

Regula Wahl-Clerici

# Roman Gold from Tresminas (Portugal)

Prospection — Mining — Treatment

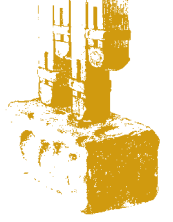


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Regula Wahl-Clerici  
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IN MEMORIAM JÜRGEN WAHL





Regula Wahl-Clerici

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Prospection — Mining — Treatment

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Front cover: *Territorium metallorum* Tresminas /Jales, Tresminas,

Galeria do Pilar: pillar and channel (photo R. Wahl-Clerici).

Back cover: *Territorium metallorum* Tresminas /Jales, Tresminas, Galeria dos Morcegos  
(photo R. Wahl-Clerici).

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## 1.0 Introduction

The deposit determines all further activities and processes in any kind of extraction of raw materials. This was valid in mining everywhere until very recently and is also reflected in the Roman remains in the *territorium metallorum* Tresminas/Jales. However, the influence of other factors should not be underestimated. They can be subsumed under the following key words: historical circumstances, technical possibilities and organisational or administrative conditions. The remains of Roman mining we were able to discover at the *territorium metallorum* Tresminas/Jales are the result of the sum of these conditions, plus the fortunate fact that the deposits of Tresminas and Gralheira were largely spared from more recent mining.

This volume studies all aspects of the mining, processing and smelting of ores at the *territorium metallorum* Tresminas/Jales. In addition to a detailed presentation of these, the prospection for gold and the water supply and stone industry are also briefly presented, as all three of them are fundamental to gold mining in the *territorium metallorum* Tresminas/Jales and have left a wealth of remains (fig. 1.0-1).<sup>1</sup>

The technical aspects presented will be supplemented in this chapter with a brief introduction into the history, administration and organisation of the site. This also includes the settlement and its inhabitants. While the first set of aspects is mostly determined from outside, that is by the historical, political and economic circumstances of the period, the second is mainly determined by the local people, at least to the extent that we are able to record them with the help of the historical, epigraphic and archaeological sources.

The following can be said about the history of the mine: although evidence of human activity dating from at least the Neolithic has been found in the wider surroundings of the three deposits, there are no clear traces of pre-Roman mining in the primary deposits of Tresminas. The same is true of Jales and Gralheira, although the Iron Age Castro dos Mouros of Cidadelhã (Freg. Alfarela de Jales) is in the immediate vicinity of the Gralheira deposit.<sup>2</sup> However, we can safely assume that panning for gold in the deposits in the rivers Tinhela and Curros and their tributaries had been established from very early on. The gold in the rivers originated in the primary deposits, from where it had been released by weathering and then settled and accumulated in the river sands over several geological periods.<sup>3</sup> The population in the west and northwest of the Iberian Peninsula was already well-known for this type of gold mining in pre-Roman times.<sup>4</sup>

However, we can undoubtedly connect the commencement of mining in the primary deposits of Tresminas, Gralheira and Jales themselves with the history of the Roman conquest. After the Romans had gained a foothold on the Iberian Peninsula during the Second Punic War (218—201 B. C.), they gradually extended their territory over a period of almost 200 years, until finally, in 30 B. C., at the end of the Roman civil war (133—30 B. C.), which to a large extent took place on the Peninsula, only very few regions in the north and northwest were not integrated into the empire.

What is striking about the war of conquest that began in 27 B. C. in the north and northwest of the Peninsula is that it apparently left fewer traces in the mountainous zones to the west and southwest of the plains near León and Astorga (both León/E), near Benavente (Zamora/E) and in northern Portugal than further east in Asturias.<sup>5</sup> It seems that this western zone was much less involved in the war and was probably pacified before 16 B. C. before being finally incorporated into the Roman Empire (fig. 1.0-2).<sup>6</sup>

In this context, the question of the provincial affiliation of the *territorium metallorum* Tresminas/Jales needs to be briefly addressed. According to Strabo, Geography 3,4,20, in earlier times the inhabitants north of the Douro had been called Lusitanians, but in his lifetime (~63 B. C.—23 A. D.)

1 Overviews: Wahl 1988; Wahl, 1993a; Wahl 1993b; Wahl/Wahl-Clerici 1993b; Wahl 1999; Wahl/Wiechowski 2006; Wahl-Clerici 2008; Wahl-Clerici/Helfert 2017a; Wahl-Clerici 2018; Ramminger et al. 2011.

2 Batata et al. 2008, 14—21.

3 This corresponds to the usual formation of a secondary deposit.

4 Strabo, Geography 3,2,9 mentions the Turdetanians and the Artabrians who wash out gold from rivers. He lists (3,3,4) the Tagus (Tagus), Mundas (Mundo), Vacua (Vouga), Durius (Douro), Lethe, “which by some persons is called Limaeas, but by others Belion”, Baenis “others say ‘Minius’” (Minho) in the west of the Iberian Peninsula as rivers rich in gold. — Of interest is also Pliny, Natural History 33,76—77: He describes that Spain had already advanced far into the sea due to gold panning in the secondary deposits.

5 Morillo Cerdán 2017; Bartenstein 2014, fig. 2; Sánchez Palencia et al. 2017; Research refers to so-called castra aestiva, i. e. marsh and summer camps, in the western part of the area. They are dated into the Late Republic or in the 1st century A. D. (see Menéndez-Blanco et al. 2017, 68). However, despite these surveys, fig. 3 shows a clear gap in this region. — The military installation published by Fonte/Costa-García in 2016 at Alto da Cerca (Freg. Carrazedo de Montenegro, Conc. Valpaços/P) was probably a marching camp at best. This means that an interpretation of the site by the authors (Fonte/Costa-García 2016, 55) as protecting of controlling the *territorium metallorum* Tresminas/Jales may be dismissed.

6 Alarcão 1988, 25—30; Bartenstein, 2014, 82—86. 122.

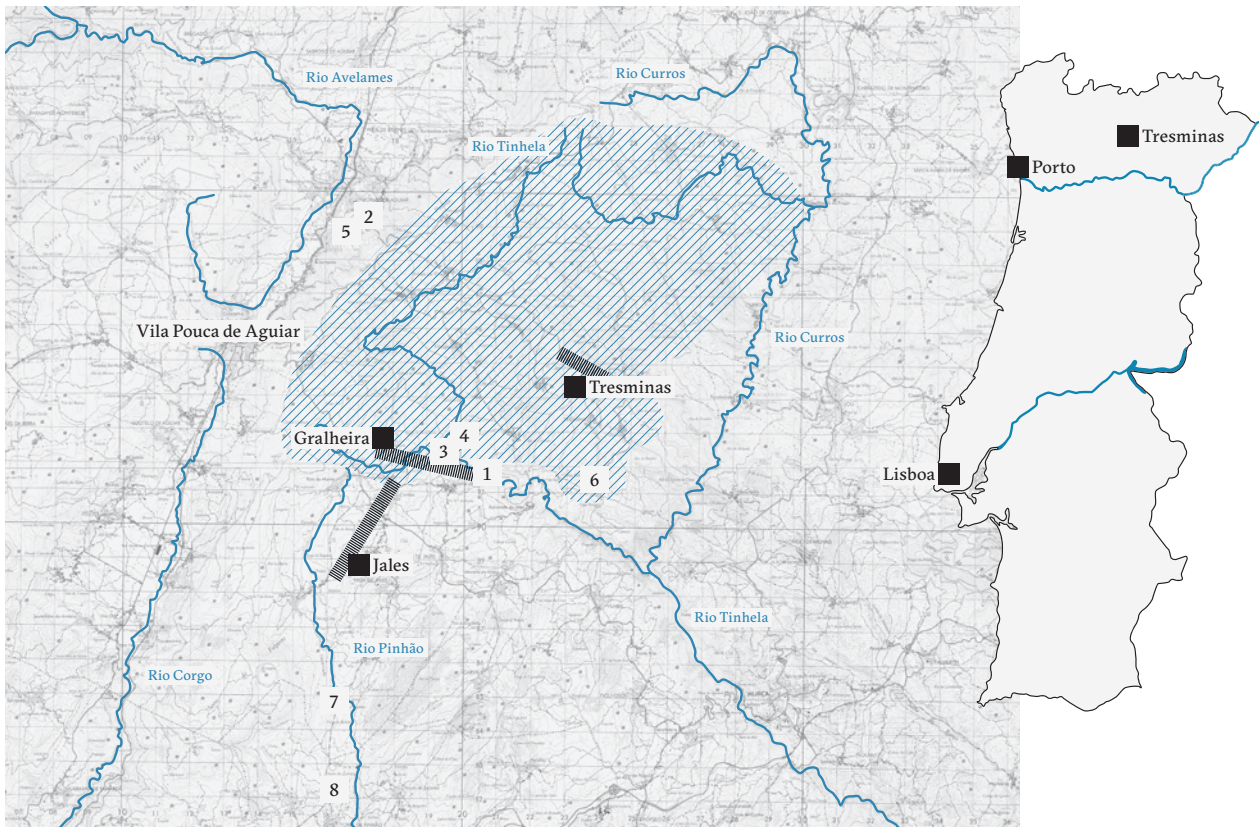


Fig. 1.0-1: *Territorium metallorum* Tresminas / Jales, overview map: 1 — Castelo dos Mouros, 2 — Castro de São Martinho de Bornes, 3 — Forno dos Mouros, 4 — Fonte da Ribeira — Quarry, 5 — Bornes — Quarry, 6 — Vales — Roman Farm, 7 — Ponte do Arco, 8 — Ponte da Cheira. (Template Carta Militar de Portugal 1:50 000 folhas 6-2 and 10-1, design: R. Wahl-Clerici and S. Mathiuet).

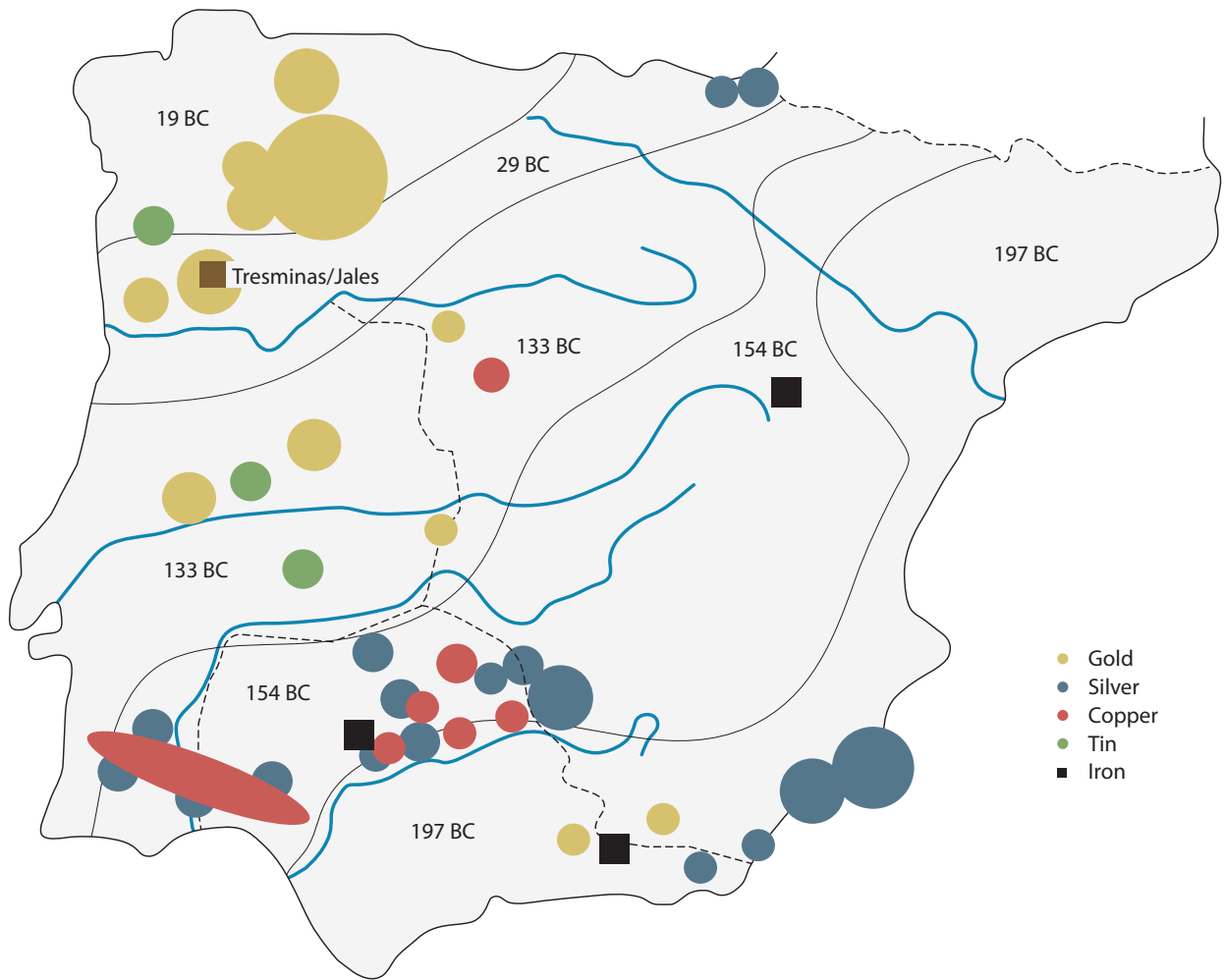


Fig. 1.0-2: Overview of the phases of the Roman conquest and the ore deposits on the Iberian Peninsula (template C. Domergue 2008, Carte 4, design: R. Wahl-Clerici, drawing: S. Mathiuet).

they were called Callaicans. Whether we may draw the conclusion from this that Tresminas was originally Lusitanian remains to be seen.<sup>7</sup> During the final conquest, which began only 3 years after the end of the Roman civil war, the Iberian Peninsula was divided into the provinces Hispania Citerior and Hispania Ulterior, with the latter including Lusitania, Baetica and Callaecia. According to Alföldy, this division prevented the unification of the at times 6 or 7 legions posted to the Peninsula under the command of a single provincial governor.<sup>8</sup> It was not until 13 B. C. that the territories last conquered were added to Hispania Citerior and Tarraconensis respectively.<sup>9</sup>

In the context of the discussion on the provincial affiliation of Tresminas, it is worth mentioning the edict of Augustus of Bembibre (Province of León/E), recorded on a bronze plaque, which refers to a *Transduriana Provincia*. In his discussion of this unique reference, Alföldy suspects that this province was established for the creation of the necessary administrative and related structures and was integrated into Hispania Citerior in 13 B. C. at the latest. The *territorium metallorum* Tresminas/Jales would of course have belonged to this province for geographical reasons.<sup>10</sup>

At latest with the conquest of the northwest of the Iberian Peninsula, the rich gold deposits of the region became the focus of the Romans. After Augustus had raised the *aurus* to the status of the main currency coin from about 27 B. C. on, the demand for gold in the Roman Empire increased enormously in a short period of time.<sup>11</sup> We know from historical sources that Augustus had the newly conquered regions systematically prospected in order to gain an overview of the gold deposits.<sup>12</sup>

As mentioned above, the panning of gold from the river sediments, which needed a large workforce, but was technically not very complex, had long been practised by the local population. This could be an indication that the spoils acquired by Rome during the conquest had already covered an initial demand for gold. It is very likely that the pre-Roman gold objects of the Iberian Peninsula, despite their variety and impressive beauty, represent only a tiny fraction of the wealth that had been present in the pre-Roman period.<sup>13</sup>

The precise date of the start of gold mining in the primary deposits of Tresminas, Gralheira and Jales in the *territorium metallorum* Tresminas/Jales can only be conjectured. An important chronological reference to the Roman activities in Tresminas is provided by the coin treasure trove found in 1894 in Vales (Freg. Tresminas, Concelho Vila Pouca de Aguiar). It consisted of denarii of Augustus for his grandsons Gaius Caesar (20 B. C.—4 A. D.) and Lucius Caesar (17 B. C.—2 A. D.) and was buried at the latest around the birth of Christ.<sup>14</sup> It is very likely that the treasure is connected to the Roman estate excavated in Vales, whose publication is in preparation. However, even though the estate can be described as being located in the vicinity of the deposits of Tresminas and Gralheira (both of which

are at a linear distance of ca. 4 km from the estate), no direct connection with the exploitation of the mines can be as yet be observed.

By contrast, the connection between the mining and the tomb inscriptions found in the area of Tresminas is clear. The earliest of the inscriptions date to the reign of Emperor Tiberius (14—37) and were erected for the immigrants from the *Colonia Clunia Sulpicia* (Peñalba de Castro, province Burgos/E) who had come to work in the mining industry.<sup>15</sup>

The only absolute date we currently have for the *territorium metallorum* Tresminas/Jales is the year 130 A. D. by the mention of the consuls on a votive altar for Jupiter, erected by a *vexillatio* of *legio VII gemina*. Two further milit-

7 For the naming of the tribes by the Romans see Edmondson 1993, 13: “First, the Romans created broad ethnic identities for their opponents, ignoring the complex, highly fragmented ethnic and regional geography of the area.” [https://www.researchgate.net/publication/42243082\\_Creating\\_a\\_provincial\\_Landscape\\_Roman\\_imperialism\\_and\\_rural\\_change\\_in\\_Lusitania](https://www.researchgate.net/publication/42243082_Creating_a_provincial_Landscape_Roman_imperialism_and_rural_change_in_Lusitania). Last view: 02.09.2019.

8 Alföldy 2000, 185. This argument is understandable against the background of the Roman civil war, much of which took place on the Iberian Peninsula.

9 Bartenstein 2014, 71—123 with an extensive discussion of the archaeological and historical sources; LeRoux 1982, 74—77; Domergue 1990, 200, who refers to the passage in Pliny’s *Natural History* 33,78, in which he mentions that 20000 pounds of gold were extracted annually from Asturias, Callaecia and Lusitania. (*vicena milia pondo ad hunc modum annis singulis Asturiam atque Callaeciam et Lusitaniam praestare quidam prodiderunt, ita ut plurimum Asturia gignat.*) Domergue can only explain this quantity by the fact that these three formed a single province between 27 and 13 B. C. until the region north of the Douro was added to Hispania Citerior; Cf. also the distribution of military installations in Augustan times: Morillo Cerdán 2002, figs. 1 and 2; Alföldy 2000, 198.

10 Alföldy 2000, 198.

11 Drexhage et al. 2002, 47, with further sources.

12 Wahl-Clerici/Wiechowski 2013, 300: According to Florus (around A. D. 100) Augustus ordered the planned prospection of the northwest (Flor. epit. 2,33,59—60). About a hundred years later, Cassius Dio (about A. D. 150 to 235) referred to Maecenas (70—8 B. C.), who was the closest confidant of Augustus in financial matters (Dio. 52,28,4).

13 For the prehistoric gold finds on the Iberian Peninsula see García Castro 1999; Blech et al. 2001; Trillmich et al. 1993; Alvarez Alcántara/Yugueros Yugueros without date.

14 Russel Castro 1952, 16: The author does not exclude that further coin treasures composed of Republican Denarii found in the region north of the Douro had been hidden in connection with the campaigns of Caesar in this region around 46 B. C. (see Russel Castro 1952, 6—37 and Castro Hipólito 1960/61, 28 with further references). On Vales, Russel Castro writes: „Próximo à povoação dos Vales, ..., descobriu também, aindo o ano passado [1894] um lavrador que arava o seu campo, boa porção de dinheiros romanos, todos de Caio César e Lúcio César no reinado de Augusto“. Outra regerência confirma que os nimismas são todos do mesmo cunho e que se trata do espécime que no catálogo de Cohen 1.ª ed., vol. I, 1859, p. 52) tem o N.º 87.

15 Wahl 1988, 239—240, note. 44; Redentor 2010, 142; Haley 1991; Holleran, without date.

ary inscriptions were also on votive altars for Jupiter. The soldiers of the *cohors I Gallica equitata civium Romanorum* erected their altar in the first half of the 2nd century.<sup>16</sup> However, the date of the votive altar erected by the soldier Quintus Annius Modestus is contested, with one author dating it to the last third of the 1st century A.D. and another in the time between A.D. 197—211.<sup>17</sup>

It is very difficult to date the work in the mines themselves, as datable evidence is rare.<sup>18</sup> In Tresminas, fortunately, it is at least possible to chart the various stages of the mining progress in the Corta de Covas. Lamp finds from the early *cuniculum* along the eastern face in the Galeria do Pilar prove that the drainage of the northern mining zone in the Corta de Covas through the channel sunk into the bottom had already taken place in the 3rd quarter of the 1st century A.D.<sup>19</sup> Lamps from the Galeria do Texugo, lying 30 metres lower down and belonging to the same system, can be dated to the Trajan period, that is the 1st quarter of the 2nd century A.D. These few dates allow to conclude that mining in the southern part of the Corta de Covas began soon after the opening of the mine (fig. 1.0-3).

However, there is a lack of chronological evidence for the mining of the deposits in the Corta da Ribeirinha and Lagoinhos in Tresminas, as well as for those of Gralheira and Jales. Within the general context, we may assume that the main mining phases also date to the 1st and 2nd centuries A.D.

We can summarise the chronology as follows: the commencement of mining can be dated to a period before Christ's birth under Roman rule. Future research may perhaps be able to find the connection between the estate at Vales with its coin treasure, and the gold mining in the deposits in the vicinity. Although they are very worn, the Republican silver denarii, which were collected as surface finds in the vicinity of the amphitheatre at Tresminas, are also important for the dating of the site.<sup>20</sup> According to what we know now, the peak period of the mine was probably between 50 and 150, which is confirmed by the military inscriptions. As J. Wahl has already suspected, the end of mining on an industrial scale must probably be associated with the economic and organisational changes under the Severan imperial family (193—235).<sup>21</sup> However, this does not rule out a continuation of the mining on a smaller scale by the remaining population.<sup>22</sup>

The settlement pattern of the *territorium metallorum* Tresminas/Jales is as follows: the largest known settlement is the next to the “Corta de Covas” opencast mine in Tresminas. It spreads mainly over the plateau, which extends mostly to the west of the opencast mine. Another small area of settlement has been found in the valley of Ribeirinha.<sup>23</sup> It is more difficult to corroborate the possible Roman settlement near the deposits of Gralheira and Jales, as the only evidence so far is the carefully executed capital of a column found in the modern building rubble on a roadside in Campo de Jales.

There is no clear evidence of settlement activity in the area of the Gralheira deposit or at Forno dos Mouros. On the contrary, everything indicates that the buildings at Forno dos Mouros were constructed for purely industrial purposes. Whether we can conclude from this that the workers of Gralheira and Forno dos Mouros still lived in the Castro of Cidadelhã or came from Tresminas must be left open.

The previous investigations in the settlement area of Tresminas have shown that the houses had been built from the outset in the typical Roman quadrangular layout. Geomagnetic surveys in a part of the area revealed that the houses were arranged along both sides of a road, as was common for Roman *vici*.<sup>24</sup> It is also noticeable that at least in the northeastern corner of the settlement, older houses were clearly covered by waste rock dumps.<sup>25</sup> As in any mining area, mining had priority over the settlement, which had to go if necessary.

The amphitheatre can be regarded as an outstanding building.<sup>26</sup> The current state of preservation proves that at least the foundation and probably also parts of the superstructure were made of stone. It can be stated that generally, amphitheatres were only built in stone in larger and more important towns or in connection with military camps.<sup>27</sup> The only amphitheatres known in the northwest of the Iberian Peninsula are those of the various capitals of the *conventii* of Bracara Augusta (Braga/P), Lucus Augusti (Lugo/E), Asturica Augusta (Astorga/E) and from the gar-

16 Wahl 1988, 240; Redentor 2010, 138.

17 1st century: LeRoux 1982, 197. Nr.91bis; 3rd century: Redentor 2010, 138—139.

18 Domergue 1990, 204: Inscription of the freedman *PUDENS* dated to A.D. 97, found in the gallery of a mine in Rio Tinto (Huelva/E), CIL II 956; The inscription of *EMILIANUS* (CIL XIII 4238) only names the day of the opening of the mine, March 7th, but not the year. Accordingly, this inscription can only be dated to the general working period of the mine between the 1st and 4th centuries. Körlin 2010, 176; Uncertified is the inscription *SABALCO* in the Galeria do Texugo, Wahl 1988, 229.

19 Wahl 1988, 240 fig. 43b.

20 Denarius of *L. Calpurnius Piso Frugi*, minted in Rom 90 B.C.; Denarius of *P. Crespius*, minted in Rom 82 B.C.; Denarius of *L. Rutilius Flaccus*, minted in Rom 77 B.C. The unpublished coins are exhibited in the Centro Interpretativo in Tresminas/Vila Pouca de Aguiar.

21 Although there is a lack of relevant research, it cannot be ruled out that the Antoninian plague (165—180/190) may have meant a first major rupture in the social and economic structures of the Empire (I thank A. Wilson, Oxford, for this suggestion).

22 This mining is made more likely by gold finds dating to later periods, such as those from a grave near Granja, a gold coin of the Visigoth king Eciija (685 minted in Sevilla) as well as a golden earring (now lost), see Parente 1980.

23 Wahl-Clerici / Helfert 2017, 55 fig. 4.

24 García Marcos/Morillo Cerdán 2015, fig. 9.

25 Wahl 1988, 234—236, pl. 48.

26 Wahl 1988, 237—238; Martins et al. 2011.

27 Wahl 1988, 237—238, fig. 2, with references; Martins 2011.

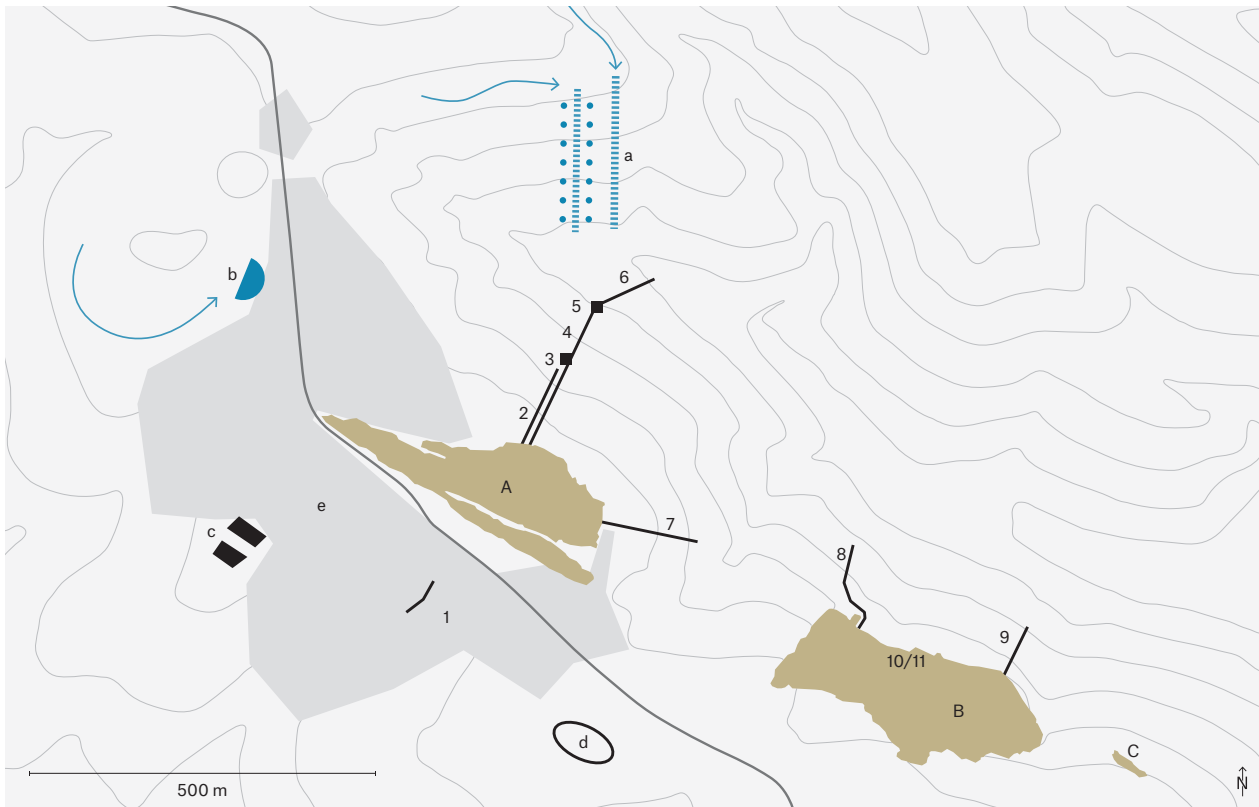


Fig. 1.0-3: *Territorium metallorum* Tresminas/Jales. Overview of the Tresminas core zone: A — Corta de Covas, B — Corta da Ribeirinha, C — Lagoinhos 1 — Galeria Esteves Pinto, 2 — Galeria Jürgen Wahl, 3 — shaft in front of Galeria Jürgen Wahl's adit to the Galeria do Pilar, 4 — Galeria do Pilar, 5 — shaft in front of Galeria do Pilar's adit to Galeria do Texugo, 6 — Galeria do Texugo, 7 — Galeria dos Alargamentos, 8 — Galeria dos Morcegos, 9 — Galeria Buraco Seco, 10 — spiral stairwell, 11 — Galeria do Pastor. a — ore-washing installations, b — water tank, c — slate quarries, d — amphitheater, e — settlement (Template Ortofotomapa Câmara Municipal Vila Pouca de Aguiar 1:10000, design: J. Wahl, R. Wahl-Clerici, M. Helfert, drawing: S. Mathiuet).

riation town of the *legio VII gemina* (León/E).<sup>28</sup> This concentration of amphitheatres in the northwest of the Iberian Peninsula is striking, because only four other amphitheatres are known from the rest of the province of Hispania Tarraconensis: in Ampurias (province of Girona/E), Tarragona (province of Tarragona/E), Cartagena (province of Murcia/E) and Segóbriga (province of Cuenca/E).

At the current state of research, it must remain speculative as to whether we can conclude from the remains of an amphitheatre — a class of building otherwise only erected in regional capitals or in a military context — that *territorium metallorum* Tresminas/Jales was of particularly large size and of organisational and administrative importance.

The modern (Latin-style) term *territorium metallorum* Tresminas/Jales, presupposes that at least all the deposits in the zone formed a unit. However, there are substantial difficulties in determining the extent of this territory. Thanks to the bronze plaques of Vipasca (Aljustrel, Distr. Beja/P) publicly mounted under Emperor Hadrian, we know that *metalla* or *territoria metallorum* had clearly defined boundaries. These were referred to as *finis metallorum* and mentioned in various paragraphs (§§ 10. 13. 17) in connection with the final ban on re-entering a mine site as an additional penalty for offences.<sup>29</sup> Nevertheless, all examples of mining districts in the various Roman provinces have in common that the sources are too few and far between in time as well as place to be able to determine the size of the *territoria* — even for just a single example.<sup>30</sup>

On this subject, however, another point needs to be included in the discussion for the *territorium metallorum* Tresminas/Jales. Pliny the Elder mentions a *Callaeciae metallum, quod vocant Albucrense* (Natural History 33,80) that is a *metallum Albucrense* in *Callaecia*. Due to the particularly low silver content in the gold, which is explicitly mentioned by Pliny in connection with this location, it was assumed that the mines mentioned here must have been the ones in Tresminas, although there is no epigraphic proof that this was the Roman name of Tresminas.<sup>31</sup> Whether the name-part “alhoc”, which is found in inscriptions from Valongo near Porto in the west right up to Salamanca (E) in the east proves that the extent of a *metallum* district cannot be determined with certainty.<sup>32</sup>

Within the context of the present work, other considerations regarding the size of a *territorium metallorum* are significant. A first important point is that the Roman mining district of Tresminas/Jales was an industrial complex. This puts the emphasis on the conditions without which a mining operation could not be maintained. These conditions will be briefly summarised here.

In addition to the settlement and its inhabitants<sup>33</sup>, who left their traces in the houses, the graves and the already mentioned inscriptions, the procurement of agricultural and forestry products was essential. We only have to think of draught and other work livestock, as well as animal products such as leather, tallow, etc., which were of

fundamental importance for the extraction and processing of the ores. Another produce was hemp for the production of ropes, which had to always be available in sufficient quantities. Baskets and other vessels made of organic and non-organic material also belonged to the basic inventory of a mining company.<sup>34</sup> The importance of the fertile valley of Vila Pouca de Aguiar, mentioned in a votive inscription commemorating the burial of a bolt of lightning, is not yet known. Few finds from Roman times have been documented so far.<sup>35</sup>

Among the most important suppliers were the forestry and the wood industry, which did not only include wood, but also charcoal burning.<sup>36</sup> The latter was not only necessary for the smelting of the processed ores, but also for the workshops of the blacksmiths, in which the picks had to be sharpened at short intervals, and for the wainwright's workshops.<sup>37</sup> Enormous quantities of wood also had to be available for fire-setting and high-quality wood was needed for the timber supports in the mines as well as for the mechanical installations.<sup>38</sup>

This very brief overview of the necessary supplies does not include the supply of basic foodstuffs, as we do not have any information on this. In Egypt, where we have more written sources, studies indicate that the organiz-

28 At the Castro of Montemozinho (Concelho Penafiel, District Porto), certain structures discovered in a recent excavation may indicate that the main square was occasionally used as an amphitheatre.

29 Edmondson 1987, 244—254.

30 For a detailed discussion see Hirt 2010, 48—82.

31 Rodríguez Colmenero 1999; For the discussion of the gold contents see chapter 4.2.

32 Summary of the literature on this subject: Redentor, A Cultura Epigráfica no Conventus Bracaraugustanus (Pars Occidentalis), 504—505. — See also the map in Daremberg/Saglio 1877—1919, 1848.

33 For the inhabitants of Tresminas: Redentor 2010; Further information may be gained from the bronze plaques of Vipasca, see Edmondson 1987, 244—254; The wax tablets of the mines in Dacia also include information on the composition of the inhabitants, see Noeske 1977; From Diodorus of Sicily, History 3,13,1 we know that the miners in the Nubian gold mines no longer worked in the mines after the age of 30, but in processing and smelting.

34 See for instance Gossé 1942, Lam. IV-VI; See also Domergue 1990, 440—460.

35 Batata et al. 2008, 26—27.

36 The estimates of Harris 2018, 216 for the production of 80 000 tons of iron per year throughout the Roman Empire result in a forest demand of 26 000 km<sup>2</sup>, which is almost 30% of the area of Portugal (92 212 km<sup>2</sup>); A comprehensive overview of wood in ancient mining is in preparation.

37 Compare the compilation of a working group in the middle quarry in the eastern Egyptian desert (unknown date): Stonecutters: 36; Forge: 3; Men on bellows and hardener: 6; Supervisor: 2; Foreman: 1; Man on hammer: 1 (Peacock/Maxfield 1997, 200 after Bülow-Jacobsen 1992, MC Inv. No. 0.1252).

38 Overview of antique quotations: Wilson 2008, 337—339.



ation of the food supply was adapted to the local conditions.<sup>39</sup>

These conditions, which are here only summarised, indicate that the *territorium metallorum* Tresminas /Jales was a true industrial district in its own right, which, at least in the area of the Tresminas gold deposit, had been established from scratch.

In addition to the areas already mentioned, we may assume that at least the complete hydrographic basin and the water supply system were part of the *territorium metallorum* Tresminas /Jales. The granite quarries were also included. Since the biotite granite is present on the valley slopes of the valleys of the two rivers Corgo and Avelames, which both originate in Vila Pouca de Aguiar, and traces of Roman stonemason's work have been found there, we can conclude that this area was also part of the *territorium*.<sup>40</sup>

These conditions are linked to questions concerning the organisation and management of the *territorium metallorum* Tresminas /Jales. Generally, newly conquered land — and with it, the deposits in it — became the property of the Emperor as the legal successor of the former ruler(s). In other words, the northwest of the Iberian Peninsula was owned by Augustus and his successors, because the Roman Empire hardly distinguished between the personal property of the Emperor (*fiscus*) and the state property (*aerarium*).<sup>41</sup>

One of the main difficulties in this discussion is that we cannot assume that the same form of organisation always prevailed during the 200 years of operation of the *territorium metallorum* Tresminas /Jales.

The following may be noted concerning the *territorium metallorum* Tresminas /Jales. It was certainly an Imperial fiscal mine under the regime called “régie directe” by Domergue. In such cases, a *procurator*, usually an Imperial freedman, was in charge of the operation and the entire profit was transferred to the Imperial treasury.<sup>42</sup> Even if there are no written sources, the planning of large-scale galleries, such as they are found in Tresminas, can be seen as clear evidence of a centralised form of organisation. The sophisticated system of the various galleries and shafts to facilitate ore extraction in the Corta de Covas is especially outstanding. The enormous effort made in the water supply of the mines also points to a central form of organisation.<sup>43</sup>

The bronze panels of Vipasca and the wax panels from the archives of the Dacian mines are evidence of another form of organisation. They indicate an ingenious system of leases under the direction of an Imperial *procurator*.<sup>44</sup> In general, all the responsibility was transferred to the lessees, who in turn imposed it on their workers as far as possible.<sup>45</sup> The concession fees compensated the state.<sup>46</sup> The Romans thus managed to make mines profitable for the state through leasing them out.<sup>47</sup>

Since gold was also mined in the Dacian mines, the argument that gold was always mined under direct state

administration loses its force. However, there are still no indications of a lease system in the northwest of the Iberian Peninsula.

