

**The Gralheira lode in the territorium metallorum Tresminas/Jales.
A "treasure trove" of ancient mining technology**

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Abstract

The little-known Roman gold mining site "Gralheira" is located near the well-explored mine of Tresminas. The 2.5 km long, almost dead straight archaeological monument from the first and second centuries AD is currently under threat from possible mining activities on the one hand and from modern waste disposal in the pits on the other. Since 2019, the Roman mining traces have been investigated by means of intensive field inspections, terrestrial 3d laser scanning and aerial photography. The following article will present first impressions and findings on this structure, as well as questions and preliminary interpretations.

Introduction

Southwest of the known Roman mine at Tresminas and northeast of the gold mine of Campo de Jales, which was in operation until the early 1990s, lies the very poorly known gold deposit of Gralheira (Concelho Vila Pouca de Aguiar, Distrito Vila Real, Portugal). The still largely unknown mining site, located in the middle of the *territorium metallorum* Tresminas/Jales (fig. 1), was intensively exploited by the Romans, mainly in the 1st and 2nd centuries AD.¹ The very straight ore vein can be traced over 7 km with only short interruptions (fig. 2), and along it, traces of Roman mining can be tracked on the surface over a length of about 2.5 km (fig. 3). About 13 km to the east of this zone and in direct continuation of its line, there is another mining zone probably also exploited in antiquity (fig. 4). The veins are anastomizing, alternatively splitting and converging. Although only the traces of mining preserved on the surface are currently accessible, this has already allowed the collection of a wealth of technical details. Deeper lying areas are presently covered partly by the rubble from ancient mining and partly by modern waste, the possibility that further objects such as prospecting shafts remains.

In many places along the kilometre-long line of Roman "Pingen" (mining sink-holes)², cuts made into the rock have been preserved. These provide significant insights into ancient mining and are probably unique in the Roman Empire.³ This brings with it the challenge of documenting the remaining traces, interpreting them if possible, and finally submitting them to scientific discussion.

¹ WAHL 1997; WAHL-CLERICI/HELFFERT 2017, 51-54; ROSA 2001; WAHL-CLERICI 2020.

² "Pingen" are smaller or larger pits or even ditches from which ores or other raw materials were originally extracted. Usually, the miners followed the ore veins. Due to erosion over the centuries, the former mining sites, some of which were very deep, are now buried with rubble and are recognisable as terrain depressions.

³ It can be assumed that similar traces were preserved in the neighbouring Campo de Jales deposit until they were destroyed by renewed mining in the 20th century. It was not until the 20th century that other veins were discovered between the Jales and Gralheira deposits.

The gold was embedded in a quartz vein, together with small amounts of other metals such as copper, silver, arsenic and lead. This type of lode was already described in antiquity. Diodorus (1st half of the 1st century BC) gives us a vivid picture of the conditions and circumstances in the Nubian mines:

Diod. Sic. 3.1.1: “At the extremity of Egypt and in the contiguous territory of both Arabia and Ethiopia there lies a region which contains many large gold mines, where the gold is secured in great quantities with much suffering and at great expense. For the earth is naturally black and contains seams and veins of a marble which is unusually white and in brilliancy surpasses everything else which shines brightly by its nature, ...”⁴

The accompanying mineral in the deposit, which he called marble, is quartz, which also shines white. It was still referred to as marble about a hundred years later by Pliny the Elder (23-79 AD).

Plin. HN 33.68: The gold dug out of the shafts is called canalicium or canaliense and hangs on the marble gravel, ... These passages of the veins run along the walls of the shafts, and hither and thither, whence comes the name, ...⁵

Deposit and gold grade

The Gralheira deposit is formed by a series of steep, WNW-ESE striking quartz lenses and veins.⁶ They are hosted in about 440–360 million years old Silurian-Devonian shales.⁷ This has made it possible to mine them largely by open-pit methods. Since the ore vein is also cut by smaller valleys, mining could be at least partially drained by this topographical situation (fig. 2, fig. 3).

Hoists had to be installed to drain the deeper layers. Archimedean screws and water wheels were often used, such as those still found *in situ*, for instance in Rio Tinto or São Domingos.⁸ A bronze vessel, presumably from a similar installation in Campo de Jales and now kept in the Padre José Rafael Rodrigues Municipal Museum in Vila Pouca de Aguiar, is probably from a bucket-chain elevator. In addition to water, other material could be moved vertically with the help of different machines. So far, capstans could be shown to have been used in the Tresminas mine by the traces preserved in the rock of two structures in use and one abandoned during construction.⁹ Finally, the old-fashioned drainage method using buckets described by Pliny for the south of the Iberian Peninsula should also be mentioned as a possibility.¹⁰

⁴ “Περὶ γὰρ τὰς ἐσχατιὰς τῆς Αἰγύπτου καὶ τῆς ὁμορουσίας Ἀραβίας τε καὶ Αἰθιοπίας τόπος ἐστὶν ἔχων μέταλλα πολλὰ καὶ μεγάλα χρυσοῦ, συναγομένου πολλοῦ πολλῆ κακοπαθείᾳ τε καὶ δαπάνῃ. τῆς γὰρ γῆς μελαίνης οὐσης τῇ φύσει καὶ διαφύας καὶ φλέβας ἐχούσης μαρμάρου τῇ λευκότητι διαφερούσας καὶ πάσας τὰς περιλαμπομένας φύσεις ὑπερβαλλούσας τῇ λαμπρότητι, οἱ προσεδρεύοντες τοῖς μεταλλικοῖς ἔργοις τῶ πλήθει τῶν ἐργαζομένων κατασκευάζουσι τὸν χρυσόν.”; see on further texts of Diodorus on gold mining and processing WAHL-CLERICI 2020, 188-193.

⁵ Plin. HN 33.68: *Quod puteis foditur, canalicum, vocant, alii canaliense, marmoris glareae inhaerens, ... vagantur hi venarum canales per latera puteorum et huc illuc, inde nomine invento, tellusque ligneis columnis suspenditur.* English translation after ‘The natural history of Pliny the Elder’ (transl. J. BOSTOCK, H.T. RILEY), Bohn Library, London 1855-1857.

⁶ Recent research in the area of the castro of Cidadelha revealed that the ore veins recorded to the south of it are clearly ditches connected to the nearby Celtiberian settlement, cf. Fig. 2.

⁷ Notícia Explicativa da Folha-06-D (Vila Pouca de Aguiar), 1:500'000 Geological Map of Portugal.

⁸ DOMERGUE 2008, 35 Fig. 5 and 6.

⁹ WAHL-CLERICI 2020, 128-131; HELFERT ET AL. 2019.

¹⁰ Plin. HN 33.97.

