resolution ALS was available for the southern part of the Rust Mountains in Hungary, and therefore the interpretation of the quarries depended just on aerial and satellite photography. Consequently, hardly any quarries could be detected, although several quarries are shown in historical maps (Fig. A3c-f).

Due to large scale surface modifications by building activities in Vienna, former quarries are hardly recognizable in the DTM data within the city. As an example, in the 18th district of Vienna (Währing), in the area of the Türkenschanzpark there have been several sand pits (Schmieger, 1924). Only some areas, for example the *Steingrueb*, provided sandstone of good quality. According to Schmieger (1924) this quarry was located at the place of the *St. Josef* church, in the so-called *Weinhaus* area, more precisely between *Gentzgasse* and the *Sternwartepark*, and provided building stones for the fortifications of Vienna and was partly also used for the construction of the Karlskirche in the 4th district of Vienna. Due to large scale modifications by buildings, these former extraction sites do not show up well in the ALS data or aerial photography. Therefore, historical maps (e.g. Marinoni, ca. 1717) combined with written sources are a more successful approach in heavily overbuilt areas.

In comparison with other quarry regions, the low number of quarries visible in the ALS data in the Quarry Region Vienna Basin Northwest is conspicuous (Tab. 4, Fig. A5). This is surprising, especially because this region is closest to *Vindobona*/Vienna, with an expected high building stone demand from the Roman period onwards. The low number of quarries in the ALS data could be explained by the enormous surface modifications, especially in the last two centuries. However, also the historical maps of this region show low number of quarries and therefore this situation may point to additional factors, for example the preference of specific rock types and/or qualities, which were not found in these areas, or the exploitation of other rock types, e.g. sandstone from the Flysch Unit.

The west side of the Vienna Basin shows a comparable higher number of quarries lacking quarry mining data points of the Geological Survey of Austria than

Table 4 (left page): Comparison of the sizes and numbers of the documented quarries from different quarry regions, based on the ALS interpretation and from historical maps of different ages. Note the dramatic increase in quarry numbers and quarry area between the Second (1809–1846) and Third Military Surveys (1872–1880), probably related to building stone demands related to the building projects in the area of the former glacis and city wall of Vienna, starting in 1857. Additionally, the more detailed mapping scale of the Third Military Survey may also contribute to the higher number of quarries.

TABLE 5 – Lithostratigraphic content of the quarries

Period	Data	Quarry Region	Type	Badenian	Sarmatian	Pannonian
2006–2010	**ALS**	**Whole study area**	**Quarries**	**342**	**119**	**27**
2006–2010	ALS	LM-NE	Quarries	80	45	1
2006–2010	ALS	LM-SW	Quarries	76	30	3
2006–2010	ALS	RH	Quarries	25	-	-
2006–2010	ALS	HM	Quarries	33	14	2
2006–2010	ALS	VB-NW	Quarries	9	14	-
2006–2010	ALS	VB-SW	Quarries	119	15	21
2006–2010	**ALS**	**Whole study area**	**Possible quarries**	**71**	**26**	**-**
2006–2010	ALS	LM-NE	Possible quarries	10	3	-
2006–2010	ALS	LM-SW	Possible quarries	15	5	-
2006–2010	ALS	RH	Possible quarries	16	-	-
2006–2010	ALS	HM	Possible quarries	6	9	-
2006–2010	ALS	VB-NW	Possible quarries	2	9	-
2006–2010	ALS	VB-SW	Possible quarries	24	-	-
2006–2010	**ALS**	**Whole study area**	**Shallow quarries**	**52**	**19**	**-**
2006–2010	ALS	LM-NE	Shallow quarries	37	-	-
2006–2010	ALS	LM-SW	Shallow quarries	3	19	-
2006–2010	ALS	RH	Shallow quarries	7	-	-
2006–2010	ALS	HM	Shallow quarries	2	-	-
2006–2010	ALS	VB-NW	-	-	-	-
2006–2010	ALS	VB-SW	Shallow quarries	3	-	-
Walter Map	**Maps**	**Whole study area**	**Quarries**	**21**	**11**	**-**
Walter Map	Maps	LM-NE	Quarries	8	6	-
Walter Map	Maps	LM-SW	Quarries	6	3	-
Walter Map	Maps	RH	Quarries	16	-	-
Walter Map	Maps	HM	Quarries	1	2	-
Walter Map	Maps	VB-NW	-	-	-	-
Walter Map	Maps	VB-SW	-	-	-	-
1st Military Survey	**Maps**	**Whole study area**	**Quarries**	**17**	**9**	**-**
1st Military Survey	Maps	LM-NE	Quarries	6	6	-
1st Military Survey	Maps	LM-SW	Quarries	2	3	-
1st Military Survey	Maps	RH	Quarries	3	-	-
1st Military Survey	Maps	HM	Quarries	2	-	-
1st Military Survey	Maps	VB-NW	-	-	-	-
1st Military Survey	Maps	VB-SW	Quarries	4	-	-
2nd Military Survey	**Maps**	**Whole study area**	**Quarries**	**33**	**18**	**3**
2nd Military Survey	Maps	LM-NE	Quarries	3	4	-
2nd Military Survey	Maps	LM-SW	Quarries	6	5	3
2nd Military Survey	Maps	RH	Quarries	9	-	-
2nd Military Survey	Maps	HM	Quarries	1	-	-
2nd Military Survey	Maps	VB-NW	Quarries	-	2	-
2nd Military Survey	Maps	VB-SW	Quarries	14	7	-
3rd Military Survey	**Maps**	**Whole study area**	**Quarries**	**187**	**110**	**14**
3rd Military Survey	Maps	LM-NE	Quarries	44	45	1
3rd Military Survey	Maps	LM-SW	Quarries	46	27	7
3rd Military Survey	Maps	RH	Quarries	21	-	-
3rd Military Survey	Maps	HM	Quarries	17	6	-
3rd Military Survey	Maps	VB-NW	Quarries	3	19	1
3rd Military Survey	Maps	VB-SW	Quarries	56	13	5

Table 5: Comparison of the documented quarries concerning their lithostratigraphic contents. The partly slightly higher numbers in comparison to Table 4 result from the fact that some quarries contain more than one lithostratigraphic unit and are therefore counted more than one time.

other quarry regions (Tabs. 1–3). Possible reasons are: (i) different properties of the rocks, for example well-cemented conglomerates and breccia *versus* relatively soft sandstones in the Leitha Mountains and Hundsheim Mountains, affecting the preservation and visibility, (ii) differences in the rock types may cause different natural erosion features influencing ALS (over-)interpretation or (iii) regional bias of the quarry mining documentation, because this part has been less investigated by the GBA quarry projects compared with other areas.

The interpretation, importance and age of the shallow quarries is especially difficult. Many of them are found in the Quarry Region Leitha Mountains Northeast in Upper Badenian and younger Corallinaceae grain- and rudstones at a level area in the eastern part of the Spittelberg (community of Parndorf). As they are situated within the large military practicing ground ("Truppenübungsplatz"), it cannot be excluded that they are related to surfaces modified by any kind of military practice. This interpretation might be supported by the fact that similar "shallow quarries" are also found on Schieferberg, about 2 km southwest of Spittelberg, but in Mesozoic dolomite marble. There, it remains unclear if shallow quarries represent an early stage of a quarry area, a different quarrying strategy or if their appearance has some age implications.

However, Figure 3 shows a very nice example of a shallow quarry (ALSSQ-51) from the saddle between Pfaffenberg and Hundsheimer Berg, which was visited in the field. According to its appearance in the field it is a shallow quarry, which is neither indicated in historical maps nor in the mining archive of the Geological Survey of Austria. This shallow quarry is located in a similar altitude and only 700 m southeast of the Jupiter sanctuary, which was established by the soldiers of the first Roman legion in Carnuntum, the Legio XV Apollinaris, on the plateau of the Pfaffenberg (Jobst, 2021) and entirely destroyed by 1985 as a result of contemporary quarrying activities (see also Thür, 2000; Gadermayr et al., 2014). This quarry might have been a very practical stone source in connection with the construction of the different buildings of this temple district.

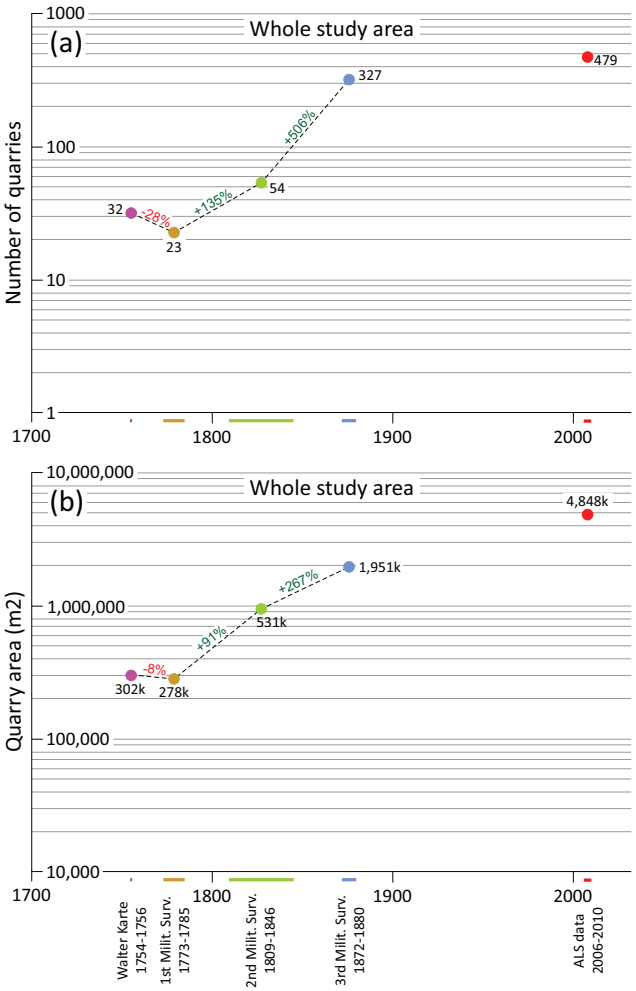


Figure 6: Changes of quarries documented in the Walter Map and the three military surveys of the whole study area. Values are based on Table 4 and rounded in this figure. As quarries documented in the ALS data lack any age information, they were not included into the calculation of the variations. Colored lines at the horizontal axis denote the period of the specific mapping campaign, data points have been drawn at the middle of these periods, **(a):** Changes of the number of quarries between the different maps, **(b):** Changes of the sum of quarry areas between the different maps.

7.2 Documentation of quarries in historical maps

Remote sensing is able to document Earth´s surface with easy access from above with constant parameters and detail; possible restrictions usually concern weather conditions (e.g. Opitz and Cowley, 2013). In contrast, historical maps were measured and drawn by people from the ground, aiming for different purposes (e.g. Cowley et al., 2001; Cosgrove, 2008) and therefore there are many possibilities for biases in map surveys e.g. (1) scale of documentation, (2) surveying techniques, (3) purpose of surveying, (4) personal abilities, knowledge, motivation, specific interests, etc., (5) time constraints, (6) weather conditions, (7) accessibility and visibility restrictions by topography and/or vegetation. Unfortunately, also the redrawing of the field documentation creating a final map adds additional biases related to (1) scale of documentation, (2) knowledge and techniques, (3) purpose of map, (4) personal abilities, knowledge, motivation, specific interests, etc., (5) time constraints. Hardly any map was originally created for the documentation of quarries, but commonly served military purposes, the documentation of property boundaries or the calculation of tax. Therefore, compared with an orthophoto or airborne laser scan, a map is a highly biased source and any interpretation should consider this fact.