Another form of organisation can be deduced from the archaeological remains and the Bembibre edict of Augustus previously mentioned.<sup>48</sup> In it, it is assumed that the mining is carried out by the (demonstrably loyal) local population. The gold is supposed to be mined under the direction of the clan aristocracy, with a certain amount having to be paid in tribute. The rest remained in the possession of the tribe or the aristocracy. This form of organization was ultimately based on the well-known Roman pattern that deliberately integrated the local upper class in the administration and assigned them executive tasks. If this led to a disintegration of the prevailing social structures, this would only work in favour of Rome.<sup>49</sup> However, it must be pointed out that there is no indication of such processes whatsoever in the *territorium metallorum* Tresminas /Jales.

39 For the supply of basic foodstuffs in the Egyptian desert see Hirt 2010, 214—217; Friedmann 2013; On the prices of individual goods in the Dacian mines see Mrozek 1971.

40 An undated votive inscription to Jupiter Fulgur from Castelo (Freguesia Telões, Concelho Vila Pouca de Aguiar), carved onto a fired clay plate, will perhaps also have to be seen in connection with the extraction of biotite granite. It was found in the crevice of a burst granite block and handed over to Francisco Martins Sarmiento by Padre Josef Brenha in October 1898. The site of a lightning strike was sealed, marking the site as Jupiter's burial ground. See CIL II 262 = AE 1947.8.

41 Ausbüttel 1998, 14—16.

42 A detailed discussion on the mine procurators can be found in Domergue 1990, 280—307; Hirt 2010, 76—79; Heil 2012; Wahl 1988, 241—242; Due to their special situation, the quarries in the Egyptian desert can be described as an extreme case. Thanks to the inscriptions preserved there, Hirt was able to work out a tight form of government organisation under military leadership (Hirt 2010, 51—53).

43 Already indicated by Domergue in 1990, 303.

44 His responsibilities are listed in the bronze plates of Vipasca Edmondson 1987, 244—254; Noeske 1977.

45 Noeske 1977, 396—403. The tables TC IX, CIL III, p. 948, and TC X. CIL III, p. 948, state that the workers had to come to work in full possession of their powers. If they did not do so, even in the case of illness or accident, the worker had to pay 5 sesterces and 8 aces/day to the tenant.

46 According to the *Lex metallis dicta* (§2), 4000 HS of the lease for a mine had to be paid before the work started.

47 See Günther 2012, 152.

48 For the discovery of the Bembibre edict, see Domergue 1990, 305; Orejas/Sánchez Palencia 2002, 589—591; Sánchez-Palencia et al. 2017.

49 Galsterer 1979, 456, note 1, mentions the Roman „schools of prince“, in which the sons of the tribal aristocracy were educated in the Roman style. Plutarch, Sertorius 14,2—3: *But most of all were they [the Celtiberians] captivated by what he [Sertorius] did with their boys. Those of the highest birth, namely, he collected together from various peoples, at Osca [Huesca/E], a large city, and set over them teachers of Greek and Roman learning; thus in reality he made hostages of them, while ostensibly he was educating them, with the assurance that when they became men he would give them a share in administra-*

In addition it remains unclear how long this type of organisation prevailed.<sup>50</sup> Doubts arise when we take into account the considerable technical requirements of all larger mines, whether they were situated in primary and secondary deposits<sup>51</sup> or in alteration zones.<sup>52</sup> Even though the Celtiberian population had had generations of experience and great knowledge and skill in gold mining<sup>53</sup>, it seems likely that they would have needed the technical support of the Romans at least at the outset of large-scale mining, for example for surface and underground surveying.<sup>54</sup> Based on other sources, such as the inscription of Nonius Datus, we can assume that the military not only had administrative and security tasks, but was also responsible for technical matters.<sup>55</sup>

How far this topic is connected with the question of the profitability of the Roman gold mines is an additional field of discussion. Domergue explicitly refers to the blatant disproportion between effort and yield in Las Médulas, if all the necessary additional work for gold mining is taken into account.<sup>56</sup> Here it can be seen that the principle established by Hirt regarding the organisation of Roman mines and quarries may be correct in most, but not all cases:

“The guiding principle of the Roman mining and quarrying administration was to keep imperial involvement to a minimum without renouncing control of these ventures.”<sup>57</sup>

This is because the gap between effort and yield did not only exist in Las Médulas, but also, for example, in the core zone of Tresminas in the *territorium metallorum* Tresminas/Jales.

One of the main difficulties in addressing this problem is the difficulty of determining the quantity of the gold mined, since the gold content is always measured in the unmined zones, so that the uncertainty factor remains high. Another uncertainty is the amount of orebody and sterile material that has been mined at all. Balancing all of this with the unavoidable expenditure on hydraulic engineering, processing and the supply industries has also led to doubts in Tresminas, as to whether the mine was ever profitable in the modern sense.<sup>58</sup>

At this point it is necessary to briefly discuss the different conditions of the deposits of Tresminas and Gralheira as well as Campo de Jales. Both had clearly defined ore veins in which the polymetallic ores with high gold content were embedded in quartz deposits. Only a small amount of sterile material had to be mined additionally in order to extract it. Processing was also less complex, as the remains at Forno dos Mouros show.<sup>59</sup> Although the gold content in both these deposits was significantly lower than in Tresminas, we can nevertheless assume that these mines were most likely profitable.<sup>60</sup>

These aspects of the history and organisational form of the *territorium metallorum* Tresminas/Jales, which have ne-

cessarily been summarised only very cursorily, prove that we may see the *territorium metallorum* as a settlement of some importance, at least during its heyday, whose deposits had probably been already exploited before the begin of the Common Era and certainly under direct Roman control during the 1st and 2nd centuries A.D. How far gold continued to be mined after the economic reforms under the Severan Emperors (193—235) and with which form of organisation is beyond our knowledge.<sup>60a</sup>

It remains to be stated that the excellent state of conservation of the mining zones of Tresminas with its wealth of monuments forms an important basis for a deeper understanding of gold mining in a primary deposit during the Principate.

*tion and authority. So the fathers were wonderfully pleased to see their sons, in purple-bordered togas, very decorously going to their schools, and Sertorius paying their fees for them, holding frequent examinations, distributing prizes to the deserving, and presenting them with the golden necklaces which the Romans call “bullae”.* See also Tacitus, Annals 3,43,1; Tacitus, Agricola 21,2.

50 For a summary of the literature see Hirt 2010, 228—232 and 356—369.

51 E. g. Las Médulas (Prov. León/E).

52 Alteration zones: for instance, the Teleno massif (Prov. León/E), Alto del Palo (Prov. Asturias/E) and Bustantigo valley (Prov. Asturias/E).

53 See also Wahl-Clerici/Wiechowski 2013, 299.

54 In addition to the sometimes very long aqueducts, which posed a particular challenge, the complex underground passages in Las Médulas (now open to the public), were also part of the project.

55 See the construction of the aqueduct tunnel of Saldae (Bejaia, Algeria) and the role of the veteran Nonius Datus. Grewe 1998, 134—139.

56 “Quand on pense aux travaux qu’a nécessités une telle exploitation (aménagement et maintien des réseaux d’aqueducs chargés d’acheminer l’eau des rivières environnantes vers le site, construction des réservoirs de stockage et d’exploitation, travaux préparatoires à l’abattage, lavage, évacuation des stériles, etc.), on peut s’étonner que tant de travaux aient été entrepris pour un si mince résultat.” Domergue 2012, 114. The entire yield of the Las Médulas (Prov. León/E) mine is thought to have been ca. 4,6 t of gold, see Domergue 2008, 209.

57 Hirt 2010, 368.

58 Wahl-Clerici (in print), Considerations on the Profitability of Roman Gold Mining in the Northwest of the Iberian Peninsula during the 1st and 2nd Centuries A. D.

59 Wahl-Clerici/Wiechowski 2012; Wahl-Clerici et al. 2012b.

60 The Campo de Jales vein was mined again between 1932 and 1990. Prospecting is taking place again and again at the Gralheira ore vein.

60a The early medieval sarcophagus of Tresminas indicates also the continuity of settlement in the area (fig. 6.0-9b), Batata et al. 2008, 28—30.

## 1.1 History of research

In this first volume of a series of scholarly publications on the *territorium metallorum* Tresminas/Jales, the monuments left behind by the work of Roman miners in a gold mine in primary deposits are presented. It is important to note that both the mining zone of Tresminas and that of Gralheira are rare examples that have not been disturbed by recent mining. Since 1997, the archaeological complex of Tresminas has been protected from further exploitation by being declared a ‘property of public interest’.<sup>61</sup> The exceptionally rich and well-preserved remains allow mining archaeologists to gain an overview of the various components and operations of an ancient gold mine.

The remains of the Roman mine of Tresminas were first described by the Portuguese cleric Jerónimo Contador de Argote (1676—1749), who visited the diocese of the Archbishop of Braga and summarised the results in his monumental work “Memórias para a História Eclesiástica do Arcebispado de Braga, Primaz das Espanhas” (1734).<sup>62</sup> The first modern essay on the mining in Tresminas was written by H. Botelho in 1907.<sup>63</sup> Other authors followed, including mining engineers who were active in Tresminas, Gralheira and Campo de Jales. However, most of these were small pamphlets, in which different aspects of Tresminas were considered in isolation.<sup>64</sup> In 1970, D. F. de Almeida presented an initial summary of the research up to this point.<sup>65</sup>

The geology and mineralogy of the deposits of Tresminas, Gralheira and Jales have recently been studied using modern methods. D. R. N. Rosa (2001) has worked on this topic particularly thoroughly in his dissertation “Metallogenesis of the Jales gold district, northern Portugal”.<sup>66</sup> Further research was carried out by L. F. Viegas and L. P. Martins (1992), F. Noronha, M. Cathelineau, M.-C. Boiron, D. A. Banks, A. Dória, M. A. Ribeiro, P. Nogueira and A. Guedes (2000), D. R. N. Rosa and S. B. Romberger (2003), P. Machado, S. Barbosa, A. Dória, M. A. Ribeiro (2006), M. A. Ribeiro, A. Dória and F. Noronha (2006), J. M. Farinha Ramos (2017) and J. I. Ferrão de Paiva Martins e C. M. Braz Martins (2017).

L. Sousa and his students from UTAD in Vila Real gave an overview of the granite and granite mining in the Concelho of Vila Pouca de Aguiar, which was published in 2012.

The most important ancient source of information on gold mining in the northwest of the Iberian Peninsula is the *Naturalis historia* of Pliny the Elder (23—79), who had been the financial procurator of the province of Hispania Tarraconensis in the years 72—74, and in this function supervised the economically important mines and personally inspected the region. In his 33rd book, sections 62—80, he compiled his detailed knowledge on gold min-

ing, describing various possibilities for ore mining and processing, thus leaving behind a valuable treasure for posterity, which every mining archaeologist is grateful to be able to consult again and again.

On the occasion of a first exploration of Tresminas in 1985, Jürgen Wahl (†2007) and the author recognized the potential of the site for the history of mining. A year later, they began the systematic exploration of the site. The first investigations in the field took place between 1986 and 1988, as part of a project of the Madrid branch of the German Archaeological Institute. In 1986, a collaboration with the German Mining Museum Bochum was begun. The results of this initial research were published in 1988 as a preliminary report in the *Madrider Mitteilungen* of the DAI. The report presented results of the surveys and excavations and also embedded the mining district in its historical as well as organisational and administrative context on the basis of the finds and epigraphic sources.

Thanks to the systematic and intensive investigation of the site during the annual surveys, the author, and J. Wahl (until 2006) were able to gain a wealth of new insights into ancient mining, geology and mineralogy as well as into metallurgical issues on site. This was done between 1990—1993 in collaboration with H.-G. Bachmann (formerly at Goethe University Frankfurt am Main and Imperial College/London), and from 1992 onwards

61 The classification of the archaeological complex of Trêsmnas as “Imóvel de Interesse Público” (Decreto n.º 67 / 97, DR, I Série-B, n.º 301, de 31-12-1997).

62 The part on Tresminas can be found in vol. II, pp. 473—482.

63 Botelho 1907.

64 L. de Albuquerque e Castro, Tresminas—Arqueologia Mineira, in: *Actas do Congresso Internacional de Etnografia*, 1 (1963); F. de Almeida, in: *Legio VII Gemin.* (1970) 291—296; H. Botelho, *APort* 12, 1907, 26—31; M. Cardozo, *RGuimar* 64, 1954, 120—133; C. A. Ferreira Almeida, in: *XII Congreso Nacional de Arqueologia* 1971 (1973) 553—562; C. García Merino, *HispanAnt* 3, 1973, 19—22; F. A. Harrison, *The Mining Magazine* 14, 1931, 142—144; J. Leite de Vasconcelos, *Revista de Arqueologia* 3, 1936, 193—195; J. Parente, in: *Actas do Seminário de Arqueologia do Noroeste Peninsular III* (1980) 131—140; H. Quiring, *Zeitschrift für das Berg-, Hütten- und Salinenwesen im Preußischen Staat* 81, 1933, 276. 277; J. Silva Carvalho, O. da Veiga Ferreira, *Estudos, Notas e Trabalhos do Serviço do Fomento Mineiro* 9, 1954, 30—33; A. Tranoy, *La Galice romaine. Recherches sur le nord-ouest de la péninsule ibérique dans l’Antiquité*, *Publications du Centre Pierre Paris 7. Collection de la Maison des pays ibériques* 7 (1981) 222—224.

65 De Almeida 1970.

66 Rosa 2001.

with A. Wiechowski, (Mineralogist RWTH Aachen) and R. Schindlmayr (formerly Bergische University Wuppertal). In 2005, the Câmara Municipal de Vila Pouca de Aguiar, with its President, Domingos Dias, and the Junta de Freguesia de Tresminas, with its President, Fernando Marques, established an archaeological park at the site under the archaeological direction of J. Wahl.

From 2010 onwards, two archaeologists with valuable experience in non-invasive field research, B. Ramminger (University of Hamburg) and M. Helfert (University of Hamburg/Goethe University Frankfurt a.M.), joined the research team. Both Prof. H.-M. von Känel and his successor Prof. M. Scholz (Archaeology and History of the Roman Provinces, Goethe University Frankfurt a.M.) supported the project with their epigraphic knowledge. From 2017 onwards, the surveyors Dr. T. Kerstens, K. Mechelke and M. Lindstaedt (all from the geodetic department of the Hafen-City University Hamburg) helped to facilitate the surveys and investigations. J. Moutinho and V. Gandra and the members of Alto Relevo Clube de Montanhismo of Valongo helped immensely in enabling the work in the hard-to-reach areas of the mining zones of Tresminas.

From 2007 to 2010, C. Batata again carried out excavations in the area of the settlement, in the area of the suspected cemetery northwest of opencast mine A, in the processing site “Forno dos Mouros” and in the Castro of Cidadelhã.<sup>67</sup> Under the direction of C. M. Braz Martins, Universidade do Minho, small-scale georadar investigations were carried out in the amphitheatre area in 2010.<sup>68</sup> E. J. Sánchez Palencia’s publication, written as part of a re-design of the Centro Interpretativo of the site, contributed only little new research on the site.<sup>69</sup>

The Câmara Municipal of Vila Pouca de Aguiar under the direction of its president, Professor Antonio Machado and Councillor Dra. Ana Rita Dias, hosted the 1st International Symposium on the *territorium metallorum* Tresminas/Jales in 2014. In the resulting publication (2017), fundamental aspects of the site were united in a single publication for the first time. Together with M. Helfert, the author contributed the first overview of the archaeological discoveries on the mining in the mining zones of Tresminas after the fundamental publication by J. Wahl (1988/1993).<sup>70</sup> A. Redentor also presented and discussed the inscriptions from the *territorium metallorum* Tresminas/Jales, which had only been discussed cursorily by J. Wahl in 1988.<sup>70a</sup>

On the occasion of another symposium in 2017, under the combined direction of the Câmara Municipal and the Associação AOURO, more recent research was discussed and a travelling exhibition was opened. The author gave a brief introduction to Roman mining on five different panels and Patricia Machado presented a documentation of the medieval church of Tresminas.

In addition to discovering and documenting the mining monuments, J. Wahl and the author were also keen to systematically locate the rich and complex remains of the

water supply system and the stone extraction sites. Particular emphasis was placed on the recording of conspicuous details and the determination of the respective contexts, so that first results could already be published.<sup>71</sup> Summaries on these topics are presented in this volume. Comprehensive presentations are in preparation for further volumes in this series.

67 Batata 2017; Batata 2009; Batata et al. 2008.

68 Martins 2011.

69 Sánchez Palencia 2015.

70a Redentor 2010.

70 Wahl-Clerici / Helfert 2017; Further contributions: Farinha Ramos, Geologie; Martins, Arqueometalurgia; Machado, Paróquia de Tresminas; Martins/Martins Ouro em Jales; Gaspar Nero, Recuperação das áreas mineiras em Portugal.

71 Water supply system: Wahl 2003; Wahl-Clerici 2013; Wahl-Clerici 2016; Wahl-Clerici 2017; Wahl-Clerici/Helfert 2017; Quarry: Wahl-Clerici et al. 2015.

## 2.0 Prospection in the *territorium metallorum* Tresminas / Jales<sup>72</sup>

Even in Roman times it was possible to draw on a wealth of experience in the search for ore deposits. The oldest known word for prospecting for gold, „sementi“, is known from pre-dynastic Egypt (around 3200 B. C.).<sup>73</sup> The prospecting activity of the Romans mainly differed from that of their predecessors in the consistency of its application and in its systematic and efficient execution.

The necessity for prospecting the conquered land in the northwest of the Iberian Peninsula was already stressed by the ancient authors Florus (around 100 A. D.) and Cassius Dio (around 150—235 A. D.). Cassius Dio (52,28,4-5) relates a conversation between Augustus (63 B. C.—14 A. D.), his general Agrippa (64—12 B. C.) and his financial advisor Maecenas (70—8 B. C.), in which the latter explained that it was essential for the state budget to first obtain an overview of the profitable sources of income, including the mines:

οὕτω γὰρ ἢ τε γῆ ἐνεργὸς ἔσται, δεσπότηαις αὐτουργοῖς δοθεῖσα, καὶ ἐκεῖνοι ἀφορμὴν λαβόντες εὐπωρότεροι γενήσονται, τό τε δημόσιον διαρκῆ καὶ ἀθάνατον πρόσοδον ἔξει. εἴτα συλλογίσασθαι ταῦτά τε καὶ τᾶλλα ὅσα ἐκ τε μεταλλείας καὶ εἰ δὴ ποθεν ἄλλοθεν βεβαίως δύναται προσιέναι, (5) καὶ μετὰ τοῦτο ἀντιλογίσασθαι μὴ μόνον τὰ στρατιωτικὰ ἀλλὰ καὶ τᾶλλα πάντα δι' ὧν καλῶς πόλις οἰκεῖται, καὶ προσέτι καὶ ὅσα ἔξ τε τὰς αἰφνιδίους στρατείας καὶ ἐξ τὰ λοιπὰ ὅσα εἴθωθεν ἐπὶ καιροῦ συμβαίνειν, ἀναγκαῖον ἔσται δαπανᾶσθαι

In this way not only will the land be put under cultivation, being sold to owners who will cultivate it themselves, but also the latter will acquire a capital and become more prosperous, while the treasury will gain a permanent revenue that will suffice for its needs. In the second place, I advise you to make an estimate of the revenues from this source and of all the other revenues which can with certainty be derived from the mines or any other source, (5) and then to make and balance against this a second estimate of all the expenses, not only those of the army, but also of all those which contribute to the well-being of a state, and furthermore of those which will necessarily be incurred for unexpected campaigns and the other needs which are wont to arise in an emergency.

This statement is generally seen as an assignment to prospect the whole of the newly captured territories of the Iberian Peninsula. Florus (98—117), who also dealt with the Augustan epoch and mining, made the—surely incorrect—assertion that the local population only learned about the mineral resources of the land through the Romans.

*Favebat consilio natura regionis; circa enim omnis aurifera est et chrysocollae minique et aliorum colorum ferax. Itaque exerceri solum iussit. Sic Astures nitentes in profundo opes suas atque divitias, dum aliis quaerunt, nosse coeperunt.*

The natural advantages of the place favoured his plan; for the whole district bears gold and is rich in *chrysocolla*, vermilion and other pigments; he, therefore, ordered that the soil should be tilled. Thus the Astures, digging deep into the ground in search of riches for others, gained their first knowledge of their own resources and wealth.

(Publius Aeneas Florus, *Epitoma de Tito Livio* 2,33, 60)

In principle, prospecting consists of two phases, which may not always leave easily distinguishable traces at the site.

- locating a deposit
- determining the boundary of a deposit

The methods for finding deposits were described several times in ancient literature for the various metals, whereas the determination of the deposit's boundaries was rarely mentioned. However, traces of the latter activity are preserved in abundance, mainly at Tresminas.

### The methods for locating a deposit

One of the simplest and most efficient methods was to search for gold in the deposits of rivers. The geographer Strabo (ca. 63 B. C.—19 A. D.), a contemporary of Augustus, refers to Poseidonius (135—51 B. C.) and briefly describes the knowledge of the gold-bearing river sands in the local population (*Geography* 3,2,9).

Ἀρτάβροισ, οἱ τῆς Λυσιτανίας ὕστατοι πρὸς ἄρκτον καὶ δύσιν εἰσίν, ἔξανθεῖν φησιν τὴν γῆν ἀργυρίῳ, καττιτέρῳ, χρυσίῳ λευκῷ (ἀργυρομιγῆς γάρ ἐστι), τὴν δὲ γῆν ταύτην φέρειν τοὺς ποταμούς· τὴν δὲ σκαλίσι τὰς γυναῖκας διαμώσας πλύνειν ἐν ἠθητηρίοις πλεκτοῖς εἰς κίστην. οὗτος μὲν περὶ τῶν μετάλλων τοιαῦτ' εἶρηκε.

<sup>72</sup> For detailed information see Wahl-Clerici / Wiechowski 2013.

<sup>73</sup> Zick et al. 1998.

But among the Artabrians, who live farthest on the north-west of Lusitania, the soil “effloresces,” he [Poseidonius] says, with silver, tin, and “white gold” (for it is mixed with silver). This soil, however, he adds, is brought by the streams; and the women scrape it up with shovels and wash it in sieves woven basket-like. Such, then, is what Poseidonius has said about the mines [of Iberia].

Strabo (Geography 3,2,8) also notes that the gold deposits are often located in arid zones. This is only true to the extent that they were found more easily in these zones because of the meagre vegetation. Finally, he notes that washing the sand produces more gold than mining it.<sup>74</sup>

The gold-bearing Tagus/Tejo was praised by Catullus (1st century B.C.) in his song 29.<sup>75</sup> According to Strabo, other gold-bearing rivers in Lusitania were the Mondego, the Vouga, as well as the Douro, which originates near Numantia, . . . and the Minho.<sup>76</sup>

With regard to the *territorium metallorum* Tresminas/Jales, the reference to the Douro is of particular importance. This allows the speculation that the sites of the *territorium metallorum* Tresminas/Jales were discovered via the river system of the Douro, namely the Rio Tua, the Rio Tinhela and the Rio Curros. The gold deposited through the weathering of the rock at Jales and Gralheira over millions of years collected in the Rio Tinhela, while the Rio Curros collected the gold from the deposit of Tresminas.

Another long-established method for finding deposits is the systematic search for abandoned mines. A testimony describing the method is preserved from pre-Roman antiquity: Seneca the Younger (around 4—65 A.D.), in his *quaestiones naturales* relates that Philip of Macedonia (around 382—336 B.C.) knew of a mine that had been abandoned for a long time, but sent out people to determine the profitability of reopening it (Q Nat. 5,15,1):

*Nunc mihi permittite narrare fabulam. Asclepiodotus auctor est demissos quam plurimos a Philippo in metallum antiquum olim destitutum, ut explorarent quae ubertas eius esset, quis status, an aliquid futuris reliquisset vetus avaritia; descendisse illos cum multo lumine et multos duraturo dies, deinde longa via fatigatos vidisse flumina ingentia et conceptus aquarum inertium vastos, pares nostris nec compressos quidem terra supereminente sed liberae laxitatis, non sine horrore visos.*

Now permit me to tell a story. Asclepiodotus is my authority that many men were sent down by Philip into an old mine, long since abandoned, to find out what riches it might have, what its condition was, whether ancient avarice had left anything for future generations. They descended with a large supply of torches, enough to last many days. After a while, when they were exhausted by the long journey, they saw a

sight that made them shudder: huge rivers and vast reservoirs of motionless water, equal to ours above ground and yet not pressed down by the earth stretching above, but with a vast free space overhead.

The observation of soil discolourations or differences in the rock, gold deposits occur most frequently in the quartz veins, which are very conspicuous in the terrain, as is the case for the veins of Gralheira and Campo de Jales (figs. 2.0-1).<sup>77</sup> Plant growth could also point to a deposit, as certain plants thrive primarily on soils containing heavy metals and are therefore suitable markers for ore deposits. For example, in spring the Serra de Sta. Justa near Valongo (District Porto, Portugal) is covered with the widespread, bright red *Rumex bucephalorus* (species: horned dock), but the plant occurs only sporadically in the *territorium metallorum* Tresminas/Jales.

In Roman times, there was no hesitation in opening up comprehensive prospection systems if deposits worthy of exploitation were suspected in the zone. The example of “Cabezas de los Pastos” (province of Huelva/E) in Andalusia, where attempts were made to capture the deposit below the gossan (intensely oxidized, weathered or decomposed rock, usually the upper and exposed part of an ore deposit) by means of around 300 shafts, shows the thoroughness of the procedure, even if success was ultimately not achieved there.<sup>78</sup>

<sup>74</sup> Also see Sánchez-Palencia et al. 2006.

<sup>75</sup> In his song 29, Catullus maligns a number of acquaintances for their inappropriate behaviour, among them the lines on the Tagus/Tejo can be found (carmina 29,19—22):

*paterna prima lancinata sunt bona,  
secunda praeda Pontica, inde tertia  
Hibera, quam scit amnis aurifer Tagus.*

His ancestral property was first torn to shreds; then came his prize-money from Pontus, then in the third place that from Spain, of which the gold-bearing river Tagus can tell.

<sup>76</sup> Strabo, Geography 3,3,4; For the references see Fernandez Nieto 1971.

<sup>77</sup> Agricola presents different prospection methods (fig. 2.0-2).

<sup>78</sup> Domergue 1989, 231—232; Domergue 1990, fig. 18. The shafts were constructed to penetrate the gossan that covers the deposits in the Pyrite belt. See also the mines of Cabezo de los Silos near La Zarza, province Huelva (Domergue 1989, H 19), as well as the mines at Sotiel Coronada near Valverde del Camino, province Huelva (Domergue 1989, H 20 and Domergue 1990, fig. 16). Furthermore, the thickness of the gossan of Vipasca/Aljustrel, district Beja is indicated at 10 to 15 m (Domergue 1989, POR 2, 495).

## Discussion of conditions in the *territorium metallorum* Tresminas / Jales

With respect to their discovery, the three large deposits in the *territorium metallorum* Tresminas/Jales need to be discussed separately. The inhabitants of the Castros of Cidadelhã must have known about the ore vein of Gralheira, which is over 2.5 km long (fig. 2.0-3). It may be assumed that this also applies to the ore vein of Campo de Jales, which is barely 400m away. Whether they already knew about the deposit of Tresminas cannot be decided at present, especially since there are other castros in the vicinity whose occupational phases have only been sporadically examined.

At no point were traces of pre-Roman mining discovered within the three deposits. If they ever existed, they would certainly have been destroyed by the Roman mining activities. It has also not yet been possible to find any of the typical accumulations of sterile material along the watercourses that occur when the river sands are washed out.<sup>79</sup>

## Determination of the boundary of the deposit

Once a deposit had been discovered, mining began as soon as possible. The next important task of the prospectors was to determine the boundaries of the deposit. As a rule of thumb each progress of mining was connected with further sounding out the mineable contents.

The importance of these prospections becomes comprehensible through inspection of the regulations covering them in the *Lex metallis dicta* of Vipasca.<sup>80</sup>

§ 15: ... *Procurator explorandi novi metalli causa ternagum a cuniculo agere / permittito ita ut ternagus non plures latitudinis et altitudinis quam quaternos pedes habeat.*

§ 15 The procurator shall permit the driving of a drift (*ternagus*) from the ditch for the purpose of discovering new mineral, on condition that the drift be not more than four feet in width and depth.<sup>81</sup>

§ 16: *Venam intra quinos denos pedes ex utroque latere a cuniculo quaerere caedereve ne liceto.*

§ 16: It shall be forbidden to look for or extract ore within fifteen feet on either side of the ditch.<sup>82</sup>

The distances given are related to the safety underground, which is particularly evident in § 16, and were mainly applied to safety considerations.

In addition to the stability of the rock, the complexity of the deposit is an important aspect when considering the preserved prospecting structures. In the mining zone

of Tresminas, for example, a large number of prospecting structures have been preserved in contrast to those of Gralheira. So far, only isolated sampling sites have been identified in Gralheira, whereas entire systems have been preserved in Tresminas (figs. 2.0-4—2.0-6). These traces make it possible to understand at least the main features of the Roman prospecting methods, in both their ideas and actions.

When researching prospecting structures, it must be borne in mind that the only structures that remained standing were those discovered to not have any mineable contents. A large number of these structures thus indicates the complexity of a deposit, which kept forcing the miners to redefine the boundaries.

## Examples of prospecting in Tresminas

Remnants of surface sampling are particularly rare, which is due in large part to the fact that if they are not discovered by chance, they can only be discovered by systematically examining the rock formations on entire slopes. Often these traces are hardly recognizable and look similar to those made by a modern geologist's hammer. In Tresminas it was only through the incorporation of a typical Roman feature characterised by a carefully cut pocket-like recess into the rock, that allowed the remains to be classified as undoubtedly antique (figs. 2.0-7, 2.0-8). As these traces in the *territorium metallorum* Tresminas/Jales are quite difficult to recognize and often are also covered by vegetation or detritus, it may be assumed that they were probably much more numerous in the past.

At the other end of the spectrum are large-scale prospecting systems to explore entire mountain ranges at different altitudes. Traces of such systems can be found especially in the mountains between the two large opencast mines Corta de Covas and Corta da Ribeirinha (figs. 2.0-5, 2.0-6). The largest and most complex system comprised the two shafts visible today in the eastern slope of the Corta de Covas as well as the Galeria dos Alargamentos with its various outgoing structures (figs. 2.0-9—2.0-12).<sup>83</sup>

In the lower areas between the two opencast mines, prospecting mines were also opened. It is known that the continuation of the Galeria do Texugo in an easterly direction is a man-sized tunnel into which additional shafts were sunk in various places. Large shafts, which can be identified by their slagheaps, were opened between the two opencast mines.

The small gallery above the roof of the Galeria do Pilar is also a prospecting building. The conspicuous accumula-

79 Sánchez Palencia et al. 2006, 271 fig. 9.

80 Edmondson 1987, 244—254.

81 Edmondson 1987, 254.

82 Edmondson 1987, 254.

83 Wahl-Clerici et al. 2012a.

tion of debris suggests that there was a connection to the shaft that leads into the Galeria do Pilar above the pillar (fig. 2.0-13).

A conspicuous accumulation of prospecting structures can be found in the southern slope of the northern mining zone of the Corta de Covas, since it was hardly conceivable that this area should be sterile (fig. 2.0-5).

Several prospection buildings were also preserved in the Corta da Ribeirinha.<sup>84</sup> A multi-stage section was created parallel to the antique western port, with at least one further gallery leading off from the western face (figs. 2.0-14, 2.0-15). The search was abandoned only after no ore had been found in the Galeria dos Morcegos system excavated below and especially in the shaft opened for this purpose (fig. 2.0-16). In the eastern part of the Corta da Ribeirinha, only a nameless gallery has been preserved from the prospecting structures, via which the sterile zone was sampled towards Lagoinhos (fig. 2.0-17).

Because of the meeting of the two prospecting zones which were opened from the western and the eastern side of the Corta da Ribeirinha, a particularly complex mine has been preserved. When a spiral stairwell (fig. 2.0-18) was cut into the rock in the western part, the eastern part was driven further at a lower level.<sup>85</sup>

The highest density of traces left by the search for the boundaries of the deposit is found in Lagoinhos. Horizontal and vertical prospection structures were opened for this purpose here (figs. 3.0.1-6, 3.0.1-12, 3.0.1-13a/b).<sup>86</sup>

The twin shafts preserved on the south-eastern edge of the Corta da Ribeirinha were sunk directly next to each other and are only separated by a rock band with a width of about 30 cm (fig. 2.0-19). Due to their position, it cannot be excluded that these circular shafts were originally located outside the Roman mining zone and were used for prospecting.

In summary, it can be stated that the mineshafts necessary for prospecting are not different from those that were built for the mining itself. When allocating the structures to mining or prospecting, it must also always be taken into account that former prospecting shafts may have later been used for mining or drainage.

Nevertheless, some characteristics of prospection may be stated:

- Prospection frequently took place in a combination of adits/tunnels, shafts and inclined shafts (figs. 2.0-10, 2.0-15, 2.0-16, 2.0-20, 2.0-21).
- Another characteristic feature is an accumulation of several small structures in a relatively clearly defined zone (figs. 2.0-5, 2.0-6, 2.0-10, 2.0-15, 2.0-16, 2.2-1, 2.2-2, 3.0.1-12, 3.0.1-13a/b, 3.0.1-16).
- In addition, there is a tendency towards arranging the various mining shafts and adits/tunnels in such a manner that they cover a larger area (figs. 2.0-5, 2.0-6).

<sup>84</sup> Wahl-Clerici et al. 2019.

<sup>85</sup> Wahl-Clerici et al. 2019.

<sup>86</sup> Wahl-Clerici et al. 2017.





Fig. 2.0-1: *Territorium metallorum Tresminas* / Jales, Gralheira, seen from the east: in the background, the long ditches and waste rock dumps of the ore vein, which at this point fans out into at least five separate veins, are visible (photo: J. Wahl).



Fig. 2.0-2: *Prospection methods after Agricola 1556/1984, 32.*



Fig. 2.0-3: *Territorium metallorum* Tresminas / Jales, the Celtiberic Castro at Cidadelhã, from the north: section of the enclosure wall near the gate on the left (photo: J. Wahl).



Fig. 2.0-4: *Territorium metallorum* Tresminas / Jales, at Gralheira: small prospecting adit excavated laterally from the mining zone (photo: R. Wahl-Clerici).



Fig. 2.0-5: *Territorium metallorum* Tresminas / Jales: overview of Corta de Covas with the prospecting shafts and adits (template: Orthophotomapa 1:5000 Vila Pouca de Aguiar; idea: R. Wahl-Clerici, design: S. Mathiuet).

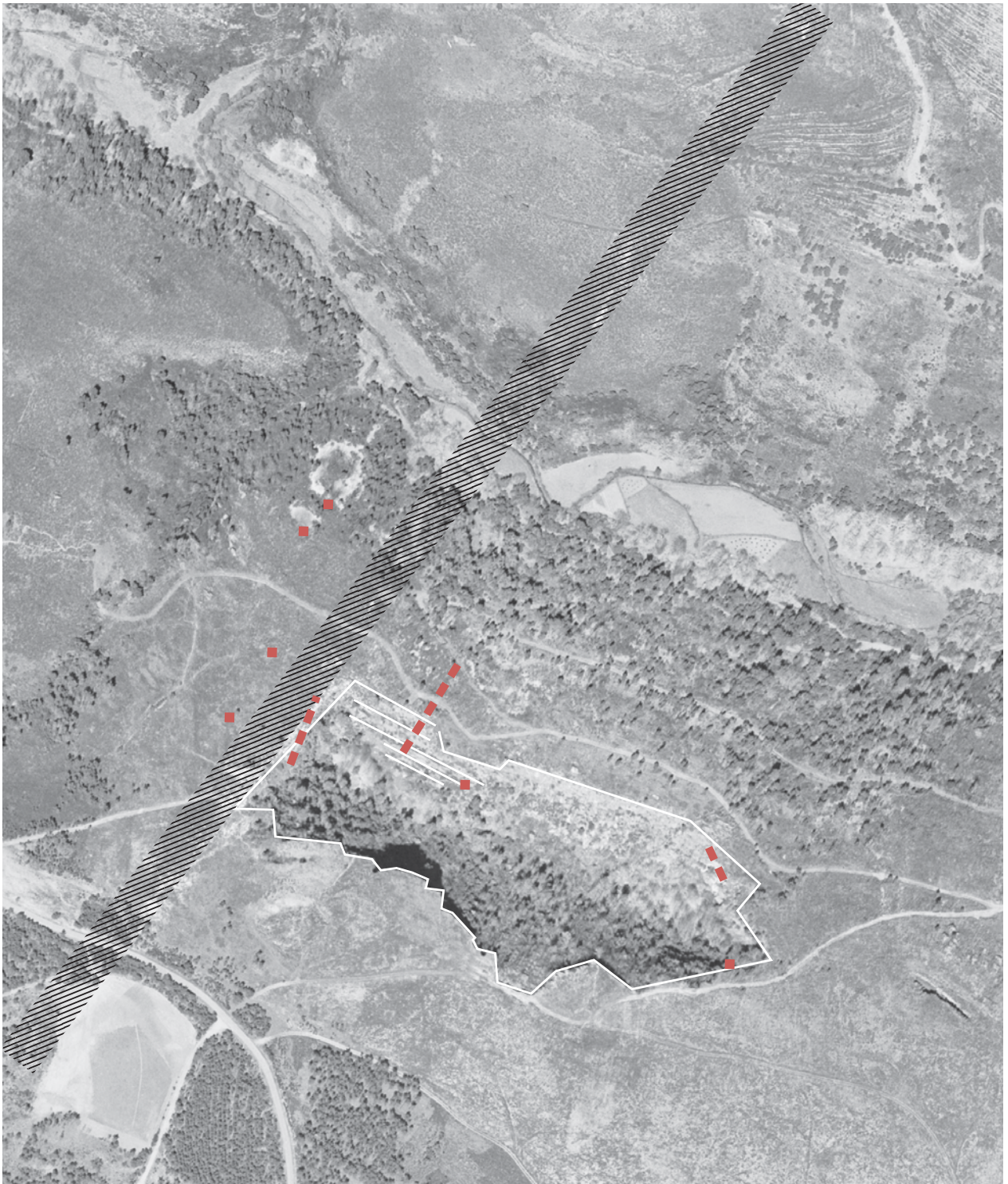


Fig. 2.0-6: *Territorium metallorum* Tresminas / Jales: overview of Corta da Ribeirinha with the prospection shafts and adits (template: Orthophotomapa 1:5000 Vila Pouca de Aguiar; idea: R. Wahl-Clerici, design: S. Mathiuet).