Whether tunnels were also built in Roman times for the ore extraction and drainage of certain zones of the Gralheira deposit could not yet be determined. Maps elaborated during the prospectings in the 20th century show the two modern buildings Galeria Alfara and the Galeria Minhoteira, both opened during these works (fig. 5).

The deposit of Gralheira has been extensively evaluated by various mineral exploration companies in the last decades, unfortunately also involving the destruction of ancient traces during prospection, especially in the western parts. The values determined and published by prospecting companies range between 3.2 g Au/t and 143.0 g Au/t.¹¹

In his dissertation "Metallogenesis of the Jales Gold District, Northern Portugal" Rosa (2001) also provides information on the gold grades of Campo de Jales, Gralheira and Tresminas. He mentions a reserve of 5.8 tonnes of gold at a grade of 6.1 g/t to a depth of 180 m below the surface for the Gralheira deposit. Rosa also notes that the reserves are relatively small and hardly worth the effort of mining at the low gold price of 1998.¹² Since the price of gold has increased about sixfold since then, the risk of renewed mining is higher now, which could negatively impact this highly delicate and unique cultural heritage.¹³

Traces of mining

In addition to the elongated trenches, the dumps in particular constitute evidence of mining. They were deposited to the sides (north and south) of the trenches and despite their erosion still reach a considerable height (fig. 6). The dumps mainly consist of the barren rock material that had to be extracted after mining and which was subsequently sorted out in an initial process by "Klauben" (picking).¹⁴

In the open cuts, an abundance of cuts and carvings could be observed, which have been well preserved thanks to the strength of the rock and will be presented in the following.¹⁵ However, the interpretation of these findings is a challenge. This is mainly due to the lack of comparative examples, which is related to the factors of

¹¹ Between 8 g and 140 g Au/t: www.steliasmines.com/storage/news_releases/Sli-News-2009-01-Jales-Drill-Hole-FINDAL.pdf. Retrieved 2 March 2017. Between 2 and 140 g Au/t: Kernow Resources & Developments Ltd (KRD) <file:///C:/Users/regul/Desktop/4.2%20in%20editing/postt809.html>. Retrieved 12 November 2019. 41.92 g Au/t: Kernow Resources & Developments Ltd, Rua de Diogo Afonso, 71, Hab. 26, Porto 4150-254, Portugal News Release. March 4, 2006. Further sources: Important basis for this are the surveys by the Direcção Geral de Geologia e Minas (L° AP/211, N° 08292, 1985). Prospecting by mining companies: St. Elias, Kernow release Jales/Gralheira survey results. 2005-03-09 16:49 ET - News Release, www.resourceworld.com, August 2007 edition. - In 1990, an advanced plan for the exploitation of the Gralheira vein was presented by RTZ, Sociedade Mineira Rio Artezia, S.A., Bureau de recherches géologiques e minieres, Consórcio Gralheira. - See also the compilation by MARTINS/MARTINS 2017, 160-163, after OSMOND 2009 with the distribution of the measured values. - HARRISON published in 1931, 139 values between 24 and 77.8 g Au/t.

¹² ROSA 2001, 9; he mentions that currently the mining concession for the deposits of Campo, Gralheira and Tresminas is held by the Canadian Target Europe Company; gold price 1997/98: 262.34 Euro / ounce (= 31.1035 g); ROSA 2001, Fig. 48: finenesses Gralheira: 600-760; Campo de Jales: 500-840; Tresminas: 900-940.

¹³ Gold price 29.12.2019: 1351,86 Euro / Ounce, 24.03.2020: 1509 Euro / ounce, 10.03.2022: 1797.15 Euro / ounce.

¹⁴ This first step of preparation is not mentioned by Pliny in HN 33.68. For early modern examples see AGRICOLA/SCHIFFER 1994, 232, also BARTELS ET AL. 2006, 149.

¹⁵ The elongated trenches of Gralheira did not require struts to secure them, as was otherwise common in antiquity, cf. Pliny HN 33.71: "*relinquuntur itaque fornices crebri montibus sustinendis*". Translation: "One leaves vaulted arches with short spaces in between to support the mountains." – Detailed account of carpentry in the Gallic gold mines in the southwest of the Massif Central: CAUJET 2000, 129-146.

- Type of deposit¹⁶
- Quality of the host rock surrounding the deposit
- State of preservation

The Gralheira deposit is a partially anastomizing, subvertical vein in a very stable host rock, in which the gold ores are bound to the main mineral quartz and polymetallic sulfides. As far as can be understood, the Roman miners opened the mine from the slope surface and followed the prospective parts into the depths. The possible necessity of building gallery supports by timber was probably much less costly than in deposits in which the rock was not quite so stable.¹⁷

The strength and type of the rock is also important for other structures and for their preservation. The crystalline schist of the zone, belonging to the Douro Group, is extremely strong, as evidenced by the excellent state of preservation of the galleries of Tresminas.¹⁸ However, the rock surface is susceptible to weathering, so that the preservation of finer cuts or carvings depends on other conditions, such as protection from exposure to the weather.

An example of the poor preservation of fine structures are these of a reel on the surface of the Sifnos deposit.¹⁹ Also in the highly weathered granite of Boticas (near Chaves/North Portugal), where the minerals are intercalated in larger and smaller veins, the few preserved pick marks were exclusively found on protected surfaces, for example within a series of prospecting adits (fig. 7).²⁰

However, the state of preservation also depends on later interventions. Since the ore deposit of Gralheira, like that of Tresminas, has been largely spared from modern mining operations, it is possible to depict, discuss and, if possible, interpret the various rock incisions and carvings.

The Gralheira lode investigations (2008-2019)

Since 1985, initial assessments in the Gralheira lode area had been repeatedly carried out by Dr Jürgen Wahl and Regula Wahl-Clerici as part of the Tresminas survey, and the value of the preserved structures was already recognised at that time. But it was not until 2011 that it was possible to begin recording the archaeological remains, at least by means of descriptions, photos and sketches.²¹

¹⁶ In his dissertation, Rosa includes deposits comparable in their formation (ROSA 2001, 174 Fig. 72), although none of these pits are in the territory of the ancient Roman Empire.

¹⁷ For the Sifnos mine see WAGNER ET AL. 1985, Supplements 5 and 8; Impressive is a corresponding construction from the gold mine of Fouilloux (dép. Haute-Vienne, F) from the 2nd and 1st centuries BC, see DOMERGUE 2008, 112, Fig. 58.

¹⁸ WAHL-CLERICI 2020, 134-177.