This study documented all quarries from historical maps and ALS data as shape files in a GIS environment and changes in number and area were calculated (Tab. 4, Figs. 6, 7). Most quarry regions covered by the Walter Map (1754–1756) show a slight reduction in the number and total area of quarries between the Walter Map and the First Military Survey (1773–1785) (Tab. 4, Fig. 7). In both

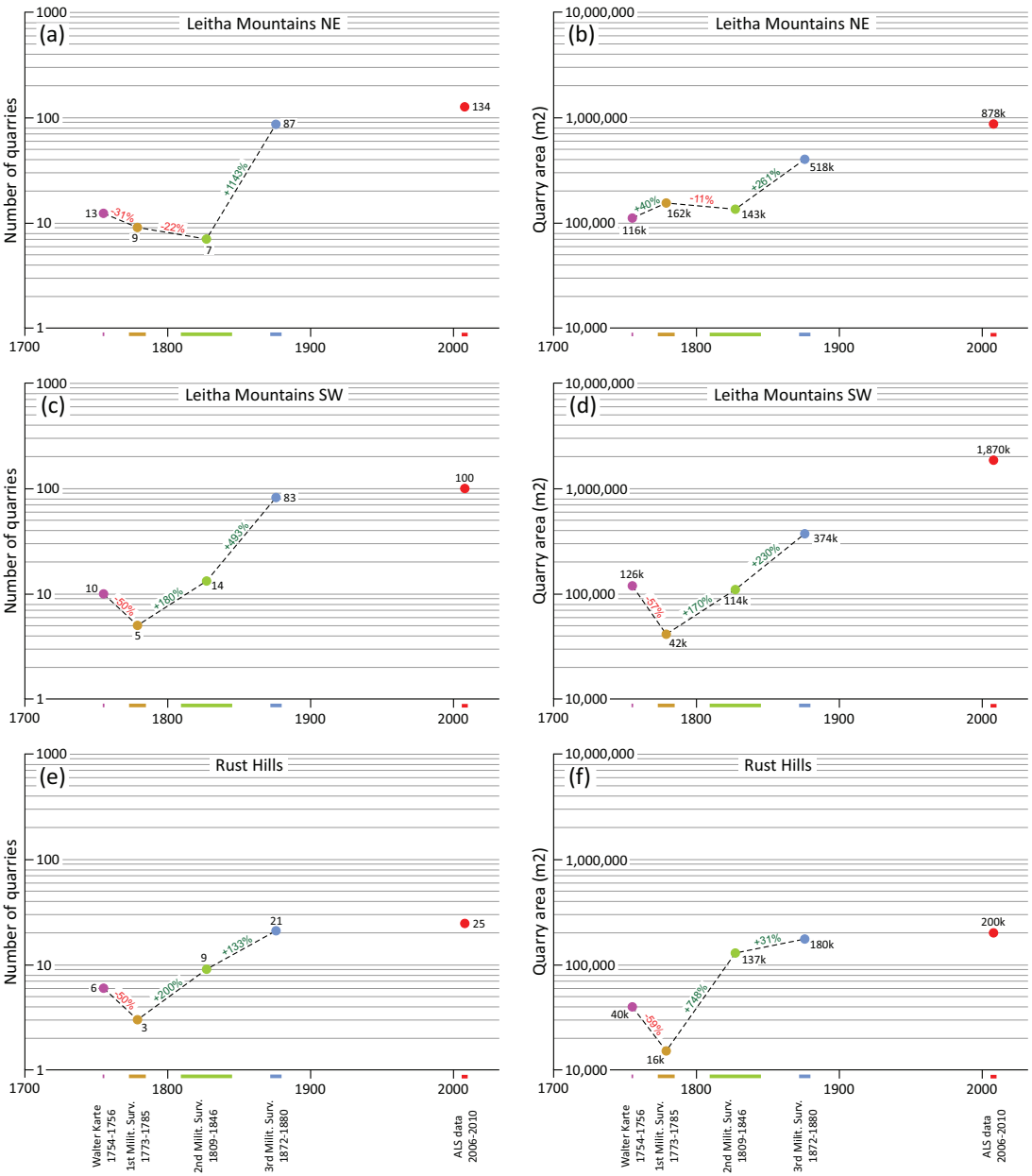
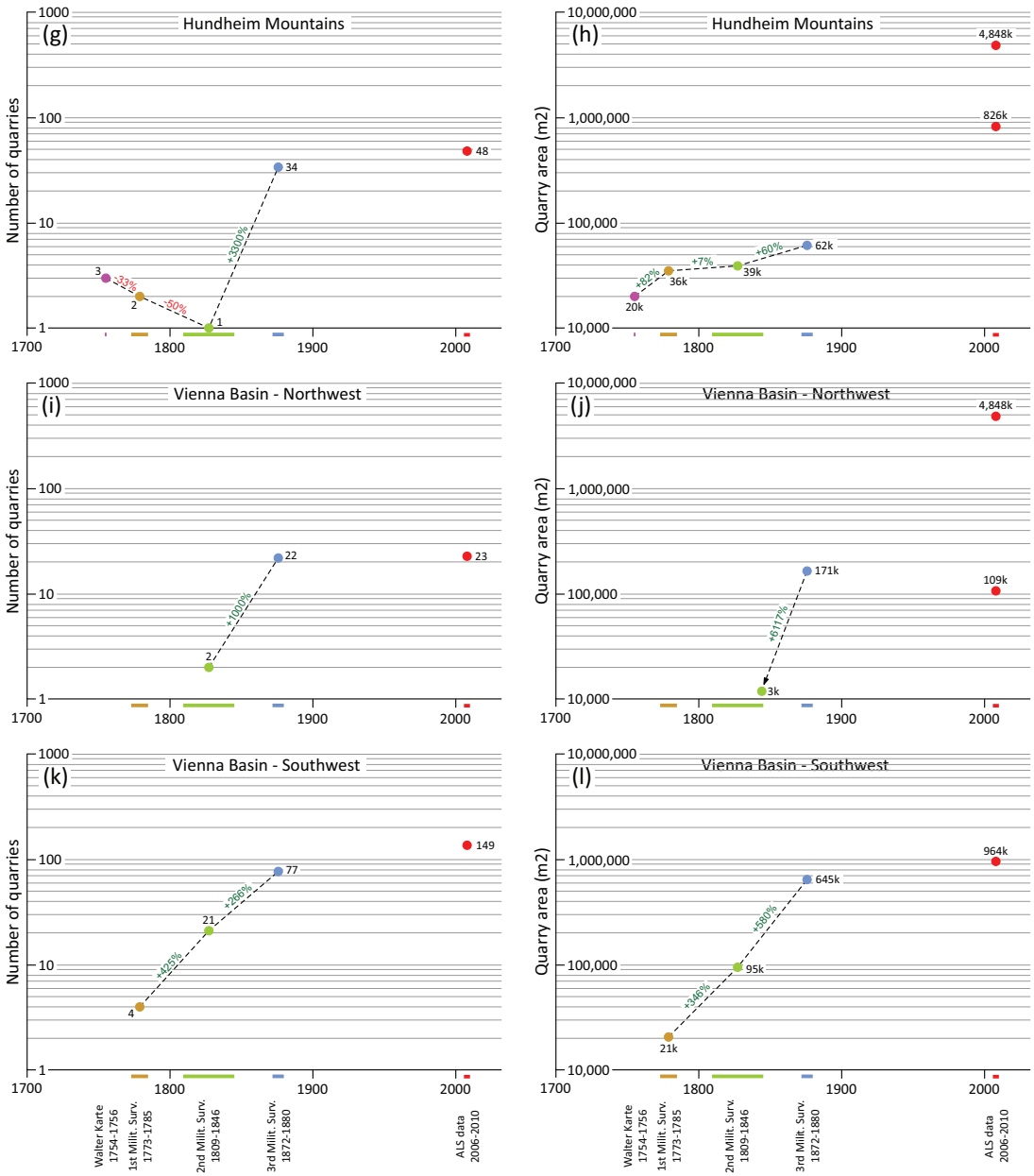


Figure 7 (p. 70, 71): Changes of quarries documented in the Walter Map and the three military surveys separated into the different quarry areas (Fig. 2). Values are shown in a logarithmic scale and are based on Table 4 and rounded in this figure. As quarries documented in the ALS data lack any age information, they were not included into the calculation of the variations. Colored lines at the horizontal axis denote the period of the specific mapping campaign, data points have been drawn at the middle of these periods. Changes of the number between the different maps are on the left side of the figure, changes of the sum of quarry areas between the different maps on the right side.

maps the general numbers are low and the slight differences could be related by the differences in the mapping scale, 1:14000 and 1:28000, respectively. The differences concerning quarries between the First Military Survey and the Second Military Survey are regionally differentiated. There is a markedly increase in quarry number and area in the quarry regions Leitha Mountains Southwest, Rust Hills and Vienna Basin Southwest. In contrast the quarry region Leitha Mountains Northeast shows a slight decrease in both, quarry number and area, while the quarry region Hundsheim Mountains shows a reduction of the number of quarries by 50 % but a slight increase in quarry area by 7 % (Tab. 4, Figs. 5, 7).

The dramatic increase in number and total area of recorded quarries from the Second Military Survey (1809–1846) to the Third Military Survey (1872–1880) in all quarry regions is striking; the quarry number increases by 506 % and quarry area by 267 % (Tab. 4, Figs. 5, 6, 7). The most important contributing factor is probably the strongly increased building activity in Vienna during the so-called Ringstraßen-Period, when the outdated fortification wall, trenches and glacis of Vienna were levelled and this large area covered with a large building program (Karrer, 1886; Kieslinger, 1972). The demand for building stone was so large that nearby quarries could not deliver enough building stones and a part was brought from



remote areas, including Aflenz near Leibnitz (Styria, Austria) as well as Mokrice und Ormož (Slovenia) (Hauer, 1873; Karrer, 1886; Seemann and Summesberger, 1999). Another important factor for the large number of quarries in the maps of the Third Military Survey is most likely also their larger scale (most areas at 1:12 500) compared with the Second Military Survey (1:28 800).

Several of the quarries mapped in the ALS data never showed up in the historical maps (Tabs. 1–3, Fig. A7). There are several possibilities: i) they existed at the time of the survey but have not been mapped – for whatever reason, ii) these quarries are younger than the surveys (i.e. after 1873, younger than the Third Military Survey), iii) these quarries are older than the surveys (i.e. before 1754, older than the Walter Map) and were not recognizable as quarries at the time of the surveys; specifically quarries of the last group should be prioritized for a ground check in a quest for Roman quarries.

In this context, quarries indicated as old or inactive in historical maps deserve further investigation: Walter Map (1754–1756): WMIQ-0, Breitenbrunn, Badenian; Second Military Survey (1809–1818): 2MSIQ-0, between Brunn am Gebirge und Perchtoldsdorf, Pannonian and Third Military Survey (1872–1880): 3MSIQ-0, Winden, SW of Hackelsberg, Badenian; 3MSIQ-1, 3MSIQ-7-9, Winden, Gruibert, Badenian; 3MSIQ-2, Bad Deutsch-Altenburg, Kirchenberg, Badenian; 3MSIQ-3, Bad Deutsch-Altenburg, northwest of Pfaffenberg, Badenian; 3MSIQ-4, Atzgersdorf, Sarmatian; 3MSIQ-5, 3MSIQ-6, Fertőrákos, Badenian; 3MSIQ-10-11, Wien, Döbling, Sarmatian; 3MSIQ-12, Stotzing, Badenian. They are indicated in the maps for example by (i) written description, e.g. "Alter

Steinbruch" (WMIQ-0), (ii) unclear outline, no quarry symbol, no road connection (e.g. 3MSIQ-0), (iii) very irregular topography (e.g. 3MSIQ-1, 3MSIQ-3) or (iv) just by a steep face (e.g. 3MSIQ-12).

7.3 Geological factors

There are hardly any archaeological prospection and survey projects, which do not use geological information in one way or another. Usually, there are neither time nor financial resources for geological mapping specifically for an archaeological study and consequently existing geological maps are used. It is therefore fundamental to understand general aspects of geological mapping – without going into detail concerning technical and methodological considerations. Generally, and especially in the context of a geoarchaeological study related to the location of quarries, one of the most important parameters is the particular scale at which geological maps are produced, because it has a tremendous impact on the information available. A scale of 1:50000 is a very common map scale, which means that 1 mm on the map corresponds with 50 m in nature. As 1 mm is more or less the minimum size of features that can be drawn or printed on maps, this means that a geological map at a scale of 1:50000 generally does not contain rock occurrences below 250 m^2 or layers below apparent 50 m thickness.

A map is a 2-dimensional representation of a 3-dimensional geological reality and there is a close link between lithostratigraphy and mapping: "*Lithostratigraphic units are bodies of rocks, bedded or unbedded, that are defined and characterized on the basis of their lithologic properties and their stratigraphic relations. Lithostratigraphic units are the basic units of geologic mapping*" (Murphy and Salvador, 1999). This relationship is crucial because the content of geological maps is based on formations, defined by their lithological properties, and by the ability to map them, which is a combination of the ability to recognize them in the field and the minimum size of their occurrence, which depends – as mentioned above – on the mapping scale, or in the words of Murphy and Salvador (1999): "*No formation is considered justifiable and useful that cannot be delineated at the scale of geologic mapping practiced in the region.*"

What can we learn from above discussion for a study on quarries: (i) in prehistory and in many archaeological periods, rock occurrences below 250 m^2 may have been economically important and therefore, possible occurrences that might be relevant for archaeological questions, are possibly not indicated in geological maps, (ii) as geological maps show the geological formations on Earth´s surface, exploited rocks might be covered by a thin cover of other rocks or sediments and might not be indicated in geological maps in this area and (iii) in many cases exploited rocks just comprise a couple of meters thick layers or beds, which are commonly not separately indicated in geological maps, (iv) one color in the map summarizes different variations of a lithology, or (v) a specific type of lithology was discovered only recently, for example the Badenian stromatolites from the south side of the Sopron Hills (Harzhauser et al., 2014).