Fig. 2.0-7a/b: *Territorium metallorum* Tresminas / Jales: remains of the smallest prospection activity outside of the mining zone in Tresminas, b detail (photo a: R. Wahl-Clerici, b: A. Wiechowski).



Fig. 2.0-8: *Territorium metallorum* Tresminas / Jales: remains of the smallest prospection activity outside of the mining zone in Tresminas (photo: R. Wahl-Clerici).



Fig. 2.0-9: *Territorium metallorum* Tresminas / Jales: Tresminas, waste rock dump pile of the Galeria dos Alargamentos from the north. The gallery lies below the rock outcrop (photo: R. Wahl-Clerici).

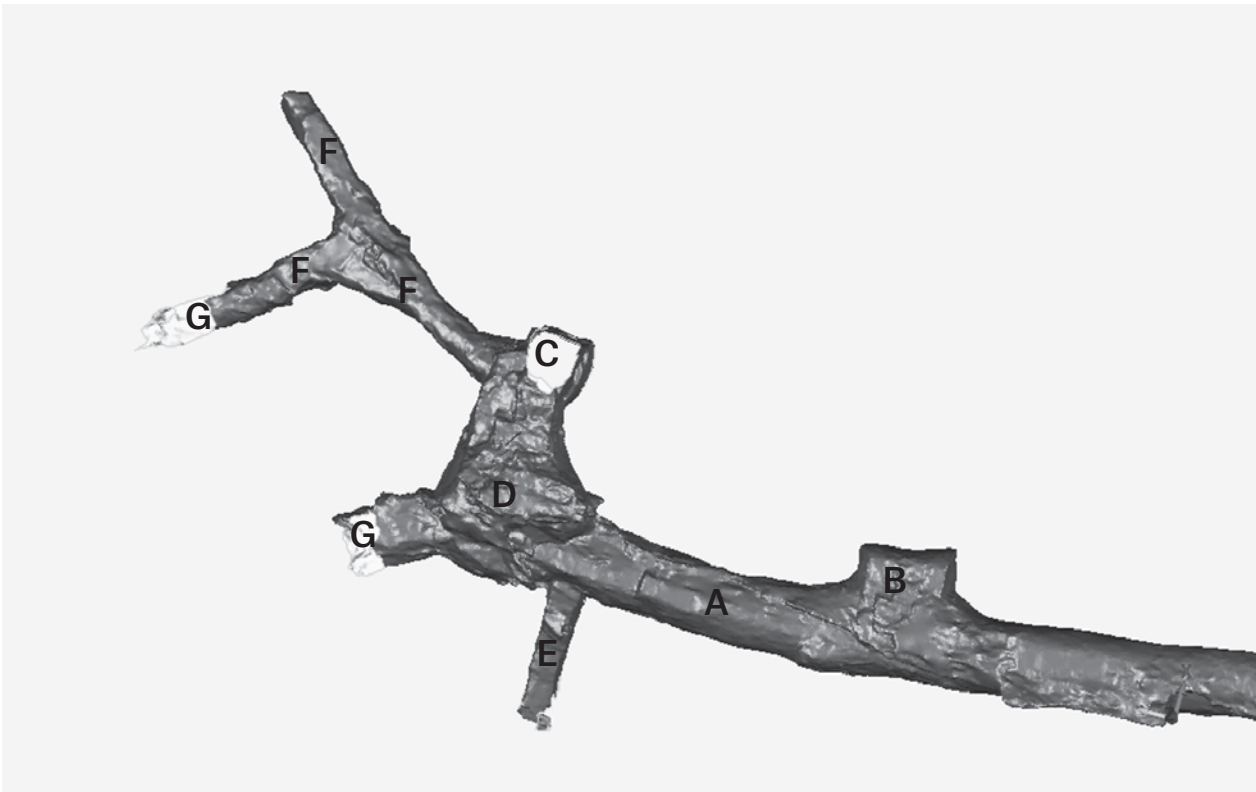


Fig. 2.0-10: *Territorium metallorum* Tresminas / Jales: Tresminas, Galeria dos Alargamentos, 3D-Laser scan (recording and processing: M. Helfert). A Galeria, B extension, C northern shaft, D end chamber, E stair shaft (see 2.1), F ancient prospecting gallery, G modern prospecting gallery, F further prospectings (possibly extensions of an ancient building (recording and editing M. Helfert).



Fig. 2.0-12: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Alargamentos: view into the prospection adit F (photo: R. Wahl-Clerici).







Fig. 2.0-11: **Territorium metallorum** Tresminas / Jales, Tresminas, Galeria dos Alargamentos: view from the east, from the gallery (A) into the final chamber (D). On the left side of picture, the beginning of stairwell (E) is visible (photo: R. Wahl-Clerici).



Fig. 2.0-13: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria do Pilar: prospecting tunnel in the ridge from the south (photo: R. Wahl-Clerici).

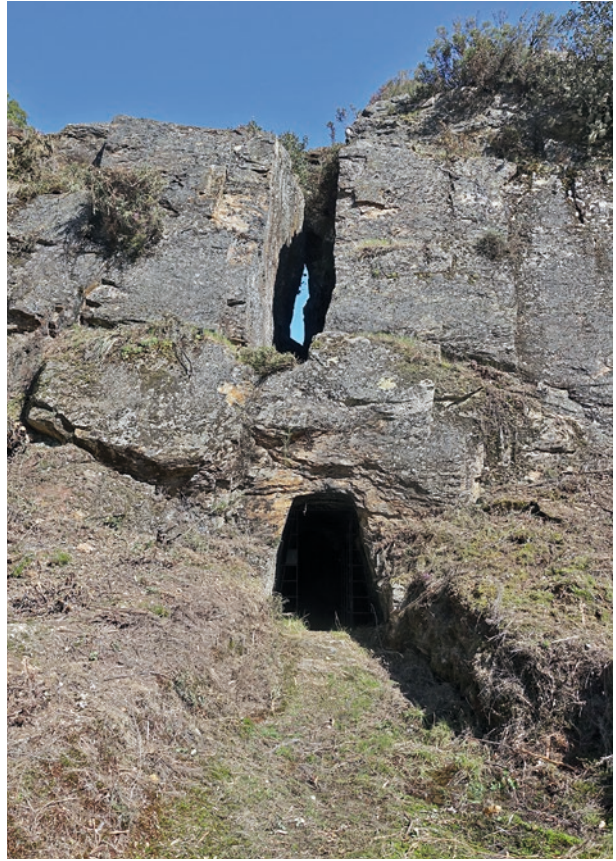


Fig. 2.0-14: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: prospecting tunnels in the area of the ancient western port, seen from the south (photo: R. Wahl-Clerici).



Fig. 2.0-15: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: detail of the prospecting adit in fig. 2.0-14 (photo: R. Wahl-Clerici).



Fig. 2.0-16: *Territorium metallorum* Tresminas / Jales. Tresminas, Corta da Ribeirinha, Galeria dos Morcegos. Prospecting shaft in the eastern face. Parallel to the north-south course of the Galeria dos Morcegos, a further gallery was constructed at the bottom of the shaft. (photo: R. Wahl-Clerici).



Fig. 2.0-17: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: prospection gallery through which the area east of the Corta was sampled (photo: R. Wahl-Clerici).



Fig. 2.0-18: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: spiral stairwell from the south (photo: R. Wahl-Clerici).

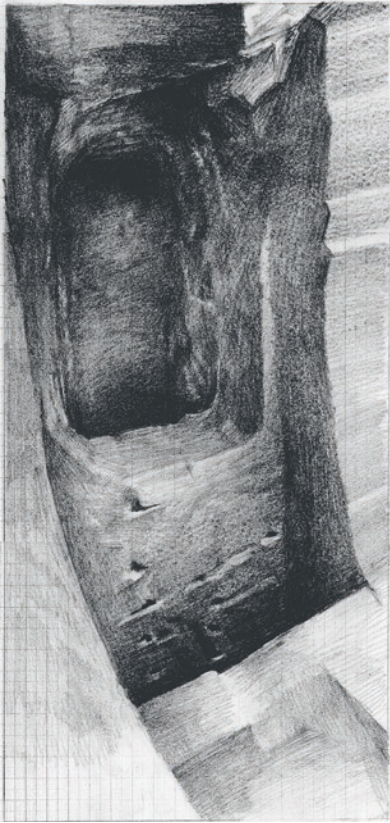


Fig. 2.0-19: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: twin shafts at the south-east border of the corta (design: P. Moser).

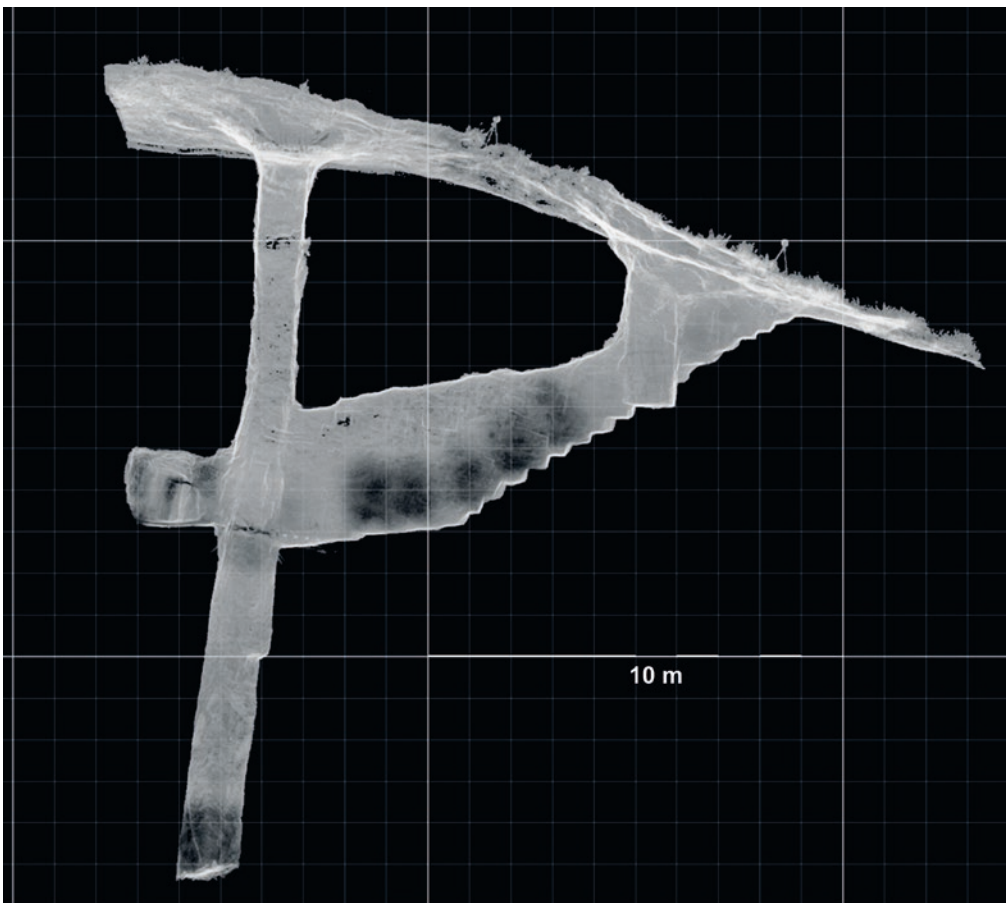


Fig. 2.0-20: *Territorium metallorum* Tresminas / Jales, Tresminas: typical prospecting tunnel with a combination of shaft, stairwell shaft and tunnel (scan and design: K. Mechelke, M. Lindstaedt).

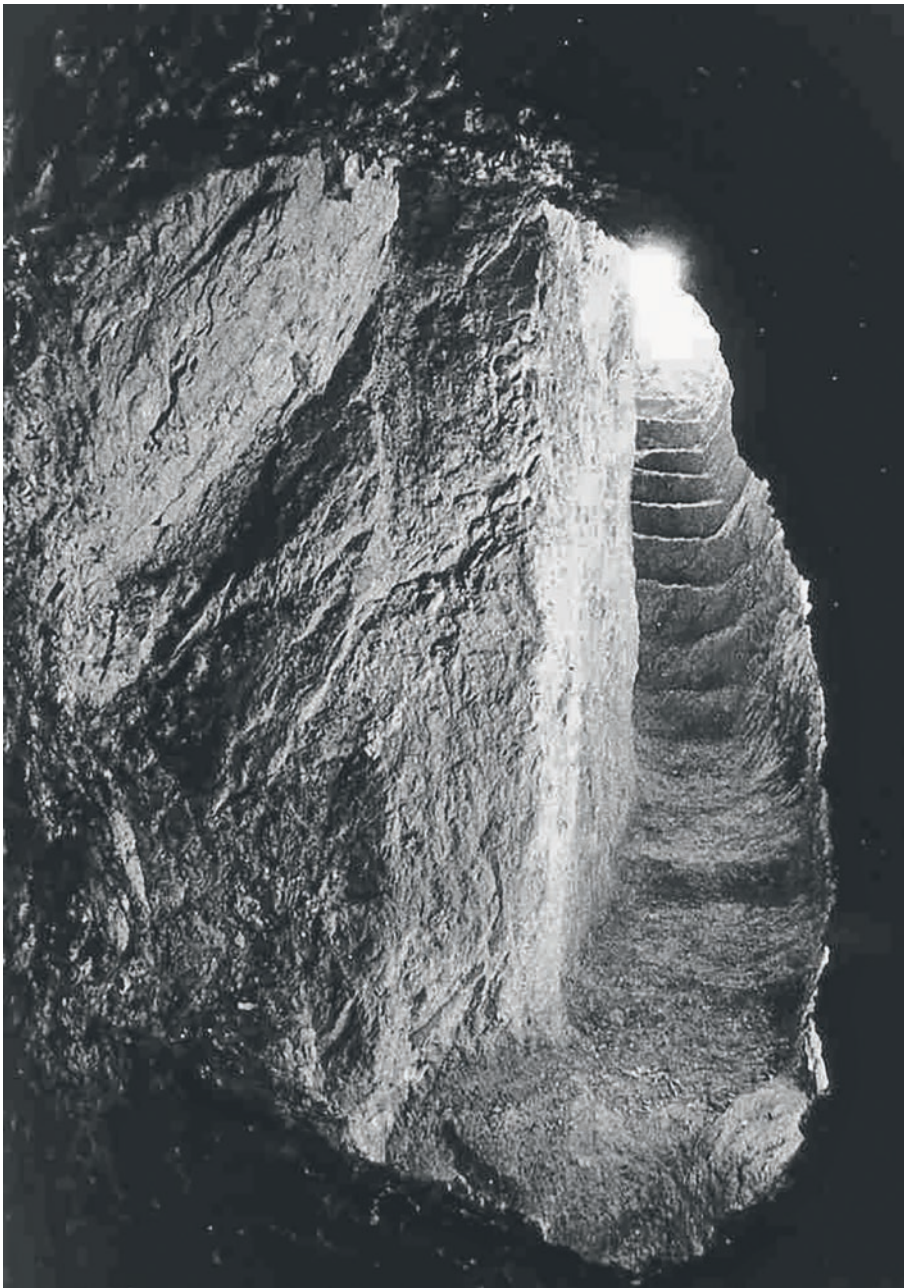


Fig. 2.0-21: Detail of fig. 2.0-20, from west (photo: J. Wahl).

## 2.1 Mining disaster and rescue operation in the Tresminas mine<sup>87</sup>

*... haud aliter collis scrutator Hiberi,  
cum subiit longeque diem vitamque reliquit,  
si tremuit suspensus ager subitumque fragorem  
rupta dedit tellus, latet intus monte soluto  
obrutus, ac penitus fractum obtritumque cadaver  
indignantem animam propriis non reddidit astris.*

Like the searcher of an Iberian hill, when he has gone below and left daylight and life afar; if the suspended ground trembles and the ruptured earth comes down with a sudden crash, he hides inside, buried by the fallen mountain, nor does the corpse, utterly smashed and crushed, return his indignant spirit to its proper stars.

Statius (ca. 45—ca. 95), *Thebaid*, 6,880—885

The Galeria dos Alargamentos and its annexes were excavated in order to be able to thoroughly prospect the mountains between the two opencast mines (fig. 1.0-3). The prospecting structures also included the stairwell, which was hewn into the southern section of the gallery. Because of its position, we know that it could only have been opened after the Galeria dos Alargamentos had been abandoned, otherwise it would have excessively obstructed cart traffic in the gallery (figs. 2.1-1, 2.1-2).

From the stairwell, which is not completely straight, as it has a slight curve to the east, a total of 14 steps are still visible today (figs. 2.1-3a/b). The width is 1.15 m, the height varies between 1.60 m (step 2), 1.90 m (broken off part of the roof at step 3) and 1.55 m (step 13). As these steps overcome a height of 2.75 m in a distance of about 5 m, the inclination was almost exactly 45°.

After step 14, which is only preserved in the eastern part, the staircase breaks off at a gap that is approx. 40—50 cm wide (figs. 2.1-4a/b). Here, a rock of approx. 5 m length (block 1) has moved downwards, including through the stairwell (fig. 2.1-5). This occurred along crevices that are approximately perpendicular to each other. The first are fissures that correspond to the stratification and schistosity of the rocks (approx. NNW-ESE, inclination 120°) and fall steeply to NNE (75°), the second are fissures that also fall steeply to NNW-SSE (inclination 20°) and run roughly parallel to the shaft (75°). The latter are transverse fissures that can be found everywhere in the area (e. g. east wall of opencast mine A, fig. 3.0-12).

If one descends the 14 steps of the shaft, one looks at a rock face that represents the surface of the fault, where the stairs moved downwards by 2—2.20 m. The crevice mentioned above, which had formed here, was filled with frag-

ments of rock. A rock wedged in the crevice above the stairs has since prevented additional rock material from tumbling down. The shaft, which had moved downwards, continues on (figs. 2.1-4a, 2.1-6). Although the bottom of the shaft is not visible because of the debris, the roof and the western face still have neatly finished surfaces, while the eastern face has been broken out and widens to the next crevice. Approximately 5 m further in the direction of the stairwell, the shaft was demolished again at another, approximately 30 cm wide crevice. Here, the shaft sank 1.4 m deep. The part of the rock that includes the stairwell (fig. 2.1-7, block 2) was not only lowered, but also turned 40 cm to the east. The roof of the lowered stairwell can be seen in the rock face. From here onwards, the stairwell is completely filled with rubble.

The stairwell was used again after its collapse. This is indicated by three lamp niches, which were cut into the rock face visible from the Galeria dos Alargamentos at the first crevice (fig. 2.1-5). These niches could only have been cut after the mine disaster, as this block was only exposed by the disaster. At the lower point D, niches were also worked into a rock face exposed by the event (figs. 2.1-6, 2.1-7). These are two round cuts with a diameter of 11 cm each, arranged at a distance of 14 cm. Their function has not yet been determined. Approximately in the middle above these two cuts, a lamp niche was carved into the rock about 20 cm above them. A dry wall at B—C, which was intended to provide protection against further falling rock material from the crevice, is another installation that could only have been built after the event.

All these installations can only be explained by a rescue operation carried out after the rock burst to recover miners and equipment that had been in the stairwell at the time of the disaster. A further argument in favour of this interpretation is the fact that the stairwell was not restored for further use at a later date. An indicator for this is the fact that the passage from B to C remained in its ruined form (figs. 2.1-4a/b, 2.1-7).

Two cuts located at step 14 under the roof and directly opposite each other are further proof for a rescue operation, as they must have served to wedge in a beam with a maximum diameter of 6 cm (fig. 2.1-8). The cut in the eastern rock face is 6 cm high and 9 cm long, while the cut in the western face was made in the form of a groove in order to allow the insertion and securing of the beam. This beam

87 Wahl-Clerici et al. 2012a.

was probably used to attach a winch, which was used to remove debris from the stairwell. There are at least three cuts deeper than those identified as lamp niches in the area of the stairwell of the Galeria dos Alargamentos. They were probably used to support the construction required to secure the winch. It can be assumed that the lower section of the stairwell was not as filled with debris immediately after the event as it is today, because much of the debris probably fell into the shaft as a result of modern prospecting work.

### Discussion of the possible causes for this localised collapse

The double lowering in the stairwell through the two rock formations could only take place if there was a cavity underneath. Natural cavities cannot be found in this old and compact Hercynian mountain range, which is about 250—420 million years old. We therefore need to look for other explanations for the formation of these cavities. Both an earthquake as well as an artificially created cavity would be a possible trigger. Both possibilities will be discussed in the following.

While an earthquake as a result of tectonic movements could have been the trigger for the damage to the stairwell, the region of the *territorium metallorum* Tresminas/Jales belongs to one of the extremely stable zones of the Iberian Peninsula and displays only weak seismic activity. Since no traces of seismic activity can be found on the surface in the vicinity of the Galeria dos Alargamentos, this hypothesis can be ruled out.<sup>88</sup> However, it is always difficult to prove earthquakes on the basis of archaeological finds, as the examples presented in the interdisciplinary workshop on 14—15 May 2004 on the subject of “Ancient earthquakes in the Alps and neighbouring regions” show.<sup>89</sup>

A more likely variant is that an artificial cavity existed under the destruction zone in the stairwell. It is now impossible to establish whether this cavity was created by a deeper prospecting tunnel or by underground work from the Corta de Covas opencast mine. In both cases, severe tremors would have been noticeable in the surrounding area and, of course, especially in the zone directly above, and the sudden collapse would have left behind damage of a magnitude similar to that of an earthquake.<sup>90</sup>

Whatever the trigger of the collapse may have been, the cuts in the rock are witnesses to the efforts of Roman miners to save or at least recover the trapped miners.

In this context, it is interesting to touch on a passage by Pliny, Natural History 33,70.72, in which he describes mining with the help of *arrugiae*:

*Arrugias id genus vocant. siduntque rimae subito et opprimunt operatos, ut iam minus temerarium videatur e profundo maris petere margaritas atque purpuras. tanto*

*nocentiores fecimus terras! relinquuntur itaque fornices crebri montibus sustinendis. [...] (72) praeacto opere cervices fornicum ab ultimo caedunt.*

The name for this class of mines is *arrugiae*; also cracks give way suddenly and crush the men who have been at work, so that it actually seems less venturesome to try to get pearls and purple-fishes out of the depth of the sea: so much more dangerous have we made the earth! Consequently arches are left at frequent intervals to support the weight of the mountain above. [...] When the work is completely finished, beginning with the last, they cut through, at the tops, the supports of the arched roofs.

In other words, the rock was brought to collapse by undercuts in order to facilitate the mining work, even if human lives were endangered. It should be mentioned that this technique has so far only been proven in the mining of alluvial deposits and that the mining of Las Médulas is mostly cited as an example of this manner of mining.<sup>91</sup>

However, the fact that the two subsidence events described here are limited to a very small area makes it unlikely that they were the result of systematic undermining. The elements of the Galeria dos Alargamentos that were closer to the opencast mine, such as the final cavern with the annexes (figs. 2.0-10, 2.0-11, 2.1-1), were not affected by the subsidence.

It thus remains impossible to clearly identify a cause for the mining disaster. We therefore will focus on the consequences of such events and on the question whether we can understand them in the mining district of Tresminas/Jales.

88 According to the information kindly provided by letter by Prof. Dr. K. Reicherter, Lehr- und Forschungsgebiet Neotektonik und Georisiken RWTH Aachen University, there are no known seismic activities in the surroundings of Tresminas in Roman times. However, such activities cannot be completely ruled out, as a NNE-SSW fracture zone adjoins the mining area to the west, in the northern part of which thermal springs occur. — This statement was confirmed by Prof. Dr. Luís Sousa of UTAD, Vila Real.

89 Waldherr/Smolka 2007, in particular the following contributions: J. Ganzert, Der Mars-Ultor-Tempel in Rom — ein Seismograph?; R. Schatzmann, Anmerkungen zur Annahme eines Erdbebens um die Mitte des 3. Jahrhunderts in *Augusta Raurica*; C. S. Sommer, *Vetustate conlapsum*, enemy attack or earthquake; H. Dolenz, Ein Erdbeben in der Stadt Alt-Virunum auf dem Magdalensberg?; M. Kandler/K. Decker/G. Gangl, Archäologische Befunde von Erdbebenschäden im Raum von *Carnuntum* und ihre seismotektonische Interpretation; K.-G. Hinzen, Archäoseismologische Untersuchungen im Rheinland.

90 Waldherr 1997, 75.

91 Domergue 2008, 138.



## Discussion of the consequences of the mining disaster in the *territorium metallorum Tresminas* / Jales

In principle, the willingness of the state to provide disaster relief was dependent on the political and social conditions of the time, which can be described as particularly stable in the 1st and 2nd centuries A.D.<sup>92</sup> It can be assumed that the giving of practical help was taken for granted and as an opportunity to distinguish oneself as a caring ruler, as a true *pater patriae*.<sup>93</sup> According to Suetonius, Caligula 31, Emperor Caligula complained bitterly that so few catastrophes occurred during his reign:

*Queri etiam palam de condicione temporum suorum solebat, quod nullis calamitatibus publicis insignirentur; Augusti principatum clade Variana, Tiberi ruina spectaculorum apud Fidenas memorabilem factum, suo oblivionem imminere prosperitate rerum; atque identidem exercituum caedes, famem, pestilentiam, incendia, hiatus aliquem terrae optabat.*

He even used openly to deplore the state of his times, because they had been marked by no public disasters, saying that the rule of Augustus had been made famous by the Varus massacre, and that of Tiberius by the collapse of the amphitheatre at Fidenae, while his own was threatened with oblivion because of its prosperity; and every now and then he wished for the destruction of his armies, for famine, pestilence, fires, or a great earthquake.

In most cases the support consisted of monetary donations, the abolition of taxes and the provision of qualified personnel for the reconstruction.<sup>94</sup> After all, the ruler not only had the duty but also — for the reasons mentioned above — the greatest interest in removing the vestiges of a catastrophe as quickly as possible.

This raises the question of who initiated the rescue operation. Solidarity among miners has a long tradition, which may have been the main reason in this case. But we also have to take into account that disasters, including natural disasters, were perceived in Roman times as a side effect of negative developments within the state. This could have led to the procurator, the caretaker sent by the emperor, being concerned that all traces of the event should be removed as quickly as possible in order to ensure that work in the mine proceeded in an orderly manner.

The features indicate that mining in the stairwell was probably not continued after the presumed salvage operation. It is also impossible to know whether the prospection in the area of the Galeria dos Alargamentos ended with the mining disaster. After the abandonment of the work in the Galeria dos Morcegos, which was abandoned due to the unprofitable mining in open-cast mine B (Corta da

Ribeirinha), an altar had probably been erected in the port area, which is indicated by a cut in the rock of the floor.<sup>95</sup> Whether this was also the case for the Galeria dos Alargamentos can no longer be determined because of the debris in the area of the adit. Lastly, we will never know whether the rescue operation was actually successful. It cannot be ruled out that under the rubble at the end of the stairwell lie the mortal remains of Roman miners.

We do not know whether the events in the stairwell of the Galeria dos Alargamentos were the mining disaster that gave rise to the lines by the poet Statius mentioned at the beginning, but it can also not be excluded if we consider the life span of the poet (around A.D. 40—around A.D. 96). However, it is certain that the miners and the inhabitants of Tresminas will have experienced the tremor of the mountain and the collapse deep in the mine as an earthquake in a broader sense, regardless of the cause.

A similar catastrophe also happened in Lagoinhos, the mining site C, so that Statius' text could also apply to what had happened there.

<sup>92</sup> Sonnabend 1999, 235.

<sup>93</sup> Winter 1998, 149; For a discussion of the mechanics of the politically instrumentalise natural disasters, or rather how the rulers dealt with them see Waldherr 1998, 63.

<sup>94</sup> Sonnabend 1999, 219. 245.

<sup>95</sup> Wahl-Clerici 2008, 54.



Fig. 2.1-1: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Alargamentos; The port of the stairwell partly projects into the floor of the Galeria de Alargamentos (photo: R. Wahl-Clerici).

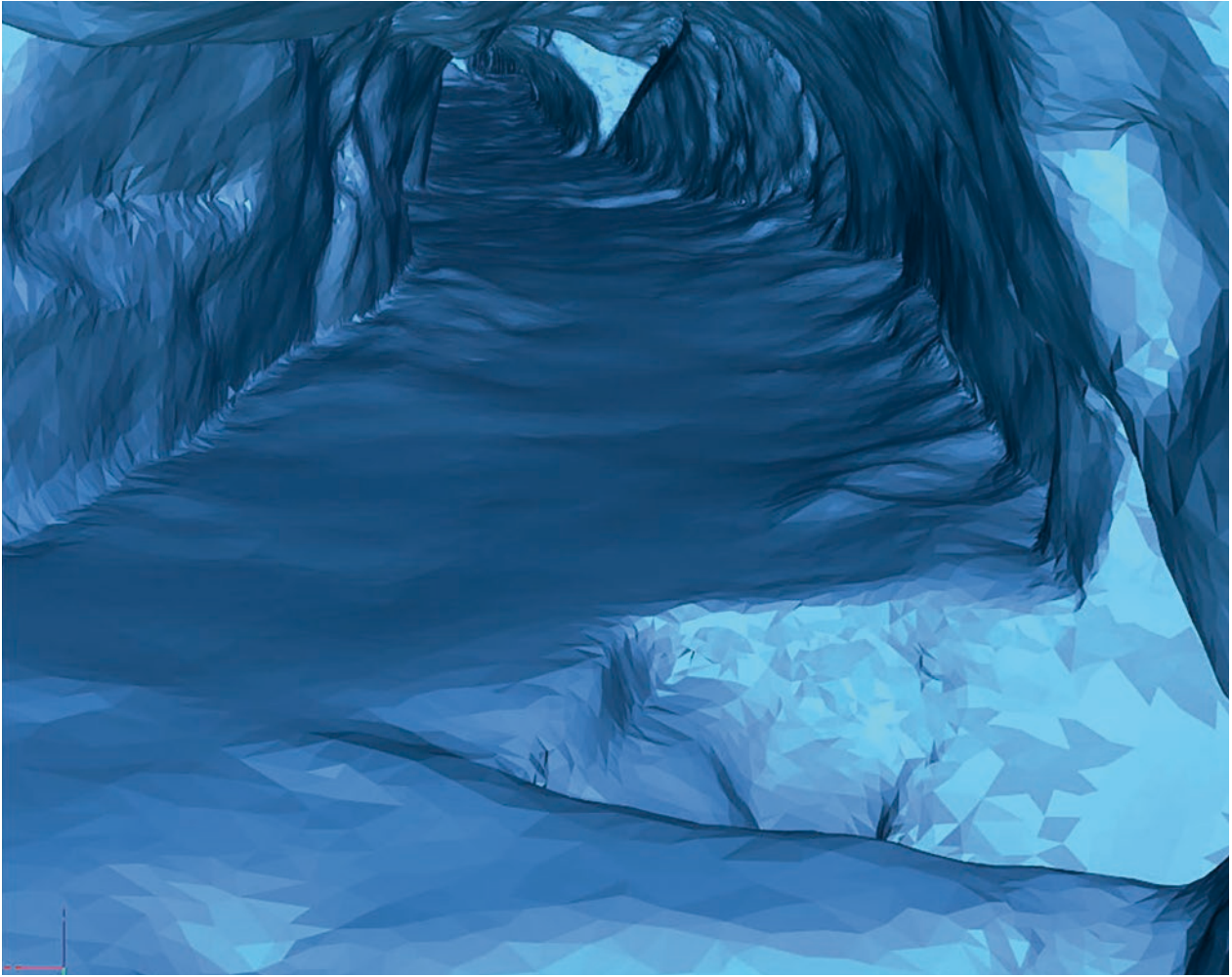


Fig. 2.1-2: **Territorium metallorum** Tresminas / Jales, Tresminas, Galeria dos Alargamentos. The construction of the gallery destroyed part of the floor of the stairwell (3D laser scan and photo: M. Helfert and B. Ramminger, processing: M. Helfert).



Fig. 2.1-3a: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Alargamentos. View into the stairwell from the north (photo: R. Wahl-Clerici).



Fig. 2.1-3b: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Alargamentos. View into the stairwell from the south (photo: R. Wahl-Clerici).

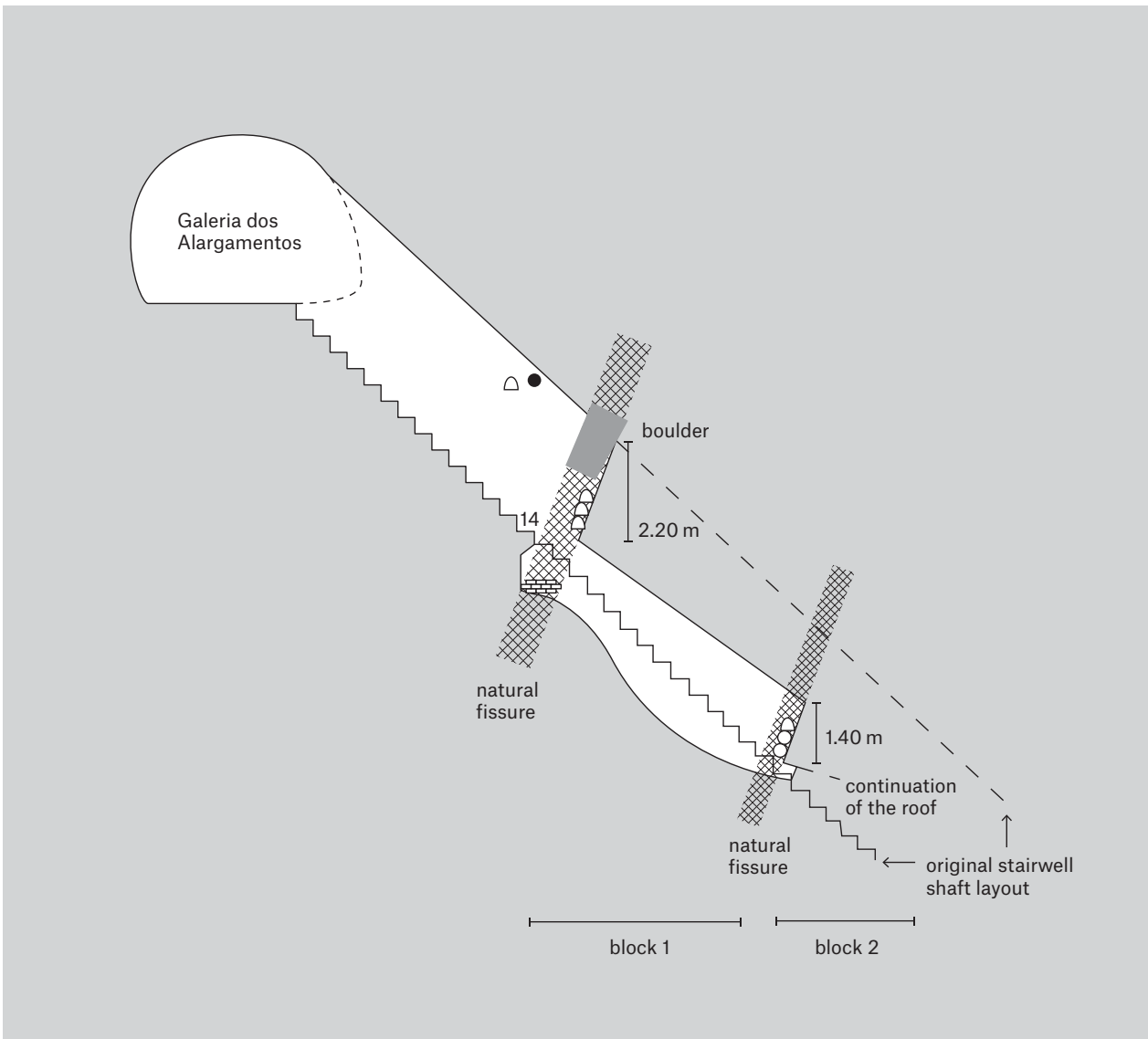


Fig. 2.1-4a: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Alargamentos: schematic profile of the stairwell (photo: R. Wahl-Clerici).

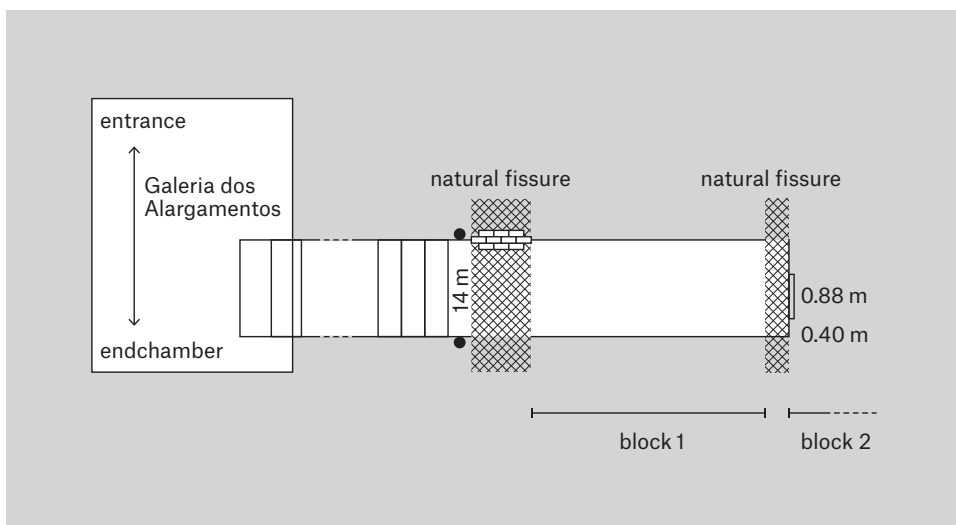


Fig. 2.1-4b: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Alargamentos: schematic plan of the stairwell (photo: R. Wahl-Clerici).