¹⁹ WEISGERBER 1985, Fig. 108, p. 117, hole (L) possibly hammered into the sinter adjacent to the marble for the stand of a turnstile reel. In the underground mines, abundant traces of work from the different mining phases have been preserved. - No such traces were discovered during our own observations in the extraction zones at La Unión and Coto Fortuna (Murcia province, E).

²⁰ Prospecting shafts can also be found in Tresminas: WAHL-CLERICI/WIECHOWSKI 2013; WAHL-CLERICI 2020.

²¹ WAHL 1988; WAHL 1993; WAHL 1997; WAHL 1999. - The recording of the findings was presented in two reports for the Portuguese monument conservation: WAHL-CLERICI/WIECHOWSKI/HELFERT Gralheira Report 2011 (not publ.); WAHL-CLERICI/WIECHOWSKI/HELFERT Gralheira Report 2015 (not publ.). These were deposited at the Câmara Municipal de Vila Pouca de Aguiar and at the Delegação da Cultura do Norte.

Another important step towards the archaeological exploration of Gralheira became possible in 2019. For the first time, the ancient structures now on the surface in an area of just under 250 m in length could be documented for the first time with the help of modern scientific methods. During earlier assessments, further excavation zones had already been recorded with photos and sketches on a makeshift basis. Unfortunately, the time frame for the work in the 2019 field season was limited to two days, so that only a short section of the deposit could be examined. It was also not always possible to completely remove the (occasionally lush) vegetation. A Faro Focus^{3D} X330 terrestrial laser scanner was used to scan the rock structures, while an Unmanned Aerial Vehicle (UAV) DJI Phantom 4 Pro 2.0 quadcopter with an adapted KLAU PPK (post-processed kinematic GNSS) system for georeferencing of the photos was used to take photogrammetric aerial images to create a digital terrain model (DTM) and a digital orthophoto. The work was carried out by the Photogrammetry & Laser Scanning Lab of the HafenCity University Hamburg.

The aerial view of the DTM shows the zone around 150 to 300 m west of the former trigonometric point Gralheira. In this representation, the individual positions, which will be discussed below, are marked with numbers from 01 to 05 (fig. 8).

Each of the five positions has its own special feature. At position 1, the elongated WNW lode is crossed by a roughly north-south running one. Of particular interest are cuts in the rock at the edge of the mining zone. Position 2 is characterised by various easily accessible cuts which are evidence of prospecting, mining, and additional installations. In position 3, the rock outcrop was worked into a surface, as could already be observed in position 1. Position 4 is a partially collapsed mining gallery and associated cuts. At position 5, the mining gallery had to be secured with timbers.

Position 1: Intersection of two quartz veins (fig. 8, fig. 9a, b).

It was already known in antiquity that high ore grades tend to accumulate at the intersections of ore veins.²² It is therefore not surprising that traces from mining accumulated here. We distinguish three different objects in Pos. 1, which do not have to be directly related. The pick marks, which resulted from direct ore extraction, are preserved very irregularly in the individual positions. They are clearly recognisable in Pos. 1a. Further marks from hewing could be identified in the small channels of Pos. 1b as well as on the small platform in the southern face of the WNW-ESE vein. In the north-south oriented vein no hewing marks are visible, which is probably at least in part due to the fact that very little of the mining face is exposed here.

Pos. 1a

Cuts are preserved east of the intersection mentioned above, in the northern face of the WNW-ESE lode. These indicate an underground mining activity following the ore vein and working from bottom to top, that is hewing upwards (fig. 10).²³ No corresponding traces from hewing could be observed in the opposite face, which is why the interpretation of the whole cannot be considered certain. Further impact marks resulting from direct ore extraction could not be identified within the intersection.

²² WEISGERBER 1985, 87.

²³ WAHL-CLERICI ET AL. 2017, Fig. 6, 7, 12, 13.

Pos. 1b

In Pos. 1b, a group of rock cuts survived. These include an artificially levelled area of the southern rock outcrop with conspicuous trenches in it (Figs. 9a, 11a, b) and, about 1.90 m below it, a small piece of rock resembling a pedestal that protrudes from the southern face and still bears remarkably well-preserved pick marks (fig. 12).

The artificially levelled rock outcrop extends over an area that is approximately oval, with a maximum dimension of 7.20 m by 2.10 m (fig. 11a, b). Two trenches were cut into it at right angles to the course of the extraction zone and another cut parallel to the extraction zone. The western trench is 1 m long, max. 35 cm wide and max. 30 cm deep; the eastern trench is 70 cm long, max. 25 cm wide and max. 25 cm deep. The western trench ends in a y-shaped cut towards the extraction zone (Fig. 9a). The eastern trench is less cleanly worked and does not have a recognisable connection to the western one. This raises the question of whether this was an additional cut that had become necessary or one that had been abandoned for whatever reasons.

We can only speculate about the purpose of these adaptations, that is the levelling and the trenches. They may have served to fix a mechanical installation, probably a hoist. In any case, the dimensions allowed the positioning of a sturdy timber with a diameter of ca. 30 or 25 cm respectively.

The small platform mentioned above lies slightly lower and somewhat to the west of these cuts (Fig. 9a). It consists of a larger central section and a higher and lower step on each side (fig. 12). As already mentioned, the cleanly worked surface shows practically no traces of use. Whether it was also part of the hoist mentioned above or was created completely independently of it cannot be decided. Due to its location at the edge of the extraction zone, we cannot ultimately rule out the possibility that it is a remnant of a former walking surface.

Pos. 1c

Pos. 1c refers to the continuation of mining in the north-south oriented ore vein towards the west, running parallel to the main ore vein. The former working face, which is now exposed, soon disappears, but the situation in the northern flank of the prominent rock outcrop suggests that ore was extracted here (fig. 13).

Position 2: Mining zone with preserved cuts of different function

On a stretch of about 30 m from east to west the remains of Pos. 2a) of a shaft,

Pos. 2b) the cut for positioning a strong beam (fig. 14) as well as Pos. 2c) a prospecting gallery (fig. 15) can be observed.

Pos. 2a)

The cross-section of the shaft measures about 2×2 m and the depth exposed today is about 6 m, however its original depth is unknown. For the sinking of the shaft, the trench (glory-hole) of 1.80 m was slightly extended. Since the entrance cannot be seen on the surface, we can only assume that a hoist, for instance a reel, was positioned here.

Pos. 2b)

About 20 m west of the shaft in pos. 2a, a conspicuously large cut with a width of 9 cm, a height of 11 cm and a depth of 8 cm could be observed in the northern face (fig. 14). Based on the dimensions, it can be assumed that it served as a beam bearing, even if a counterpart is missing in the southern face. It is conspicuous that there it is just the one

cut, which is why we can hardly assume that it was used for the timbering of the shaft. In addition, the rock here is very stable and the entire width of the working face is exposed. We can therefore conclude that it is possible that this cut was also the site of a hoist.