Of the 479 quarries recorded in ALS data, 198 (41 %) are not recorded in the quarry data base of the Geological Survey of Austria (Tab. 1), most of them in the western Vienna Basin. Of the 108 possible quarries mapped in ALS data, 88 (83 %) are not recorded in the quarry data base (Tab. 2) and of the 71 shallow quarries, 56 (79 %) are not recorded in the quarry data base (Tab. 3). Finally, 30 probable burial mounds have been interpreted in the ALS data.

Interpreted quarries were associated with data points of the quarry data base of the Geological Survey of Austria, when they were located within 100 m distance (Figs. 3d, 4d). Of the three different quarry types mapped in the ALS data, 59 % of the quarries, but only 17 % of the possible quarries and 21 % of the shallow quarries are in the data base of the Geological Survey of Austria. This fact can be explained by the generally smaller and less eye-catching appearance of the latter two types. Additionally, the association between mining data base point and interpreted quarry is not always straight forwards, because data base positions were originally taken from maps or later measured with hand-held GPS devices, which may measure inaccurate positions, especially in forested areas, where most of the old quarries are situated.

With a few exceptions, showing small areas (e.g. Figs. 3c, 4c, 10c), geological information has not been included in the figures of this work to increase the visibility of the mapped quarries. The GIS data of all documented quarries of this study have been included into the online Supplement C and their geological context can easily be accessed from the Web Map Service (WMS) of the Geological Survey of Austria (https://www.geologie.ac.at/en/services/web-services).

The combination of high-resolution topography from ALS data with geological information, e.g. orientation of bedding and lithostratigraphy, is commonly important for understanding the location of quarries. For example, the Sarmatian sandstones in the area of the Türkenschanzpark in Vienna show more or less horizontal bedding and are covered by several meters of loose sand. Therefore, the large artificial surface modifications in the park area are mainly related to 19th century sand pits, while most of the quarries are located at lower levels in the Gentzgasse and Krottenbachstraße, where these sandstones were cropping out (Fig. A5d).

Table 5 shows the chronostratigraphic age of the calcareous sandstone and limestone of the documented quarries. The three types of quarries recorded in the ALS data, are clearly dominated by the Badenian stage (465 quarries) compared with the Sarmatian (164 quarries) and Pannonian (27 quarries). The quarries recorded in the historical maps show a very similar distribution, Badenian (258 quarries), Sarmatian (148 quarries) and Pannonian (27 quarries). Interestingly, there are no quarries

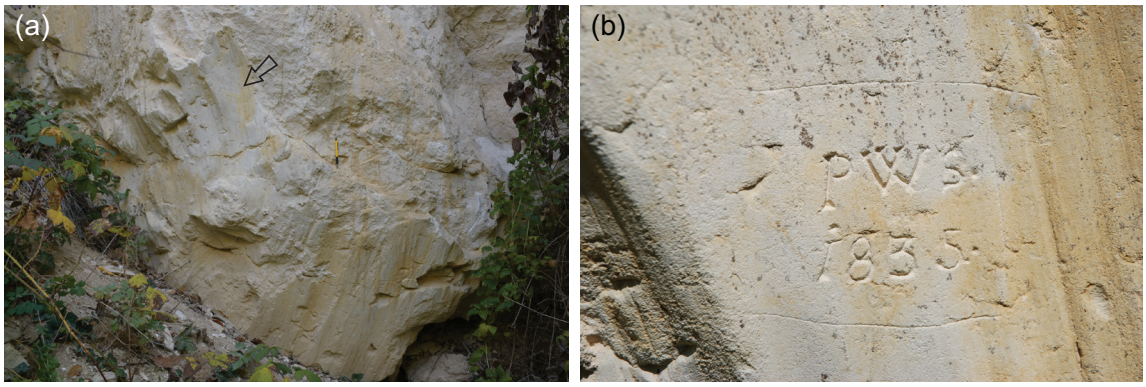


Figure 8: Graffito from the quarry northwest of Breitenbrunn (ALSQ-71, WMIQ-0), written into a slickenside of a subvertical normal fault, **(a):** Overview showing the southwest part of the normal fault (Fault surface: 100/71, Lineation: 038/59). The position of the graffito is indicated by the arrow; yellow retractable pencil for scale is 14.7 mm long, **(b):** Close up of the graffito reading "PWS. 1835." (GPS: UTM33, 628712 E, 5312632 N, 211 m asl).

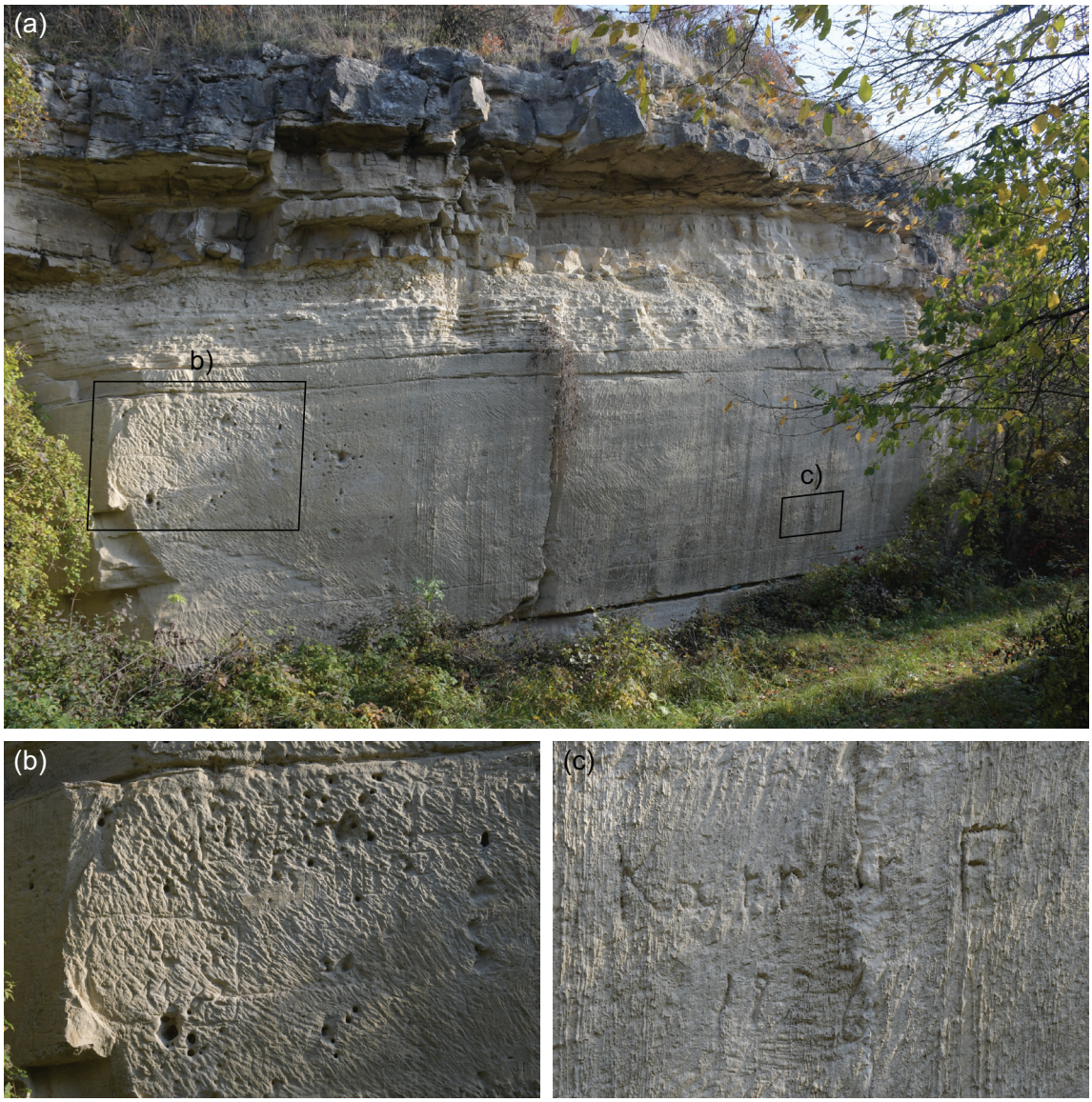


Figure 9: Quarry face with pick marks and graffiti from the large quarry 1.8 km west-southwest of Au am Leithaberge (1MSQ-0, 2MSQ-18, 3MSQ-125, ALSQ-243, Tabs. 1, B2–B4 and Fig A2), **(a):** Overview of the quarry face (trending 320–140) with the location of the graffiti indicated. Details of the pick marks and graffiti are unfortunately obscured by sediment washed down the rock face, **(b):** Several unclear graffiti higher up in the quarry face, **(c):** Graffito probably reading "Karrer F. 1897" (GPS: UTM 33, 614781 m E, 5308054 m N, 231 m asl). The graffito is most likely related to Felix Karrer (1825–1903), the bustling investigator of the Neogene sediments in the Vienna Basin and founder of the important building stone collection of the National History Museum Vienna (Berwerth, 1903).

documented in Pannonian sandstone in the Walter Map (1754–1756) and First Military Survey (1773–1785), they only appear on younger maps (Tab. 5).

7.4 Age information

Age determination of quarries from remote sensing data is obviously challenging and demands observations in the field, usually requires intensive surveys and/or excavations (e.g. Mackensen, 2010; Karl, 2021). Age estimates based on quarrying traces usually are doubtful, because quarrying techniques remained almost unchanged for centuries. Additionally, work traces are more intensively studied for marble quarries (e.g. Waelkens et al., 1990; Karl, 2021), but to a much less extent in porous calcareous sandstone, which is much softer and thus allows for different techniques (e.g. Wurster, 1969; Soles, 1983; Korres, 1988; 2000). Additionally, porous calcarenite and sandstone quarry faces are much less weathering resistant and thus traces are strongly weathered (Fig. 8b) or commonly lost.

In our study, the use of historical maps, photos and paintings of quarries turned out to be very useful for providing some time information of quarries. All of these sources represent time slices allowing broad age estimation. Additionally, historical maps and images may show quarries, that have been destroyed completely by subsequent quarries or which are refilled completely and therefore are not visible in ALS data. Historical maps also contain additional information, for example: "Alter Steinbruch" (old quarry), or names of former owners (Walter 1754–1756). Last but not least historical maps document variations in the number of quarries and quarry areas (Tab. 4). Further, rare graffiti found on some quarry faces (Figs. 8, 9) represent a minimum age indication as well as a control for the map information. For example, the graffito from the ALSQ-71 quarry northwest of Breitenbrunn reading "PWS. 1835.", represents a minimum age limit for the quarry. Interestingly, the only map that shows a quarry there is the map by Walter (1754–1756) (WMIQ-0).

7.5 Key study Bad Deutsch-Altenburg

The region of Bad Deutsch-Altenburg has been selected, because of its proximity to Carnuntum and the existence of a plethora of relevant studies relating to quarries, concerning aspects of topography (Maynzeck, 1717; Walter, 1754–1756; First, Second and Third Military Survey; Streffleur, ca. 1840), large-scale cadastral maps (Henner, 1819), geology (Burgerstein, 1882; Karrer, 1900; Wessely, 1961; Fuchs et al., 1985; Pivko, 2012; Gadermayr et al., 2014), archaeology (Tragau, 1897; Kandler, 2000; Thür, 2000), history (Lachmayer, 1999; Farka, 2000; Geng-Sesztak et al., 2000) as well as historical photographs and drawings (Farka, 2000; Geng-Sesztak et al., 2000; Springer and Sacken, 2000). Without this exceptional amount of existing research data in Bad Deutsch-Altenburg, interpretations concerning the evolution of the quarryscape there would have been much more difficult. The drawback of this area, however, are the still ongoing intensive quarrying activities since the 19th century, which destroyed a lot of evidence (Fig. 10). The key study Bad Deutsch-Altenburg measures only < 5 km^2, or only 0.5 % of the whole ca. 950 km^2 large study area, but nicely shows the potential of our geoarchaeological prospection approach.

Figure 10d shows the interpretation of the quarryscape of the Pfaffenberg near Bad Deutsch-Altenburg, based on a combination of different kinds of data, including satellite imagery, a high resolution digital elevation model, geological map and historical maps. The evolution of this small quarry area reflects the evolution of the whole study area. Only few quarries (2) are indicated in the First Military Survey (1773–1781), even fewer (1) in the Second Military Survey (1809–1818) and a dramatic increase in quarries (21) in the Third Military Survey (1872–1873). The ALS interpretation shows 33 quarries and a shallow quarry (ALSSQ-51), which was already mentioned above. Of the quarries in the ALS data, many have been mapped in the historical maps, but not all (Fig. 10d), which are potentially interesting. Even more important are two areas, directly northwest and west of the Pfaffenberg, which are suspicious by their very irregular, rough, "unnatural" terrain indicated in the map by Streffleur (ca. 1840) and in the Third Military Survey (1872–1873), full of irregular small hills and depressions (Fig. 10e). For all these reasons, these areas have been interpreted as inactive quarries (3MSIQ-2, 3MSIQ-3) (Table B4). Both areas have never been drawn as quarries, neither in any historical map – also including the maps by Anonymous (ca. 1828), Streffleur (ca. 1840) and Burgerstein (1882) – nor in the ALS data (Figs. A4, 10), nor in historical records (Geng-Sesztak and Springer, 2000). The area northwest of Pfaffenberg is almost completely destroyed by later road building and a railway line and is not further discussed here (Fig. 10).