Fig. 2.1-5: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Alargamentos: view onto the rock at position B. The three lamp niches are clearly visible (photo: R. Wahl-Clerici).



Fig. 2.1-6: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Alargamentos: view into the stairwell from position C towards position D, the floor is completely filled with debris (photo: R. Wahl-Clerici).



Fig. 2.1-7: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Alargamentos: view of the collapsed roof of the stairwell at position D. Two of the three cuts in block 2 can be seen (photo: R. Wahl-Clerici).



*Fig. 2.1-8: **Territorium metallorum** Tresminas / Jales, Tresminas, Galeria dos Alargamentos: cuts in the rock in order to allow the insertion and securing of a crossbeam, in order to attach a winch to help with the clearing of debris during the rescue work (photo: R. Wahl-Clerici).*



## 2.2 The U-shaped staircase and the shaft<sup>96</sup>

The extraordinary diversity of the prospecting structures also includes a system consisting essentially of two components, which lies approximately in the middle of the northern slope in the Corta da Ribeirinha (fig. 1.0-3 10/11). Starting from two different mining areas, a U-shaped staircase and a tunnel were used to sound out the contents in the surrounding area immediately adjacent to the mining zones. In the area presented here, the two working faces overlap.

The study of this unique construction forced us to place it in the context of the further conditions in the Corta da Ribeirinha (see also 3.0 Corta da Ribeirinha). Very soon it became clear that this opencast mine was originally exploited as two independent mining zones and was only merged after the construction of the edifices discussed here. Without this qualification and without the models created of the discoveries with the help of 3D laser scan measurement, it would not have been possible to understand the construction, which is still in its original state (figs. 2.2-1—2.2-3).

### The stairwell of the U-shaped staircase

The rectangular plan of the stairwell was opened in the northern junction of one of the long trench-like mining sinkholes in the northern flank of the Corta da Ribeirinha (fig. 2.2-4). In its two- respectively three-part basic form it is much like several individual straight staircases, which are twice bent at right angles. The straight port area and its continuation, which returned in parallel without any great distance between the two parts, mainly served in order to overcome differences in height, while the short middle section containing the actual staircase mediated between these two (fig. 2.0-18).

The design of the port area indicates that the original intention was to prospect the deposit by means of a horizontal gallery (figs. 2.2-3—2.2-5). This had an original height of approx. 130cm<sup>97</sup>, but was soon sunk by 40cm, so that a clear width of approx. 170cm × 110cm was created. Traces of a horizontal extension are only preserved on the first 90cm or so in the ceiling of the port area.<sup>98</sup> Subsequently, the horizontal advance stopped, as is proven by the irregularly carved depressions in the upper ceiling section, which were no longer hewn out. The tunnel was then converted into a stairwell. It is characteristic for a prospecting construction that the steps are only minimally worn.

In the central area, where a small chamber of just 160—190cm wide was created for the multiple turns of the stairwell, the staircase was only extended by a flat and wide step of 15cm high, connected to a platform of 80cm × 97cm (fig. 2.2-6 A, B). These constructions resulted in a room with a minimum height of 145cm, the floor of which formed by flat steps is in noticeable contrast to the steep port stairs. After the first turn to the east, the staircase continues with two 29cm high and even steps (fig. 2.2-6 C) and a further area of 50cm × 48cm (fig. 2.2-6 D). The last remainder of the former steep continuation of the staircase is a south-facing step, which had not been worked out over the entire width of the inclined shaft, and which was preserved approx. 60cm below the small platform (fig. 2.2-6 E). There can be no doubt about the existence of this now vanished staircase, which is confirmed by a correspondingly oriented and inclined shaft ceiling (fig. 2.2-7).

In the area of the small chamber described above, vertical cuts and a rectangular, almost square opening indicate that this is the place where formerly a vertical shaft or shaft section existed (fig. 2.2-6 F), the lower end of which was probably destroyed by the insertion of the Galeria do Pastor. However, without any indications of the position and shape of the lower end of the vertical shaft, it is impossible to either determine its function or its position in the sequence of the construction of the shafts (fig. 2.2-8).

### The Galeria do Pastor

The Galeria do Pastor, today connected to the stairwell in its lower part, was opened from the east from a mining area about 4m lower. Traces of hewing above the port indicate the original direction of the building progress from this side (fig. 2.2-9). The preserved rock structures show that the mining face was gradually lowered. In contrast to the traces of hewing above its port, which are only superficial today,

<sup>96</sup> This is the summary of the first publication, see: Wahl-Clerici et al. 2019.

<sup>97</sup> Comparably low clear heights also exist in other prospecting constructions in Tresminas. For example, the remains of a prospecting gallery with a maximum height of only 1.15m was preserved in Lagoinhos (Wahl-Clerici/Wiechowski 2013, 321—323). The prospecting tunnel located directly below the stairwell also has a comparatively low height of just 1.45m.

<sup>98</sup> See also Cauuet 2005, 40 figs. 3—4.

the Galeria do Pastor itself was designed as a prospecting structure and driven deeper into the mountains, narrowing after about 5 m from the port. It is difficult to now reconstruct the different heights of the mining on the basis of the few remaining traces, as the entire gallery was sunk at a later date. Despite extensive excavations at the beginning of the 1990s, the lowest level has not yet been found (fig. 2.2-10).

The neatly worked ceiling from the port to the area of the stairwell opening suggests that in the course of its construction, the lower part of the shaft in question, whose size and shape can no longer be determined, was destroyed. A short prospecting gallery (fig. 2.2-11) incorporated into the southern face, has the same level in the ceiling, so that it can probably also be assigned to an early construction phase of the Galeria do Pastor. However, its position, which is offset to the preserved lower end of the stairwell, is evidence against a direct connection between the two. It cannot be said whether the slightly curved flat staircase, which led to the lower prospecting gallery, was connected to the spiral stairwell.

### The relationship between stairwell and Galeria do Pastor

The projection of all the tunnels and shafts on a west-eastern plane (figs. 2.2-1, 2.2-2) and a north-southern plane (fig. 2.2-3) shows the various constructions preserved in the zone. As the positioning of the various elements deviates slightly from each other, this shows that there was no coordinated concept for the whole construction. Rather, it confirms the impression already gained in the course of the discussions of the individual construction elements, namely that a spatial unit was only created by opening the lower section of the staircase or the blind shaft between the staircase shaft and the Galeria do Pastor. Due to the position of the two constructions at the transition between the western and eastern areas of the Corta da Ribeirinha (fig. 2.2-12), it cannot be ruled out that they were opened according to the specific progress of the mining in the respective zones, and presumably also at different times. However, today it is no longer possible to determine how long the interval between the two constructions may have been. It is likely that the reaction to the prospecting results in the staircase shaft came quite soon after the planning and/or the construction of the Galeria do Pastor from the east.

## Results

The U-shaped staircase as well as the Galeria do Pilar were constructed in order to sample the deeper zone under the already fully exploited gold-bearing areas in the Corta da Ribeirinha.<sup>99</sup> The continuation of the eastern mining zone by means of the Galeria do Pilar corresponds to the usual procedure, whereas U-shaped staircase shafts are rather rare in Roman mining. While an underground “*déscend-erie hélicoïdale*” was found in the Dacian gold mines, this can rather be called a staircase with a turn.<sup>100</sup> Two other round stair shafts were opened in the Roman gold mine area, especially in the prospecting area adjacent to the “*Fojo das Pombas*” mining zone (Valongo, Porto district / P) (fig. 2.2-13).<sup>101</sup>

Since the construction of a turning staircase, which is space-saving in principle, would not have been absolutely necessary in the area presented here, we must assume that the prospectors expected further gold reserves worthy of mining in this section of the mountain.

The two constructions are also of special importance in understanding the Roman approach to exploiting the Corta da Ribeirinha. At the beginning, the opencast mine, which today seems to be a single unit, was divided, into a (possibly older) eastern part and a western part. The two mining zones were only united after the opening of the Galeria do Pastor and the spiral stairwell. Even if this only provides us with a relative indication of the chronology, this example helps us to gain a deeper understanding of the approach of the Roman miners, and along with it mining history.

99 The sampling of the Serviço de Fomento Mineiro, recorded in 1979, plan 1988, revealed only traces of gold.

100 Cauuet 2005, 40 fig. 3.

101 We would like to thank J. Moutinho and V. Gandra (Alto Relevo — Clube de Montanhismo, Valongo/P), who made these thus far unpublished prospection constructions accessible to us and supported us during the recording. The hoard find from the Fojo das Pombas, consisting mainly of bronze vessels, is dated to the 2nd century at the latest (Mendes Pinto 2000, 403); Rosumek 1982, 67–68 refers to spiral staircases in Laurion (Lavrio, Attika/GR), in a quarry at Pellenz (Lkr. Mayen-Koblentz/D) and in the mine of Cala (prov. Murcia/E). However, these are no longer mentioned in later literature.

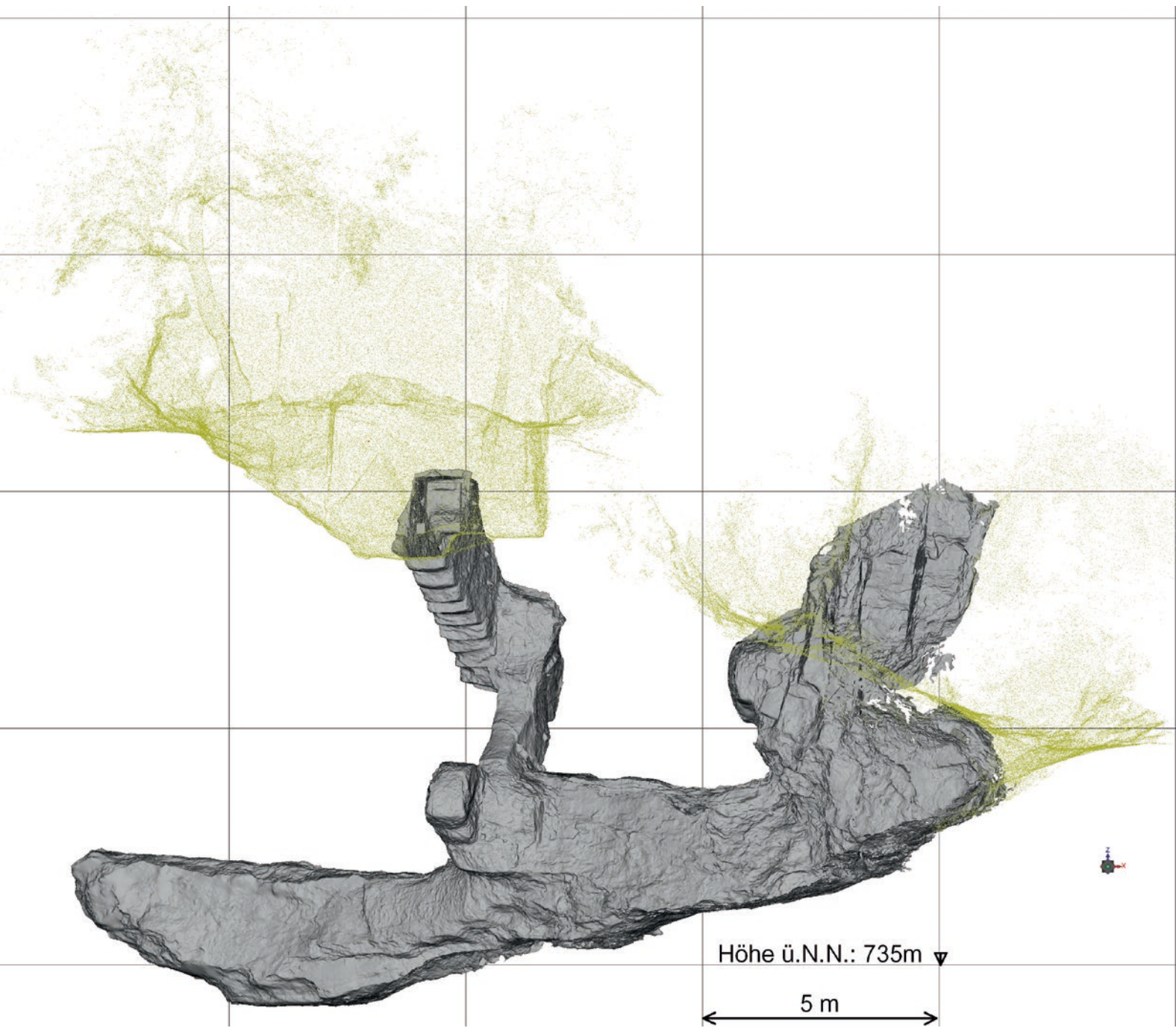


Fig. 2.2-1: *Territorium metallorum* Tresminas / Jales. Tresminas, Corta da Ribeirinha: 3D-model overview of the stairwell of the U-shaped staircase and the Galeria do Pastor from the south (imaging: K. Mechelke).

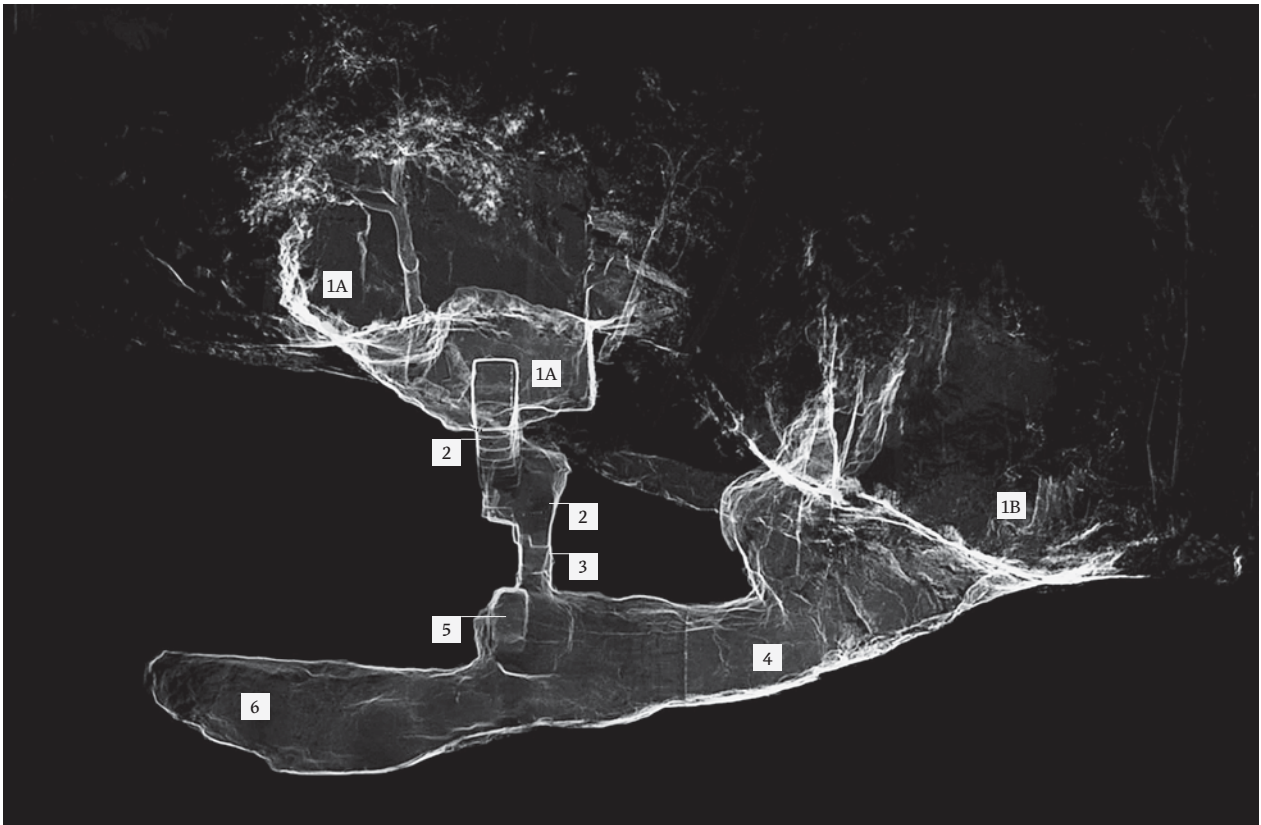


Fig. 2.2-2: *Territorium metallorum* Tresminas / Jales. Tresminas, Corta da Ribeirinha: point cloud of the cross-section of the U-shaped stairwell (above) and the beginning of the Galeria do Pastor (below) projected onto a single plane, seen from the south.

1A Corta da Ribeirinha — western side; 1B Corta da Ribeirinha — eastern side; 2 stairwell U-shaped staircase; 3 well; 4 Galeria do Pastor; 5 prospecting; 6 extension of the prospecting (recorded by K. Mechelke, M. Lindstaedt; identification R. Wahl-Clerici).



Fig. 2.2-3: *Territorium metallorum* Tresminas / Jales. Tresminas, Corta da Ribeirinha: view of the point cloud of the stairwell of the U-shaped staircase with the port (above) and the Galeria do Pastor (below) projected onto a single plane, seen from the east (recording and imaging: K. Mechelke, M. Lindstaedt).



Fig. 2.2-4: *Territorium metallorum* Tresminas / Jales. Tresminas, Corta da Ribieirinha. The port of the stairwell of the U-shaped staircase was opened in one of the long mining zones. Seen from the southeast (photo: R. Wahl-Clerici).



Fig. 2.2-5: *Territorium metallorum* Tresminas / Jales. Tresminas, Corta da Ribieirinha: interior view of the port area of the stairwell of the U-shaped staircase. View towards the port (photo: Th. Schierl).

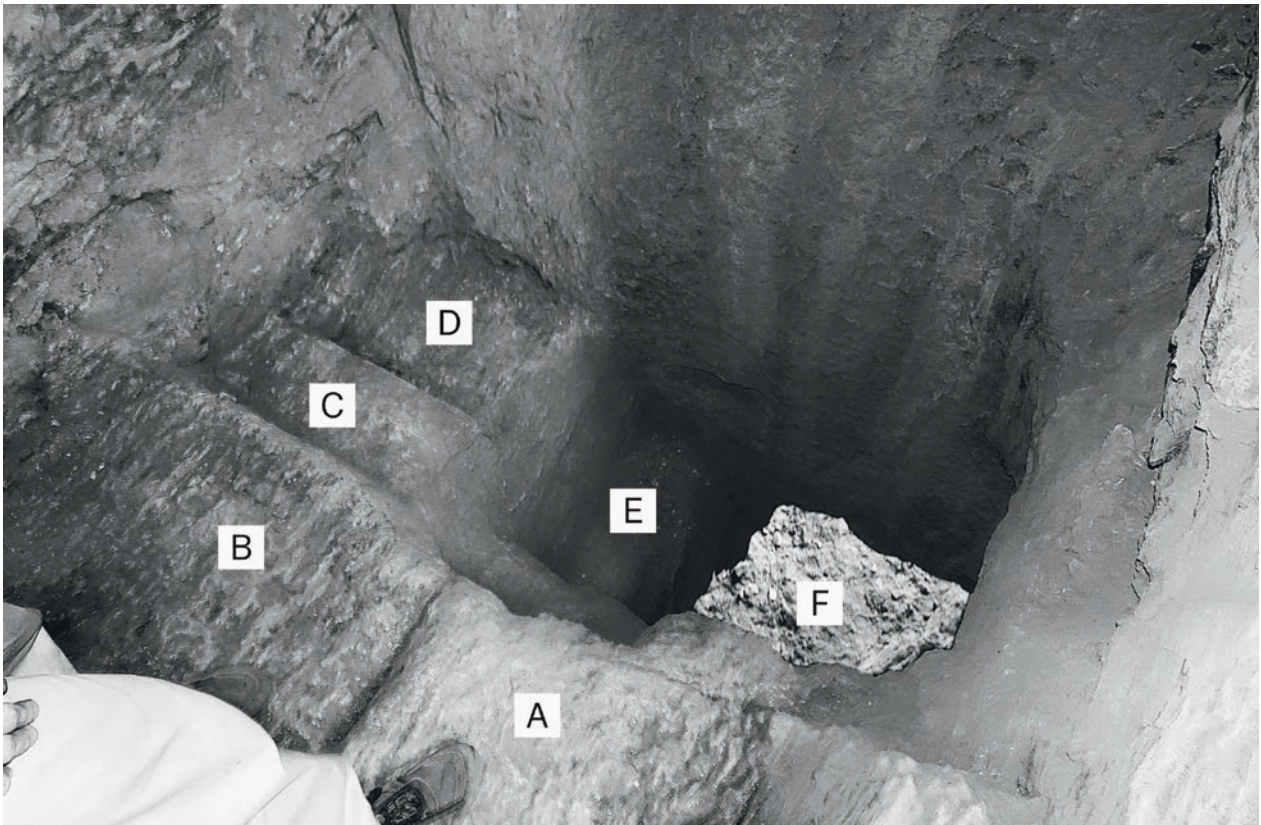


Fig. 2.2-6: *Territorium metallorum* Tresminas / Jales. Tresminas, Corta da Ribeirinha: the lower part of the stairwell with the terms mentioned in the text and with a view of the Galeria do Pastor mining zone from the west. — A-E steps; F blind shaft from the U-shaped staircase to the Galeria do Pastor (photo: R. Wahl-Clerici).



Fig. 2.2-7: *Territorium metallorum* Tresminas / Jales. Tresminas, Corta da Ribeirinha: section through the point cloud of the stairwell of the U-shaped staircase; view from east. The steps are clearly visible as are the steps in the ceiling and the connecting shaft to the Galeria do Pastor (recording and imaging: K. Mechelke, M. Lindstaedt).



Fig. 2.2-8: *Territorium metallorum* Tresminas / Jales. Tresminas, Corta da Ribeirinha: transition zone between the original stairwell (above) and the Galeria do Pastor mining zone. The blind shaft and the sloping ceiling, which originally belonged to the stairwell, are clearly visible. It is likely that a part of the ceiling had to be cut out vertically for the blind shaft. In the lower part of the picture an approx. 1.30 m deep prospecting tunnel, as well as an earlier part of the mining area in the Galeria do Pastor can be seen (photo: R. Wahl-Clerici).



Fig. 2.2-9: *Territorium metallorum* Tresminas / Jales. Tresminas, Corta da Ribeirinha, Galeria do Pastor: the traces of hewing above the port bearing witness to the mining progress are clearly visible. This zone of the Galeria was once used for mining, while the lower areas of the Galeria consisted only of a gallery for prospecting. Seen from the southeast (photo: R. Wahl Clerici).



Fig. 2.2-10: *Territorium metallorum* Tresminas / Jales. Tresminas, Corta da Ribieirinha: view from the east into the continuation of the Galeria do Pastor. The original level of this mining zone has not yet been uncovered. At the bottom left of the picture, the remains of steps, which according to our current level of knowledge are not connected to the U-shaped stair shaft, are visible (photo: R. Wahl-Clerici).



Fig. 2.2-11: *Territorium metallorum* Tresminas / Jales. Tresminas, Corta da Ribieirinha: remains of the western working face preserved in the Galeria do Pastor (seen from the east), with the prospecting gallery (left) and the worked steps in the lower part of the Galeria do Pastor (below) (photo: R. Wahl-Clerici).





Fig. 2.2-12: **Territorium metallorum** Tresminas / Jales. Tresminas, Corta da Ribieirinha: northern slope of the opencast mine. The preserved rock banks of the mining area in the western zone and on both sides of the ancient access area (lower left) as well as the rugged northern end in the eastern zone (upper right) are clearly visible. Seen from the southwest (photo: J. Wahl).



*Fig. 2.2-13: Serra da Santa Justa, Valongo (conc. Valongo, distr. Porto), Fojo das Pombas: circular U-shaped staircase shaft, the staircase was continued straight after the lower section (photo: R. Wahl-Clerici).*

## 3.0 Exploitation of the auriferous deposits<sup>102</sup>

The three ore deposits in the *territorium metallorum* Tresminas/Jales (Tresminas, Gralheira and Campo de Jales) provide the most important evidence of Roman gold mining in primary deposits. Fortunately, those of Tresminas and Gralheira were only minimally affected by more recent mining activities, so that the abundance of monuments here makes it possible to understand the various ways in which mining was carried out.

The *territorium metallorum* Tresminas/Jales is also known to contain deposits in which silver or tin dominate as valuable metals. Since most of these pits are located in the immediate vicinity of the remains of Roman mining, the Roman aqueduct or even the cemetery, it must be assumed that those ores were also mined. It has not yet been possible to chronologically classify these mining sites, which is why they are not presented here. Various medieval documents refer to tin mining in Tresminas, but gold is never mentioned.<sup>103</sup>

### Deposit Overview

The *territorium metallorum* Tresminas/Jales contains three different ore mineralisations with notable amounts of gold (fig. 3.0-1):

- Tresminas
- Gralheira
- Jales

Basically, all deposits within the mining zone at Tresminas were worked in the traditional miner's fashion by using hammer and iron, at times with the help of fire-setting.

#### Tresminas

The deposit area at Tresminas can be subdivided into three separate zones or mining areas (fig. 3.0-2):

1. The Corta de Covas = Opencast mine A
2. Corta da Ribeirinha = Opencast mine B
3. Lagoinhos = Exploitation Zone C

The deposits at Corta de Covas and Corta da Ribeirinha were for the most part exploited by surface mining, while at Lagoinhos, ore was extracted by deep mining.

The gold deposits of Tresminas were mined by the Romans in the two large open-cast mines Corta de Covas and Corta da Ribeirinha as well as in the underground mine Lagoinhos; in all cases the deposits were exploited

almost to exhaustion.<sup>104</sup> The metal ore was probably bound to quartzite and quartz-phyllite, which occurred in a zone up to 150 m wide parallel to the schistosity of Silurian meta-sediments.<sup>105</sup> The steeply rising strata of this vein strike out evenly from WNW to ESE. The areas of metal ore were predominantly chloritic muscovite sericite schist, which were strongly silicified. The main minerals of the ore were quartz, pyrite, arsenic gravel and magnetic gravel.<sup>106</sup> The gold, which is consistently very fine-grained (1–170 µm), is very closely interwoven with these minerals. It contains up to approx. 20% silver (fig. 3.0-3). The three mining zones are arranged along a line parallel to the strike and dip of the rocks.<sup>107</sup>

The complexity of the Tresminas deposit has resulted in the preservation of an extraordinary wealth of monuments. These do not only allow a detailed reconstruction of Roman prospecting activities, but they also document the progressive expansion of the mine, as well as the various stages of processing. In addition, the mining monuments in Tresminas prove that the gold had been concentrated in long and thin “lenticular” formations.

#### *The Corta de Covas = Opencast mine A*<sup>108</sup>

The opencast mine of Corta de Covas is around 430 m long and up to 140 m wide. The maximal depth preserved lies at about 60 m, situated above 786 m above sea level (MSL). The present state is only partly representative of the terrain conditions after the mine was given up in Antiquity.

<sup>102</sup> The basics of the mineralogical-geological explanations were provided by Annemarie Wiechowski. Also see Noronha et al. 2000; Rosa 2001; Rosa/Romberger (2003); Ribeiro et al. 2006; Farinha Ramos 2017 and Martins/Martins 2017.

<sup>103</sup> See Machado 2017 on the medieval documents. There is evidence of two silver mining sites of uncertain date. Since they are located in the northern part of the Fonte da Ribeira quarry, it can be assumed that they were mined in Roman times. One of the mines, probably for tin, is located in the area of the Roman cemetery and must have been known to the Romans. Nevertheless, we do not know whether tin was mined here in Roman times. The same is true for the tin mine at Revel, which was partly exploited in the 20th century and for the remains of mining in the area of Alto da Capelinha, through which an aqueduct tunnel led, east of Covas.

<sup>104</sup> Wahl-Clerici 2008; Wahl-Clerici 2011; Wahl-Clerici et al. 2011; Wahl-Clerici et al. 2017; Helfert et al. 2019.

<sup>105</sup> The earth age of the Silurian is 430–395 million years old.

<sup>106</sup> Rosa 2001; Noronha et al. 2000; Ribeiro et al. 2006; Machado et al. 2006.

<sup>107</sup> Wahl-Clerici et al. 2012b, 111.

<sup>108</sup> Wahl-Clerici 2010; Wahl-Clerici/Helfert 2017, 65-69; Helfert et al. 2019.

A prominent rock ridge divides the Corta into two main mining zones (figs. 3.0-4, 3.0-5). The Galeria Esteves Pinto was excavated after some time from the southern slope flank in order to ensure the drainage of the older, southern part. It seems that the gold concentrations to the north were discovered at an early stage via the prospecting structures high in the rock ridge. This is indicated by the preserved stairwell, which goes through the rock ridge and was opened from the south to the north (figs. 3.0-6, 3.0-7). The conspicuous depression in the separating rock ridge could be an indication that in an early excavation phase, the northern part used to be drained by the Galeria Esteves Pinto as well.

The southern part still largely corresponds to the antique state in its surface area. The depth that was reached in Antiquity can be determined by analysing the height of the Galeria Esteves Pinto towards the channel dug into its floor (fig. 3.0-8). The floor of the gallery lies at 810 m MSL. Conspicuous accumulations of stamp and ore mills near the opencast mine indicate an earlier access from the south to the opencast mine, which had been used before the opening of the Galeria Esteves Pinto. As early as Roman times, it was probably partially filled up with spoil material and finally largely destroyed by modern road construction.

In the northern part, the individual mining areas can be distinguished thanks to the soundings of the Serviço de Fomento Mineiro in the 1980s (fig. 3.0-9). The cross section recorded at that time indicates that the greatest depth reached at least 722 m NN, which is almost exactly the same as the maximum depth of the channel used to drain the Galeria do Pilar opencast mine. Drainage installations were needed for deeper zones.<sup>109</sup>

The slopes of the southern mining zone still largely show their original shape, while rockfalls in the northern area have changed the appearance of the open-cast mine (fig. 3.0-10). This also applies to the striking rock face in the eastern part of the open pit, which was created by the spalling of rock along a natural crevice.<sup>110</sup> The twin shafts now visible in the slope were inside the mountains in Roman times and were connected to the Galeria dos Alargamentos, but not to the open cast mine (figs. 3.0-11, 3.0-12). When the Roman abandoned the mine, the Corta de Covas was somewhat shorter and considerably narrower than it is now, but in certain places it was twice as deep.

The exploratory work of the Serviço de Fomento Mineiro in the 1950s through to the 1980s provided us with even more knowledge about the areas of the Corta de Covas which today are hidden under the rock fall material. At the same time, archaeological research has also enabled us to draw attention to problems that were not simply associated with the drilling carried out purely for prospecting purposes. We know from the level of the Galeria Esteves Pinto (810 m above sea level) that the southern mining zone was exploited to a depth of more than 30 m. Since the depth of the bottom of the channel is unknown, it was probably

a few metres more. And, as always, there was the possibility that there might have been drainage from even deeper levels by lifting the water, so that not even the bottom of the channel of the Galeria Esteves Pinto would provide a definitive value for the ultimate depth reached (fig. 3.0-9).

The accumulation of fire sites at the deepest point of open pit A is significant. The results of the cross-sections of the Serviço de Fomento Mineiro indicate that the current situation corresponds to the final stage of extraction (figs. 3.0-13—3.0-15).

It cannot be ruled out that from the open pit, underground mining was also carried out in certain areas. This is mainly indicated by the mining accident in the stairwell shaft of the Galeria dos Alargamentos.

#### *The Corta da Ribeirinha = Opencast mine B*

The Corta da Ribeirinha no longer is the same as it was after the Romans abandoned the mine. This is mainly due to the erosion of the southern slope, as it can be assumed that this was originally much steeper and thus the excavation zone narrower (fig. 3.0-16). All the remaining traces of excavation of mining are located on the northern slope and in the areas adjacent to it (figs. 3.0-17a/b/c, 3.0-18). The deepest point of the open pit was in the area of the drainage tunnel “Buraco Seco”, that is at 724 m above sea level in the open pit and thus at approximately the same level as the maximum mining depth reached in the Corta de Covas.

Originally, the gold in the Corta da Ribeirinha was mined in two separate open pits, the boundary of which can mainly be determined by the situation in the area of the Galeria do Pastor and the spiral stairwell (fig. 3.0-2 10/11). The difference in the appearance of the northern slope between the two parts is also striking. Finally, both the western and eastern ancient access areas to the mining zones can be identified (figs. 3.0-19, 3.0-20). While the western one is still in use today, the eastern one can no longer be used, as gold was extracted from the extension in the open pit, thus creating a rugged rock face.

Parallel to the western access, a system of galleries and both straight and inclined shafts was constructed to sample the rock (figs. 3.0-21—3.0-23). The highest level shows a typical trapezoidal and cleanly worked out cross-section. In order to continue the prospection, the bottom of the same was sunk in stages, although the sides became more irregular.

It seems that a richer gold deposit was found in the deeper part of the Corta, and the Galeria dos Morcegos was excavated to exploit it. This gallery, which is at least in part very generously sized, has a width of 4 m on the first 50 m,

<sup>109</sup> Height of the port of the Galeria do Pilar: 744 m. Gradient up to the open pit area approx. 3 m. Depth of the channel 23 m. The calculation thus results in 724 m NN.

<sup>110</sup> Rosa 2001, fig. 9.

but was never completed. This proves that the Romans expected much more from the gold deposit than was ever extracted.

The spiral stair shaft and the Galeria do Pastor, which are now connected by an underground mine, were also excavated for prospection (fig. 3.0-2 10/11). Thanks to a precise analysis of the system they formed, we were able to determine that the two structures were built independently of each other, i. e. that they were excavated from the two separate opencast mines. It is possible that the two mines only grew together at a later stage.

Finally, two sites belonging to the Corta da Ribeirinha, where the extracted material was processed, could be identified.

### The Campo de Jales and Gralheira deposits

The deposits at Gralheira and Jales are lodes where the ore is bonded to long quartz veins (figs. 2.0-1, 3.0-1, 3.0-24, 3.0-25). Diodorus of Sicily (1st half of the 1st century B. C.), History described these lodes (3.12.1):

Περὶ γὰρ τὰς ἐσχάτας τῆς Αἰγύπτου καὶ τῆς ὁμορροῦσης Ἀραβίας τε καὶ Αἰθιοπίας τόπος ἐστὶν ἔχων μέταλλα πολλὰ καὶ μεγάλα χρυσοῦ, συναγομένου πολλοῦ πολλῆ κακοπαθεία τε καὶ δαπάνη. τῆς γὰρ γῆς μελαίνης οὐσίας τῆ φύσει καὶ διαφύας καὶ φλέβας ἐχούσης μαρμάρου τῆ λευκότητι διαφερούσας καὶ πάσας τὰς περιλαμπομένας φύσεις ὑπερβαλλούσας τῆ λαμπρότητι, οἱ προσεδρεύοντες τοῖς μεταλλικοῖς ἔργοις τῷ πλήθει τῶν ἐργαζομένων κατασκευάζουσι τὸν χρυσόν.

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, and here the overseers of the labour in the mines recover the gold with the aid of a multitude of workers.

The mineral described by Diodorus as marble is in fact quartz, although a hundred years later, Pliny, Natural History 33,68 is still referring to it as marble:

*Quod puteis foditur, canalicium vocant, alii canaliense, marmoris glareae inhaerens, non illo modo, quo in oriente sappiro atque Thebaico aliisque in gemmis scintillat, sed micans amplexu marmoris. vagantur hi venarum canales per latera puteorum et huc illuc, inde nomine invento.*

Gold dug up from shafts is called 'channelled' or 'trenched' gold; it is found sticking to the grit of marble, not in the way in which it gleams in the lapis lazuli of

the East and the stone of Thebes and in other precious stones, but sparkling in the folds of the marble. These channels of veins wander to and fro along the sides of the shafts, which gives the gold its name;

The gold mineralisation at Jales is mainly bonded to Variscan middle and coarse-grained porphyritic two-mica granite (age 292 +/- 12 million years) and connected to steep quartz veins, running in north-northeast or north-east-southwest direction. These are 0.01—2m thick and run over a length of up to two kilometres. In the contact zones between granite and slate, these veins change direction and turn eastward to the cleavage areas of meta sediments to split up. Two of these veins, the 'Campo vein' and the 'Desvio vein' were exploited between 1933 and 1992 by the mining company "Minas de Jales Lda." The Romans had already mined these veins to a depth of about 120 m (figs. 2.0-1, 3.0-24). The quartz veins are banded and contain, in addition to quartz, arsenopyrite as the main mineral. Gold and electrum (gold with an amount of silver of over 20 per cent) are embedded into the quartz, arsenopyrite, sulphides and sulphosalts amalgamated to these minerals. Silver is also found also in the minerals argentite, galenite, tetrahedrite and argyrite (fig. 3.0-3).

The deposit at Gralheira is composed of a number of quartz lenses, veins or vein clusters that strike out in a west-northwest to east-southeast direction, embedded into Ordovician slates. The mineralisation can be traced over a distance of about five kilometres at a width of between one and 50m. As far as is known the Romans exploited the widest parts and reached a depth of about 140m. Course and structure of the vein are similar to the one at Jales.