Pos. 2c)

The prospecting gallery, which is only preserved over a distance of 20-30 cm and was the width of a man, was opened in the northern face of the excavation zone (fig. 15). We are either looking at the rest of a longer gallery that was originally driven from the slope surface from the south and subsequently destroyed by mining, or the gallery was opened from the extraction zone, presumably to sample a small quartz vein. This is also suggested by the small "window", which was additionally worked into the face. This "window" was extended somewhat in an easterly direction, which can be seen from the small cavity in it.

Position 3: Rock outcrop worked into a surface

A levelled area directly adjoining the mining of the ore vein to the north has an almost polished appearance. From the aerial photograph (fig. 16) we can see that the beginning in the east cannot be clearly determined, as part of it may be covered by rubble. The area stretches over a distance of about 8.50 m and has a width of max. 1 m. In the west, the area ends shortly before pos. 4, which is positioned in an abandoned part of the rock outcrop. In the absence of further cuts or other traces of any function, the question arises as to what this levelled area was used for.

No traces would have been left, for example, by the process of 'picking', the separation of the barren rock from the ore, before processing. However, the idea that such an effort in levelling a surface was made for this process alone is difficult to imagine. Moreover, the dumps adjoining the extraction zone to the south, that is on the other side of the extraction zone (!), are not more extensive than elsewhere (fig. 8). It is therefore more likely that this area was used for the storage of the ore picked from the barren rock. Another possibility we cannot exclude is that this flat surface was prepared for the installation of yet another mechanical device, such as the clearly less neatly levelled area at Pos. 1c.

Position 4: Concentration of cuts, including some for supports, in the area of the northern slope of the trench (fig. 17a, b).

At Pos. 4, the former excavation zone is partly filled with rubble or has completely collapsed. Well preserved are the rock cuts in the northern slope and the adjoining rock outcrop. Visible are round and square cuts arranged at different levels and more or less mirrored next to a 105 cm wide access opening. Below this, a larger quadrangular cut with a width of 28 cm, a depth of 25 cm and a height of 30 cm can be identified. It probably served as bearing for a larger beam (fig. 17a, b). It is not possible to determine whether the much smaller cut to the east of it was also part of the same construction. It could also have been part of the timbering of a gallery, which may already have been necessary in antiquity to keep the mining face clear. A mining face, which was originally open, but is now underground due to collapse, can be found about 400 m east of the zone presented here (fig. 18).

It is difficult to understand the various elements, as they may be the remains of different constructions and technical installations that were used either simultaneously

or successively. The absence of cuts in the southern face complicates the interpretation. We cannot rule out the possibility that a hoist was also installed here.

Position 5: Remains of struts

To the west of the collapsed trench (glory hole) is a mining face that is still open, but conspicuously narrow with a width of just 45 cm. The preserved opposing cuts prove that it had to be secured in Roman times already, so that this is not the original width of the passage. The timbers had been inserted into the holes in the northern face and were then slid into the open-topped cuts in the southern face (fig. 19). The two broader cuts in front on both sides of the trench were probably used to anchor a reel.

Results

Even the small section of the excavation zone of Gralheira presented here demonstrates that an extraordinary number of rock cuts have been preserved. Openings for timbers to secure a mining face and the remains of prospecting can be clearly identified. The situation is different with the cuts, which presumably have to be interpreted as serving to install hoists or other installations for the securing of entrances and other elements. The results from the extraction zone of Tresminas, which also belongs to the *territorium metallorum* Tresminas/Jales, show that we must always expect unfinished constructions or even only preparations for such constructions, since certain constructions were planned and started in advance to ensure the continuous overall work progress.²⁴ If, contrary to expectations, a different situation arose during the extraction, these already prepared cuts were not used, but left as is.

What remains inexplicable is the carefully levelled surface in pos. 3. We must not hastily conclude from the parallel example in pos. 1 that this also had been preparatory work that had been discarded before being put to use.

In connection with the traces presented here, we should also point out a conspicuous feature in Pos. 1a. Here, a noticeable termination of the extraction from the east can be seen, which can be dated to an earlier period. This raises the question of whether we may use this to interpret the organisation of the mining, that is, whether this may be an indication that the mining at Gralheira was divided into lots. This would be contrary to the mining situation in the Tresminas mine, where it could be clearly demonstrated that at least in open pit A (the Corta de Covas), mining was carried out under a central direction.²⁵ However, in order to be more certain about this question it would be preferable if similar features were to be discovered in other places. As there is just a single feature indicating this at the moment, the organisation of the Gralheira mine into lots can only be a hypothesis for now.

Precisely because the interpretation of these objects is so difficult and ambiguous, it is, in our opinion, particularly important that the Gralheira ore vein be examined in more detail. Only after a thorough survey it will be possible to better understand the various rock cuts. In the Tresminas mining zone, excellent examples of the positioning of mechanical and other technical installations have been preserved underground. However, these can obviously only be used to a limited extent as comparisons for the surface structures of Gralheira. In principle, underground

²⁴ See, for example, the unfinished horse capstan or whim/göpel construction in the Galeria do Pilar and the Galeria dos Morcegos in Tresminas, which was never fully put to use: HELFERT ET AL. 2019; WAHL-CLERICI 2020, 128-131.

²⁵ WAHL-CLERICI 2020, 118-133.

installations are better preserved than surface ones, as they have not been exposed to the weather and further destruction during the intervening centuries.

Further investigations are planned at the Gralheira extraction zone from 2023 onwards. In addition to the clearing of vegetation and descriptive documentation, the 3D laser scanning is to be continued. Furthermore, it is our intention to create a detailed terrain model by means of airborne laser scanning in order to obtain precise mapping of the course of the trench (glory-holes) and the dimensions of the tailings. In view of the probable threat of damage by future gold mining, further research of this mining monument is essential.