The irregular terrain indicated in the Third Military Survey (1872–1873) (3MSIQ-3), is located in the area of the present railway station of Bad Deutsch-Altenburg, the Hainburgerstraße and northeast of Neustiftgasse (Fig. 10). Groller (1900, Tafel I, Lageplan B) indicates small irregular depressions in this area and a railway line, which is neither indicated in the Third Military Survey (1872–1873) nor in the map of Burgerstein (1882). There, the geological map indicates Badenian and Sarmatian sediments (Fuchs et al., 1985) (Fig. 10c). As none of the historical maps shows any quarries in this area, any possible quarrying activity should be older than the Walter Map (1754–1756). There are also no historical accounts of quarries in this area (Geng-Sesztag and Springer, 2000). Could it be a Roman quarry?

The area in question is located only ca. 1.5 km northeast of the Roman legionary fortress of Carnuntum, in a similar altitude range and directly at the Roman road from Carnuntum along the Danube towards the east (Figs. 5, 10). Burgerstein (1882) carried out one of the first and most detailed geological studies in Bad Deutsch-Altenburg

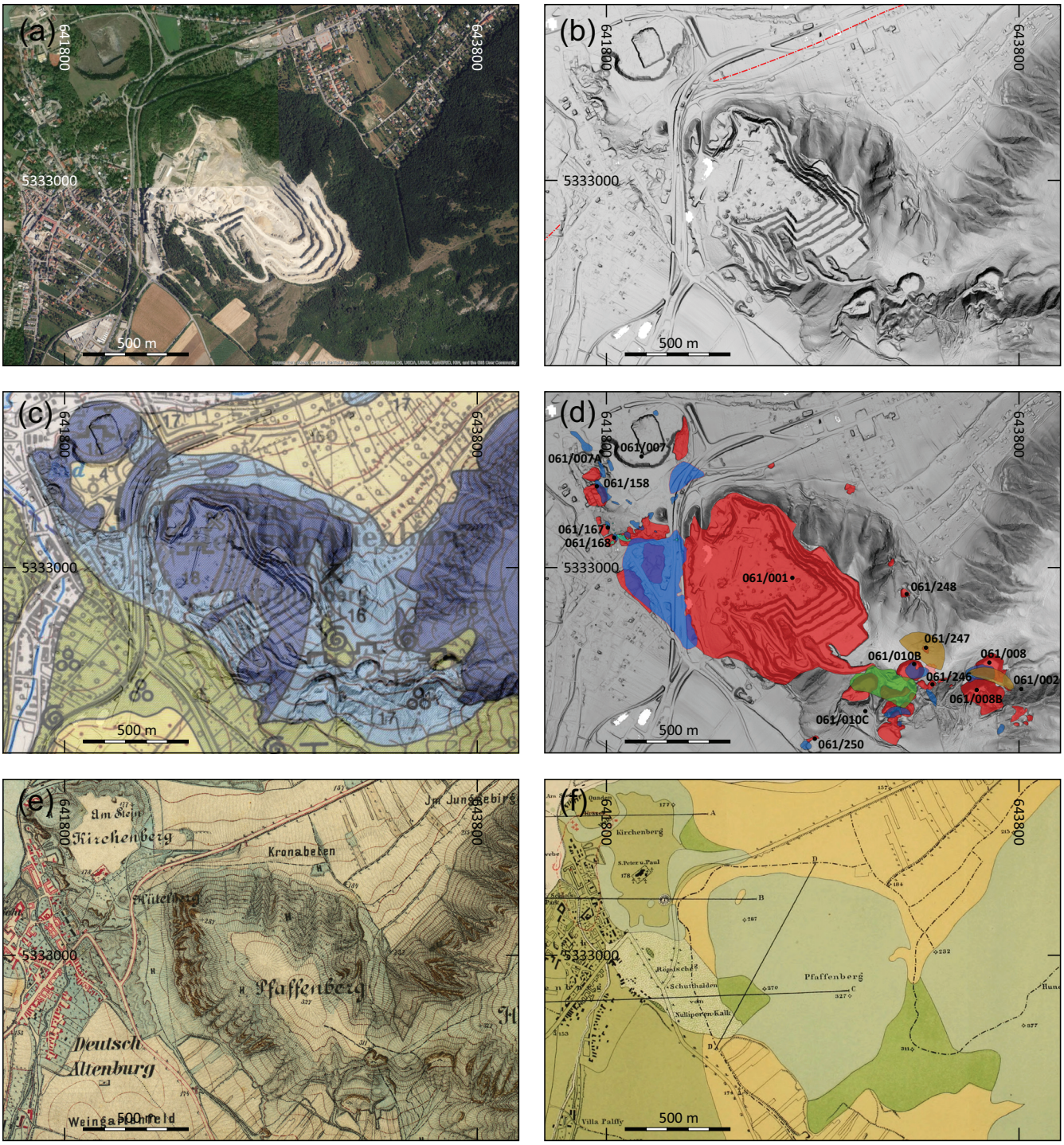


Figure 10: Quarryscape of the Pfaffenberg in Bad Deutsch-Altenburg and two possible Roman? quarries in the Quarry Region HM, **(a):** Satellite image, World Imagery, ESRI. Most quarries are hidden in the forests, **(b):** Visualization of 1x1 m ALS data as combination of the DTM in gray shades, standard deviation stretch, 50 % transparent hillshade, azimuth 315° and 45° illumination angle, standard deviation stretch and 50 % transparent slope map with inverted standard deviation stretch. The red line indicates the position of the Roman road according to Groller (1902), **(c):** Visualization of 1x1 m ALS data with the geological map by Fuchs et al. (1985), **(d):** Interpretation of the ALS visualization and historical maps: brown: quarries (First Military Survey); green: quarries (Second Military Survey); turquoise: quarries (Streffleur, c. 1840); blue: quarries (Third Military Survey); red: quarries (ALS data); light red: shallow quarry (ALS data). Bold numbers are points of the mining archive of the Geological Survey of Austria, **(e):** Third Military Survey (1872 – 1873) showing very uneven terrain north and northwest of Pfaffenberg, **(f):** "*Römische? Schutthalden vom Nulliporen-Kalk*" (English: Roman? debris of corallinaceae limestone) in the map of Burgerstein (1882).

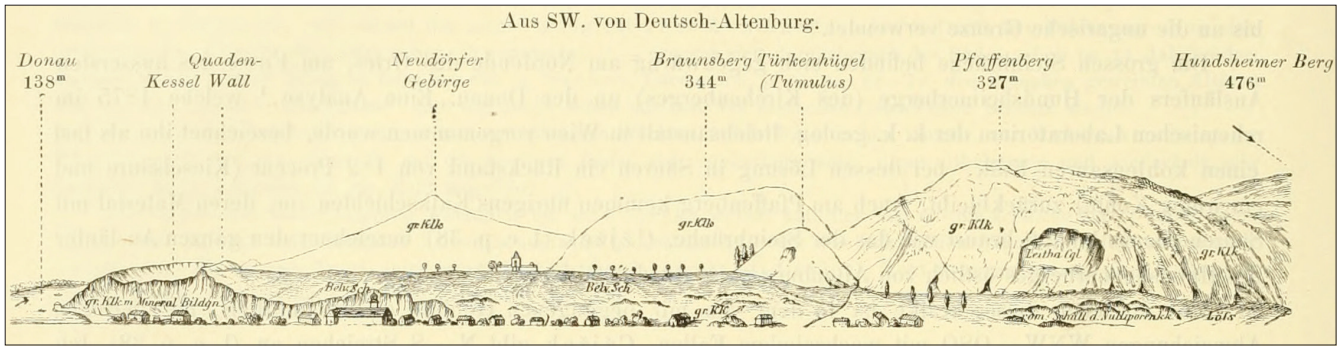


Figure 11: Sketch of Bad Deutsch-Altenburg and Pfaffenberg towards east-northeast showing the very uneven topography of the area of the possible Roman? quarry (Burgerstein, 1882).

Figure 12: Oil painting *„Tumulus of Deutsch Altenburg"* in exhibition hall XIII of the Natural History Museum Vienna by Robert Russ (c. 1889) (photo: Alice Schumacher, NHM Wien) showing yellowish, relatively soft, horizontally bedded sedimentary rocks, probably quarried in different levels and towards the left the uneven topography, outlined in the Third Military Survey (Fig. 10).

with a geological map at a scale of 1:12 500. Additionally, he presents a landscape sketch of the Pfaffenberg and its foot from the west-southwest, giving the best depiction of this relict possible quarry area (Fig. 11).

Burgerstein (1882, 111–112) writes about this area: *„Von der westlichen kleineren Leithaconglomeratmasse am Südwest-Abhange des Pfaffenberges … zieht sich gegen den Ort zu zerlapptes, sanfthügeliges Terrain, welches aus einer Anhäufung von losen Nulliporenstücken oder Schutt von Nulliporenkalk besteht und auf der Karte für sich ausgeschieden ist; man sieht dieses Material an dem Chausseéeinschnitt, welcher die Hügelreihe durchschneidet, gut aufgeschlossen; nach dem Einblick, den man bei Anlage der Chausseé bekam, sind es möglicherweise die (dann colossalen) Massen von Abraum aus altrömischen Steinbrüchen."* (English: From the western, smaller Leitha conglomerate occurrence on the southwest slope of Pfaffenberg … towards the village, there is an irregular, hilly terrain, which consists of an accumulation of loose Corallinaceae pieces or fragments of Corallinaceae limestone, which was outlined on the map; the material is well exposed in the road cutting, which cuts the hilly terrain; according to the insights gained during the road construction, this rubble is possibly the (enormous) debris of old-Roman quarries (see Fig. 10f).

Robert Russ made an oil painting for the exhibition hall XIII of the Natural History Museum Vienna, inaugurated in 1889 (Jovanovic-Kruspel and Schumacher, 2014), showing the northern part of the area under discussion towards the north with the tumulus and the church Mariae Himmelfahrt on top of Kirchenberg in Bad Deutsch-Altenburg and the Danube in the background. The foreground of the painting (Fig. 12) shows yellowish, relatively soft, horizontally bedded sedimentary rocks, probably quarried in different levels and towards the left the uneven topography, outlined in the Third Military Survey.

Another very important information in this context is Tragau (1897, 195), writing about the excavation of one of the towers in the eastern flank of the legionary fortress wall of Carnuntum: *„Zur Verwendung kam das beste Gestein der Umgegend, Leithakalk aus den Brüchen des Hundsheimer-, Pfaffen- und Kirchenberges. Tatsäch-*

lich fanden sich zwischen Deutsch-Altenburg und dem Fuße des Pfaffenberges (Tafel II, Abb. 2a) zahlreiche Abfälle von Steinzurichtung, welche mit dem im Lager und im Castell am Stein verwendeten Material übereinstimmen" (English: The best rock of the surrounding was used, Leitha Kalk from the quarries of Hundsheimer Berg, Pfaffenberg and Kirchenberg. Actually, between Bad Deutsch-Altenburg and the foot of Pfaffenberg (plate II, Fig. 2a), there is a lot of quarrying waste, which match in material the rocks used in the camp and fortification *am Stein*).

Felix Karrer, one of the most eminent experts on Neogene sediments in the Vienna Basin in the 19th century and founder of the building stone collection of the Natural History Museum Vienna sampled the Carnuntum excavation for this collection. He described the Badenian limestones south of the railway station of Bad Deutsch-Altenburg "*Nulliporenkalk*" (Corallinaceae limestone) (Karrer, 1900, p. 4). Figure 13 shows a sample of a coralline algae rich rudstone from a house construction site in the Hainburgerstrasse 29.

As the area of this potential Roman quarry is by far the closest (only 1.5 km distance) and easiest accessible outcrop of Neogene calcareous sandstone (directly at the Roman road between Carnuntum and Gerulata (Groller, 1902) and at almost the same altitude as the city and legionary fortress Carnuntum) it is a prime candidate for the stone supply for Carnuntum. The area is about 700 m long and 300 m wide, with a surface of 18 ha (Figs. 10, 11). Using just the part, which is mapped as Badenian limestone in the modern geological map (Fuchs et al., 1985), the area is still 680 m long and 220 m wide with an area of 10 ha and thus ranges among the largest quarries and possible quarries in the study area (Tab. 4).