### Gralheira

The Gralheira deposit runs a minimum length of about 3.5 km, although not all parts of it are auriferous and therefore remained unexploited. In several parts the lode fans out into up to five sub clusters (figs. 2.0-1, 3.0-25). The Gralheira ore vein has been sampled repeatedly since the 1930s. The relatively high gold content in it endangers this extraordinary cultural heritage site, which is one of the rare examples of the exploitation of an ore vein that has been preserved since Antiquity.<sup>111</sup>

According to current knowledge, mining in this area was carried out purely as opencast mining, for which both

111 Harrison 1931; Important sondages have been done 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 a highly advanced plan for the exploitation of the vein of Gralheira was presented by RTZ, Sociedade Mineira Rio Artezia, S.A., Bureau de recherches géologiques e minieres, Consórcio Gralheira.

long and narrow exploitation trenches were excavated (figs. 3.0-26, 3.0-27) and shafts sunk (fig. 3.0-28). These trenches are now often filled up to the slope surface and for this reason can often only be identified by working traces or spoil heaps (figs. 3.0-29, 3.1-5). At some points, the sides of these trenches have collapsed, some of which had already needed to be substantially supported in Roman times (fig. 3.0-30), so that one may be pardoned for (incorrectly) assuming that this had been underground mining (figs. 3.0-31a, 3.0-32). Furthermore, an abundance of stroke marks and cuts for the insertion of technical installations (figs. 3.0-31b, 3.0-33, 3.0-34) testify to the care and efficiency of the Roman approach. This evidence is not exclusive to those mining zones that are still easily identifiable, so that it must be assumed that a thorough survey of these traces could still reveal unexpected treasures (figs. 3.0-35, 3.0-36).

As far as is known, the natural slope of the terrain was mainly used to drain the mining zone. However, additional galleries had to be built to provide drainage on the lower levels. The Galeria Minhoteira, built in a transverse position to the ore lode, drained the mining zone in the direction of the Rio Tinhela. At the end of the 20th century, this gallery was used for the drift of a large prospection project. Old ground plans feature two more galleries that have not yet been identified.

#### *Campo de Jales*

The ore lode at Jales was exploited during the 20th century A. D. by the company Minas de Jales Lda using deep mining techniques. These works destroyed almost every trace of pre-modern mining. On the surface, only a few traces of ancient mining are visible, e. g. remains of long exploitation trenches south of the modern road N212 that runs from Vila Pouca de Aguiar to Murça (fig. 3.0-37). On the other side of that road, further remains of mining parallel to the road 1172-1 were finally covered with rubble by the end of the last century.

Fortunately, the ancient mining zones are indicated in the modern plans of the mine, enabling us to reconstruct the general outline of Roman mining works (fig. 3.0-24). The overall plan shows the irregular sinking mining area at the places where it was probably possible to extract ore with a high gold content. The maximum depth was reached at about 125 m, with the entire ore lode extending over a length of about 1300 m.

Unfortunately, no specific details can be obtained from this overall plan, especially in terms of drainage systems, ore transportation mechanisms or measures to support the mineshafts. The drainage would have in particular presented a substantial challenge to Roman engineers, as the terrain is rather even and the mining zone stretches over a broad pass, not allowing for drainage by tunnels on the surface as do those at Tresminas or Gralheira.

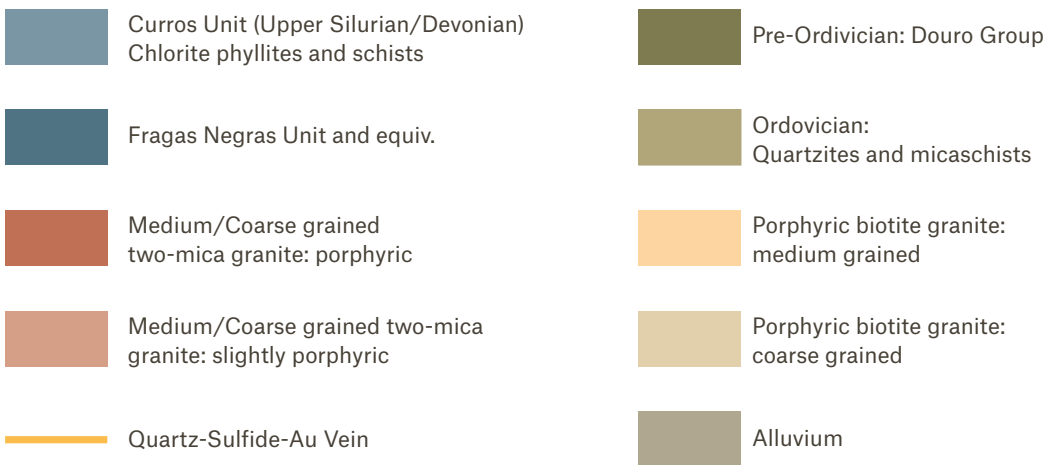
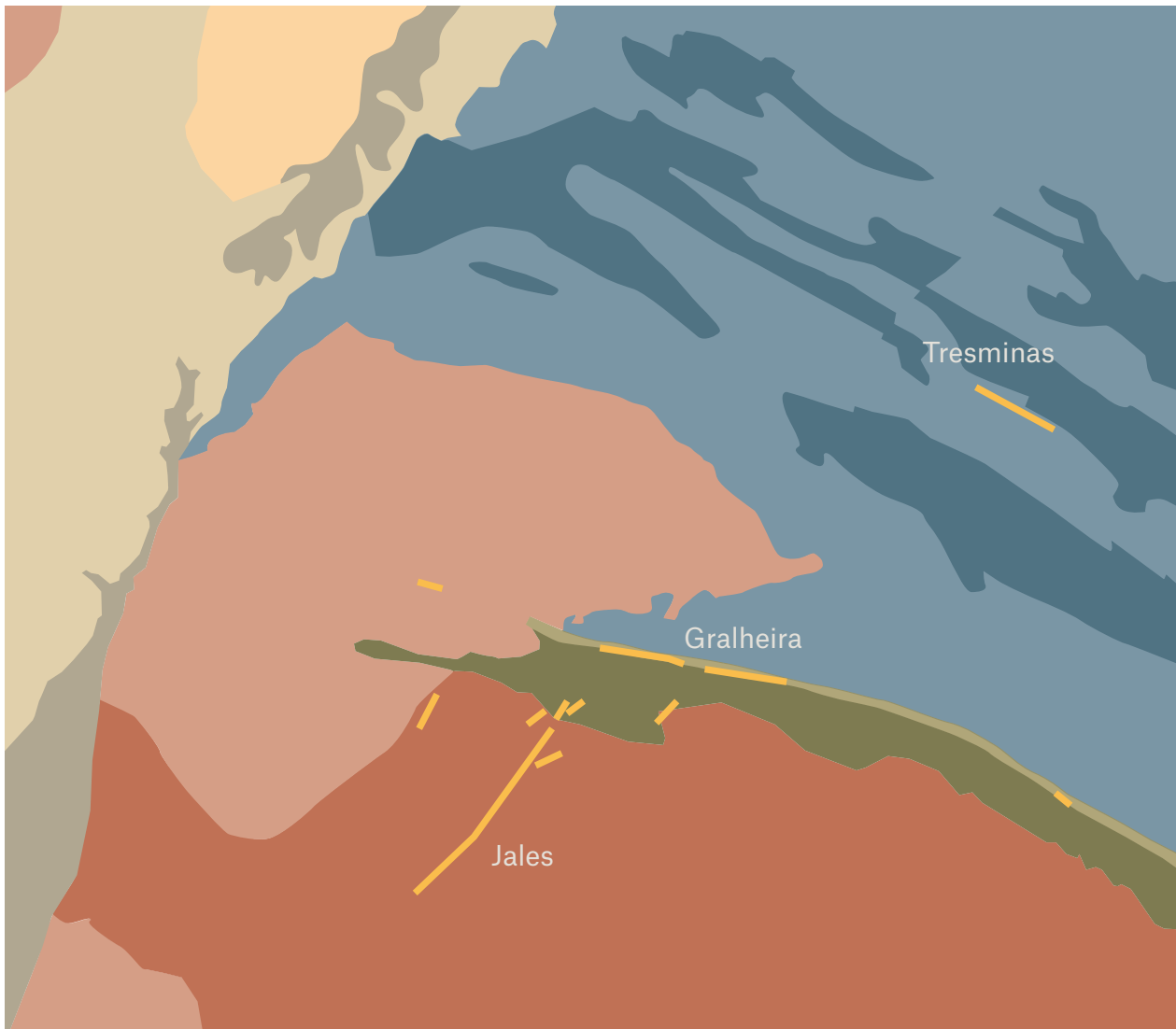


Fig. 3.0-1: Geological map (schematized) with the gold-bearing deposits.  
(After Rosa/Romberger 2003 and extract from the Carta dos Ocorrências  
minerais — folha 2 — Trás-os-Montes, Scale 1:200 000.)

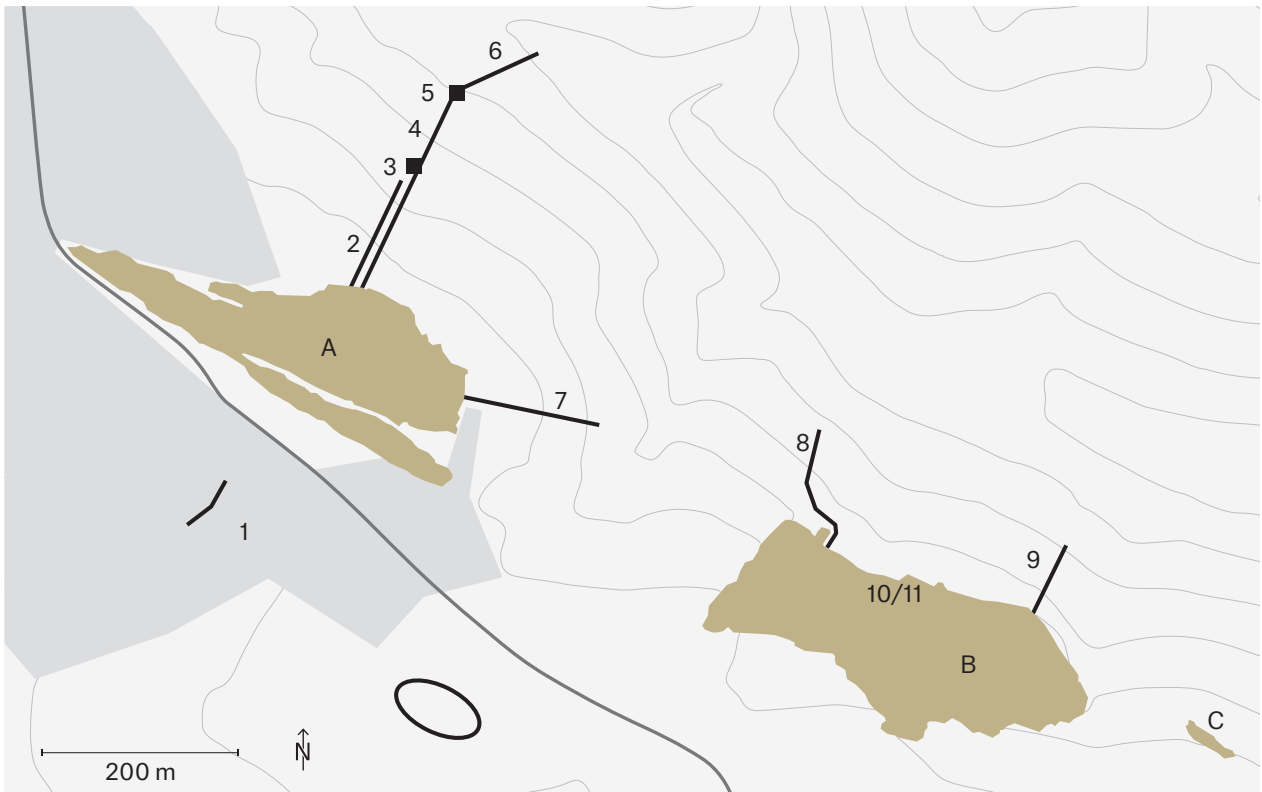


Fig. 3.0-2: *Territorium metallorum* Tresminas / Jales. Overview of the Tresminas core zone:

A — Corta de Covas, B — Corta da Ribeirinha, C — Lagoinhos 1 — Galeria Esteves Pinto, 2 — Galeria Jürgen Wahl, 3 — shaft in front of Galeria Jürgen Wahl's adit to the Galeria do Pilar, 4 — Galeria do Pilar, 5 — shaft in front of Galeria do Pilar's adit to Galeria do Texugo, 6 — Galeria do Texugo, 7 — Galeria dos Alargamentos, 8 — Galeria dos Morcegos, 9 — Galeria Buraco Seco, 10 — Spiral stairwell, 11 — Galeria do Pastor. (Template Ortofotomapa Câmara Municipal Vila Pouca de Aguiar 1:10 000, design: J. Wahl, R. Wahl-Clerici, M. Helfert, drawing: S. Mathiuet).

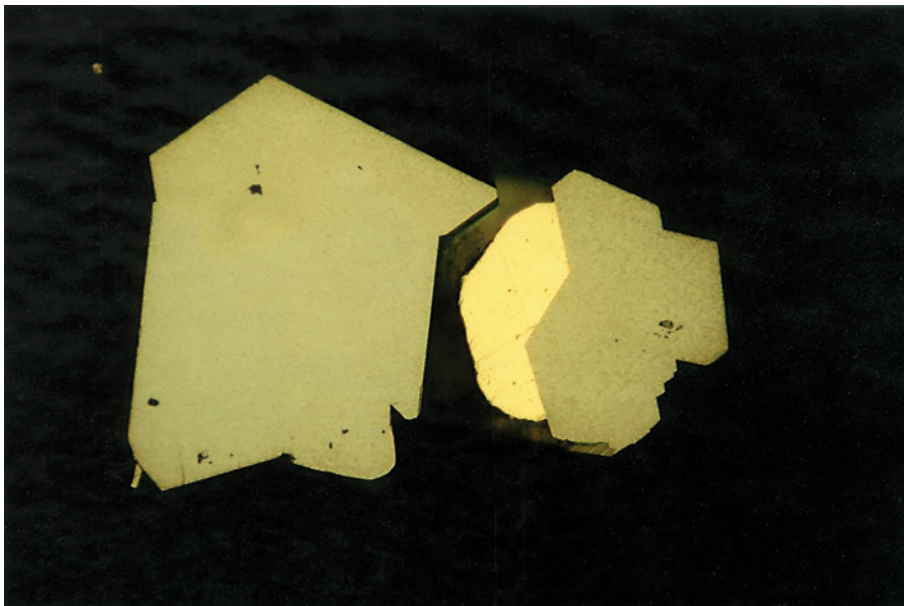


Fig. 3.0-3: *Territorium metallorum* Tresminas / Jales, Campo de Jales: gold (yellow) in contact with arsenopyrite. Black: non-metallic minerals. Thin section in oil immersion, the long edge of the image measures 342  $\mu\text{m}$  (image: RWTH Aachen / D).





Fig. 3.0-4: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas from the west. In the foreground the northern extraction zone, on the right the southern extraction zone, separated by the rock left standing (photo: R. Wahl-Clerici).



Fig. 3.0-5: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas from the east: view of the northern extraction zone with the rock face towards the southern mining zone (photo: R. Wahl-Clerici).



Fig. 3.0-6: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, from the north: view onto the sterile rock face between the two extraction zones with the stairwell shaft sunk for prospecting (photo: A. Wiechowski).



Fig. 3.0-7: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, from the south: view on the stairwell shaft for prospection (photo: R. Wahl-Clerici).



Fig. 3.0-8: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, from the south: entrance of the Galeria Esteves Pinto, with the drainage channel and cart tracks sunk into the sole (photo: J. Wahl).

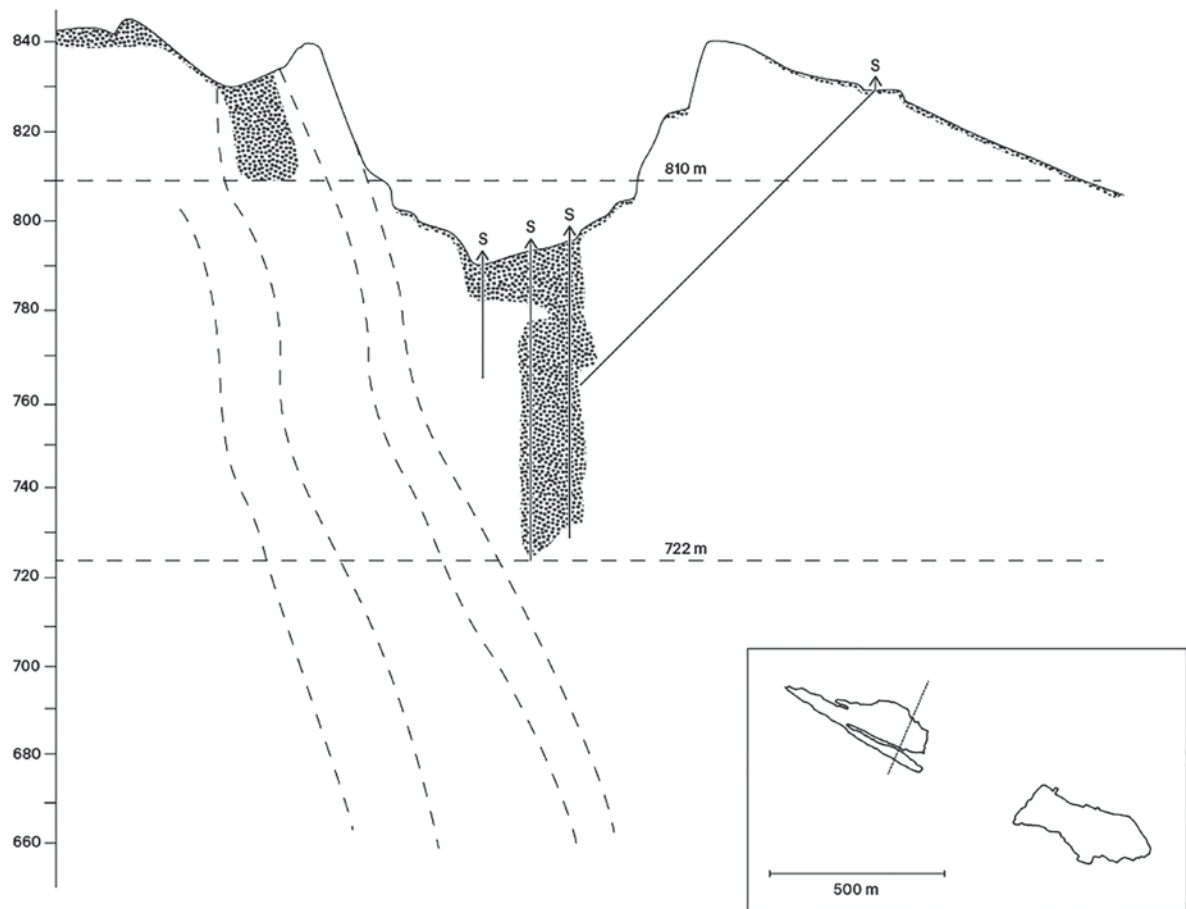


Fig. 3.0-9: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: north-south-section through the Corta at the lowest point sounded (S = sondage). The depth of the southern mining zone was adapted to the level of the Galeria Esteves Pinto. Lower right: position of the sondage (after Direcção geral de geologia e minas, Serviço de Fomento Mineiro, Divisão de Prospecção de Minérios Metálicos, SFM-SPE-1987-88, design: R. Wahl-Clerici, S. Mathiuet).



Fig. 3.0-10: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: rock fall in 2019 (photo: R. Wahl-Clerici).



Fig. 3.0-11: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, from the west: eastern slope with the twin shafts, which were connected by galleries on several levels (photo: R. Wahl-Clerici).



Fig. 3.0-12: **Territorium metallorum** Tresminas/Jales, Tresminas, Corta de Covas: detail of the natural crevices on the eastern slope (photo: R. Wahl-Clerici).

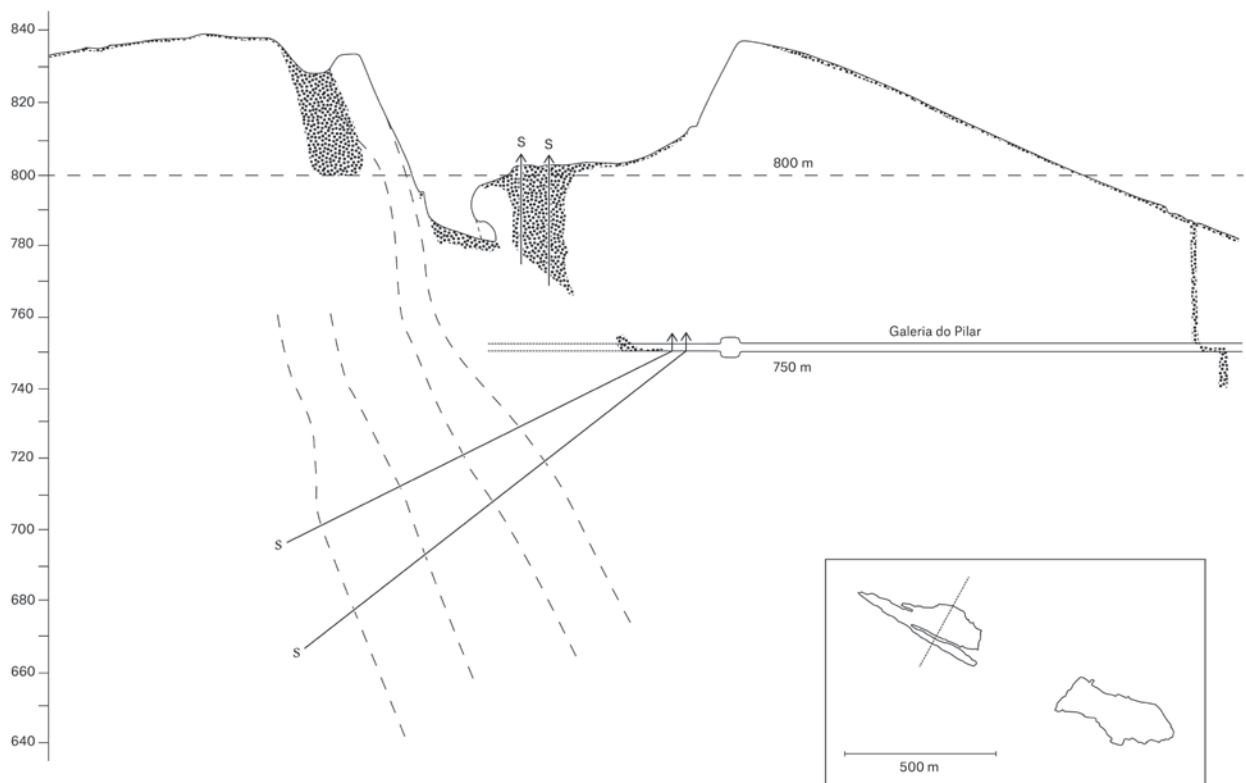


Fig. 3.0-13: **Territorium metallorum** Tresminas/Jales, Tresminas, Corta de Covas: north-south section through the Corta in the areas of the fire setting. Lower right: position of the sondage (after Direcção geral de geologia e minas, Serviço de Fomento Mineiro, Divisão de Prospeccção de Minérios Metálicos, SFM-SPE-1987-88, design: R. Wahl-Clerici, S. Mathiuet).

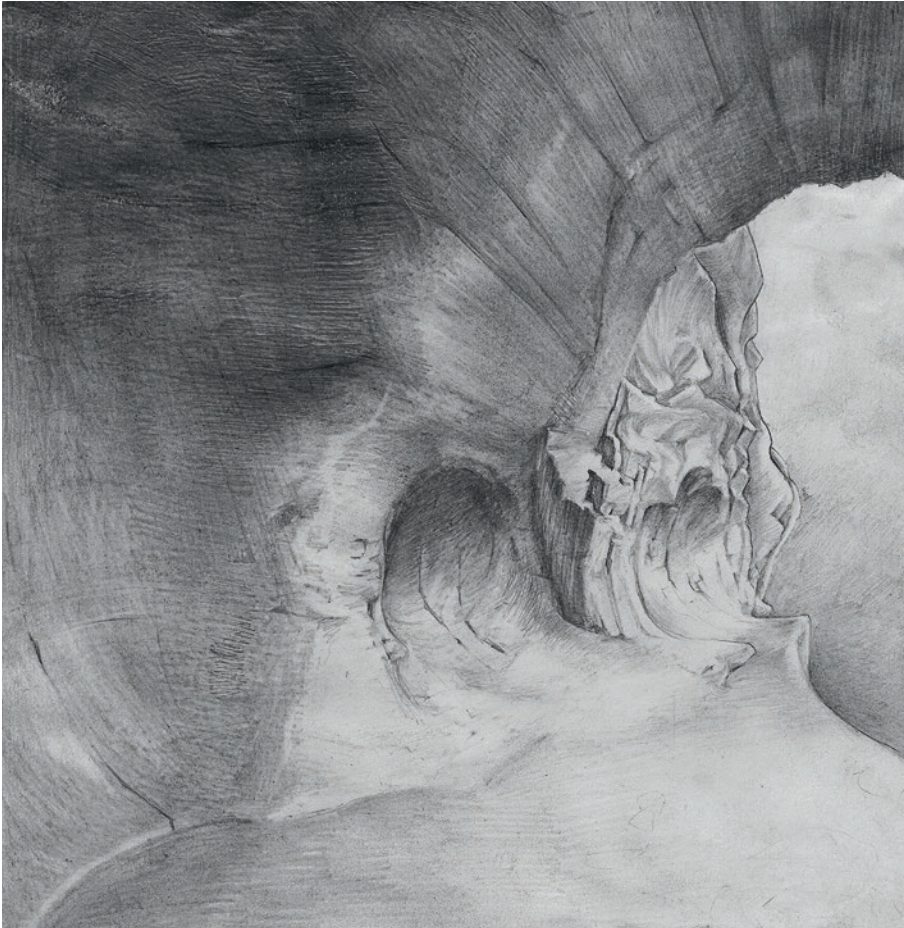


Fig. 3.0-14: *Territorium metallorum*  
Tresminas / Jales, Tresminas, Corta de  
Covas: fire-setting points  
(drawing: P. Moser).



Fig. 3.0-15: *Territorium metallorum* Tresminas / Jales, Tresminas,  
Corta de Covas: fire setting in order to open a gallery (photo: R. Wahl-Clerici).



*Fig. 3.0-16: **Territorium metallorum** Tresminas / Jales, Tresminas, Corta da Ribeirinha, from the southwest: view onto the northern slope with the various remains of the Roman extraction in the western and eastern parts (photo: R. Wahl-Clerici).*





*Fig. 3.0-17a: **Territorium metallorum** Tresminas / Jales, Tresminas, Corta da Ribeirinha: on the left of the picture the northern slope with the remains of the Roman extraction. On the right of the picture the southern slope formed by rock falls (photo: R. Wahl-Clerici).*

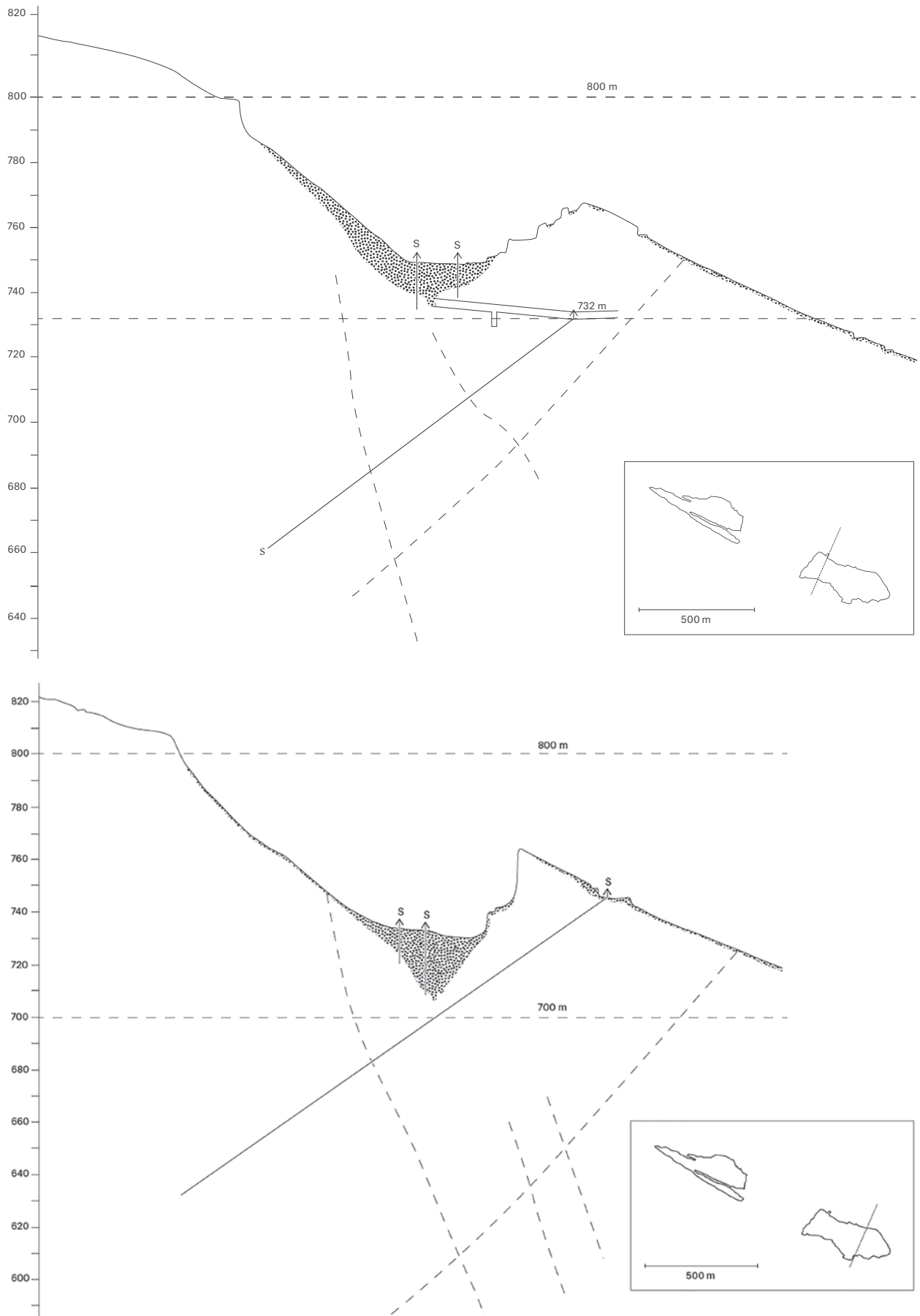


Fig. 3.0-17b/c: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: north-south sections through the Corta in the western and eastern parts. Lower right: position of the sondages (after Direcção geral de geologia e minas, Serviço de Fomento Mineiro, Divisão de Prospecção de Minérios Metálicos, SFM-SPE-1987-88, design: R. Wahl-Clerici, S. Mathiuet).



Fig. 3.0-18: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: eastern part of the northern slope with the remains of a very early gallery (photo: R. Wahl-Clerici).



Fig. 3.0-19: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha, from the north: former eastern entrance to the open pit mine (photo: R. Wahl-Clerici).





Fig. 3.0-20: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha, from the north: western entrance to the open pit mine, still in use (photo: R. Wahl-Clerici).



Fig. 3.0-22: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: the upper level of the prospecting system at the western entrance. The oldest carefully worked trapezoidal gallery is still well visible, they were sunk in stages (drawing: P. Moser).



Fig. 3.0-21: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha, from the south: western entrance to the open pit mine, with the prospection works continuing to the south (photo: R. Wahl-Clerici).

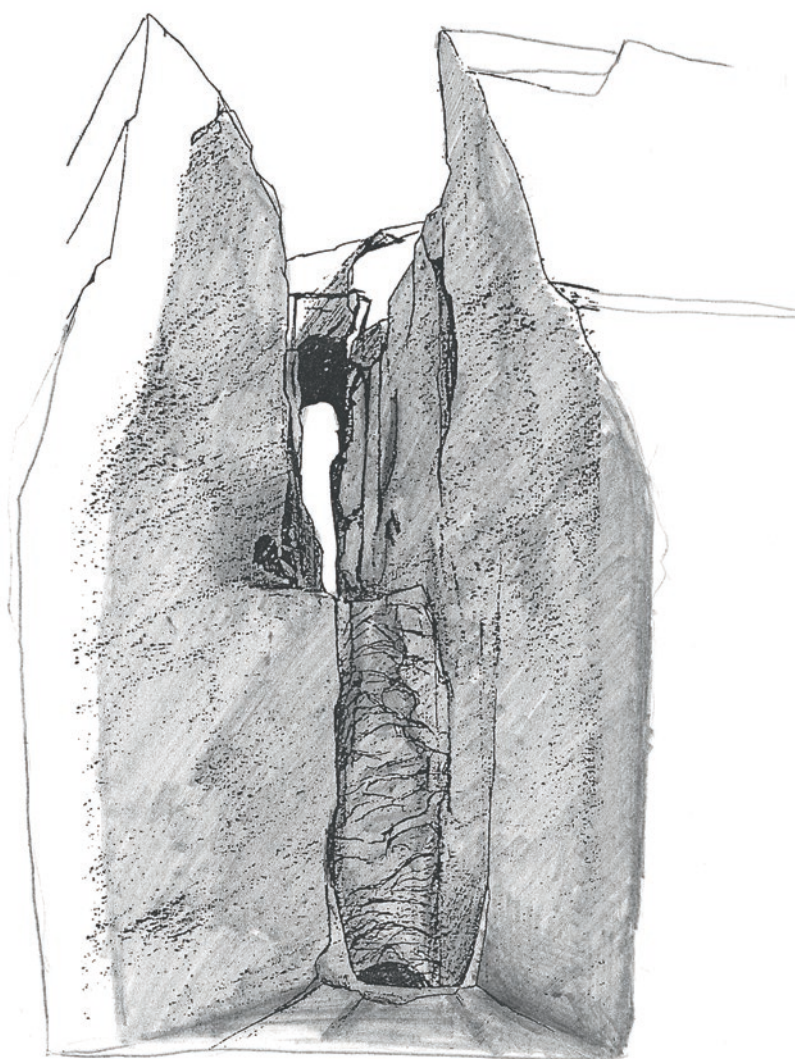


Fig. 3.0-23: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: the prospection works in fig. 3.0-22, seen from the south (drawing: P. Moser).



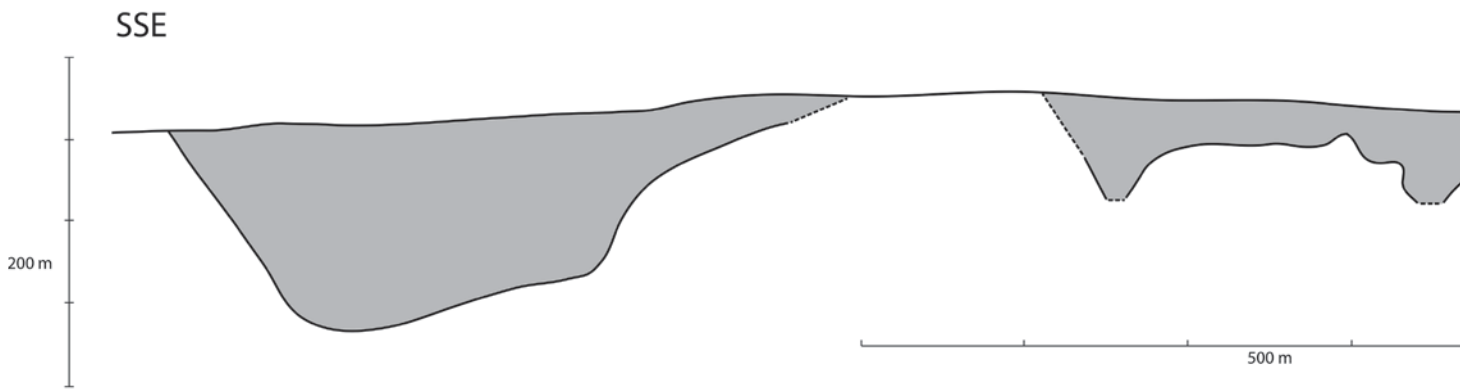


Fig. 3.0-24: *Territorium metallorum* Tresminas / Jales, Deposit of Campo de Jales: section through the ore lode of Jales with an indication of the Roman extraction (template: Minas de Jales Ltda., design: J. Wahl).