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Gralheira figure captions

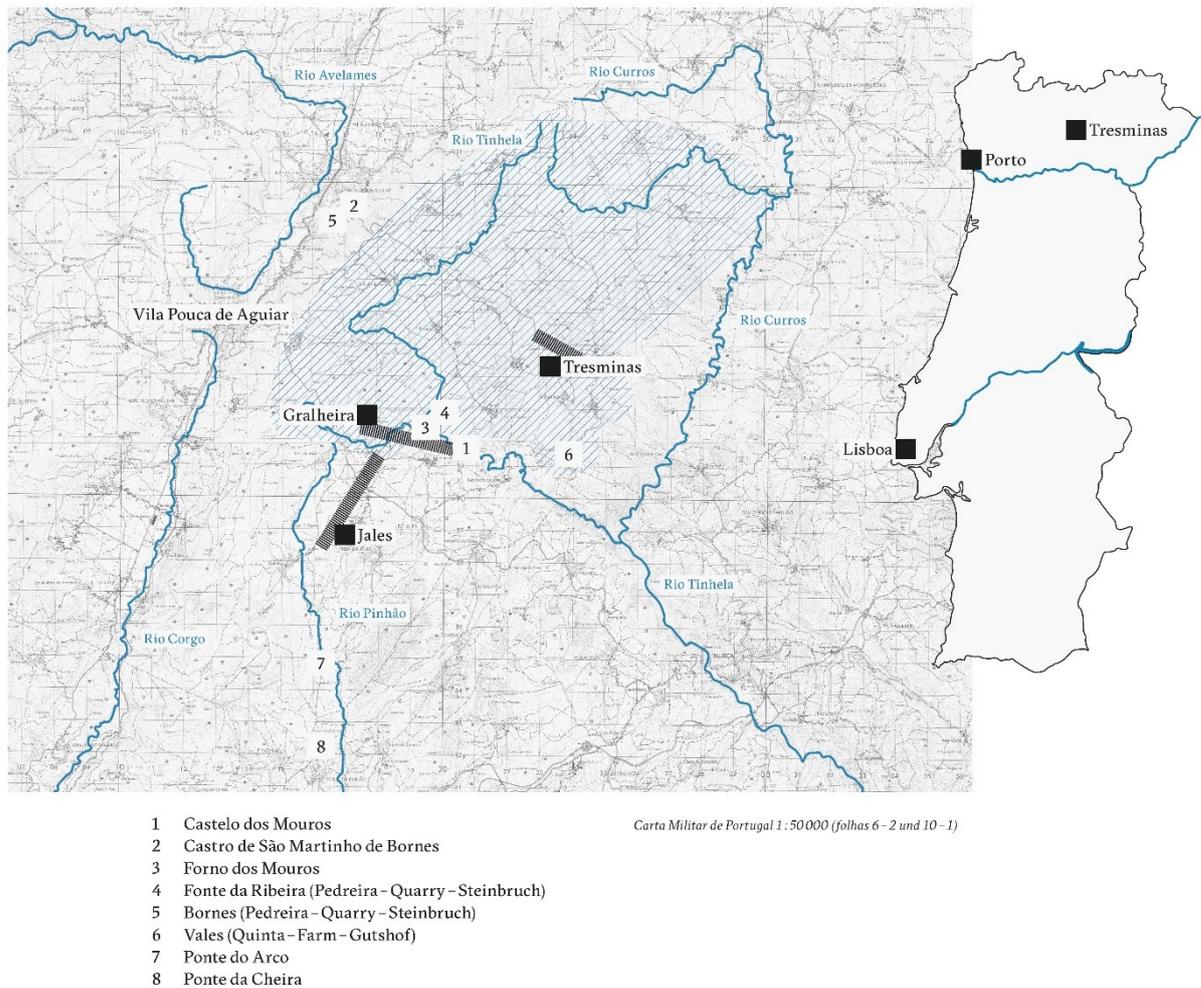


Fig. 1 Overview of the *territorium metallorum* Tresminas/Jales (template: Carta Militar de Portugal 1:50,000 folhas 6-2 and 10-1, illustration R. Wahl-Clerici and S. Mathiuet).

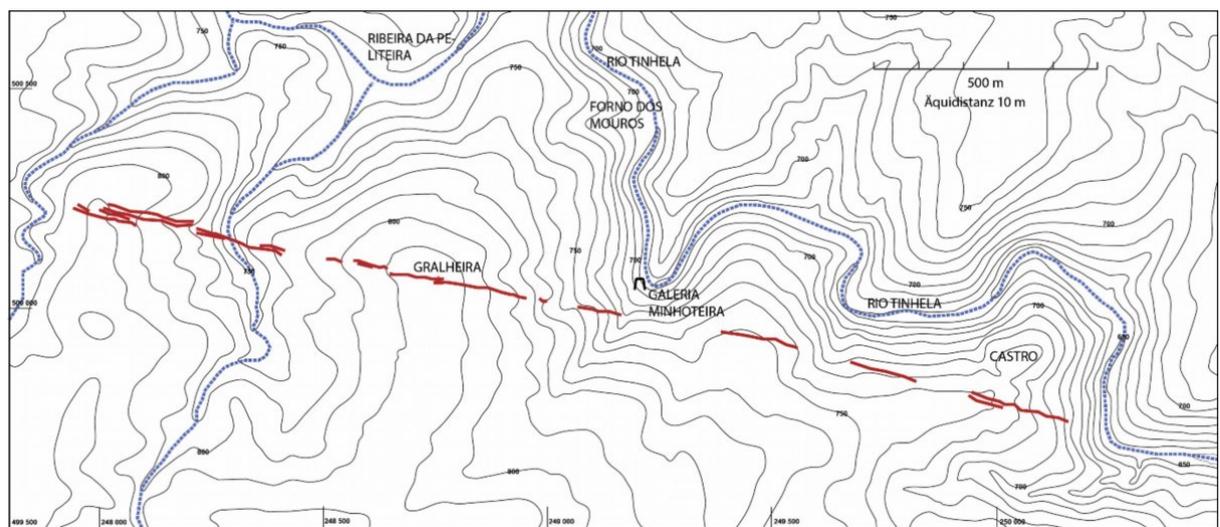


Fig. 2 *territorium metallorum* Tresminas/Jales, Gralheira ore vein: section of the Gralheira lode with the trench glory-holes and the entrance area of the Galeria Minhoteira (template: Ortofotomapa 1:10'000 Câmara Municipal Vila Pouca de Aguiar, RTZ, Sociedade Mineira Rio Artezia, S. A., Bureau de recherches géologiques e miniers, Consórcio Gralheira, 12.06.1990, illustration R. Wahl-Clerici).



Fig. 3 *territorium metallorum* Tresminas/Jales, Gralheira ore vein: in the foreground, the exploited trench (glory-hole) is visible on the left and a sterile rock outcrop on the right. In the background, the exploited parallel trench is visible on the right and the dumps of the former Mina de Jales Ltda. on the left (photo: J. Wahl).



Fig. 4 *territorium metallorum* Tresminas/Jales, Gralheira ore vein: remains of mining north of Murça about 13 km east of the section discussed here (41.4369618N, -7.4597731W) (photo: R. Wahl-Clerici).