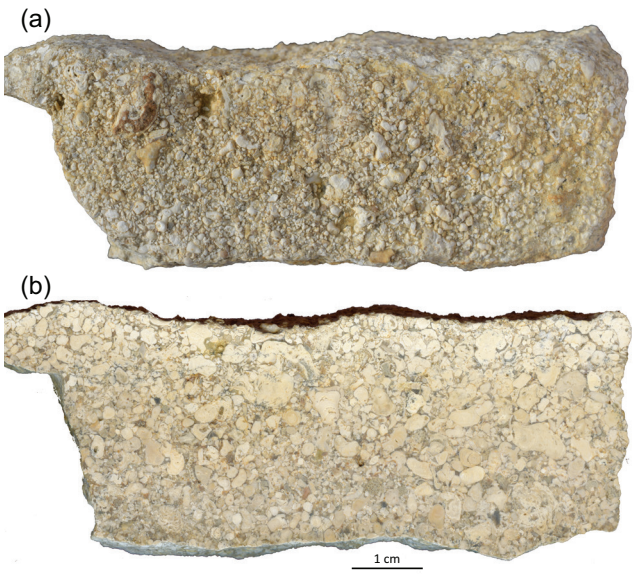


Figure 13: Rock sample from the possible Roman? quarry in Bad Deutsch-Altenburg (Fig. 10e, f) from a house construction site at Hainburgerstraße 29, **(a):** Photography, **(b):** Scan of a polished section. Rudstone, rich in coralline algae, foraminifera, bryozoans and Echinoidea fragments (Sample number ED20/BDS/3, GPS: UTM33, 642026 E, 5332929 N, 163 m asl).

Very similar areas, which have been mapped as uneven terrain in the Third Military Survey like the one discussed at the foot of Pfaffenberg include "*Gruibert*" in Winden am See (3MSIQ-1, ALSQ-66) (see also Rohatsch, 2017) and "Hoher Berg" in Stotzing (3MSIQ-12, ALSQ-237) (Tabs. 1, B4).

8. Outlook

The present geoarchaeological remote sensing and historical map documentation of quarries in the southern Vienna Basin, Leitha Mountains and Hundsheim Mountains, the hinterland of the Roman legionary fortresses and settlements of Vindobona and Carnuntum provides a new, extensive and diachronic data base not only for the Roman period, but also for quarrying since at least the Bronze Age (e.g. Willvonseder, 1938; Berg, 1954; Kaus, 1991), especially the 19th century (Schmid, 1894; Hanisch and Schmid, 1901; Schafarzik, 1909) and up to the present (Lachmayer, 1999; Heinrich et al., 2010). Additionally, the documented quarries represent fundamental information for the Federal Monuments Authority Austria (Bundesdenkmalamt), which is responsible for the definition of protected areas concerning cultural and industrial heritage.

Some desirable future research steps are summarized here. Priority should be given to quarries, possible quarries and shallow quarries which have not been covered by the database of the Geological Survey of Austria so far and those which have never been indicated in any of the investigated historical maps.

1) Documentation of bed thicknesses is very important, because this measurement controls the maximum producible block sizes and thus could be used as one parameter for provenance analyses.

2) The appearance of sediments may show large variations in lateral and vertical directions, especially coastal deposits like the investigated Sarmatian and Badenian sandstone, calcarenites/-rudites and limestone of the present study. Thus, sampling of characteristic beds in quarries would tremendously improve the basis for provenance analysis. Meta-data of samples should include precise GPS location and position in a detailed lithostratigraphic section. Standardized rock samples could be included in the rock collections of the Geological Survey of Austria or the Natural History Museum.

3) Thin-sections of selected samples allowing for the study of the carbonate micro-facies, detrital clasts and especially the micro-fossil content are highly desirable.

4) More knowledge about the local archaeological context of quarries (e.g. settlements, roads, etc.) is very important, archaeological surveys in quarries and surroundings as well as the detailed comparison of archaeological stone objects and rock samples.

5) The evaluation of historical records like cadastral registers, invoices of building projects (e.g. "*Wiener Stadterweiterungsfonds*"), tax records, etc. are very much needed.

6) In 2019 the whole Burgenland was covered by new ALS data with 0.5 m resolution and new ortho-photos. Both are freely accessible under compliance to Creative Commons crediting the creator https://geodaten.bgld.gv.at/de/downloads/hoehenmodelle-orthofotos.html. These data could be used to investigate quarry evolution in comparison with the ALS data from 2010 used in the present study.

7) The calculation of the quarry areas is an important progress compared with only point data, but as a next step the estimation of quarried rock volume is tempting. However, many uncertainties concerning post operational erosion, filling and of course the extreme difficulties concerning age estimation recommend cautiousness.

8) Quarry faces with tool traces shown in Figure 8 are still a hardly documented cultural heritage in the research area and definitely deserve more attention. Especially the importance of the graffiti (Figs. 8, 9) concerning their meaning and chronological implications is hardly explored so far. Their 3-dimensional documentation (e.g. with image-based-modelling) is desirable. Civil drones with cameras could be used to investigate the quarries in the proving ground at Bruckneudorf to avoid hazard imposed by unexploded ammunition.

9. Conclusions

Airborne laser scanning data provide a very useful, fast and cost-efficient method for the prospection and documentation of quarries. As quarries are usually comparably large and well visible archaeological features, 1 x 1 m resolution is sufficient for their detection. In our study, the combination of elevation with hill shade and slope were the preferred visualization during prospection. In some areas a combination of elevation with slope and local relief model as well as elevation with slope and openness improved interpretations.

There is hardly any age information of quarries in remote sensing data, therefore this documentation is a diachronic inventory. In this context, the use of historical maps as well as historical photography and paintings turned out to be very useful, because they represent specific time slices of their development and change.

Documenting the outline of quarries in a GIS environment adds very important additional information concerning extend and area compared with point information and should become standard in quarry research.

Quarries, possible quarries and shallow quarries, recorded in the remote sensing study, which have not been registered in the mining archive of the Geological Survey of Austria so far and those which have never been indicated in any of the investigated historical maps should be investigated in more detail.

The prospection of old quarries is very challenging, because most of them have been quarried also in subsequent periods, destroying virtually all pre-existing traces. Therefore, areas with suspicious uneven terrain, which have never been outlined as quarries, or have been mapped as old quarries, or those which have been mapped as uneven areas – especially in the Third Military Survey – represent highly interesting targets for more detailed studies. Examples represent areas northwest and west of Pfaffenberg in Deutsch-Altenburg, "*Gruibert*" in Winden am See and "*Hoher Berg*" in Stotzing. Shallow quarries, which neither appear in historical maps nor in the mining archive of the Geological Survey of Austria, like the one from the saddle between Pfaffenberg and Hundsheimer Berg, deserve more detailed field work as well.

Last but not least, as archaeological prospection commonly deals with the interpretation of Earth´s surface, which represents a combination of geological and anthropogenic formation processes, every archaeological prospection needs at least partly geoarchaeological expertise.

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References

Abu-Jaber, N., Bloxam, E. G., Degryse P., Heldal, T., 2009. QuarryScapes. Ancient Stone Quarry Landscapes in the Eastern Mediterranean. Geological Survey of Norway Special Publication, 12, 1–183.

Anonymous, 1828. Deutsch-Altenburg in Nied. Österreich im J. 1828. C. 1:4000, Széchényi-National Library, TK 346. https://maps.hungaricana.hu/en/OSZKTerkeptar/345 (accessed on 10 March 2022).

Antonelli, F., Santi, P., Renzulli, A., Santoro Bianchi, S., 2016. The Architectural Reuse of Roman Marble and Stone Spolia in the Early Medieval Monte Sorbo Church (Sarsina, Central Italy). Archaeometry, 58/3, 353–370. https://doi.org/10.1111/arcm.12170.

Berg, F., 1954. Ein Steinkistengrab der älteren Urnenfelderkultur aus Siegendorf, pol. Bez. Eisenstadt. Burgenländische Heimatblätter, 16/1, 1–8.

Berka, R., 2015. Zur Geologie der großen Beckengebiete des Ostalpenraumes. Abhandlungen der Geologischen Bundesanstalt, 64, 71–141.

Berwerth, F., 1903. Notizen. Zur Erinnerung an Felix Karrer. Annalen des k. k. naturhistorischen Hofmuseums, XVIII, 3–8.

Beutler, F., 2013. Die zwei Amphitheater von Carnuntum und deren Datierung. In: Eck, W., Fehér, B., Kovács, P., Studia Epigraphica in memoriam Géza Alföldy, Antiquitas, Reihe 1, Abhandlungen zur Alten Geschichte, 61. Habelt, Bonn, 19–37.

BMLFUW (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft), 2014a. Flächenverzeichnis Donaugebiet von der Enns bis zur Leitha. Beiträge zur Hydrografie Österreichs, 62, 172 pp. and CD-ROM.

BMLFUW (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft), 2014b. Flächenverzeichnis der Flussgebiete: Leitha-, Rabnitz- und Raabgebiet. Beiträge zur Hydrografie Österreichs, 63, 140 pp. and CD-ROM.

Bonomo, A.E., Acito, A.M., Prosser, G., Rizzo, G., Munnecke, A., Koch, R., Bentivenga, M., 2019. Matera´s old quarries: geological and historical archives that need protection and valorization. Geoheritage, 11, 1603–1619, https://doi.org/10.1007/s12371-019-00413-x.

Brequin de Demenge, J.B., 1755. Carte des environs de Schönbrun et ceux de Laxemburg, levée en Novembre et Décembre MDCCLIV et Avril MDCCLV par ordre de sa majesté imperiale et royale. 222x110 cm, ca. 1:10 800, 6 parts, Österreichische Nationalbibliothek, Kartensammlung, Alb. Port. 186-12, https://onb.digital/search/339607 (accessed on 10 March 2022).

Burgerstein, L., 1882. Geologische Studie über die Therme von Deutsch-Altenburg an der Donau. Denkschriften der kaiserlichen Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Klasse, 45/2, 107–122.

Cavazza, W., Roure, F., Spakman, W., Stampfli, G.M., Ziegler, P.A., 2004. The TRANSMED Atlas. The Mediterranean Region from Crust to Mantle. Springer, Berlin, 141 pp, https://doi.org/10.1007/978-3-642-18919-7.

Cosgrove, D., 2008. Geography & Vision. International Library of Human Geography, 12, Tauris, London, 256 pp.

Cowley, D.C., Harrison, J.G., Halliday, S.P., 2001. 'Well Shelterd and Watered': Menstrie Glen, a Farming Landscape near Stirling. Royal Commission on the Ancient and Historical Monuments of Scotland, Edinburgh, 71 pp.

Čžjžek, J., 1852. Geologische Verhältnisse der Umgebungen von Hainburg,des Leithagebirges und der Ruster Berge. Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt, 3/4, 35–55.

Decker, K., Peresson, H., Hinsch, R., 2005. Active tectonics and Quaternary basin formation along the Vienna Basin Transform fault. Quaternary Science Reviews, 24, 307–322, https://doi.org/10.1016/j.quascirev.2004.04.012.

Djurić, B., 2019. The Logistics behind Ancient Art. The Case of Noricum and Pannoniae. In: Porod, B., Scherrer, P., Akten des 15. Internationalen Kolloquiums zum Provinzialrömischen Kunstschaffen. Der Stifter und sein Monument: Gesellschaft – Ikonographie – Chronologie. 14. bis 20. Juni 2017 Graz/Austria. Schild von Steier, Beiheft 9 / Veröffentlichungen des Instituts für Archäologie der Karl-Franzens-Universität Graz, 16, 8–38.

Doneus, M., 2013. Openness as visualization technique for interpretative mapping of airborne Lidar derived digital terrain models. In: Lasaponara, R., Masini, N. (eds.), New perspectives of remote sensing for archaeology. Remote Sensing, 5/12, 6427–6442, https://doi.org/10.3390/rs5126427.

Doneus, M., Briese, C., Fera, M., Janner, M., 2008. Archaeological prospection of forested areas using full-waveform airborne laser scanning. Journal of Archaeological Science, 35, 882–893, https://doi.org/10.1016/j.jas.2007.06.013.

Doneus, M., Briese, C., 2010. Airborne Laser Scanning in Forested Areas – Potential and Limitations of an Archaeological Prospection Technique. In: Cowley, D.C. (ed.), Remote Sensing for Archaeological Heritage Management. Proceedings of the 11th EAC Heritage Management Symposium, Reykjavík, Iceland, 25–27 March 2010, EAC Occasional Paper, 5 / Occasional Publication of the Aerial Archaeology Research Group, 3, 59–76.

Doneus, M., Kühtreiber, T., 2013. Airborne Laser Scanning and Archaeological Interpretation – Bringing Back the People. In: Opitz, R., Cowley, D.C. (eds.), Interpreting Archaeological Topography – Airborne Laser Scanning, 3D data and ground observation. Oxbow Books, Oxford, 32–50.

Dörflinger, J., Wagner, R., Wawrik, F., 1977. Descriptio Austriae – Österreich und seine Nachbarn im Kartenbild von der Spätantike bis ins 19. Jahrhundert. Ed. Tusch, Wien, 215 pp.