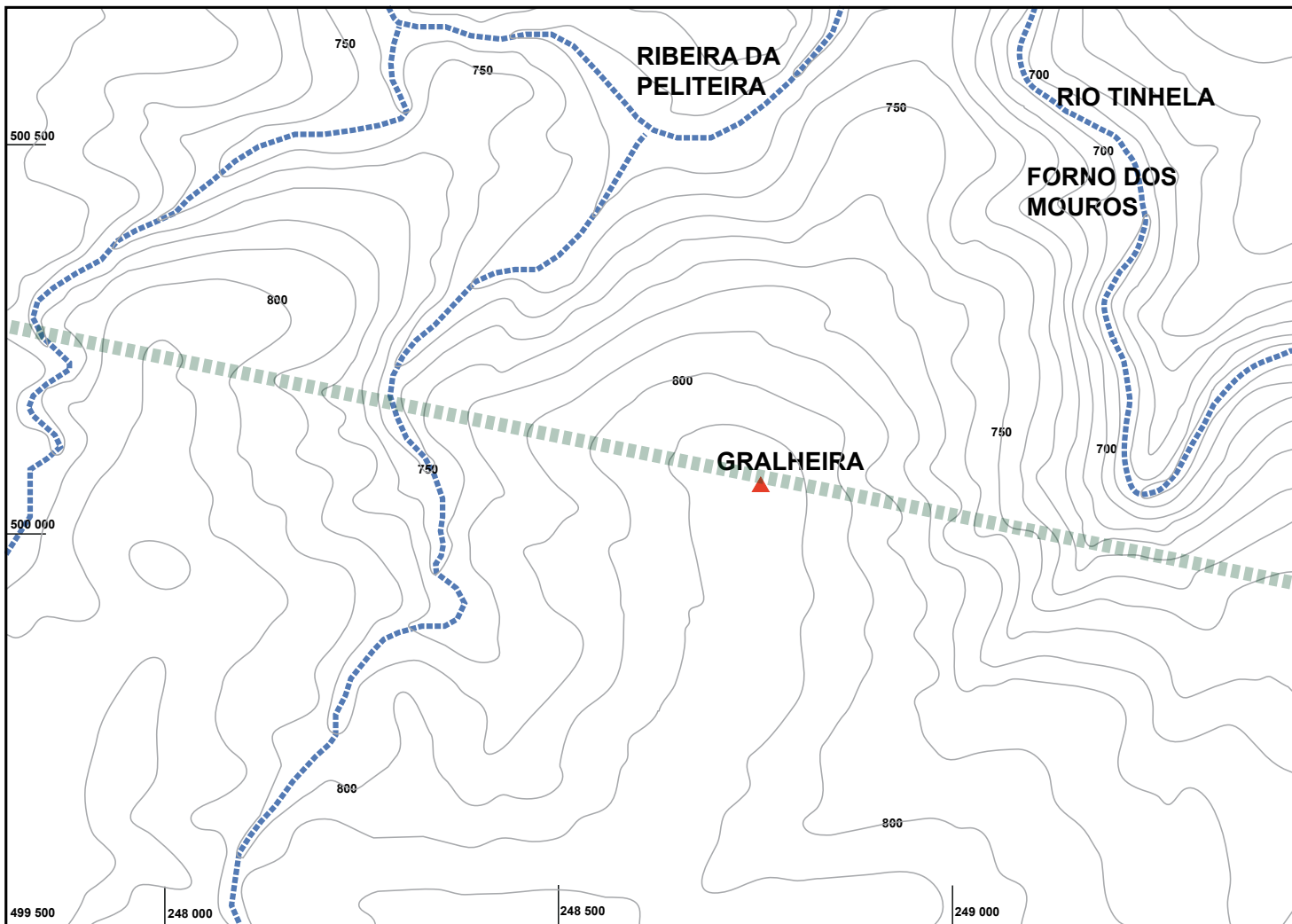


Fig. 3.0-25: *Territorium metallorum* Tresminas / Jales, Deposit of Gralheira: schematized plan of the ore vein (template: Ortophotomapa 1:10000 Câmara Municipal Vila Pouca de Aguiar, RTZ, Sociedade Mineira Rio Artezia, S.A., Bureau de recherches géologiques e minières, Consórcio Gralheira, 12.06.1990, design: R. Wahl-Clerici).





Fig. 3.0-26: *Territorium metallorum* Tresminas / Jales, Gralheira, from east-northeast: crossing of two quartz veins with polymetallic ores. South of the glory-hole trench, remains of the rock outcrop have been preserved (photo: R. Wahl-Clerici).



Fig. 3.0-28: *Territorium metallorum* Tresminas / Jales; Gralheira: the shaft is visibly wider than the later extraction zone (photo: R. Wahl-Clerici).



*Fig. 3.0-27: **Territorium metallorum** Tresminas / Jales, Galheira: extraction zone with remains of the glory-hole trench and the waste rock dump (photo: R. Wahl-Clerici).*



Fig. 3.0-29: *Territorium metallorum* Tresminas / Jales, Gralheira: waste rock dumps (photo: R. Wahl-Clerici).



Fig. 3.0-30: *Territorium metallorum* Tresminas / Jales, Gralheira: extraction zone, not yet completely collapsed with cuts to house the wooden supports (photo: R. Wahl-Clerici).



Fig. 3.0-31a: *Territorium metallorum* Tresminas / Jales, Gralheira; from the southeast: a completely collapsed former open pit mine with the remains of an entrance in the northern working face (photo: R. Wahl-Clerici).



Fig. 3.0-31b: *Territorium metallorum* Tresminas / Jales, Gralheira; detail of 3.0-33a: remnants of a door-construction? (Photo: R. Wahl-Clerici).



Fig. 3.0-32: *Territorium metallorum* Tresminas / Jales, Gralheira: former open pit mine, completely collapsed (photo: R. Wahl-Clerici).



Fig. 3.0-33: *Territorium metallorum* Tresminas / Jales, Gralheira: worked rock area within the extraction zone. The hacking traces indicate that this ledge was not used as a floor (photo: M. Lindstaedt).



Fig. 3.0-34: *Territorium metallorum* Tresminas / Jales, Gralheira: small channels, probably for an installation worked into the rock after flattening it (photo: M. Lindstaedt).



Fig. 3.0-35: *Territorium metallorum* Tresminas / Jales, Gralheira: cut into the rock for an installation (photo: R. Wahl-Clerici).





Fig. 3.0-36: *Territorium metallorum* Tresminas / Jales, Galheira: view onto the rock area to the north of the glory-hole trench, which has been conspicuously flattened for an unknown function (photo: R. Wahl-Clerici).



Fig. 3.0-37: *Territorium metallorum* Tresminas / Jales, Campo de Jales: southwest of the road from Vila Pouca de Aguiar to Murça (N212), the last remains of the Roman mining in the Campo de Jales vein is visible (Google Earth, recording date 31.08.2013).

### 3.0.1 The Lagoinhos mining zone<sup>112</sup>

In addition to the two large open-cast mines Corta de Covas and Corta da Ribeirinha, the gold-bearing ore was also mined in Lagoinhos, which is connected to the former in the east in alignment with the strike of the metamorphic schists and the deposits it contains. For a long time, Lagoinhos was interpreted as another open pit mine, only the more detailed investigations in recent years have shown that the whole zone had been exploited underground (figs. 3.0.1-1, 3.0.1-2).

In 2015 and 2016, decisive new discoveries were made by the speleological group „Alto Relevo, Clube de Montanhismo“ from Valongo (District Porto / Portugal) by descending into deeper extraction zones which had been known of, but never been examined (fig. 3.0.1-3).

The complex extraction conditions in Lagoinhos, the collapse of the hanging wall<sup>113</sup>, together with the partial collapse of the southwestern slope both on the surface and underground make for a very confusing first impression. The interpretation of the mining progress is made more difficult by the existence of at least four distinguishable underground levels with further collapses (figs. 3.0.1-2, 3.0.1-4—3.0.1-5a/b).

The Lagoinhos mining zone can be fundamentally divided into an open area and an underground area. The underground mine is accessible without any additional aid over a length of about 90m and a maximum width of 8.30m. The deeper mining zone, which was more thoroughly explored for the first time in 2015, shifts slightly to the northeast of the open area, mainly located below the dotted line (marking the closed area) in figs. 3.0.1-4—3.0.1-10. The different positions of the open and underground mining zones are related to the inclination of the gangue (worthless rock) of 85° or 70° to the northeast (figs. 3.0.1-7, 3.0.1-10).

In the Lagoinhos mining zone, a noticeable accumulation of prospecting remains can be observed (figs. 3.0.1-11—3.0.1-14). This demonstrates that the ore deposit was thoroughly sampled in all directions, even though the ore worth mining was essentially limited to a long and rather narrow zone of hitherto unknown depth (fig. 3.0.1-15).<sup>114</sup>

#### The extraction zone that is open to the air today

Traces of hammer and pick were preserved in large parts of the northeastern slope. In most cases, they cannot be traced up to the surface of the slope, leading to the conclusion that the ore was mined underground in this area as well and that the hanging wall had collapsed.

Figures 3.0.1-13a/b show the situation on the northeastern slope. To the left of the picture (fig. 3.0.1-13b), after the first rock edge, the opening is visible, which was created by the extraction cutting an older prospecting shaft. In the continuation to the right, the zone with the traces

of working with hammer and pick can be discerned, with the boundary to the former hanging wall clearly visible. A large and striking rock fall is approximately in the middle of the picture. The tool traces continue to the right as well as below it. However, at the current stage of research it is impossible to answer the question as to whether these are the remains of a connection or perhaps a stabilization between two mining zones.

#### The preserved part of the underground extraction area

The beginning of this extraction zone is marked by shaft 1 (P-1) with an elongated cross-section, which can be traced from the surface to a depth of about 28m, despite subsequent changes due to mining and collapses. Already Pliny mentioned vaults to improve stability (fig. 3.0.1-16).<sup>115</sup> The southeastern wall of this shaft is especially striking because of its several extensions, which were carefully cut into the rock. Access to the deeper levels is still possible today through this shaft, despite the fracture, i. e. “the collapse of the roof or layers of rock above the ore into the mining cavity”<sup>116</sup>, which strongly distorts the impression of level 1 (N-1) (fig. 3.0.1-17).

Floor 1 (N-1) continues in an incline over approx. 30m further into the rock. The northeastern wall of this level is especially remarkable, as the traces of hammer and pick have been preserved over a height of at least 5m (fig. 3.0.1-10). The extraction zone was abandoned on various levels. The southeastern boundary is marked by sampling point 174. Other more or less distinct gradations can be identified further on, as well as the boundary between the extraction zone and the collapsed southeastern wall (fig. 3.0.1-17). The end of the extraction zone is characterised by two lower lying working faces at different levels and three prospecting levels (PR-2-4)<sup>117</sup> for further sampling of the rock in all directions (fig. 3.0.1-18)

The actual mining zone on the level (N-1) is accessible from an area that is above ground today. In this zone, sampling sites by the Portuguese State Serviço de Fomento Mineiro, today Instituto Geologico e Mineiro, are concentrated. This office carried out a thorough prospecting survey in the 1980s. To this day, these have left their traces,

<sup>112</sup> This chapter is a shortened version of Wahl-Clerici et al. 2017

<sup>113</sup> The rock above the ore.

<sup>114</sup> Wahl-Clerici / Wiechowski 2013.

<sup>115</sup> Pliny, Natural History 33,71: *relinquuntur itaque fornices crebri montibus sustinendis* (Archways are often left standing to support the mountains).

<sup>116</sup> Weisgerber 1985, 240.

<sup>117</sup> The prospecting structures are described differently in figs. 3.0.1-4 and 3.0.1-5. Prospection structures PR-1 corresponds to A and PR2 = L. There are no further overlaps.

in the form of red squares around the sampling points. We are also aware of the results obtained for Lagoinhos. The plan figure 3.0.1-6 shows that, with one exception, all gold-bearing samples originate from the former extraction zone; however, the geologists did not differentiate between the actual extraction area and zones with caved-in rocks.

The conditions in the area of the deeper levels 2, 3 and 4 (N-2, N-3, N-4) (figs. 3.0.1-4, 3.0.1-10, 3.0.1-15), which are only accessible through shaft 1 (P-1), are particularly complex. The large cavity present today was only created by the widening of the mining area, starting from above the original cavity. Also noteworthy is the insight gained by walking through the eastern area on level 3 (N-3), namely that there was at least one further access through a blind shaft<sup>118</sup> (P-3?) between levels 1 and 2 (N-1, N-2). The remains of a prospecting section (PR-6) as well as a gradation in the southeastern face<sup>119</sup> are indications for the continuation of the former level (N-3) and prove the existence of the earlier extraction level, which is still preserved in the southeastern part (N-3). At the southeastern end, traces of a shaft (P-4?) can be seen.

The deepest level 4 (N-4) is heavily silted and partly lies below the level of the water that collects here. This water obviously has no runoff and can only escape through the smallest crevices in the metamorphic schist (figs. 3.0.1-2, 3.0.1-5a/b, 3.0.1-15).<sup>120</sup> It may be assumed that the Romans ensured drainage by installing artificial water elevation.<sup>121</sup>

The dotted lines in the general plan (fig. 3.0.1-4) indicate possible extraction zones. It seems quite possible that the two port zones of shaft 1 (P-1) and shaft 2 (P-2) met underground.

With the help of the well-developed prospecting section PR-5 (fig. 3.0.1-12) the rocks were explored in a north-east direction.

The waste-rock dumps accumulated north of the mining zone are conspicuously small in relation to those of the Corta de Covas and Corta da Ribeirinha open-cast mines (fig. 3.0.1-19). Also noticeable is the lack of stamp mills or their fragments at Lagoinhos, as they are found in masses in the other mining areas and the associated processing zones. Even though most of the stone material from which the stamp mills were erected probably was transported to Ribeirinha, it would be reasonable to assume that at least a few fragments would still have remained. We therefore do not know where the material from Lagoinhos was processed.<sup>122</sup>

## Results

This very brief overview of the new research results in Lagoinhos increases our knowledge of Roman mining in the territory *metallorum Tresminas* / Jales, based mainly on the large open pit mines of Tresminas.

- Lagoinhos was a purely underground mining operation.

- Practically no sterile material had to be mined in addition to the rock containing the ore.
- Processing did not take place directly on site, which is exceptional.

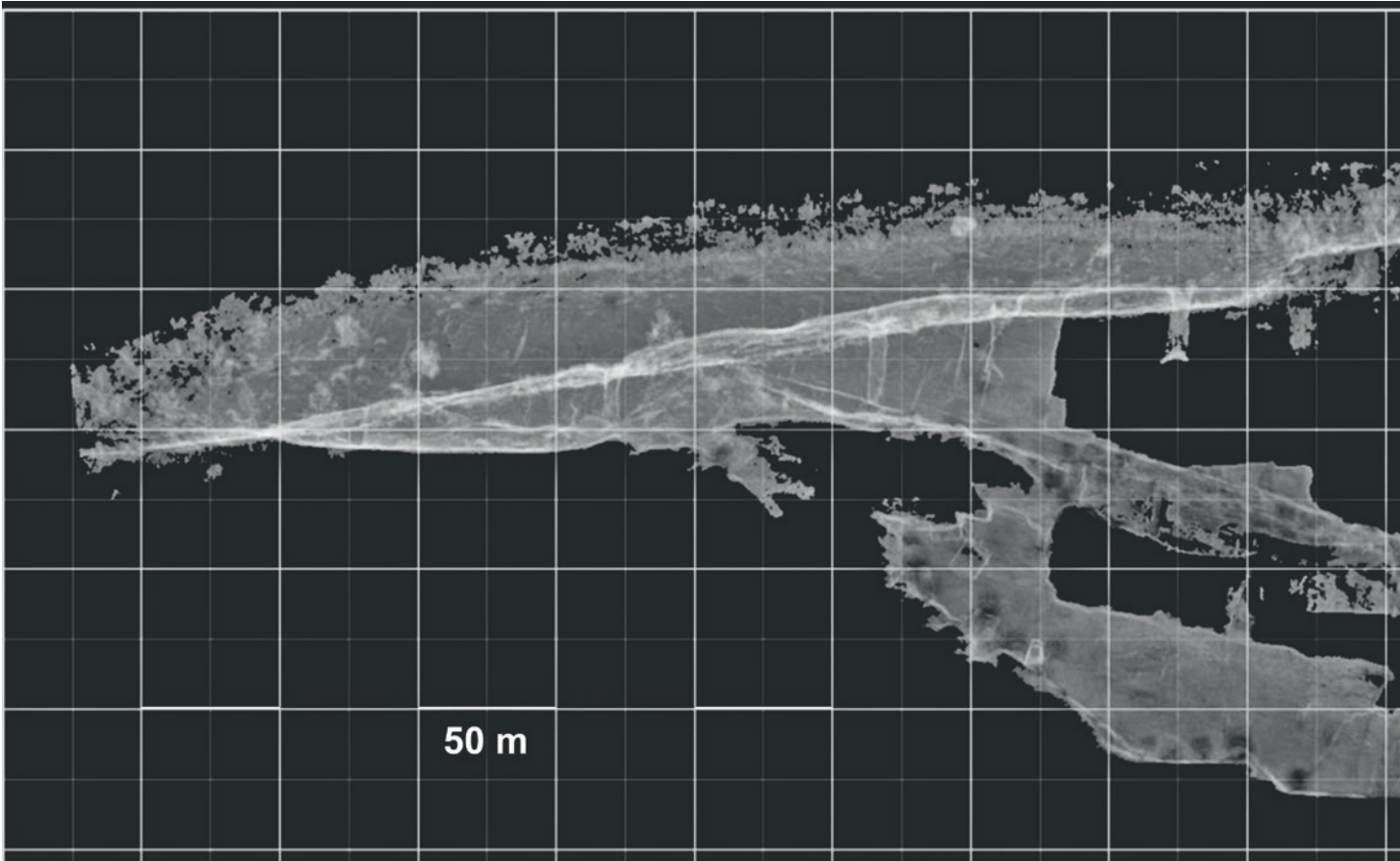
118 Blind shaft: a shaft that connects two levels but does not reach above ground.

119 Face: the end of a drift or stope, in which work is taking place.

120 The members of the speleological group "Alto Relevo" visited this part in September 2015, in October 2016 and in September 2017.

121 Domergue 1990, 440—460.

122 Wahl-Clerici et al. 2017.



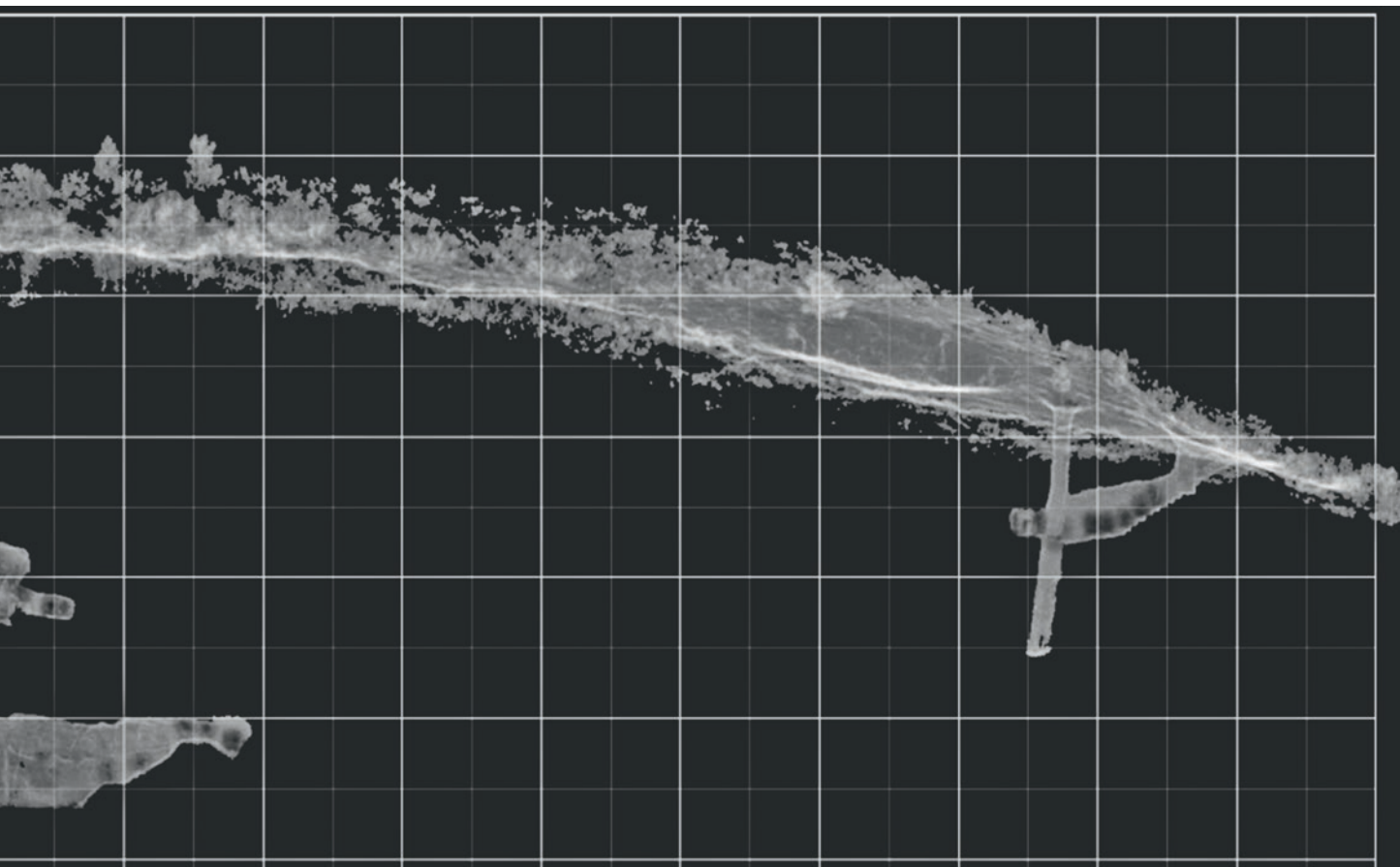
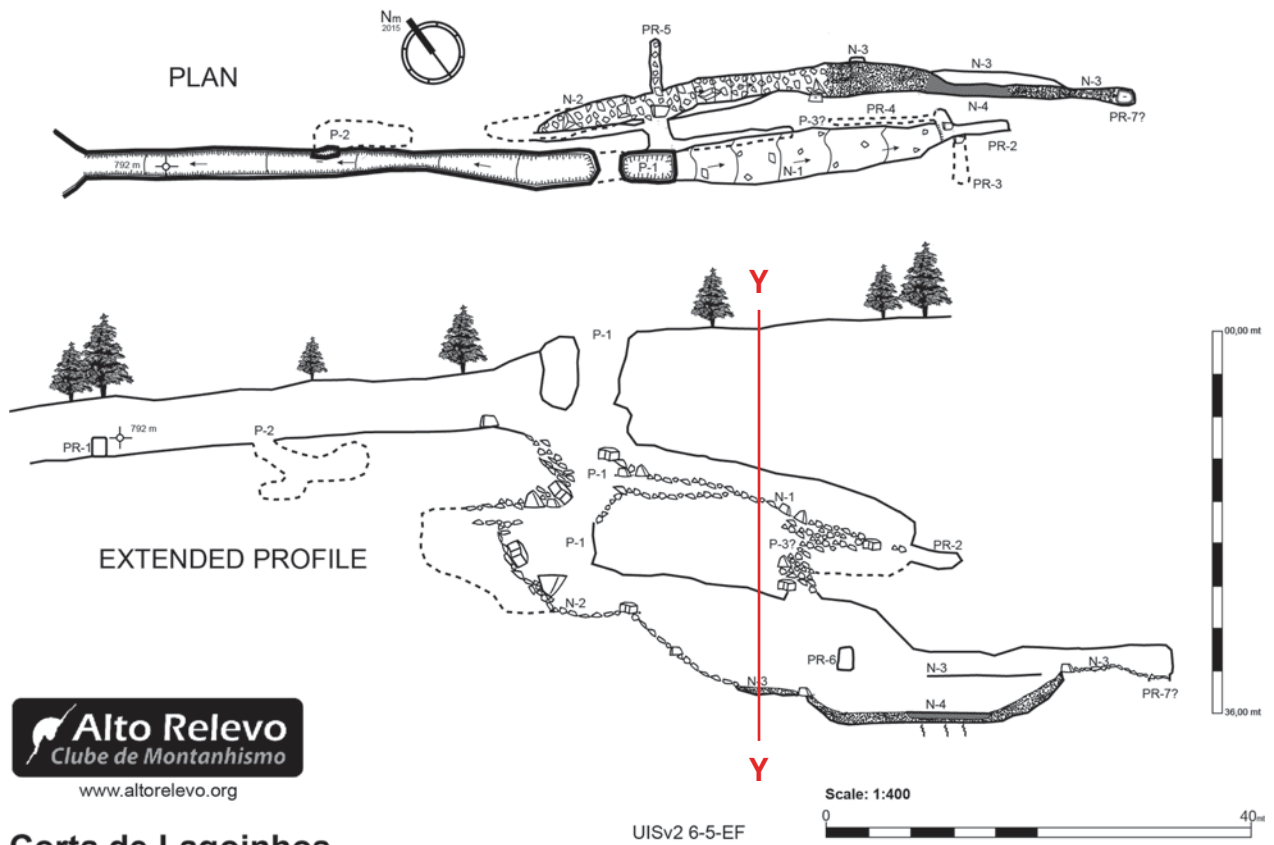


Fig. 3.0.1-2: **Territorium metallorum** Tresminas / Jales, overview on the Roman mine of Lagoinhos and the prospection in the east (figs. 2.0-23, 2.0-24), Y — Y' marks the section in fig. 3.0.1-6 (scan and design: K. Mechelke, M. Lindstaedt).

Fig. 3.0.1-1: **Territorium metallorum** Tresminas / Jales, Lagoinhos: view from the west into the former underground mine, which is now open due to the collapse of the rock (photo: R. Wahl-Clerici).



Fig. 3.0.1-3: *Territorium metallorum* Tresminas / Jales, Lagoinhos: access to shaft P-1 (photo: R. Wahl-Clerici).



**Alto Relevo**  
Clube de Montanhismo  
www.altorelevo.org

### Corta de Lagoinhos

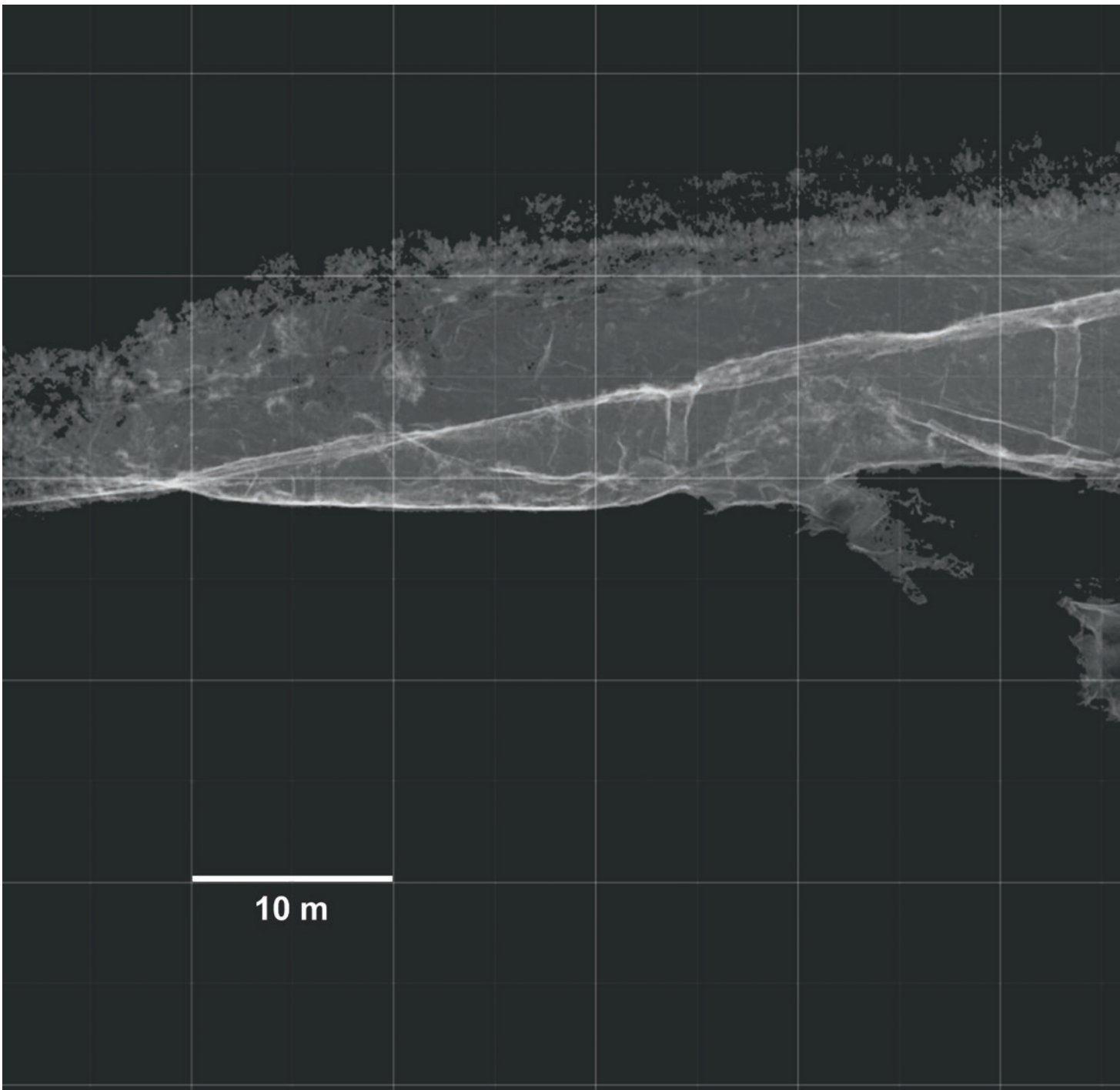
N 41,493278 W -7,515167 (WGS84)  
Vila Pouca de Aguiar - Portugal

**Cavity ID:** id292  
**Development:** 121m  
**Topographic team:** Carlos Mendes, Hugo Santos, João Moutinho, Luis Sousa, Vítor Gandra  
**Topography date:** 30 Ago 2015  
**Equipment:** Disto A3(x) Leica  
**Final drawings:** Vítor Gandra

Legend	Plan	Profile	Plan	Profile	
Coordinates and Altitude			Abyss		
Possible continuation			Mud		
Contour lines			Water		
Blocks/debris			Estimate measure		
Open abyss at the surface			Sinkhole		

Fig. 3.0.1-4: *Territorium metallorum* Tresminas / Jales, Lagoinhos: plan (top) and vertical section (bottom) of Lagoinhos showing the shafts (P) and prospecting structures (PR), Y — Y marks the section in figs. 3.0.1-6 and 3.0.1-7 (survey: V. Gandra / J. Moutinho, ARCM Valongo; design: V. Gandra / R. Wahl-Clerici).





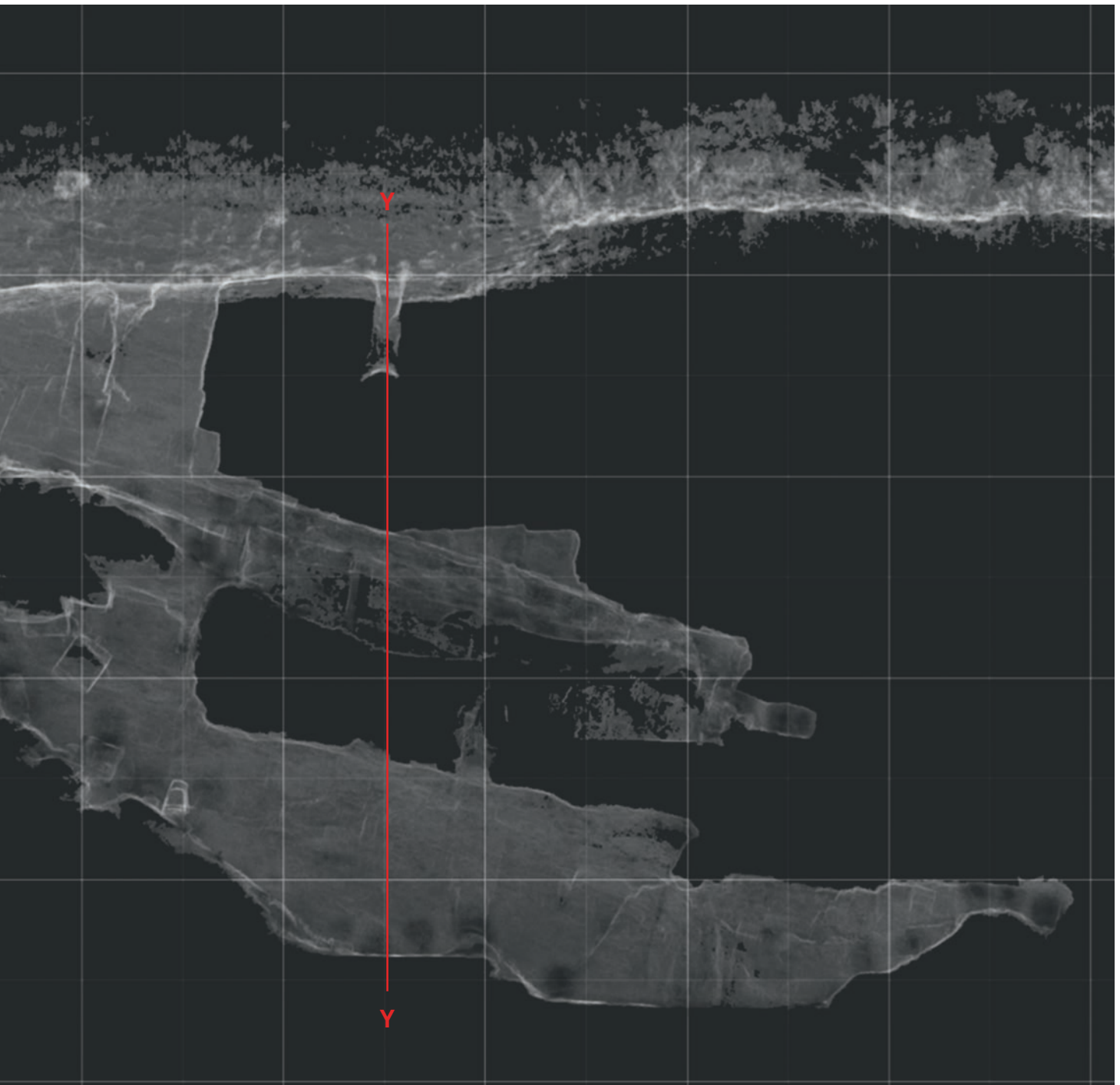
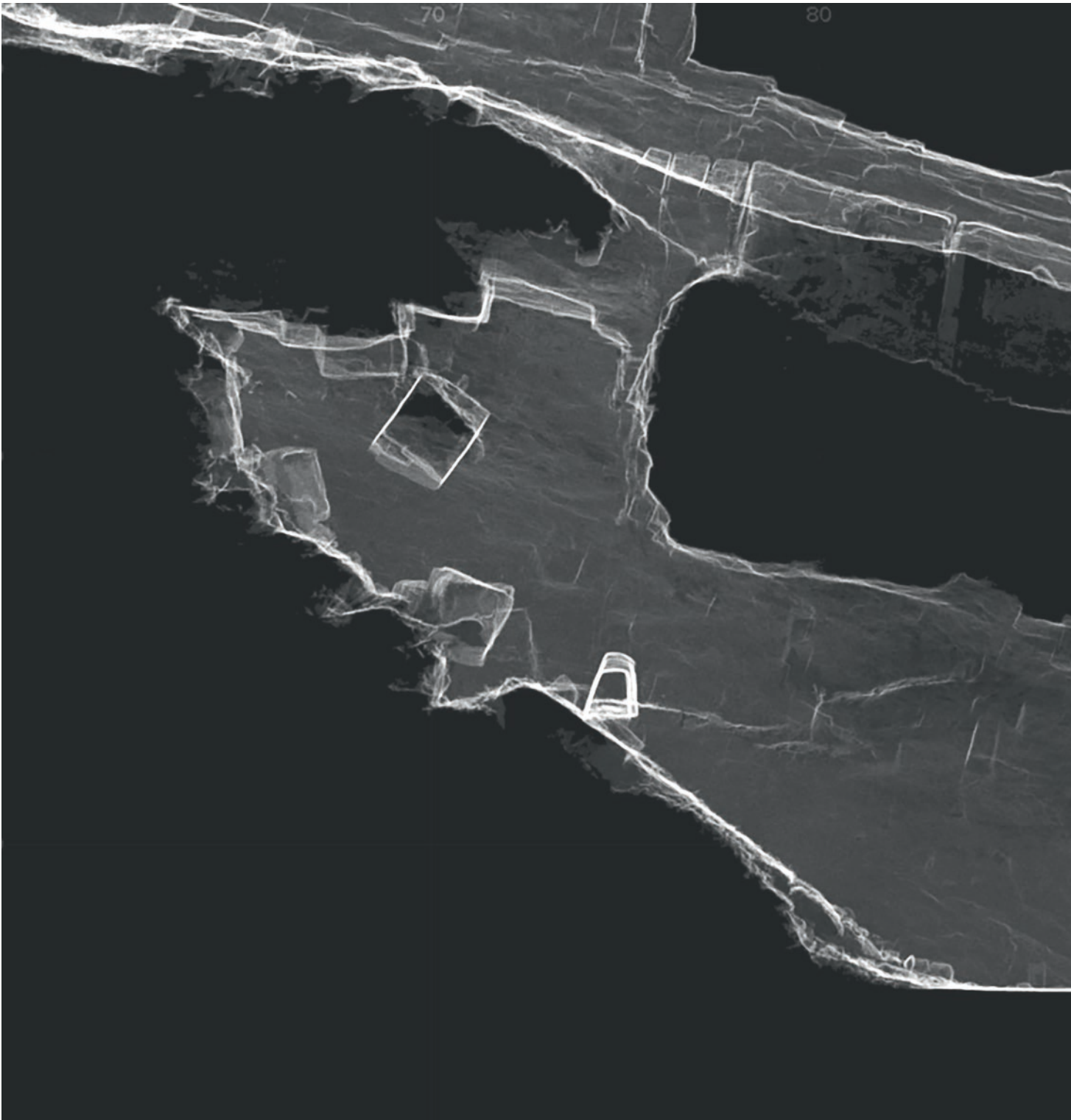


Fig. 3.0.1-5a: *Territorium metallorum* Tresminas/Jales, Lagoinhos: the part of the Roman mining work, Y — Y mark the section in Figs. 3.0.1-6 and 3.0.1-7 (scan and design: K. Mechelke, M. Lindstaedt).