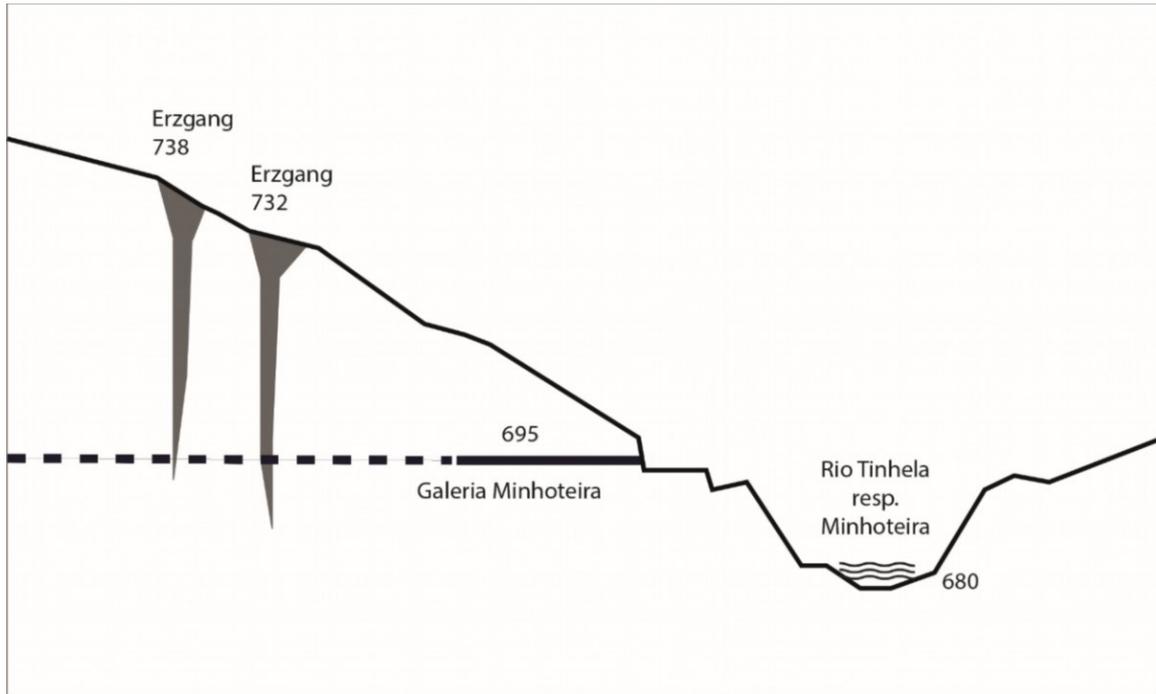


Fig. 5 *territorium metallorum* Tresminas/Jales, Galheira ore vein: NNO-SSW section through the deposit with the Roman trench (glory holes) in the area of Galeria Minhoteira. (template: Direcção Geral de Geologia e Minas, Porto, 1985, design: R. Wahl-Clerici).



Fig. 6 *territorium metallorum* Tresminas/Jales, Galheira ore vein: the tailings or scree heaps accumulated at the side of the trench (photo: R. Wahl-Clerici).



Fig. 7 Complex Roman prospect in the gold deposit of Poço das Freitas (Bobadela, Concelho Boticas, P) (photo: R. Wahl-Clerici).

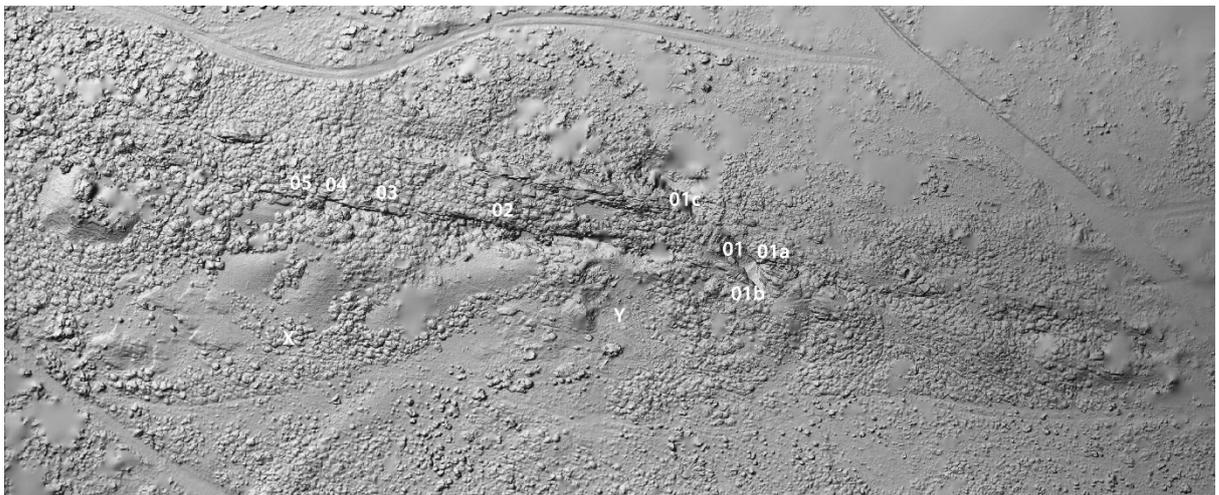


Fig. 8 *territorium metallorum* Tresminas/Jales, Gralheira ore vein: the numbering indicates the individual positions discussed in this paper, X = ancient dumps, Y = modern destruction in an ancient dump. Digital terrain model generated by dense image matching of the UAV imagery (HCU Hamburg, M. Lindstaedt, K. Mechelke).