Dowling, R., Newsome, D., 2018. Handbook of Geotourism. Elgar, Cheltenham Glos, 520 pp.

Draganits, E., 2009. The archaic sanctuary on Despotiko Island (Cyclades): Geological outline and lithological characterization of the building stones, with their possible provenance. Austrian Journal of Earth Sciences, 102, 91–102.

Draganits, E., Rohatsch, A., Herdits, H., 2008. Römersteine entlang der burgenländischen Bernsteinstraße. In: Tiefenbach, J. (ed.), Spuren römischen Lebens im Burgenland. Wissenschaftliche Arbeiten aus dem Burgenland, 124, 37–58.

Eppensteiner, W., 1999. Zur Geschichte der Abbautechniken. In: Lachmayer, H., Steinbruch. Hollitzer Wissenschaftsverlag, Wien, 29–34.

Farka, C., 2000. Der Kirchenberg. Archäologie und Geschichte im Bereich der Marienkirche von Bad Deutsch-Altenburg, Niederösterreich. Hollitzer Baustoffwerke, Bad Deutsch-Altenburg, 199 pp.

Favaretto, I., Vio, E., Minguzzi, S., da Villa Urbani, M., 2000. Marmi della Basilica di San Marco: capitelli, plutei, rivestimenti, arredi. Rizzoli, Milano, 223 pp.

Fuchs, W., Wessely, G., Grill, R., 1985. 61 Hainburg an der Donau – 62 Pressburg. Geologische Karte der Republik Österreich 1:50000, Geologische Bundesanstalt, Wien.

Gadermayr, N., Kurzweil, H., Strasser, W., 2014. Petrografie und ausgewählte technische Eigenschaften von Inschriftenträgern aus dem römischen Tempelbezirk auf dem Pfaffenberg bei Carnuntum. Jahrbuch der Geologischen Bundesanstalt, 154/1–4, 41–70.

Genser, K., 2006. Die Entwicklung des oberpannonischen Limes bis Kaiser Hadrian. In: Humer, F., Legionsadler und Druidenstab: Vom Legionslager zur Donaumetropole. Textband, Sonderaustellung aus Anlass des Jubiläums „2000 Jahre Carnuntum", Archäologisches Museum Carnuntinum, Bad Deutsch-Altenburg, 21. März 2006–11. November 2007, St. Pölten, Amt der Niederösterreichischen Landesregierung, Abteilung Kultur und Wissenschaften, St. Pölten, 73–84.

Geng-Sesztak, G., Krems, W., Lachmayer, H., 2000. Bad Deutsch-Altenburg – Bild einer Gegend. Böhlau, Wien, 360 pp.

Geng-Sesztak, G., Springer, K., 2000. Die Steinbrüche. In: Geng-Sesztak, G., Krems, W., Lachmayer, H. (eds.), Bad Deutsch-Altenburg – Bild einer Gegend. Böhlau, Wien, pp. 285–311.

Grammer, B., Draganits, E., Gretscher, M., Muss, U., 2017. LiDAR-guided archaeological surveys: Lessons from the ancient Greek polis of Colophon (Ionia, Western Anatolia). Archaeological Prospection, 24, 311–333, https://doi.org/10.1002/arp.1572.

Groller, M., 1900. Topographie der Umgebung von Carnuntum. Der Römische Limes in Österreich, I, Alfred Hölder, Wien, 11–18.

Groller, M., 1902. Straßenforschung. Der Römische Limes in Österreich, III, Alfred Hölder, Wien, 5–18.

Gugl, C., 2006. Die Anfänge des Carnuntiner Legionslagers. In: Humer, F. (ed.), Legionsadler und Druidenstab: Vom Legionslager zur Do-

naumetropole. Textband, Sonderaustellung aus Anlass des Jubiläums „2000 Jahre Carnuntum", Archäologisches Museum Carnuntinum, Bad Deutsch-Altenburg, 21. März 2006–11. November 2007, St. Pölten, Amt der Niederösterreichischen Landesregierung, Abteilung Kultur und Wissenschaften, St. Pölten, 220–228.

Gugl, C., 2015. Carnuntum. Legionslager – canabae legionis – Auxiliarkastell – Stadt. In: Gassner, V., Pülz, A., Der römische Limes in Österreich. Führer zu den archäologischen Denkmälern, Österreichische Akademie der Wissenschaften, Wien, 278–291.

Hanisch, A., Schmid, H., 1901. Österreichs Steinbrüche. Verzeichnis der Steinbrüche, welche Quader, Stufen, Pflastersteine, Schleif- und Mühlsteine oder Dachplatten liefern. Carl Graeser & Co., Wien, 352 pp., http://www.literature.at/viewer.alo?viewmode=fullscreen&objid=10245 (accessed on 10 March 2022).

Gugl, C., Kastler, R., 2007. Legionslager Carnuntum. Ausgrabungen 1968–1977, Der Römische Limes in Österreich, 45. Verlag der Österreichischen Akademie der Wissenschaften, Wien, 554 pp.

Harzhauser, M., Daxner-Höck, G., Piller, W.E., 2003. An integrated stratigraphy of the Pannonian (Late Miocene) in the Vienna Basin. Austrian Journal of Earth Sciences, 95–96, 6–19.

Harzhauser, M., Piller, W.E., 2004. Integrated stratigraphy of the Sarmatian (Upper Middle Miocene) in the western Central Paratethys. Stratigraphy, 1/1, 65–86.

Harzhauser, M., Peckmann, J., Birgel, D., Draganits, E., Huemer, J., Mandic, O., Theobalt, D., 2014. Stromatolite formation in the Paratethys Sea during the Middle-Miocene Climate Transition as witness of the Badenian Salinity Crisis. Facies, 60, 429–444, https://doi.org/10.1007/s10347-013-0391-z.

Harzhauser, M., Kranner, M., Mandic, O., Strauss, P., Siedl, W., Piller, W.E., 2020. Miocene lithostratigraphy of the northern and central Vienna Basin (Austria). Austrian Journal of Earth Sciences, 113/2, 169–200, https://doi.org/10.17738/ajes.2020.0011.

Hauer, F., 1873. Catalog ihrer Ausstellungs-Gegenstände bei der Wiener Weltausstellung. K. K. Geologische Reichsanstalt, Wien, 200 pp.

Häusler, H., 2010. Erläuterungen zur Geologischen Karte 78 Rust. Geologische Karte der Republik Österreich 1:50000, Geologische Bundesanstalt, Wien, 191 pp.

Häusler, H., 2019. Erläuterungen zur Geologischen Karte 77 Eisenstadt. Geologische Karte der Republik Österreich 1:50000, Geologische Bundesanstalt, Wien, 211 pp.

Heinrich, M., Kollar, B., Moshammer, B., Rabeder, J., Doneus, M., 2010. Aufnahme historischer Steinbrüche im Leithagebirge. PANGEO AUSTRIA 2010, 15.-19. Sept. 2010, Leoben, Abstract Volume, Journal of Alpine Geology, 52, 137–138.

Henner, H., 1819. Gemeinde Deutschaltenburg in N:ÖsterreichV:U:W:W. Franziszeischer Kataster, 1:2 800, Wien.

Hermann, P., Pascher, G., Pistotnik, J., 1993. 78 Rust. Geologische Karte der Republik Österreich 1:50000, Geologische Bundesanstalt, Wien.

Hohenegger, J., Ćorić, S., Wagreich, M., 2014. Timing of the Middle Miocene Badenian Stage of the Central Paratethys. Geologica Carpathica, 65/1, 55–66, https://doi.org/10.2478/geoca-2014-0004.

Hohensinner, S., Lager, B., Sonnlechner, C., Haidvogl, G., Gierlinger, S., Schmid, M., Krausmann, F., Winiwarter, V., 2013. Changes in water and land: the reconstructed Viennese riverscape from 1500 to the present. Water History, 5, 145–172, https://doi.org/10.1007/s12685-013-0074-2.

Horváth, F., Bada, G., Szafián, P., Tari, G., Ádám, A., Cloetingh, S., 2006. Formation and deformation of the Pannonian basin: Constraints from observational data. In: Gee, D.G., Stephenson, R.A., European lithosphere dynamics. Geological Society, London, Memoirs, 32, 191–206.

Hudson, J.A., Cosgrove, J.W., 2019. Understanding building stones and stone buildings. CRC Press/Balkema, Leiden, 349 pp.

Humer, F., 2014. Carnuntum: wiedergeborene Stadt der Kaiser. Philipp von Zabern, Mainz, 168 pp.

Humer, F., Konecny, A., Maschek, D., 2005. Zivilstadt Carnuntum – Haus I. Die Grabungen im römischen Stadtviertel des Archäologischen Parks Carnuntum in den Jahren 2001 und 2002. Carnuntum Jahrbuch, 2004, 89–177.

Insulander, S., Kronberger, M., Moshammer, B., Mosser, M., 2018. Stone Objects from Vindobona (Austria): Provenance of local stone in a historico-economical setting. In: Coquelet, C., Creemers, G., Dreesen, R., Goemaere, É. (eds.), Roman ornamental stones in North-Western Europe. Natural resources, manufacturing, supply, life & after-life. Études et Documents Archéologie, 38, Namur, 151–162.

Jobst, W., 2021. Das Heiligtum des Jupiter Optimus Maximus auf dem Pfaffenberg/Carnuntum. Ausgrabungen und Funde im Spannungsfeld der Interessen. Der römische Limes in Österreich, 41/3, Österreichische Akademie der Wissenschaften, Wien, 990 pp.

Jobst, W., Rudolf, E., Dinstl, A., Gabler, D., Knibbe, K., Rauchenwald, A., 1988. Carnuntum-Zivilstadt 1986–87. Bericht der Ausgrabungen. Carnuntum Jahrbuch, 1987, 151–240.

Jovanovic-Kruspel, S., Schumacher, A., 2014. Das Naturhistorische Museum – Baugeschichte, Konzeption & Architektur. Naturhistorisches Museum Wien, Wien, 264 pp.

Kandler, H., 2000. Der Kirchenberg von Bad Deutsch-Altenburg und seine archäologischen Denkmäler. In: Farka, C. (ed.), Der Kirchenberg. Archäologie und Geschichte im Bereich der Marienkirche von Bad Deutsch-Altenburg, Niederösterreich, Hollitzer Baustoffwerke, Bad Deutsch-Altenburg, 13–38.

Karl, S., 2021. Das römerzeitliche Marmorsteinbruchrevier Spitzelofen in Kärnten: Montanarchäologische Forschungen. Fundberichte aus Österreich Beihefte, 1, 240 pp.

Karrer, F., 1886. Die Monumentalbauten in Wien und ihre Baumaterialien. Monatsblätter des Wissenschaftlichen Club in Wien, VII/6, Ausserordentliche Beilage Nr. III, 51–61.

Karrer, F., 1900. Aus Carnuntum. Monatsblätter des Wissenschaftlichen Club in Wien, XXII/1, 2–6.

Kaur, G., Frascá, M.H., Pereira, D., 2021. Natural stones: Architectonic heritage and its global relevance. Episodes, 44/1, 80 pp.

Kaus, M., 1991. Das frühurnenfelderzeitliche Steinkistengrab von Sommerein – Stockäcker. Archäologie Österreichs, 2/1, 27–30.

Keferstein, C., 1828. Teutschland, geognostisch-geologisch dargestellt und mit Charten und Durchschnittszeichnungen erläutert. 5/3, Landes-Industrie-Comptoir, Weimar, 425–454.

Kerschner, M., Prochaska, W., 2011. Die Tempel und Altäre der Artemis in Ephesos und ihre Baumaterialien. Jahreshefte des Österreichischen Archäologischen Institutes in Wien, 80, 73–154.

Kieslinger, A., 1949. Die Steine von St. Stephan. Herold, Wien, 486 pp.

Kieslinger, A., 1972. Die Steine der Wiener Ringstrasse: Ihre technische und künstlerische Bedeutung. Die Wiener Ringstrasse. Bild einer Epoche, Band IV, Franz Steiner Verlag, Wiesbaden, 665 pp.

Kokalj, Z., Hesse, R., 2017. Airborne laser scanning raster data visualization – A guide to good practice. Prostor – Kraj – Čas, 14, Založba ZRC, Ljubljana, 88 pp.

Kokalj, Z., Somrak, M., 2019. Why not a single image? Combining visualizations to facilitate fieldwork and on-screen mapping. In: Verhoeven, G., Cowley, D., Traviglia, A. (eds.), Archaeological remote sensing in the 21st-century: (re)defining practice and theory. Remote Sensing, 11/7, 747, https://doi.org/10.3390/rs11070747.

Κοκκορού-Αλευρά, Γ., Πουπάκη, Ε., Ευσταθόπουλος Α., 2010. Αρχαία ελληνικά λατομεία. Οργάνωση χώρου και εργασίας, τεχνικές λατόμησης και λάξευσης, τρόποι μεταφοράς, κόστος, διασπορά και χρήση λίθων (Ancient Greek quarries. Work and space organization, mining and hewing techniques, methods of transport, cost, dissemination and use of stone). Πολιτιστικό Ίδρυμα Ομίλου Πειραιώς, Αθήνα, 83 pp.