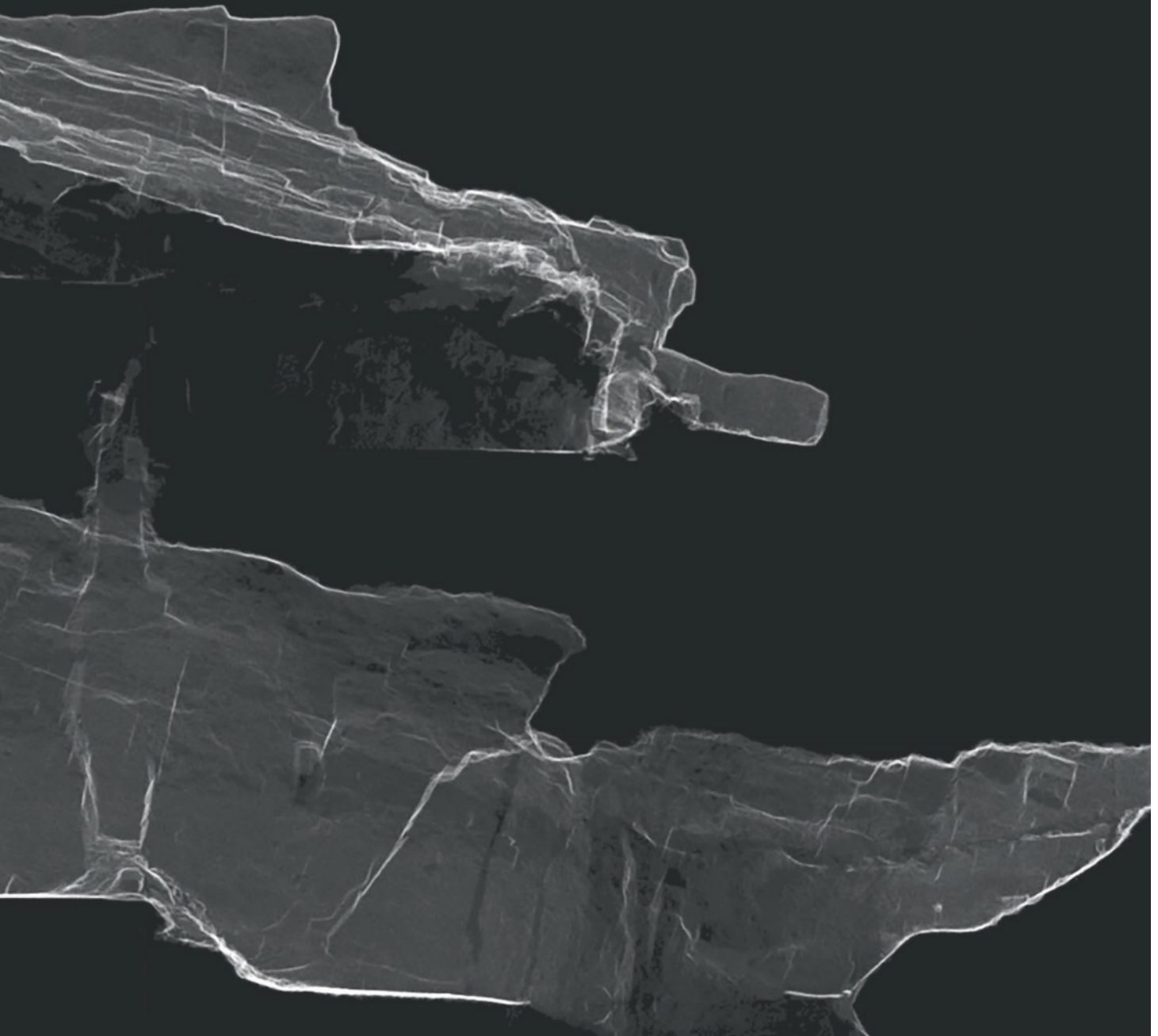


Fig. 3.0.1-5b: *Territorium metallorum* Tresminas / Jales, Lagoinhos: longitudinal section of the central part of the Roman mine (detail of fig. 3.0.1-5a). Well visible are the various prospectings and the structures of the schist (scan and design: K. Mechelke, M. Lindstaedt).

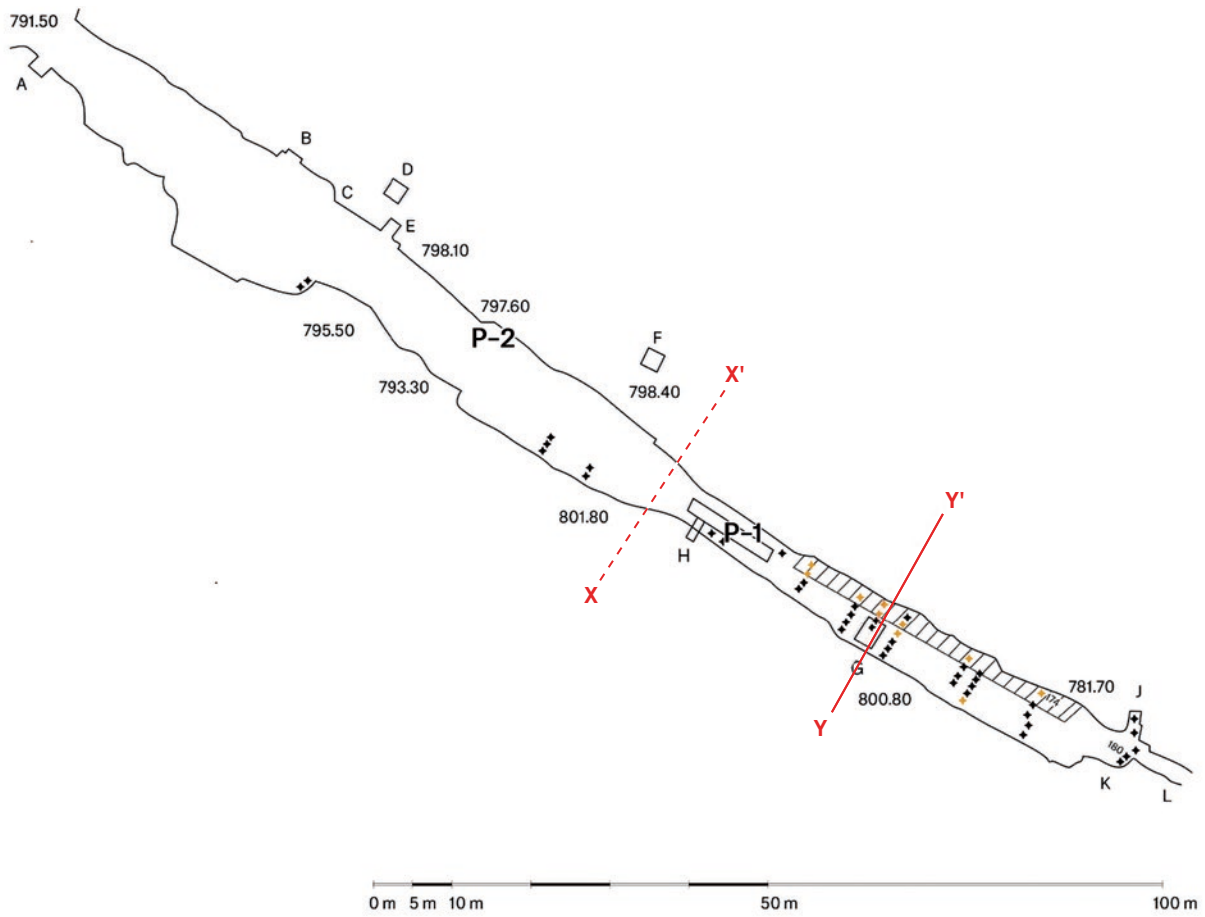


Fig. 3.0.1-6: *Territorium metallorum* Tresminas / Jales, Tresminas, Lagoinhos: plan of the Lagoinhos mining zone. Shaded: the Roman mining area. The remains of the Roman prospecting work and the shafts P-1 and P-2 (cf. Fig. 3.0.1-4) are registered. The sampling points are marked with asterisks, the gold-bearing ones are yellow. Samples 147 and 174 are highlighted due to their high gold content. X — X' marks the limit between the open and the underground part, Y — Y' marks the section in fig. 3.0.1-6 (template Serviço de Fomento Mineiro, execution R. Wahl-Clerici).

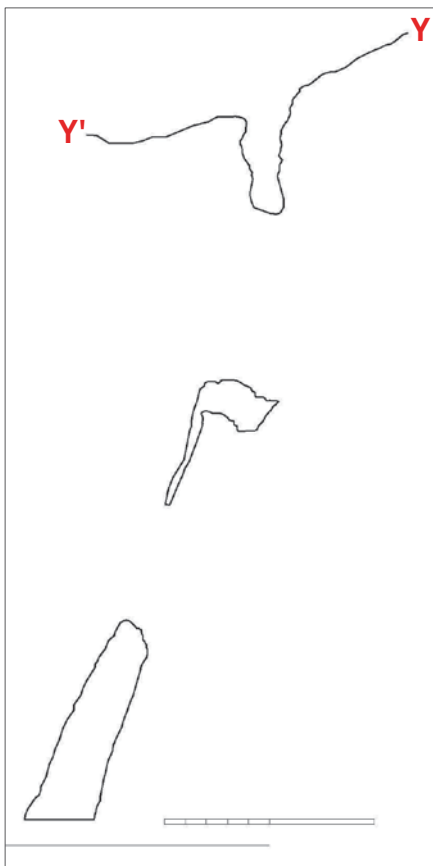


Fig. 3.0.1-7: *Territorium metallorum* Tresminas / Jales, section Y — Y' of Lagoinhos (scan and design: K. Mechelke and M. Lindstaedt).

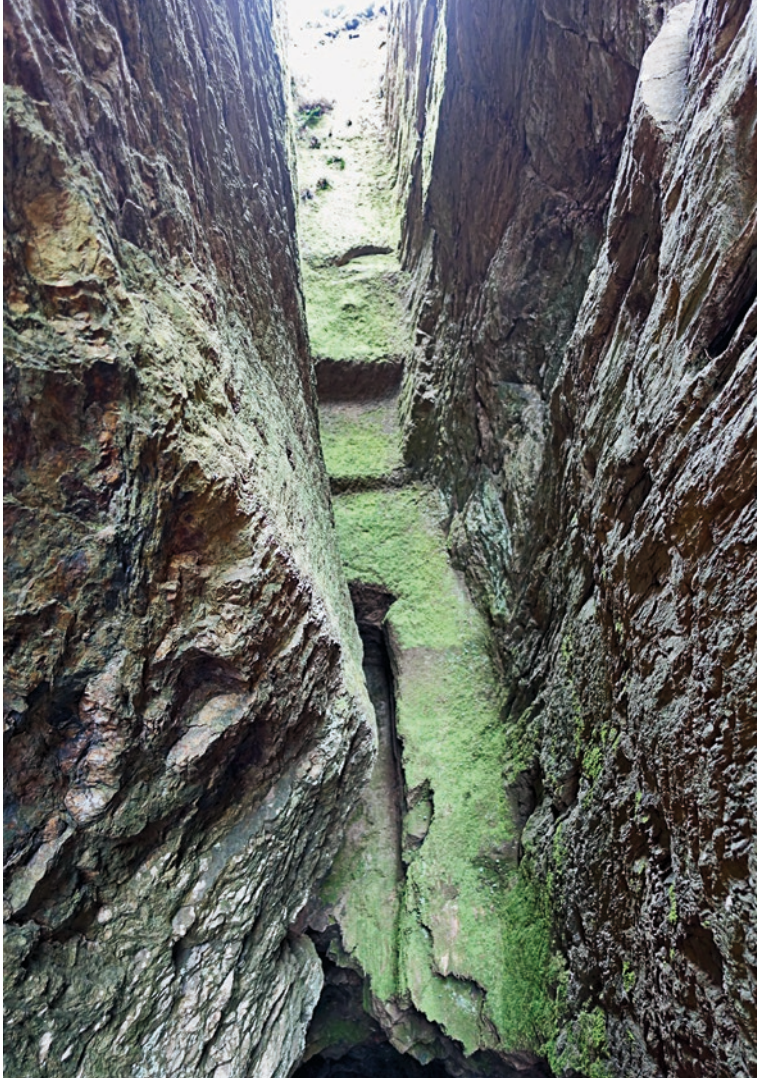


Fig. 3.0.1-8: *Territorium metallorum* Tresminas / Jales, Lagoinhos: transition between open-air and underground mining area. In this zone, there are a strikingly large number of cuts which were made for insertion of timber props to secure the pit. Seen from the west (photo: R. Wahl-Clerici).



Fig. 3.0.1-9: *Territorium metallorum* Tresminas / Jales, Lagoinhos: well-preserved extraction zone with tool marks and lamp niches in the north-north-eastern wall (photo: R. Wahl-Clerici).



*Fig. 3.0.1-10: **Territorium metallorum** Tresminas / Jales, Lagoinhos: view from the west into the underground mining zone. The persons are located between N-2 and N-3 in figs. 3.0.1-4, 3.0.1-5 (photo: J. Moutinho/ ACRM Valongo).*



Fig. 3.0.1-11: *Territorium metallorum* Tresminas/Jales, Lagoinhos: the sample in nr. 180 is sterile, below are the prospections PR-2 and PR-4. View towards the east-end of the mining area. (R. Wahl-Clerici).



Fig. 3.0.1-12: *Territorium metallorum* Tresminas/Jales, Lagoinhos: view from the south into the prospection stope PR-5 (photo: J. Moutinho/ACRM Valongo).



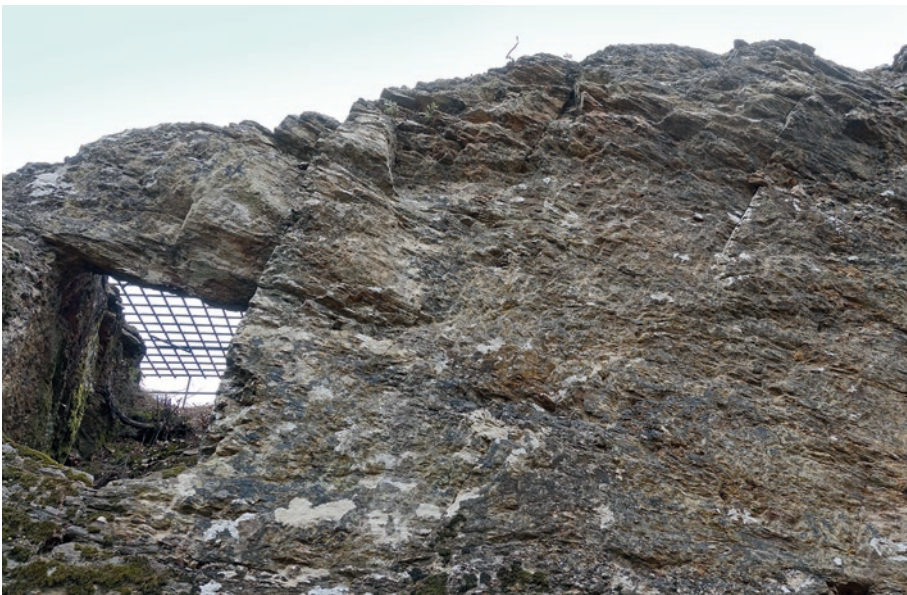


Fig. 3.0.1-13a/b: *Territorium metallorum* Tresminas/Jales, Lagoinhos: view into a former prospecting shaft (E) in the NNE slope, which was disturbed by later extractions. It is visible that the mining did not reach the slope surface (photo: R. Wahl-Clerici). Fig. 3.0.1-14: *Territorium metallorum* Tresminas/Jales, Lagoinhos: view of the



*prospection tunnels E,  
used to sample the rock in northern direction (photo: R. Wahl-Clerici).*



*Fig. 3.0.1-15: **Territorium metallorum** Tresminas / Jales,  
Lagoinhos: view from the west to level NS. The profile of an  
older extraction gallery (stope) is clearly visible  
(photo: J. Moutinho/ACRM Valongo).*



Fig. 3.0.1-16: *Territorium metallorum* Tresminas / Jales, Lagoinhos: view of the NNE wall in the area that is open to the air today. Tool traces are clearly visible, ending about 50—70 cm below the rock. In the foreground a rock that was probably left standing to improve stability (photo: R. Wahl-Clerici).



Fig. 3.0.1-17: *Territorium metallorum* Tresminas / Jales, Lagoinhos: view of the gradual end of extraction (left). On the right side of the picture the natural rock fall is visible (photo: R. Wahl-Clerici).



Fig. 3.0.1-18: *Territorium metallorum* Tresminas / Jales, Lagoinhos: end of the extraction zone with two parallel working points and with the lamp niches in the not disturbed sidewall (photo: R. Wahl-Clerici).



Fig. 3.0.1-19: *Territorium metallorum* Tresminas / Jales, Lagoinhos: view from the northwest onto the area of the waste rock dumps (photo: R. Wahl-Clerici).

## 3.1 Extraction techniques

... *hos igne et aceto rumpunt, saepius vero, quoniam id cuniculos vapore et fumo strangulat, caedunt fractariis clibras ferri habentibus egeruntque umeris noctibus ac diebus per tenebras proximis tradentes;*

... which are burst asunder by means of fire and vinegar, though more often, as this method makes the tunnels suffocating through heat and smoke, they are broken to pieces with crushing-machines carrying 150 lbs. of iron, and the men carry the stuff out on their shoulders, working night and day, each man passing them on to the next man in the dark, while only those at the end of the line see daylight.

This is how Pliny (Natural History 33,71) describes the two mining techniques used in primary deposits. As so often, he provides us with a few keywords which we would then like to bring into line with our findings. In this section of the text he speaks of iron hammers supposed to weigh 150 pounds, i.e. 48.75 kg. Even the description that the fragments were carried out exclusively by shoulder day and night can hardly apply to Tresminas, as the cart tracks preserved in the galleries demonstrate (figs. 3.3-2, 3.3-4, 3.3-11—3.3-13).

Along with the Galeria do Buraco Seco, most of the prospection tunnels (stopes) are too narrow for cart traffic, so that the material indeed had to be carried out (fig. 3.1-1). In the Jales mine, several parts of iron rings were collected. Attached to these were leather bags, in which rock and water could be lifted to the surface (figs. 3.1-2, 3.1-3).<sup>123</sup> Baskets made exclusively of organic material have also rarely survived. Baskets of Esparto grass have been found in the mines around Cartagená (E).<sup>124</sup>

### Hammer and pick

The traces of Roman mining preserved in the *territorium metallorum* Tresminas/Jales are typical for the work with hammer and pick, still the symbols of mining. A large number of these tool marks help us to document the miners' approach (figs. 3.0.1-13b, 3.0.1-16, 3.1-4, 3.1-5), but also to understand the variety of possibilities for facilitating the work, such as the use of natural rock fissures (fig. 3.1-6). However, this type of tool is rarely found in the preserved extraction zones or the large galleries. Here, careful planning seems to have been the first step, with the necessary work carried out strictly to plan. An extraordinarily high level of surveying work may be connected to this, as even minor mistakes in execution had major consequences.

Of the tools, hammers, chisels and a pickaxe have survived (figs. 3.1-7a/b/c/d, 3.1-8). They were made from the

iron extracted in the *territorium metallorum* as a by-product of gold mining following metallurgical surveys.<sup>125</sup> Illustrations of these tools can be found on the relief of the miners from the mine „Los Palazuelos“ (Carboneros, Prov. Jaén / E) (fig. 3.1-9).

### Fire-setting

The technique of fire-setting, already found in the Neolithic period, made the work much easier, because setting fire is the method of detonation used until explosives were available for mining.<sup>126</sup> So far, fire-setting could only be detected in the mining zone of Tresmina and only above ground (figs. 3.1-10, 3.1-11). Underground traces of this mining technique were already used in the 3rd millennium B.C., as the example of Kestel (TR) proves. They are also known from the Roman mines in the Serra de Santa Justa (Valongo, Porto / E). The calotte-shaped cavities are formed by knocking off the crumbly rock, which requires only little force.

Testimonies from the 18th and 19th centuries give detailed descriptions of fire-setting. Friedrich Wilhelm Heinrich von Trebra, in 1785 'vice-master of the mountain' for Saxony and Zellerfeld, justifies the use of the technology as follows:

„The setting on fire ... in the Rammelsberge ... is the only help to conquer the otherwise almost insurmountable rock. Powder and steel are of little use.

123 Alarcão 1997, 106—112; Agricola et al. 1950, 158; The iron rings were collected in the Campo de Jales vein during modern extraction by the Minas de Jales Ltda. and kept in the small museum there. Today they are exhibited in the Museu Municipal Padre José Rafael Rodrigues, Vila Pouca de Aguiar.

124 Alarcão 1997, 110, 9, from Aljustrel (Distr. Beja, P); Gossé 1942, 53 and Lam. IV,3, from Mazarrón; Domergue 1990, Pl. 17a, from Mazarrón; Pl. 20a, from Pedreras Viejas (both Prov. Murcia / E).

125 Martins 2017, 104—105.

126 Further sources: Diodorus Siculus 12,4; Vitruvius 8,3,19: „So also pearls; and flints, which neither iron nor fire can dissolve of itself, when they are heated in the fire and sprinkled with acid, fly asunder and are dissolved.“; further sources also in context with Hanibals crossing of the Alps: Py et al. 2012, 133—136; A. Gundelwein, Bergbautechnik, in Roseneck 2001, fig. 155 below (Neolithic fire-setting in Wales) and 156 with further literature to more examples from the Neolithic and Bronze age; B. Heublein, Goethe und der Montan-tourismus am Rammelsberg, in Roseneck 2001, 206—214; A. Gundelwein, Feuer und Wasser, in Roseneck 2001, 160—171; Craddock 1995, 54 fig. 2.221 from the bronze-age mine Mt. Gabriel (IRL); Craddock 1995, 33—37 figs. 2.6—2.7.

There are tough parts in the slate, in which 6000 drill bits are required to cut a single Lachter [a measurement of length of about 2 m]. [...] It is precisely this toughness that has prevented and made difficult all the far-reaching attempts at blasting in this mountain.”<sup>127</sup>

In the 18th and early 19th centuries, it was part of an educational journey to observe the fire-setting in the copper mines of the Rammelsberg in the Harz Mountains (D). Famous philosophers and poets like Gottfried Wilhelm Leibniz (1646—1716), Charles de Montesquieu (1689—1755), Johann Wolfgang von Goethe (1749—1832), Heinrich von Kleist (1777—1811) as well as Hans Christian Andersen (1805—1875) left impressions of their visit.<sup>128</sup>

In Goslar we drove to the Rammelsberg, where the ores are burnt down in large caves with fire lit with wooden piles, and everybody works naked from the heat. One believes oneself to be in hell or at least in the workshop of the Cyclopes.

Heinrich von Kleist, 1801.<sup>129</sup>

Another possible auxiliary technique cited in the literature on ancient mining is the *ruina montium* method described by Pliny.<sup>130</sup> It should be noted that so far there is no evidence for this method being used in Tresminas.<sup>131</sup>

The assumption that ancient mining at Tresminas was aided by the use of hydropower must also be rejected. No traces that would prove this to be the case have been discovered, and the natural crystalline slate is not suitable for this purpose. If no tool marks can be identified at many extraction sites, this is due to the weathering of the rock surface.

The idea that the channel in the Galeria do Pilar served to flush out the rock and ore must also be rejected.<sup>132</sup> This would have required an enormous water pressure, which was never created with the help of the known water supply system. In addition, no water basins could be observed in the extraction zone.<sup>133</sup>

127 B. Heublein 2001, 209—210; Rammelsberg bei Goslar in Niedersachsen (D).

128 B. Heublein 2001, 210.

129 Quoted after K. Liebmann, Heinrich von Kleist und der Harz. Zum 150. Geburtstag des Dichters. In: Der Harz 10, 1927, 175—176.

130 Pliny, Natural History 33,66, 33. 72—73.

131 Domergue 1990, 479 suggests that this technique may also have been used in Tresminas, although only further research will really bring clarity.

132 Domergue 1990, 480.

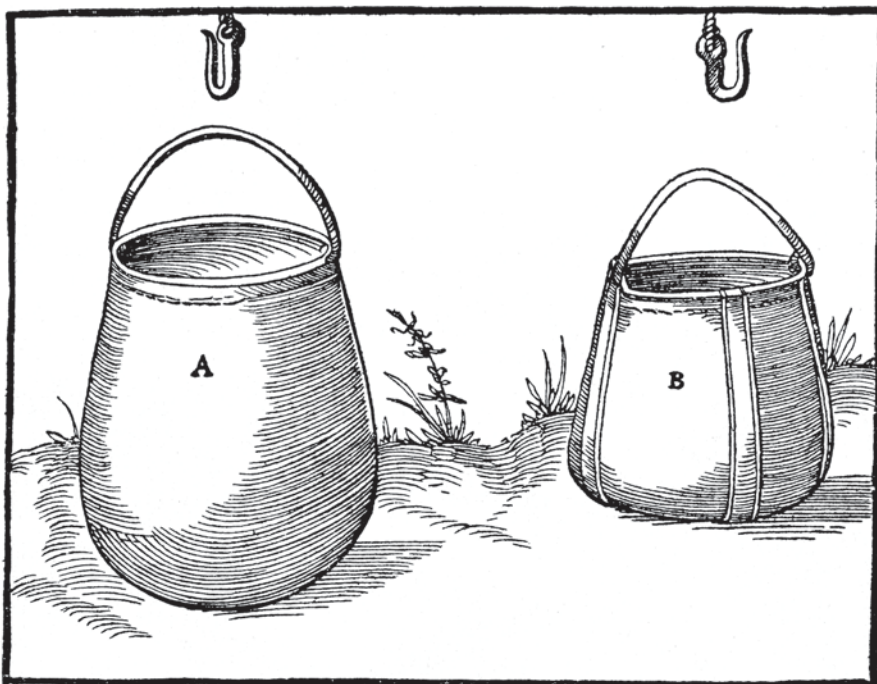
133 Wrongly asserted by for instance Sánchez Palencia 2015.



Fig. 3.1-1: *Territorium metallorum* Tresminas/Jales, Tresminas; Corta da Ribeirinha; Galeria do Buraco Seco. Adit opening in the Corta (photo: R. Wahl-Clerici).



Fig. 3.1-2: Iron-ring of a leather bucket from Jales, now in the Museu Municipal Padre José Rafael Rodrigues Vila Pouca de Aguiar (photo: J. Wahl).



*Die Ringebulge A. Die Streichbulge B.*

3.1-3: Leather buckets with iron-rings (after Agricola 1556/1984, 129).





Fig. 3.1-4: *Territorium metallorum* Tresminas/Jales. Tresminas, Lagoinhos: tool marks in the underground extraction zone with niches for lamps right under the roof. This makes it impossible for this face to have been worked from the floor to the roof (photo: R. Wahl-Clerici).



Fig. 3.1-5: *Territorium metallorum* Tresminas/Jales, Gralheira: distinctive tool marks (photo: R. Wahl-Clerici).



*Fig. 3.1-6: Territorium metallorum Tresminas / Jales, Tresminas, Corta de Covas: stairwell for prospection. For the eastern wall, a natural fissure was used (photo: R. Wahl-Clerici).*



Fig. 3.1-7a: **Territorium metallorum** Tresminas / Jales, Jales: worn-out pick, length 17,6 cm, width max. 7,35 cm, height max. 5,45 cm, 2588 g, now in the Museu Municipal Padre José Rafael Rodrigues Vila Pouca de Aguiar (photo: J. Wahl).



Fig. 3.1-7b: **Territorium metallorum** Tresminas / Jales, Jales, pick, length 28 cm, width max. 8,4 cm, height max. 6,0 cm, 5045 g, now in the Museu Municipal Padre José Rafael Rodrigues Vila Pouca de Aguiar (photo: J. Wahl).

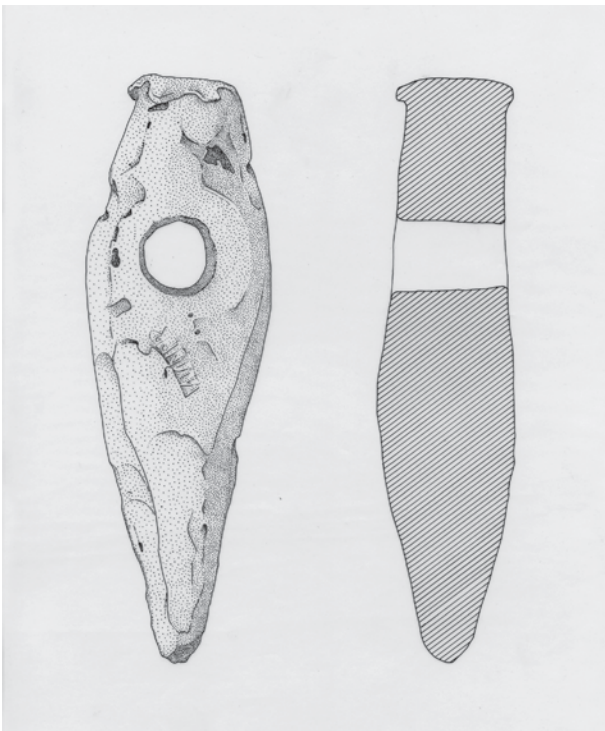


Fig. 3.1-7c: **Territorium metallorum** Tresminas / Jales, Jales, worn-out pick, reading of the mark (manufacturer or owner?): [...]MIANI...?, length 20,3 cm, width max. 6,6 cm, height max. 4,7 cm, 1912 g, now in the Instituto Geológico Mineiro, Col. Serv. Geol. Lisboa (drawing: R. Heer).

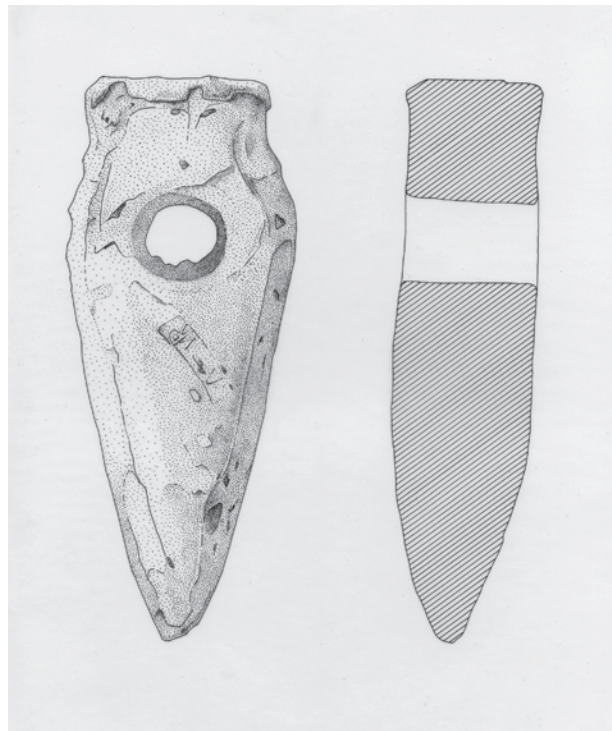


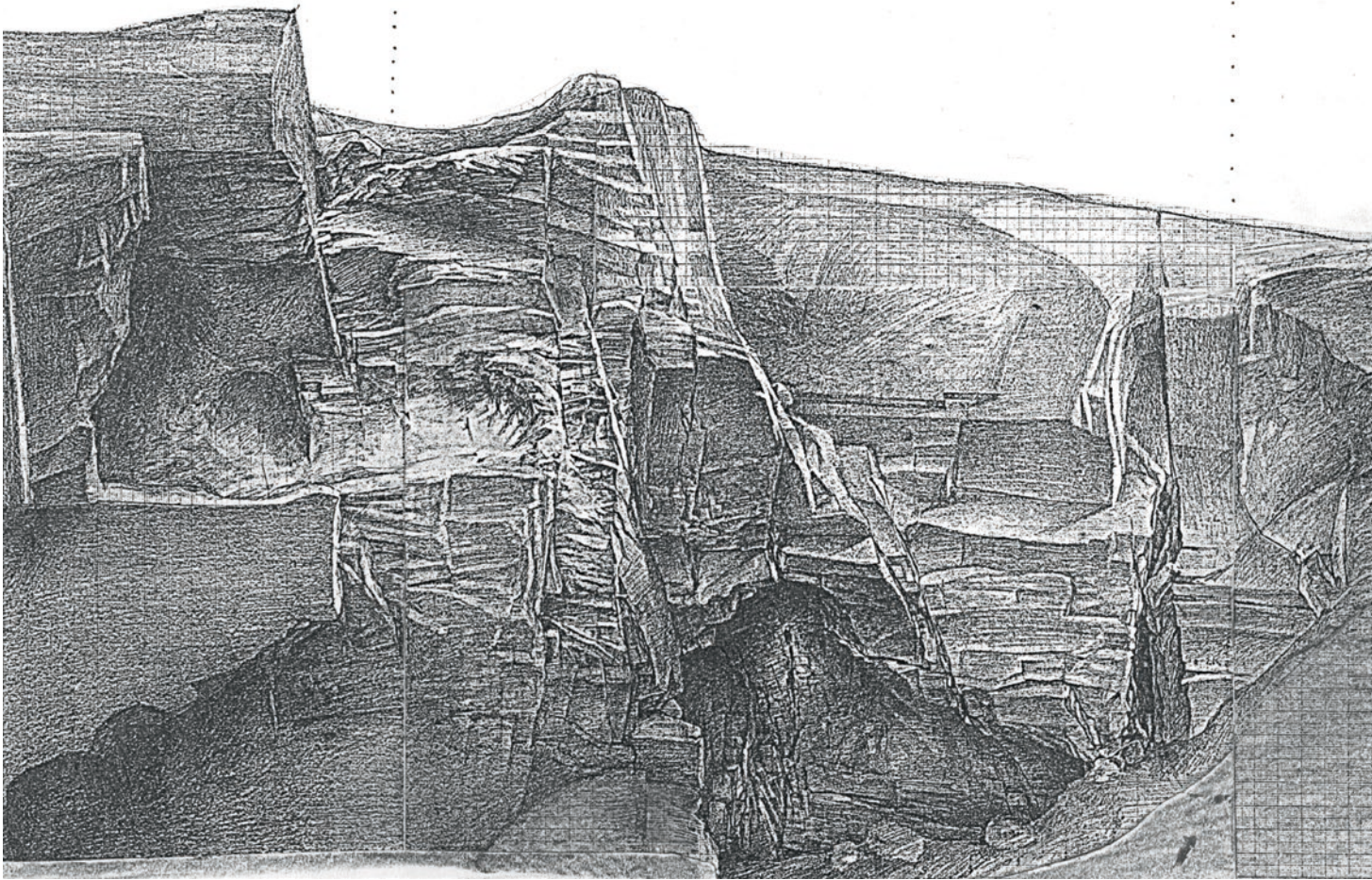
Fig. 3.1-7d: **Territorium metallorum** Tresminas / Jales, Jales: worn-out pick, marks on both sides, not readable, length 19,3 cm, width max. 5,2 cm, height 5,2 cm, 2884 g, now in the Instituto Geológico Mineiro, Col. Serv. Geol. Lisboa (drawing: R. Heer).



*Fig. 3.1-8: Territorium metallorum Tresminas / Jales, Jales: well used pickaxe, length 51,7 cm, width max. 7,25 cm, height max. 6,0 cm, 3914 g, now in the Museu Municipal Padre José Rafael Rodrigues Vila Pouca de Aguiar (photo: J. Wahl).*



*Fig. 3.1-9: Los Palazuelos (Province Jaén / E): miners (Bergbaumuseum Bochum / D).*



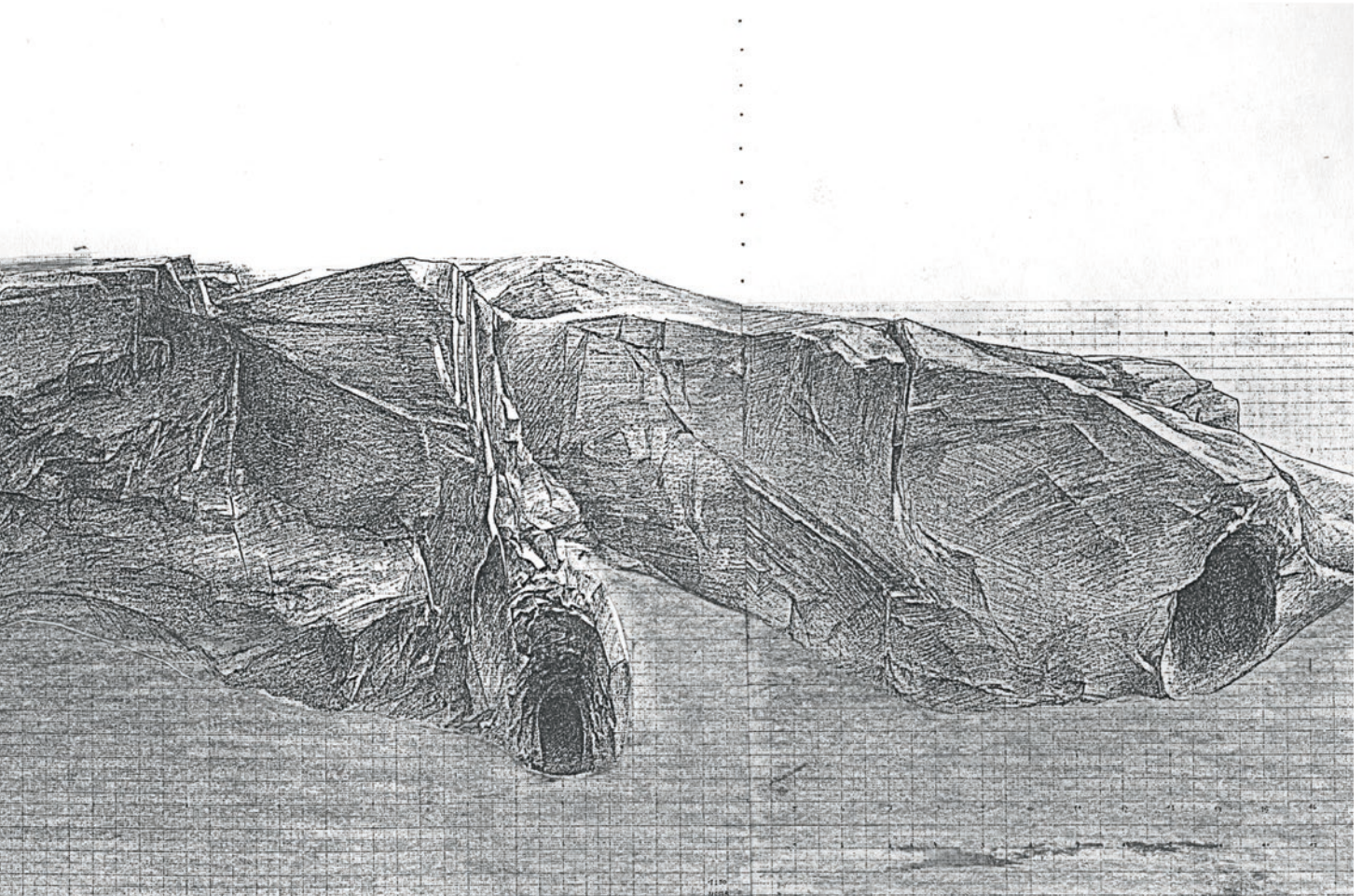


Fig. 3.1-10: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: rock face with remains of fire-setting (drawing: P. Moser).