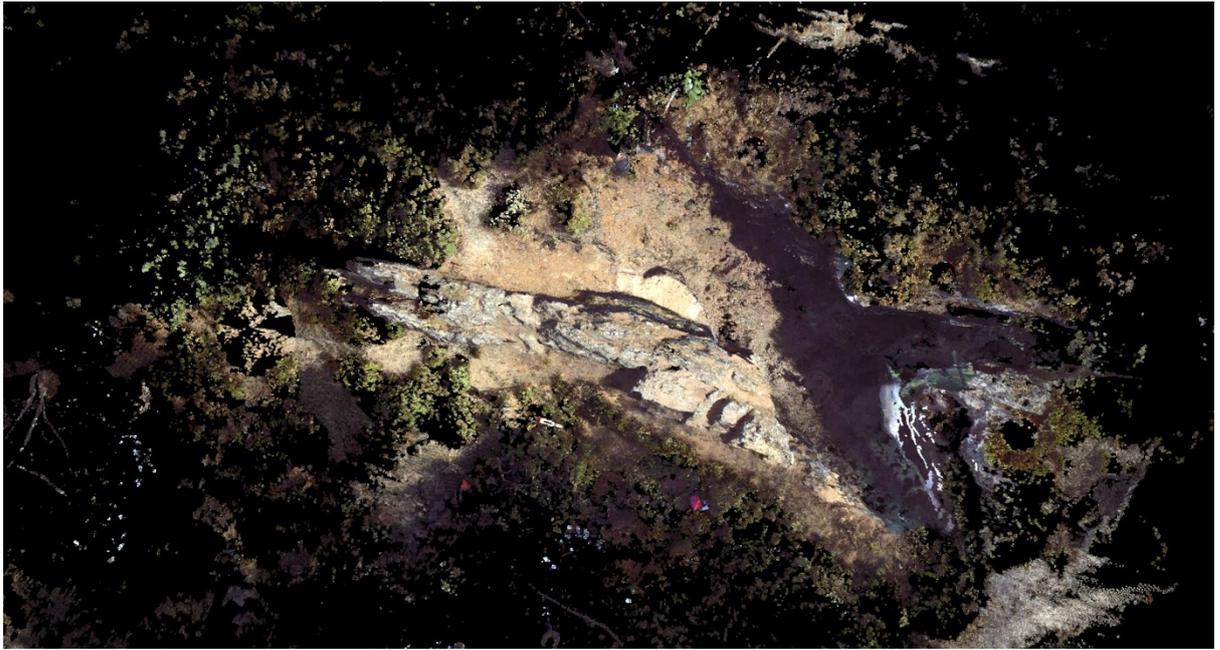


Fig. 9a *territorium metallorum* Tresminas/Jales, Gralheira ore vein: top view of Pos. 1. The two ore veins cross each other at an angle of about 40 degrees. In the middle of the picture the small rocky ledge as well as the channels and the Y-shaped cut of Pos. 1b adjoining it are visible (UAV photo: HCU Hamburg, M. Lindstaedt, K. Mechelke).



Fig. 9b *territorium metallorum* Tresminas/Jales, Gralheira ore vein, overview of Pos. 1: view from northwest to the crossing point, the main vein is in the shade (photo: R. Wahl-Clerici).



Fig. 10 *territorium metallorum* Tresminas/Jales, Gralheira ore vein, view of Pos. 1a from the south: the worked part in the main vein is clearly distinguished from the collapsed ridge and the standing remains of an earlier mining phase to the west by the pick marks and the holes for fixing struts above it (photo: R. Wahl-Clerici).



Fig. 11a *territorium metallorum* Tresminas/Jales, Gralheira ore vein, Pos. 1b: the levelled section with the small trenches cut in it, as seen from the west (photo: R. Wahl-Clerici).



Fig. 11b *territorium metallorum* Tresminas/Jales, Gralheira ore vein, Pos. 1b: the levelled section with the small trenches cut in it as seen from the south (photo: HafenCity University Hamburg, M. Lindstaedt, K. Mechelke).



Fig. 12 *territorium metallorum* Tresminas/Jales, Gralheira ore vein, Pos. 1b: the small platform in the area of the mining zone (photo: R. Wahl-Clerici).



Fig. 13 *territorium metallorum* Tresminas/Jales, Gralheira ore vein, Pos. 1c: continuation of the vein crossing the main vein towards the west. No pick marks or other marks from working could be determined on the surface (photo: R. Wahl-Clerici).



Fig. 14 *territorium metallorum* Tresminas/Jales, Gralheira ore vein, Pos. 2b: view from the south to the cut, which presumably served as a beam bearing (photo: R. Wahl-Clerici).

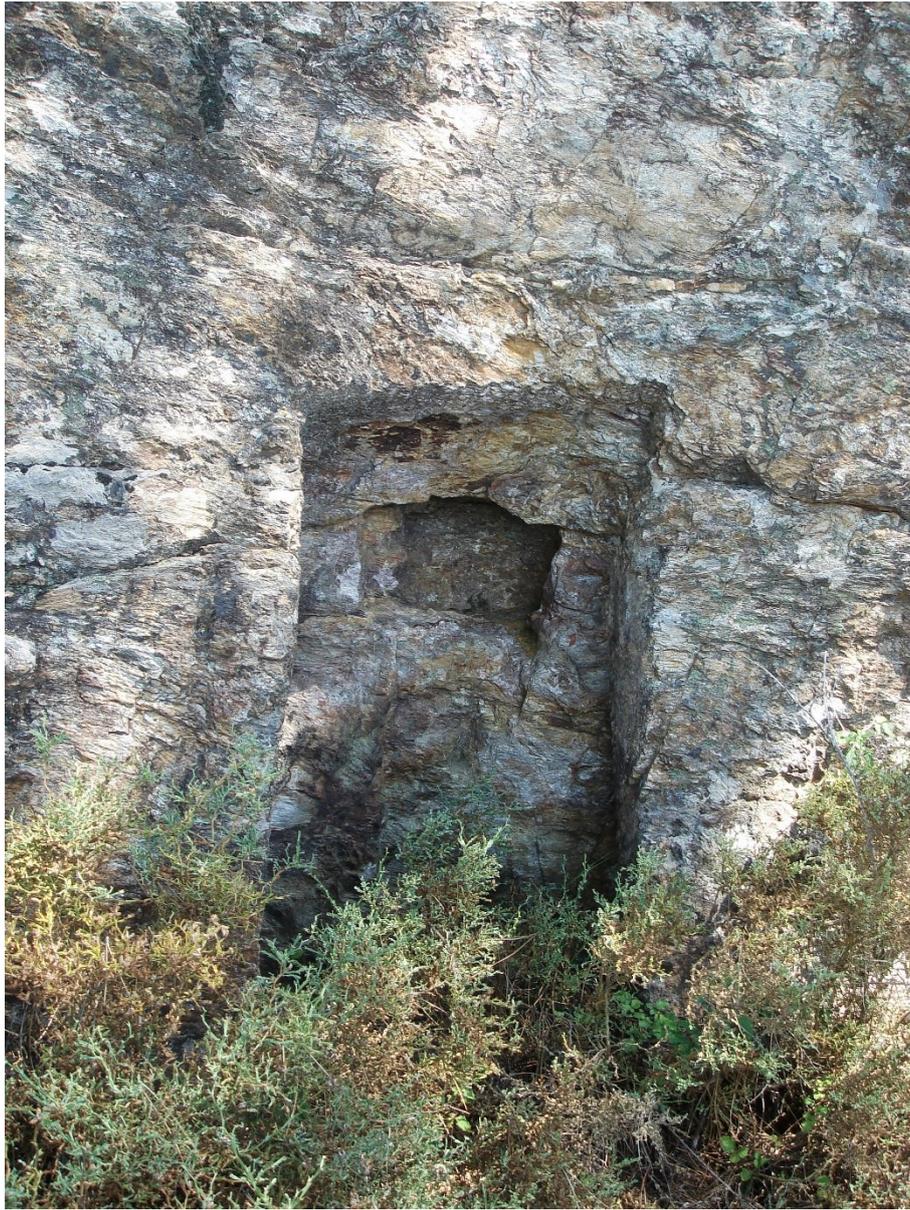


Fig. 15 *territorium metallorum* Tresminas/Jales, Gralheira ore vein, Pos. 2c: view from the south into the short prospecting gallery (photo: R. Wahl-Clerici).