Korres, M., 1988. The geological factor in ancient Greek architecture. In: Marinos P.G., Koukis G.C., The engineering geology of ancient works, monuments and historical sites: preservation and protection. Proceedings of an international symposium organized by the Greek national group of IAEG, Athens, 19–23 September 1988, Vol. 3, Balkema, Rotterdam, 1779–1793.

Korres, M., 2000. The stones of the Parthenon. Melissa, Athens, 69 pp.

Kremer, G., 2012. Götterdarstellungen, Kult- und Weihedenkmäler aus Carnuntum. Corpus signorum imperii romani, Carnuntum Supplement, 1, Verlag der Österreichischen Akademie der Wissenschaften, Wien, 696 pp.

Kremer, G., Uhlir, C., Unterwurzacher, M., 2009. Kult- und Weihedenkmäler aus Marmor in Carnuntum. In: Gaggadis-Robin, V., Hermary,

A., Redde, M., Sintes, C. (eds.), Les ateliers de sculpture régionaux: techniques, styles et iconographie. Actes du Xe colloque international sur l'art provincial romain, Arles & Aix-en-Provence, 21–23 Mai 2007, 663–681.

Kremer, G., Kitz, I., Moshammer, B., Heinrich, M., Draganits, E., 2018. Stone monuments from Carnuntum and surrounding areas (Austria) – Petrological characterization and quarry location in a historical context. In: Matetić Poljak, D., Marasović, K. (eds.), ASMOSIA XI – Interdisciplinary Studies of Ancient Stone. Proceedings of the Eleventh International Conference of ASMOSIA, Split, 18–22 May 2015, 557–565.

Kremer, G., Insulander, S., Draganits, E., Kronberger, M., Moshammer, B., Mosser, M., Rohatsch, A., 2021. Stone Supply for Carnuntum and Vindobona – Provenance Analysis in a Historico-Economical Context. In: van Limbergen, D., Taelman, D. (eds.), The Exploitation of Raw Materials in the Roman World: A Closer Look at Producer-Resource Dynamics, Panel 4.4, Proceedings of the 197th International Congress of Classical Archaeology, Cologne/Bonn, 22–26 May 2018, Archaeology and Economy in the Ancient World 27. Propyleum, Heidelberg, 47–62, https://doi.org/10.11588/propylaeum.706

Kronberger, M., 2005. Siedlungschronologische Forschungen zu den canabae legionis von Vindobona. Die Gräberfelder. Monografien der Stadtarchäologie Wien, 1. Phoibos, Wien, 342 pp.

Kronberger, M., Mosser, M., 2015. Wien – Vindobona. Legionslager – canabae legionis – Zivilsiedlung. In: Gassner, V., Pülz, A. (eds.), Der römische Limes in Österreich. Führer zu den archäologischen Denkmälern, Österreichische Akademie der Wissenschaften, Wien, 242–267.

Kronberger, M., Heinrich, M., Moshammer, B., Mosser, M., 2010. Preliminary results of an interdisciplinary project on Roman stone material and historic quarries in Vienna. In: Láng, O., Stipanits, U. (eds.), Vindobona – Aquincum. Herausforderungen und Ergebnisse in der Stadtarchäologie. Aquincum Nostrum, II.6, 61–68.

Lachmayer, H., 1999. Steinbruch. Hollitzer Wissenschaftsverlag, Wien, 80 pp.

Lezzerini, M., Pagnotta, S., Legnaioli, S., Palleschi, V., 2019. Walking in the streets of Pisa to discover the stones used in the Middle Ages. Geoheritage, 11, 1631–1641, https://doi.org/10.1007/s12371-019-00372-3.

Loisl, J., Tari, G., Draganits, E., Zámolyi, A., Gjerazi, I., 2018. High-resolution seismic reflection data acquisition and interpretation, Lake Neusiedl, Austria, NW Pannonian Basin. In: Németh, B., Tari, G., Radivojević, D., Tomljenovic, B., Krézsek, C. (eds.), Special section: Characterization of hydrocarbon and geothermal resource potential and carbon sequestration opportunities of the Pannonian Basin. Interpretation, 6/1, SB77–SB97, https://doi.org/10.1190/INT-2017-0086.1.

<lupa.at> Harl, F., Harl, O., Ubi erat lupa. Bilddatenbank zu antiken Steindenkmälern. http://lupa.at (accessed on 10 March 2022).

Mackensen, M., 2010. Das severische Vexillationskastell Myd(---)/Gheriat el-Garbia am limes Tripolitanus (Libyen). Bericht über die Kampagne 2009. Mitteilungen des Deutschen Archäologischen Instituts Römische Abteilung, 116, 363–458.

Malecki, G., Heinrich, M., 1999. Lagerstättendokumentation und Rohstoffforschung. In: Bachl-Hofmann, C., Cernajsek, T., Hofmann, T., Schedl, A., (eds.), Die Geologische Bundesanstalt in Wien: 150 Jahre Geologie im Dienste Österreichs (1849–1999), Böhlau, Wien, 524–531.

Marinoni, J.J., c. 1717. Mappa über die zwischen dem Löbl Kloster Monserrat, und dem Jungfrau Kloster zu Thuln, durch vergleich vertauschte vierachtel Weingarten, wie auch über die verglichene beyder seits Grundbuch granitz Scheidung. Wiener Archivinformationsystem, Signatur: 2.2.6.10.A1.6.6, https://www.wien.gv.at/actaproweb2/benutzung/image.xhtml?id=PWyKuP-8guOpQk8OoEt5uKeM0+8OkdD4Jp25sfgC2ACs1 (accessed on 10 March 2022).

Maschek, D., 2008. Neue Untersuchungen im sog. „Peristylhaus" der Zivilstadt Carnuntum. In: Grabherr, G., Kainrath, B. (eds.), Akten des 11. Österreichischen Archäologentages in Innsbruck, 23.–25. März 2006, IKARUS 3. University Press, Innsbruck, 159–166.

Masriera, A., Caminal, A., Navarro, R., Planella, V., Samper, J.A., 2005. Les roques del Temple de la Sagrada Família. Un itinerari petrogràfic a través dels seus elements arquitectònics i ornamentals. Treballs del Museu de Geologia de Barcelona, 13, 83–113.

Maynzeck, J.H., 1717. Mappa continens dominia inter Posonium et Neostadium, vel integra vel partes Leita fluvio adiacentes, cursum Leita in hoc tracta et partem Danubii. 160 x 35 cm. Magyar Nemzeti Levéltár, Budapest, 70, No. 30, https://maps.hungaricana.hu/en/MOLTerkeptar/11032 (accessed on 10 March 2022).

Molnár, G., Timá, G., Biszak, E., 2014. Can the First Military Survey maps of the Habsburg Empire (1763–1790) be georeferenced by an accuracy of 200 meters? 9th International Workshop on Digital Approaches to Cartographic Heritage Budapest, 4–5 September 2014, 127–132.

McMillan, A.A., Gillanders, R.J., Fairhurst, J.A., 1999. Building Stones of Edinburgh. 2nd ed., Edinburgh Geological Society, Edinburgh, 235 pp.

Moshammer, B., Rohatsch, A., Hodits, B., Draganits, E., Heinrich, M., Kremer, G., Kronberger, M., Mosser, M., Insulander, S., Kitz I., 2018. Applied geological and cultural aspects of Leitha Limestone in Roman times (Middle Miocene, Eastern Austria). Geophysical Research Abstracts, 20, EGU2018-18923.

Mosser, M., 2003. Die Steindenkmäler der legio XV Apollinaris. Wiener Archäologische Studien, 5, Forschungsgesellschaft Wiener Stadtarchäologie, Wien, 319 pp.

Mosser, M., Adler-Wölfl, K., Binder, M., Chinelli, R., Chmelar, W., Czeika, S., Dembski, G., Gruppe, S., Gschwantler, K., Hejl, E., Jäger-Wersonig, S., Jawecki, C., Kieweg-Vetters, G., Litschauer, C., Öllerer, C., Sakl-Oberthaler, S., Tarcsay, K., Wedenig, R., 2010. Die römischen Kasernen im Legionslager Vindobona. Die Ausgrabungen am Judenplatz in Wien in den Jahren 1995–1998, Monografien der Stadtarchäologie Wien, 5, Museen der Stadt Wien – Stadtarchäologie, Wien, 1016 pp.

Murphy, M.A., Salvador, A., 1999. International Stratigraphic Guide — An abridged version. Episodes, 22/4, 255–271, https://doi.org/10.18814/epiiugs/1999/v22i4/002.

Müller, M., Mader, I., Chinelli, R., Jäger-Wersonig, S., Sakl-Oberthaler, S., Eisenmenger, U., Czeika, S., Litschauer, C., Öllerer, C., Eleftheriadou, E., 2011. Entlang des Rennwegs. Die römische Zivilsiedlung von Vindobona. Wien Archäologisch, 8, Stadtarchäologie Wien, Wien, 136 pp.

Opitz, R.S., Cowley, D.C., 2013. Interpreting archaeological topography: Airborne laser scanning, 3D data and ground observation. Oxbow Books, Oxford, 268 pp.

Papageorgakis, J., Mposkos, E., 1988. Building stones of the Minoan Palace of Knossos. In: Marinos P.G., Koukis, G.C. (eds.), The Engineering Geology of Ancient Works, Monuments and Historical Sites: Preservation and Protection. Vol. 2, Balkema, Rotterdam, 649–659.

Partsch, P., 1831. Geognostische Bemerkungen über die Artesischen Brunnen in und um Wien. Gerold, Wien, 27–48.

Pearson, M.P., Pollard, J., Richards, C., Welham, K., Casswell, C., French, C., Schlee, D., Shaw, D.,

Simmons, E., Stanford, A., Bevins, R., Ixer, R., 2019. Megalith quarries for Stonehenge's bluestones. Antiquity, 93/367, 45–62, https://doi.org/10.15184/aqy.2015.177.

Pereira, D., Marker, B.R., Kramar, S., Cooper, B.J., Schouenborg, B.E., 2015. Global heritage stone: Towards international recognition of building and ornamental stones. Geological Society London Special Publications, 407, 275 pp.

Piller, W.E., Harzhauser, M., 2005. The myth of the brackish Sarmatian Sea. Terra Nova, 17, 450–455, https://doi.org/10.1111/j.1365-3121.2005.00632.x.

Piller, W.E., Harzhauser, M., Mandic, O., 2007. Miocene Central Paratethys stratigraphy – current status and future directions. Stratigraphy, 4/2–3, 151–168.

Piller, W.E., Egger, H., Erhart, C.W., Gross, M., Harzhauser, M., Hubmann, B., van Husen, D., Krenmayr, H.-G., Krystyn, L., Lein, R., Lukeneder, A., Mandl, G., Rögl, F., Roetzel, R., Rupp, C., Schnabel, W., Schönlaub, H.P., Summesberger, H., Wagreich, M., Wessely, G., 2004: Die stratigraphische Tabelle von Österreich 2004 (sedimentäre

Schichtfolgen). Kommission für die paläontologische und stratigraphische Erforschung Österreichs der Österreichischen Akademie der Wissenschaften und Österreichische Stratigraphische Kommission, Wien.

Pivko, D., 2012. Miocene limestone as dressed stone for Carnuntum Roman town and surrounding settlements in Upper Pannonia (Austria, Slovakia, Hungary). In: Gutiérrez Garcia-Moreno, A., Pilar Lapuente Mercadal, P., Rodà de Llanza, I. (eds.), Interdisciplinary studies on ancient stone, Proceedings of the IX Association for the Study of Marbles and Other Stones in Antiquity (ASMOSIA) Conference, (Tarragona 2009). Documenta, 23, Institut Català d'Arqueologia Clàssica, Tarragona, 480–486.

Pivko, D., Hudáčková, N., Hrabovský, J., Sládek, I., Ruman, A., 2017. Palaeoecology and sedimentology of the Miocene marine and terrestrial deposits in the "Medieval Quarry" on Devínska Kobyla Hill (Vienna Basin). Geological Quarterly, 61/3, 549–568, https://dx.doi.org/10.7306/gq.1357.

Plöchinger, B., Karanitsch, P., 2002. Faszination Erdgeschichte mit Brennpunkt Mödling am Alpenostrand. Heimat Verlag, Mödling, 238 p.

Ratschbacher, L., Merle, O., Davy, P., Cobbold, P., 1991a. Lateral extrusion in the Eastern Alps, part I: boundary conditions and experiments scaled for gravity. Tectonics, 10, 245–256, https://doi.org/10.1029/90TC02622.

Ratschbacher, L., Frisch, W., Linzer, H.-G., Merle, O., 1991b. Lateral extrusion in the Eastern Alps, part II: structural analysis. Tectonics, 10, 257–271., https://doi.org/10.1029/90TC02623.

Rohatsch, A., 1991. St. Stephan – Herkunft, Petrographie und Verwitterung der Baugesteine des Albertinischen Chores. Mitteilungen der Gesellschaft der Geologie- und Bergbaustudenten Österreichs, 37, 141–155.

Rohatsch, A., 2005. Neogene Bau- und Dekorgesteine Niederösterreichs und des Burgenlandes. In: Schwaighofer, B., Eppenstiner, W. (eds.), „Junge" Kalke, Sandsteine und Konglomerate – Neogen. Nutzbare Gesteine von Niederösterreich und Burgenland, Mitteilungen IAG BOKU, 9–56.

Rohatsch, A., 2017. Die geologischen Verhältnisse und die historische Steingewinnung von Winden am See. In: Gemeinde Winden am See (ed.), 800 Jahre Winden am See, 1217 – 2017, Gemeinde Winden am See, Winden am See, 3–37.

Rohatsch, A., Moshammer, B., Hodits, B., Draganits, E., Heinrich, M., 2016. Steindenkmäler und Steingewinnung im Raum Carnuntum-Vindobona – Vorstellung des geologischen Teils eines interdisziplinären Projektes. In: Humer, F., Kremer, G., Pollhammer, E., Pülz, A. (eds.), Akten der 3. Österreichischen Römersteintagung in Carnuntum, 2.-3. Oktober 2014, Hainburg a. d. Donau, Amt der NÖ Landesregierung, Abteilung Kunst und Kultur, Wien, 177–183.

Rohatsch, A., Kronberger, M., Insulander, S., Mosser M., Hodits, B., 2018. Stone objects from Vindobona (Austria) – Petrological characterization and provenance of local stone in a historico-economical setting. In: Matetić Poljak, D., Marasović, K. (eds.), ASMOSIA XI – Interdisciplinary Studies of Ancient Stone. Proceedings of the Eleventh International Conference of ASMOSIA, Split, 18–22 May 2015, 363–372.

Roth, L., 1883. Geologische Notitzen aus dem Leithagebirge. Föltany Közlöny, 13, 257–264.

Royden, L.H., 1985. The Vienna Basin: A thin-skinned pull-apart basin. In: Biddle, K.T., Christie-Blick, N. (eds.), Strike slip deformation, basin formation and sedimentation. Society for Sedimentary Geology Special Publication, 37, 319–338, https://doi.org/10.2110/pec.85.37.0303.

Russell, B., 2013a. The Economics of the Roman Stone Trade. Oxford Studies on the Roman Economy, Oxford University Press, Oxford, 449 pp.

Russell, B., 2013b. Gazetteer of Stone Quarries in the Roman World. Version 1.0. http://oxrep.classics.ox.ac.uk/databases/stone_quarries_database (accessed on 10 March 2022).

Schaaff, H., 2016. Antike Tuffbergwerke am Laacher See-Vulkan. Monographien des Römisch-Germanischen Zentralmuseums, 107, Römisch-Germanisches Zentralmuseum, Mainz, 251 pp.

Schafarzik, F., 1909. Detaillierte Mitteilungen über die auf dem Gebiete des ungarischen Reiches befindlichen Steinbrüche. Publikationen der königlich ungarischen Geologischen Reichsanstalt, Budapest, 544 pp.

Schmid, H., 1894. Die Kalksteinbrüche der Randgebirge des Wiener Beckens, insbesondere des Leithagebirges. Der österr. ungar. Bildhauer und Steinmetz: Officielles Organ der Wiener Bildhauer-Genossenschaft, 2/15, 241–243; 2/16, 259–261; 2/17, 277–279; 2/18, 293–295; 2/19, 309–311.

Schmid, H., 1968. Das Jungtertiär an der SE-Seite des Leithagebirges zwischen Eisenstadt und Breitenbrunn (Burgenland). Wissenschaftliche Arbeiten aus dem Burgenland, 41, 1–74.

Schmieger, A., 1924 Die Türkenschanze. In: Währinger Heimatkunde (ed.), Währing. Ein Heimatbuch des 18. Wiener Gemeindebezirkes. 2. Teil, Währinger Heimatkunde, Wien, 161–173, https://austria-forum.org/web-books/wahring02de1924iicm/000073 (accessed on 10 March 2022).

Schmitsberger, O., Brandl, M., Penz, M., 2019. Neu entdeckte Radiolaritabbaue in Wien. Bedeutung und Nutzung der St. Veiter Klippenzone im Neolithikum. Archaeologia Austriaca, 103, 163–174, https://doi.org/10.1553/archaeologia103s163.

Schönlaub, H.P., 2000. Burgenland – Erläuterungen zur Geologischen Karte des Burgenlandes 1:200000. Geologie der Bundesländer, Geologische Bundesanstalt, Wien, 130 pp.

Schmölzer, A., 1933. Die Bausteine des Leithagebirges. Burgenländische Heimatblätter, 2, 145–157.

Schuster, R., Daurer, A., Krenmayr, H.-G., Linner, M., Mandl, G.W., Pestal, G., Reitner, J.M., 2019. Rocky Austria. The geology of Austria – brief and colourful, 3rd ed., Geological Survey of Austria, Vienna, 80 pp.

Seemann, R., Summesberger, H., 1999. Wiener Steinwanderwege. Brandstätter, Wien, 159 p.

Siedl, W., Strauss, P., Sachsenhofer, R.F., Harzhauser, M., Kuffner, T., Kranner, M., 2020. Revised Badenian (middle Miocene) depositional systems of the Austrian Vienna Basin based on a new sequence stratigraphic framework. Austrian Journal of Earth Sciences, 113/1, 87–110, https://doi.org/10.17738/ajes.2020.0006.

Sohs, F., 1963. Das Neogen am Westrande des Leithagebirges (zwischen Hornstein und Sommerein). Dissertation, Universität Wien, Wien, 191 pp.

Soles, J.S., 1983. A Bronze Age quarry in Eastern Crete. Journal of Field Archaeology, 10/1, 33–46, https://doi.org/10.1179/009346983791504390.

Springer, K., Sacken, K., 2000. Bad Deutsch-Altenburg: Fotos – Bilder – Karten. Eine Dokumentation. Hollitzer Baustoffwerke, Bad Deutsch-Altenburg, 48 pp. and 8 CD-ROMs.

Streffleur, J. c., 1840. Dorf Deutsch Altenburg sammt Umgebung. 1:1 728, 58.5 x 72.5 cm, Országos Széchényi Könyvtár, Budapest, TK 2074, https://maps.hungaricana.hu/en/OSZKTerkeptar/2073 (accessed on 10 March 2022).

Summesberger, H., Seemann, R., 2008. Geologische Spaziergänge Wien Innere Stadt: Vom Maria-Theresien-Denkmal zum Stephansdom. Geologische Bundesanstalt, Wien, 64 pp.

Thür, H., 2000. Der Tempelbezirk auf dem Pfaffenberg. In: Geng-Sesztak, G., Krems, W., Lachmayer, H. (eds.), 2000. Bad Deutsch-Altenburg – Bild einer Gegend. Böhlau, Wien, 315–325.

Timár, G., Biszak, S., 2010. Digitizing and georeferencing of the historical cadastral maps (1856–60) of Hungary. In: Livieratos, E., Gartner, G. (eds.), Proceedings of the 5th International Workshop on Digital Approaches in Cartographic Heritage. Vienna, 22–24 February 2010, 559–564.

Timár G., Biszak S., Székely B., Molnár G., 2010. Digitized Maps of the Habsburg Military Surveys – Overview of the Project of ARCANUM Ltd. (Hungary). In: Jobst, M. (ed.), Preservation in Digital Cartography. Lecture Notes in Geoinformation and Cartography. Springer, Berlin, 273–283.

Timár, G., Molnár, G., Székely, B., Biszak, S., Varga, J., Jankó, A., 2006. Digitized maps of the Habsburg Empire: The map sheets of the Second Military Survey and their georeferenced version. Arcanum, Budapest, 59 pp.

Toula, F., 1906. Geologische Exkursionen im Gebiete des Liesing- und

des Mödlingbaches. Vorarbeiten für eine in Vorbereitung befindliche geologische Karte im Maßstabe 1:25000. Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt, 55/1, 243–326.

Tragau, C., 1897. Ausgrabungen in Carnuntum. I. Die Befestigungsanlagen von Carnuntum. Archäologisch-epigraphische Mitteilungen aus Österreich-Ungarn, 20, 173–204.

Trnka, G., 2011. The Neolithic radiolarite mining site of Wien – Mauer-Antonshöhe (Austria). In: Biró, K.T., Markó, A. (eds.), Emlékkönyv Violának. Papers in honour of Viola T. Dobosi. Hungarian National Museum, Budapest, 287–296.

Ulbrich, K., 1952. Die Grenzkarte Ungarn-Niederösterreich von C. J. Walter (1754–56). Burgenländische Heimatblätter, 14, 108–121.

Unterwurzacher, M., Uhlir, C., Kremer, G., 2010. The provenance of marble artefacts from the Roman metropolis of "Carnuntum", Austria. Geologia Colombiana, 35, 162–174.

Unterwurzacher, M., Uhlir, C., 2012. Monumente aus Marmor – Materialanalyse und Herkunftsbestimmung. In: Kremer, G. (ed.), Götterdarstellungen, Kult- und Weihedenkmäler aus Carnuntum. Corpus signorum imperii romani, Carnuntum Supplement 1, Verlag der Österreichischen Akademie der Wissenschaften, Wien, 421–430.

Waelkens, M., de Paepe, P., Moens, L., 1990. The quarrying techniques of the Greek World. In: True, M., Podany, J. (eds.), Marble: Art historical and scientific perspectives on ancient sculpture. Papers delivered at a symposium organized by the Departments of Antiquities and Antiquities Conservation and held at the J. Paul Getty Museum April 28–30, 1988, J. Paul Getty Museum, Malibu, 47–72.

Walter, C.I., 1754–1756. Aufnahmskarte der wirklichen Grenzen zwischen dem Königreich Ungarn u. dem Erzherzoghtum Österreich unter der Ens ... 1:13 700, HM Hadtörténeti Intézet és Múzeum, B IX c 1402, https://maps.hungaricana.hu/en/HTITerkeptar/2925/?list=eyJxdWVyeSI6ICJ3YWx0ZXIifQ (accessed on 10 March 2022).

Weber-Hiden, I., 2017. Die ältesten Inschriften aus Carnuntum. In: Kovács, P. (ed.), Tiberius in Illyricum. Contributions to the history of the Danubian provinces under Tiberius' reign (14–37 AD). University of Debrecen, Department of Classical Philology and Ancient History, Budapest, 193 pp.

Wessely, G., 1961. Geologie der Hainburger Berge. Jahrbuch der Geologischen Bundesanstalt, 104, 273–349.

Wessely, G., 2006. Niederösterreich. Geologie der österreichischen Bundesländer, Geologische Bundesanstalt, Wien, 416 pp.

Wessely, G., 2007. Geologie und Paläontologie von Bad Vöslau (Niederösterreich). Jahrbuch der Geologischen Bundesanstalt, 147/1–2, 419–448.

Wiedl, T., Harzhauser, M., Piller, W.E., 2012. Facies and synsedimentary tectonics on a Badenian carbonate platform in the southern Vienna Basin (Austria, Central Paratethys). Facies, 58, 523–548, https://doi.org/10.1007/s10347-011-0290-0.

Wiedl, T., Harzhauser, M., Kroh, A., Ćorić, S., Piller, W.E., 2013. Ecospace variability along a carbonate platform at the northern boundary of the Miocene reef belt (Upper Langhian, Austria). Palaeogeography Palaeoclimatology Palaeoecology, 370, 232–246, https://doi.org/10.1016/j.palaeo.2012.12.015.

Wiedl, T., Harzhauser, M., Kroh, A., Ćorić, S., Piller, W.E., 2014. From biologically to hydrodynamically controlled carbonate production by tectonically induced palaeogeographic rearrangement (Middle Miocene, Pannonian Basin). Facies, 60, 865–881, https://doi.org/10.1007/s10347-014-0408-2.

Willvonseder, K., 1938. Das Steinkistengrab der älteren Urnenfelderzeit von Illmitz im Burgenland. Wiener Prähistorische Zeitschrift, 25, 1938, 109–128.

Wurster, W., 1969. Antike Steinbrüche an der westlichen Nordküste Aeginas. Archäologischer Anzeiger, 1969, 16–31.

Zámolyi, A., Salcher, B., Draganits, E., Exner, U., Wagreich, M., Harzhauser, M., Gier, S., Fiebig, M., Lomax, J., Surányi, G., Diehl, M., Zámolyi, F., 2017. Latest Pannonian and Quaternary evolution at the transition between Eastern Alps and Pannonian Basin: new insights from geophysical, sedimentological and geochronological data. International Journal of Earth Sciences, 106, 1695–1721, https://doi.org/10.1007/s00531-016-1383-3.

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