Fig. 16 *territorium metallorum* Tresminas/Jales, Gralheira ore vein, Pos. 3 and 4: in the aerial view the flat worked zone from the pink point to and including the south of the tripod is visible. From pos. 4 the small "passage" (see fig. 17a & b) is visible (Orthophoto (15 mm/pix) from UAV images, HCU Hamburg, M. Lindstaedt, K. Mechelke).

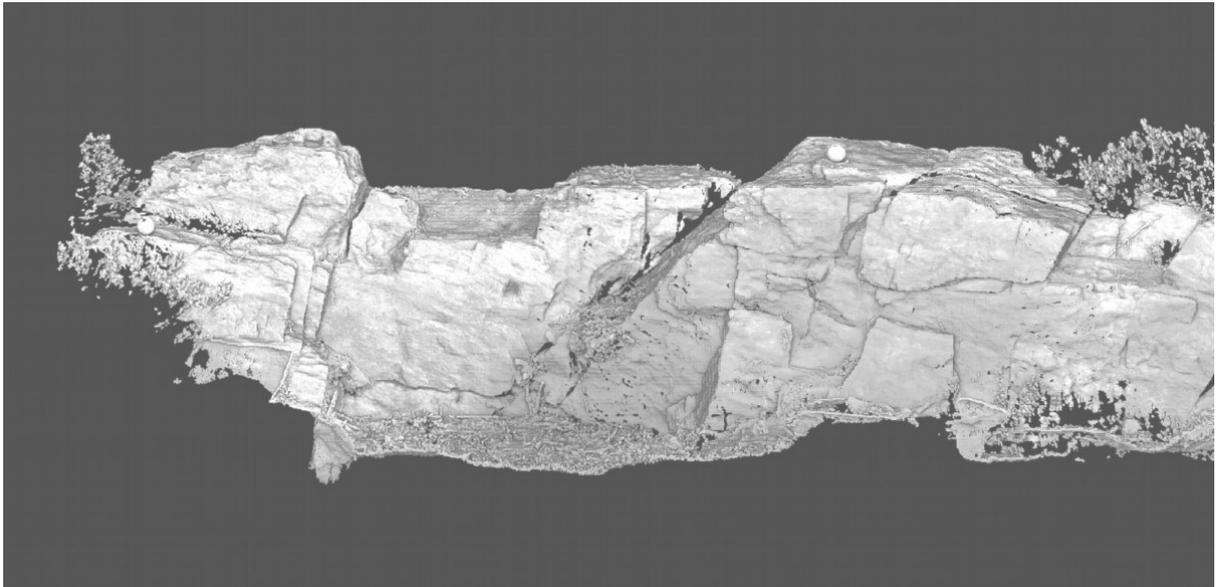


Fig. 17a *territorium metallorum* Tresminas/Jales, Gralheira ore vein, Pos. 4 from the south: 3D laser scan model (HCU Hamburg, M. Lindstaedt, K. Mechelke).

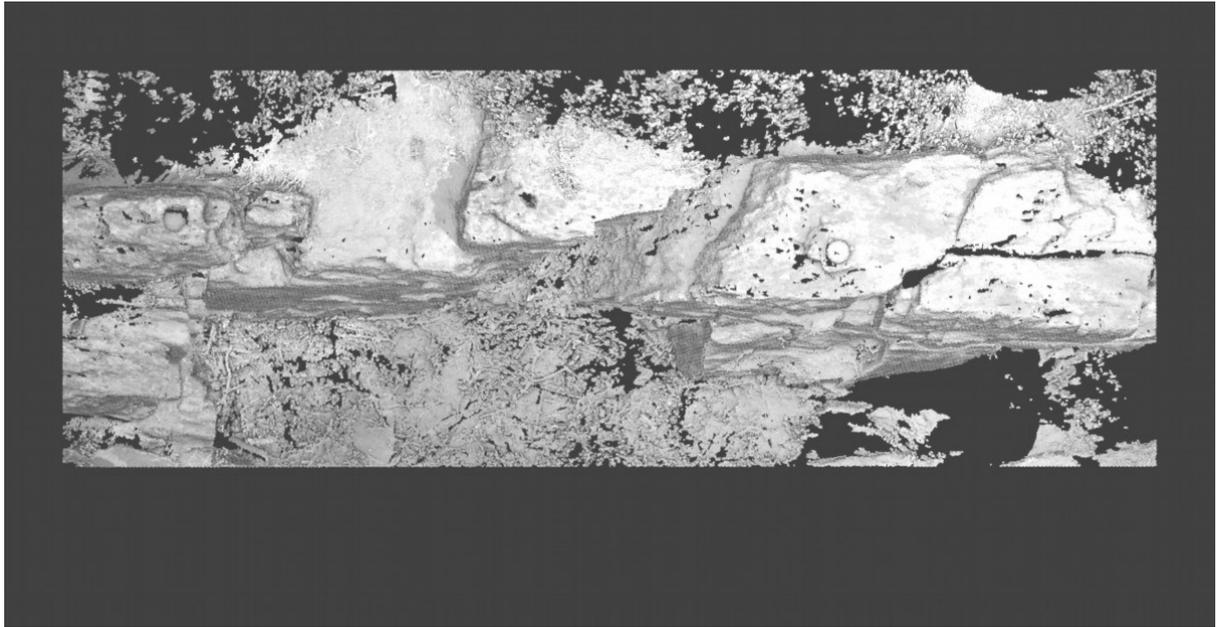


Fig. 17b *territorium metallorum* Tresminas/Jales, Gralheira ore vein, Pos. 4 from above: 3D laser scan model, top view (HCU Hamburg, M. Lindstaedt, K. Mechelke).



Fig. 18 *territorium metallorum* Tresminas/Jales, Gralheira ore vein: Completely collapsed, originally open extraction site (photo: R. Wahl-Clerici).



Fig. 19 *territorium metallorum* Tresminas/Jales, Gralheira ore vein, Pos. 5: view into the site which has collapsed up to a short distance. The three folding rulers mark the positions of the bracing timbers. In front of the foremost strut, cuts are visible that may have served to position a reel (photo: R. Wahl-Clerici).