Fig. 3.1-11: *Territorium metallorum* Tresminas / Jales. Tresminas, Corta de Covas: remains of fire-setting with the typical dome shaped traces in the rock (photo: J. Wahl).

## 3.2 Mining progress in the Corta de Covas<sup>134</sup>

The exceptional state of preservation of the mining monuments in the Corta de Covas enables us for the first time to trace the progress of the exploitation of a deposit in a large opencast mine step by step, from opening to abandonment. The fundamental prerequisite for this is the recording of the relationships between the various monuments. This is the only manner in which it is possible to describe the individual advances in more detail.

In order to document these dynamic events, we have decided to break down the processes in the presentation into “actions” and “functional units”. The term “actions”

(A) refers to the actual work carried out by the Romans, while the term “functional units” [FU] refers to those elements that were jointly in function at a certain stage.

It should be noted that it is not always possible to establish a clear sequence of different actions, as is e.g. the case for actions (A03) and (A04).

The various galleries for extraction and drainage were excavated at the smallest zone of the hill and therefore approximately on one level.

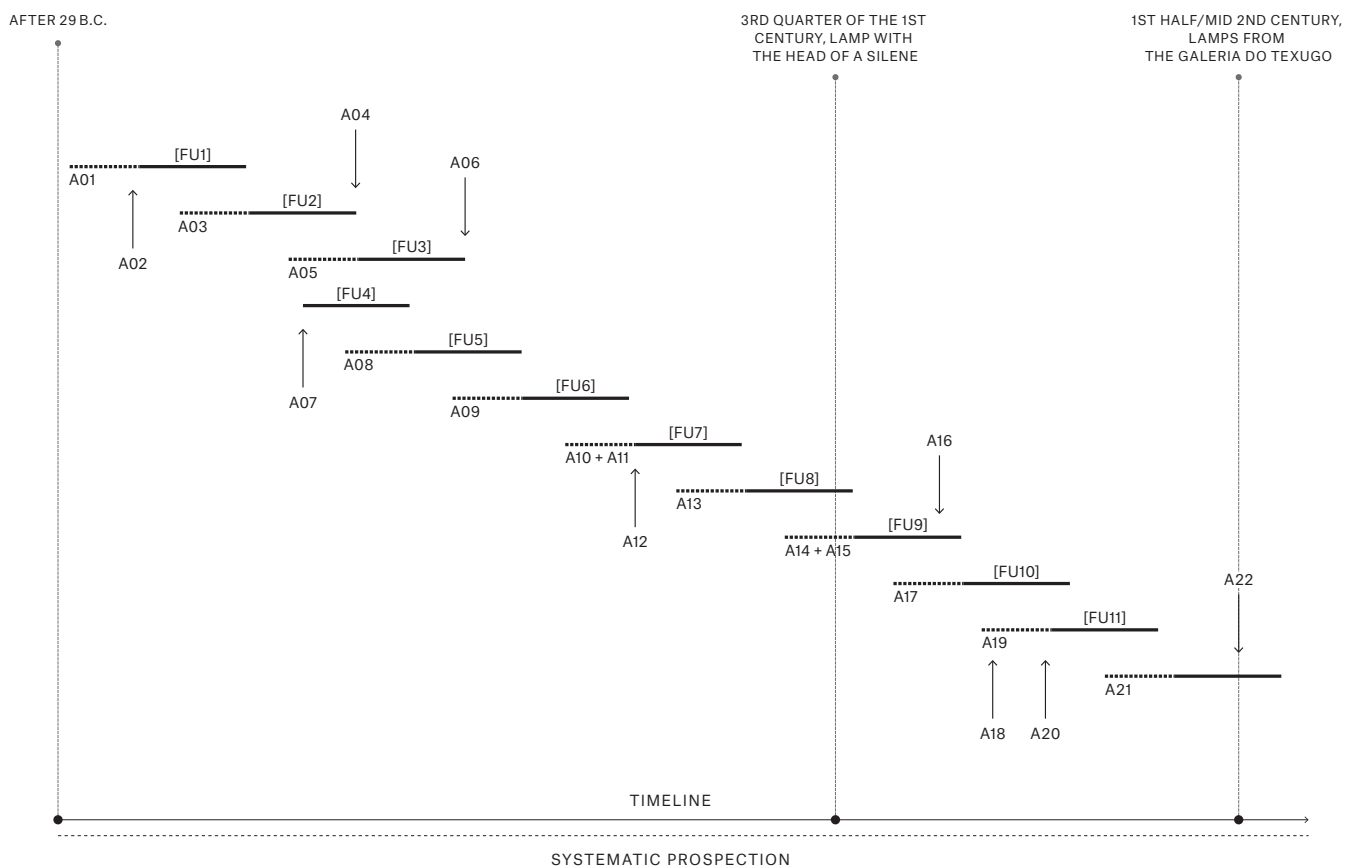


Fig. 3.2-1: Table with the different steps of the mining progress in the Corta de Covas, FU = Functional Unit, A = Action (template R. Wahl-Clerici, design: S. Mathiuet).

<sup>134</sup> Wahl-Clerici 2010; Wahl-Clerici 2013; Wahl-Clerici/Helfert 2017, 65–69.

## Remarks

In the table shown, the problem is that the phases of the actions and the functional units are always of the same length, which hardly corresponds to reality. However, since we are not yet able to determine the duration of the individual phases even approximately, we consider it sensible to stick to this schematic representation.

Not only can the various actions taken during the mining be put into a chronological sequence in the Corta de Covas, but they can also be roughly dated. The few chronological indicators that help us to do this are inserted into the scheme. Distinctive key points are the final conquest of the area of Tresminas in 29 B. C., as well as the lamp fragments recovered in the Galeria do Texugo, which can be dated to the first half / the mid-2nd century. A volute lamp decorated with the head of a *silene* on the discus was found in a *cuniculus* rendered obsolete by the collapse of the channel and provides a chronological reference point for the construction of the channel. For as long as the *cuniculi* were in use, they were also cleaned, and the lamp would most likely have been removed in the process. The extraction must have already attained a substantial size by the end of the 1st century, as proven by the areas excavated up to that time.<sup>135</sup> It seems that the deposit in open pit A must already have been emptied around the mid-2nd century and had to be abandoned.

Since the mining of a deposit always has to be adapted to the conditions, it can hardly be assumed that the entire system of structures was already fully planned when the first galleries were built.

However, the sequence of the various galleries and shafts and their interaction can only be described as elaborate and extremely well thought out. This is also indicated by the optimisation of the processing by throwing the freshly extracted material down through the more than 40 and 30m deep shafts. In this way, the amount of work involved in the stamp-mills could be reduced significantly (see Processing).

135 Wahl 1988, 240.



### 3.2 Mining progress in the Corta de Covas (open pit A)

#### Actions

- (A01) General and particular prospection of the site.
- (A02) Opening of the southern area in the Corta de Covas (southern mining zone).
- (A03) Construction of the Galeria Esteves Pinto (construction time approx. 5 ½ years).
- (A04) Opening of various prospection structures, including the shaft for the stairs in the north flank of the southern extraction zone (see 2.0 Prospection).

#### Functional units (figs. 3.2-2a/b)

- [FU 1] Extraction in the southern area of opencast mine A. The waste rock dumps accumulated south of the Corta de Covas are partially preserved (fig. 3.2-3).
- [FU 2] Continuation of the extraction in the southern area, and possible start of extraction in the northern area of the Corta de Covas (figs. 3.0-6, 3.0-7). After the opening of the Galeria Esteves Pinto, the extraction and drainage were carried out through this route. (figs. 3.2-4—3.2-6).

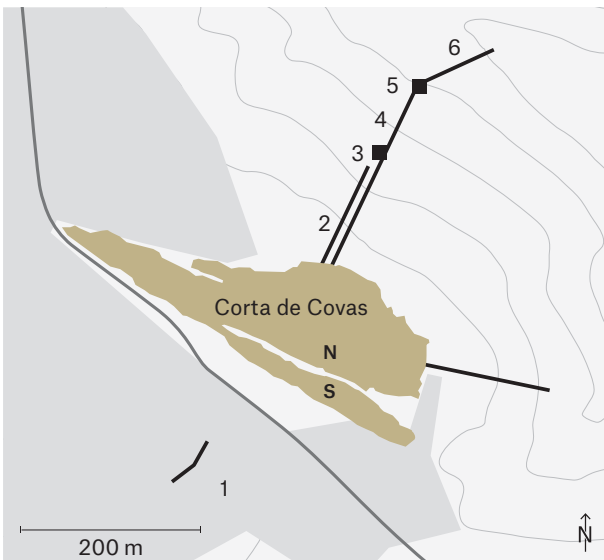


Fig. 3.2-2a: *Territorium metallorum Tresminas / Jales*. A — Corta de Covas (S = southern zone, N = northern zone) 1 — Galeria Esteves Pinto, 2 — Galeria Jürgen Wahl, 3 — shaft in front of Galeria Jürgen Wahl's adit to the Galeria do Pilar, 4 — Galeria do Pilar, 5 — shaft in front of Galeria do Pilar's adit to Galeria do Texugo, 6 — Galeria do Texugo, 7 — Galeria dos Alargamentos (template Ortofotomapa Câmara Municipal Vila Pouca de Aguiar 1: 10 000, design: J. Wahl, R. Wahl-Clerici, M. Helfert, drawing: S. Mathiuet)

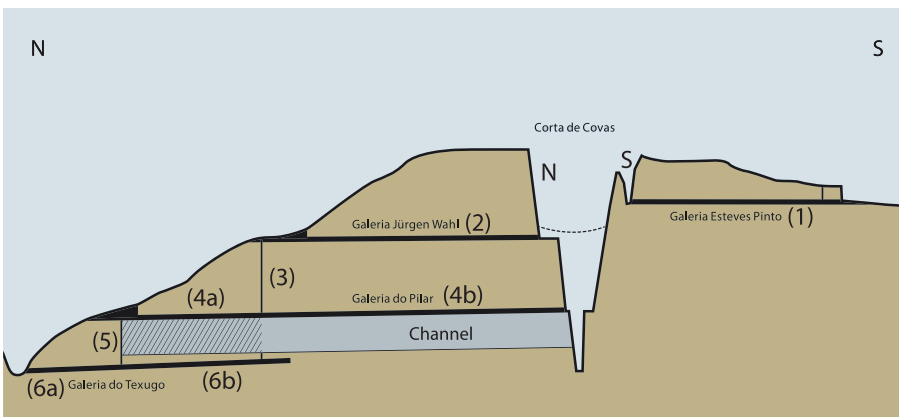


Fig. 3.2-2b: *Territorium metallorum Tresminas / Jales*. Cross-section of the Corta de Covas, complete (template J. Wahl, R. Wahl-Clerici, design: S. Mathiuet).

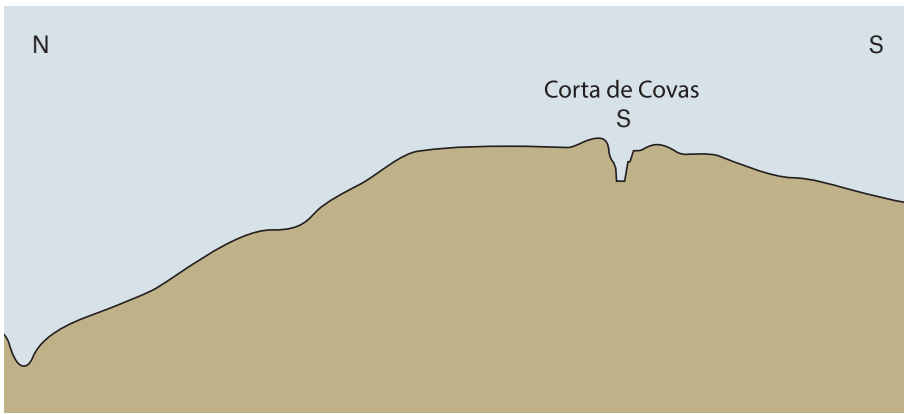


Fig. 3.2-3: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, cross-section: start of the extraction in the southern zone [FU1].

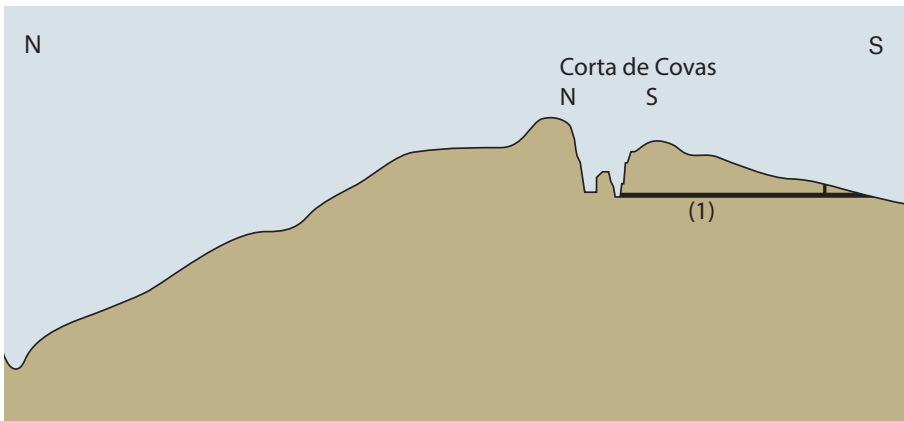


Fig. 3.2-5: *Territorium metallorum* Tresminas / Jales, Tresminas [FU2/3].



Fig. 3.2-4: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, cross-section: continuation of the extraction in the southern zone. Beginning of the extraction in the northern zone after mineable gold grades had been identified by the prospection in the shaft of the stairs (figs. 3.0-7, 3.1-8) [FU2].



Fig. 3.2-6: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: opening of the Galeria Esteves Pinto, entrance from the south [FU2/3] (photo: R. Wahl-Clerici).

(A05) Driving of the channel into the bed of the Galeria Esteves Pinto.

[FU 3] Thanks to the channel, extraction in the southern zone could be further lowered. The cuts in the rock for the covering of the channel prove that the Galeria Esteves Pinto was still in use for extraction (figs. 3.2-7, 3.2-8).

(A06) Abandonment of mining in the southern area of the opencast mine and the Galeria Esteves Pinto.

(A07) Opening of mining in the northern part of Corta de Covas took place at this point at the latest.

[FU 4] In the first phase, the extraction and drainage of the northern mining zone was done either with the help of surface installations or through discharge into the southern mining zone and thus through the Galeria Esteves Pinto. An indication for the latter is the conspicuous disruption in the ridge separating the two zones (fig. 3.2-9).

(A08) Construction of the Galeria Jürgen Wahl (construction time approx. 6 years).

[FU 5] Opening of the Galeria Jürgen Wahl for the extraction and drainage of the mining zone after reaching a depth of at least 40 m. The dump was piled up in front of the entrance of the Galeria. (fig. 3.2-10b).

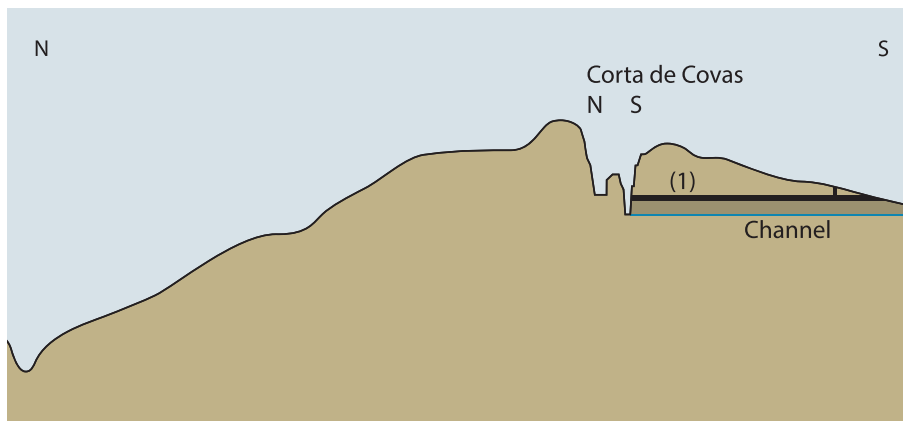


Fig. 3.2-7: *Territorium metallorum Tresminas / Jales, Tresminas*, cross section with the channel in the Galeria Esteves Pinto [FU4].



Fig. 3.2-8: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, Galeria Esteves Pinto: the cart tracks and channel and the cuts for the covering of the channel are visible in the floor [FU3/4] (photo: J. Wahl).



Fig. 3.2-9: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: view from the north of the ridge between the two mining zones with the conspicuous disruption in between [FU4] (photo: R. Wahl-Clerici).

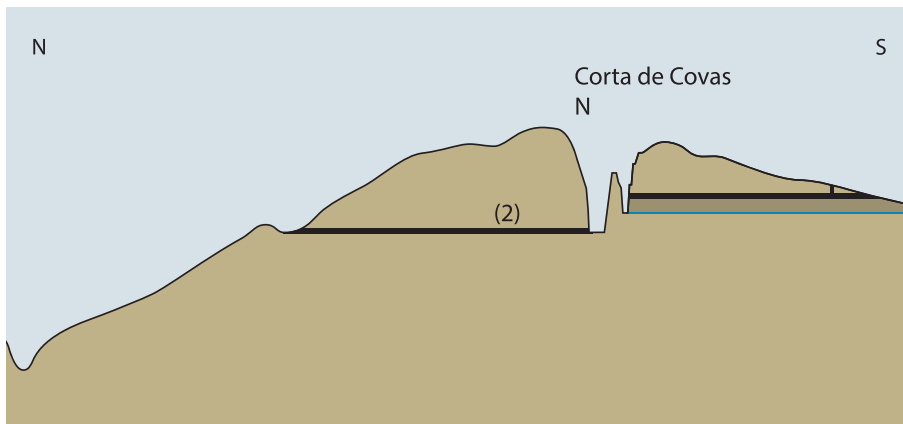


Fig. 3.2-10a: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: functional units [FU4] and [FU5].



Fig. 3.2-10b: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: view from the north into the former entrance area of the Galeria Jürgen Wahl, completely covered with waste rock material [FU5] (photo: R. Wahl-Clerici).

(A09) Soon afterwards, the sinking of the shaft and the lowering of the section between the port of the Galeria do Pilar and the shaft began (construction time approx. 3 ½ years). During the sinking of the shaft, the prospecting tunnel in the roof of the Galeria do Pilar was constructed (see 3.3.1).<sup>136</sup>

(A10) Excavating of the Galeria do Pilar up to the opencast mine A.

(A11) Construction of the pillar in the Galeria do Pilar to protect it from falling material from the waste rock dump, which also necessitated the extension of the gallery in the eastern side wall to enable cart traffic to pass the pillar.

(A12) Abandoning of the Galeria Jürgen Wahl.

(A13) Sinking the shaft in front of the entrance area of the Galeria do Pilar and excavating the Galeria do Texugo up to the shaft (construction time approx. 2 ½ years).

[FU 6] Continuation of the extraction operations in the northern Corta de Covas area. The extracted material is brought to the surface of the slope through the Galeria Jürgen Wahl and from there it is poured through the shaft to the level of the Galeria do Pilar in the form of the so-called “throwing extraction”. Finally, the material is transported from there to the surface by carts. The processing starts the accumulation of the waste rock dump in front of the Galeria do Pilar (figs. 3.2-11a/b/c).

[FU 7] Extraction through the Galeria do Pilar from the opencast mine to the entrance. Construction of the pillar. In the early phase, drainage took place through a small channel cut into the eastern heading face (figs. 3.2-12a/b).

[FU 8] Transport of the material to the surface through the Galeria do Pilar, the shaft in the entrance area (by “throwing extraction”) and the Galeria do Texugo. The process was the same as that which took place at the higher level in the Galeria Jürgen Wahl, the shaft and the Galeria do Pilar (figs. 3.2-13a/b).<sup>137</sup>

<sup>136</sup> It is noteworthy that the shaft had to be sunk through the waste rock dump of the Galeria Jürgen Wahl, which was a severe handicap during construction. Due to the topography, however, a different position for the Galeria do Pilar and the shaft was not desirable.

<sup>137</sup> Helfert et al. 2019.

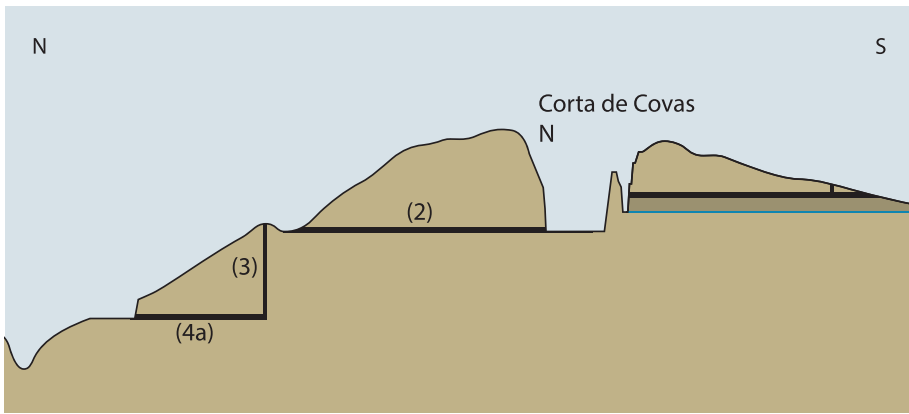


Fig. 3.2-11a: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: functional unit [FU6]



Fig. 3.2-11b: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: entrance to the shaft in front of the Galeria Jürgen Wahl [FU6] (photo: R. Wahl-Clerici).



Fig. 3.2-11c: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: entrance area of the Galeria do Pilar. At this stage of the utilisation of the Galeria, the small channels on both sides between the floor and the heading face were sufficient for drainage [FU6] (photo: J. Wahl).

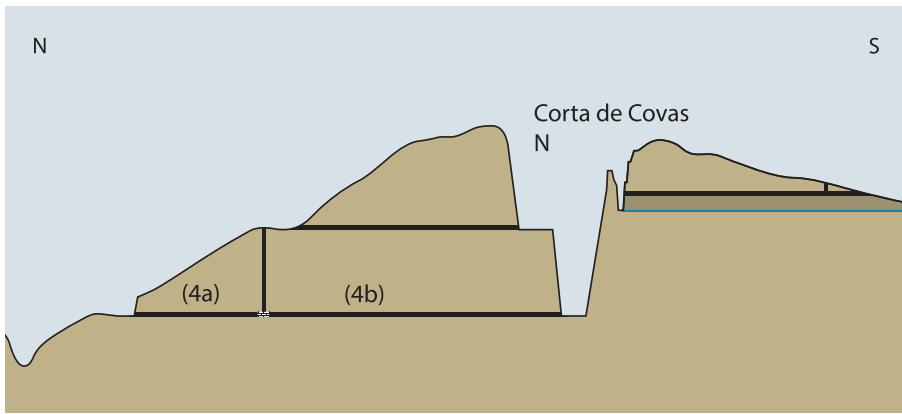


Fig. 3.2-12a: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: functional unit [FU7].

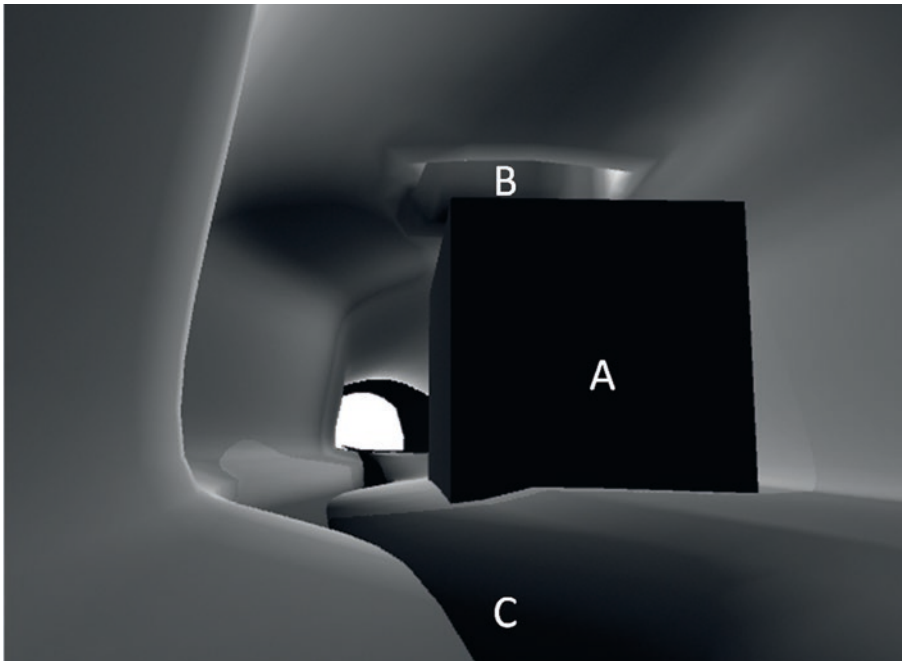


Fig. 3.2-12b: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, from the north towards the opencast mine: the construction of the pillar below the shaft between the Galeria Jürgen Wahl and the Galeria do Pilar necessitated an extension of the passage area in the eastern side wall [FU7] (template J. Wahl, R. Wahl-Clerici, design: C. Wahl).

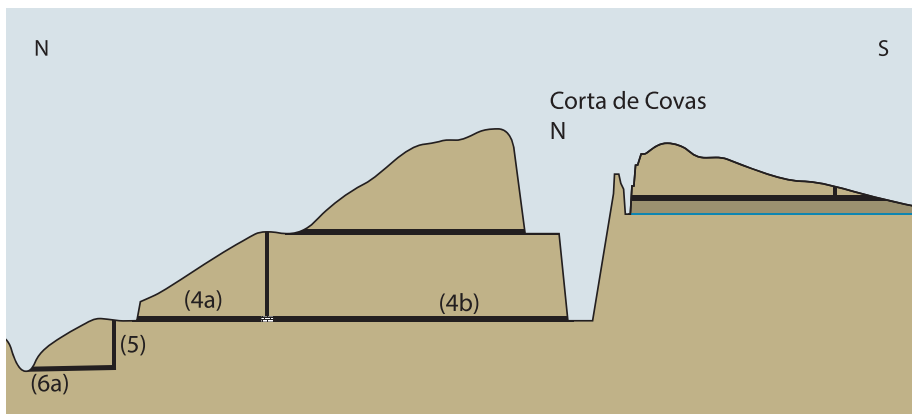


Fig. 3.2-13a: *Territorium metallorum* Tresminas/Jales, Tresminas, Corta de Covas: functional unit [FUS].



Fig. 3.2-13b: *Territorium metallorum* Tresminas/Jales, Tresminas, Corta de Covas, Galeria do Texugo (photo: J. Wahl).



(A14) Opening and gradual lowering of the channel in the Galeria do Pilar.

(A15) Abandoning of the *cuniculi* along the heading faces of the Galeria do Pilar.

(A16a) Installation of the lifting devices in the Galeria do Pilar, in the area of the transition to open-cast mine.<sup>138</sup>

(A16b) Preparation for the installation of a first, never completed lift powered by a capstan.

(A16c) Construction of a second capstan, which was positioned a little closer to the entrance and which was used.

(A17) Excavating the Galeria do Texugo into the area of the pillar of the Galeria do Pilar.

[FU 9] Driving a channel into the Galeria do Pilar after the opencast mine had reached a depth that was below the floor of the Galeria do Pilar. The depth of the channel was adjusted in steps to the level of extraction (fig. 3.2-14).

[FU 10] Lifting of the material by means of a winch to the level of the Galeria do Pilar. From there, it was brought to the entrance area and thrown down into the Galeria do Texugo (see FU 8), (figs. 3.2-15a/b/c, 3.2-16, 3.2-17a/b, 3.2-18, 3.2/19).

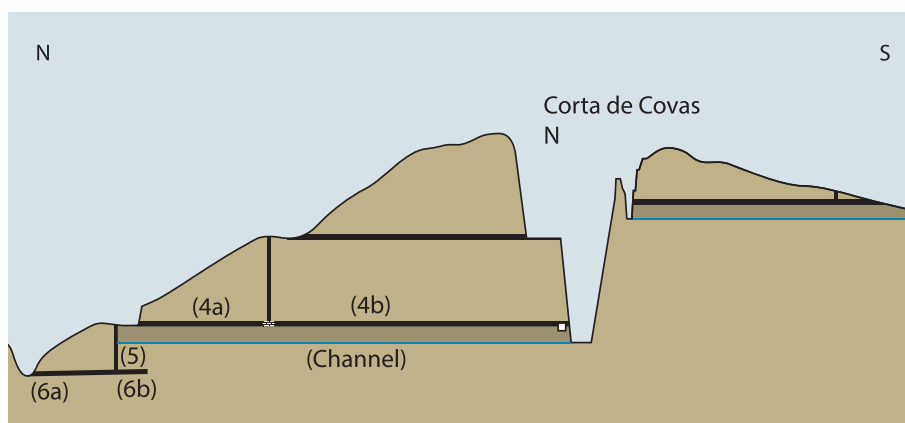


Fig. 3.2-14: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: functional unit [FU9].

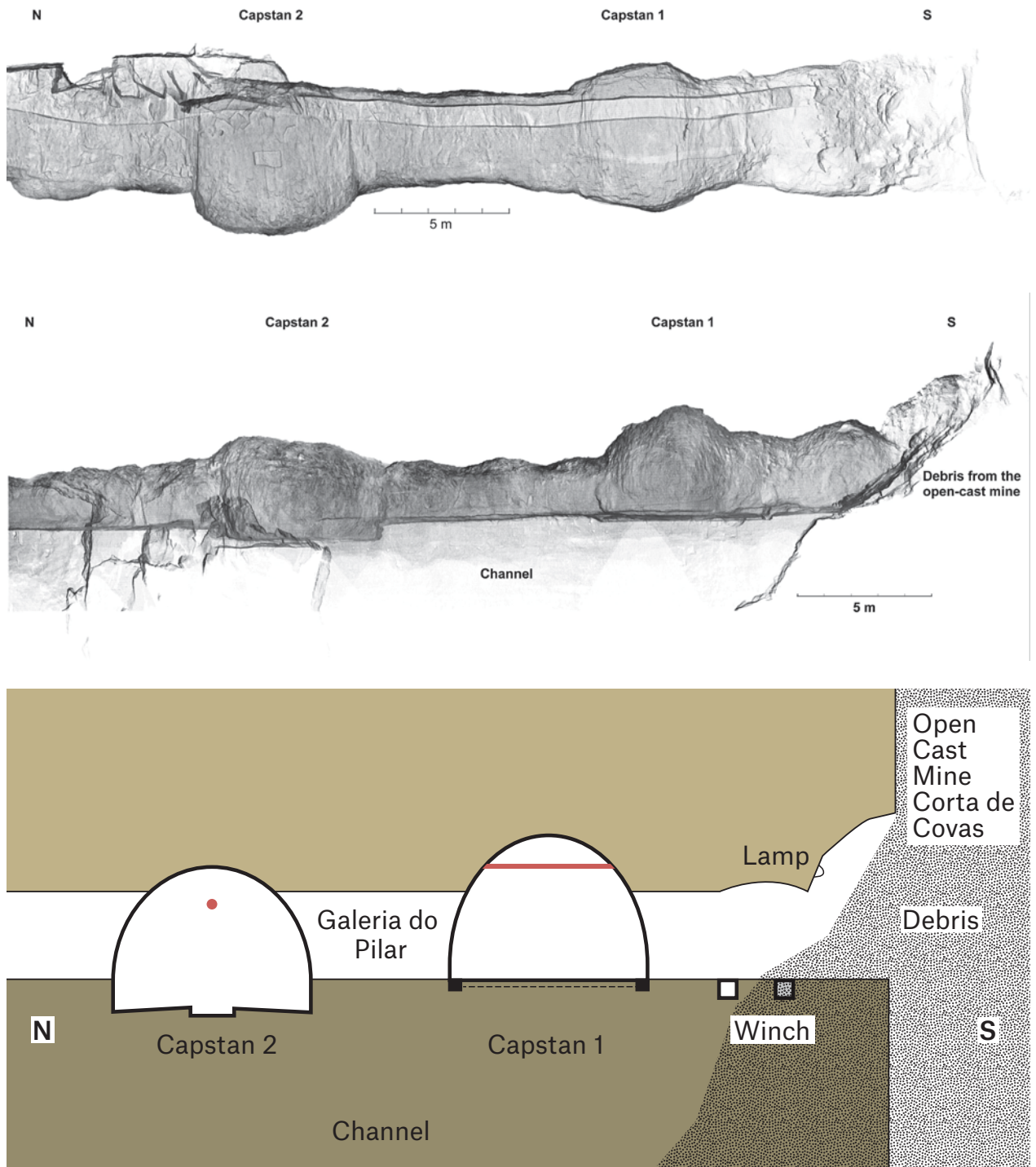


Fig. 3.2-15a/b/c: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: a/b point clouds of the 3D laser scan image of the situation in the end area towards the opencast mine in the Galeria do Pilar, c strongly schematized representation of the situation (a/b recording and design: K. Mechelke and M. Lindstaedt, design: R. Wahl-Clerici).



Fig. 3.2-16: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: traces of the fixing of a winch. Functional unit [FU10a] (photo: R. Wahl-Clerici).

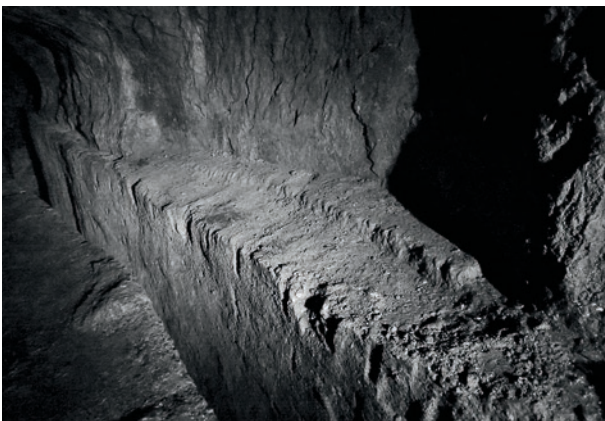


Fig. 3.2-17a/b: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, Galeria do Pilar: unfinished extension for a lift powered by a capstan [FU10b] (photo: R. Wahl-Clerici).



Fig. 3.2-18: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: cuts in the rock for the lift powered by a capstan [FU10c] (photo: A. Wilson).

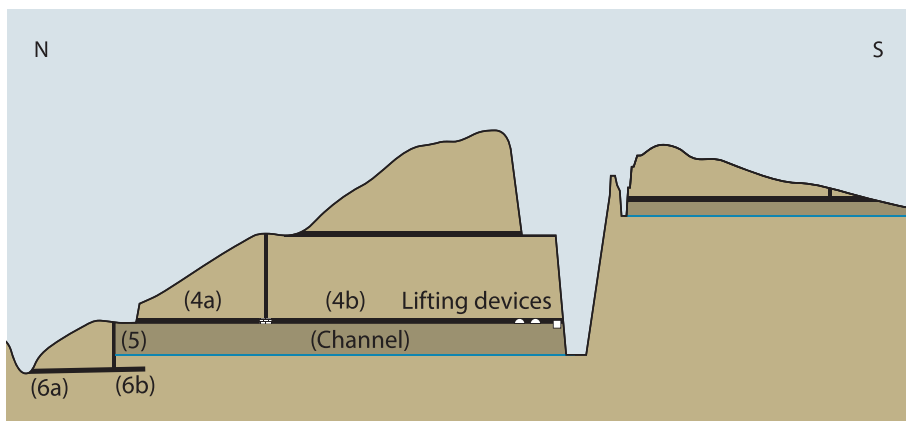


Fig. 3.2-19: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, further deepening of the channel in the Galeria do Pilar.

(A18) Excavating a blind shaft between the Galeria do Texugo and the channel in Galeria do Pilar.

(A19) Intentional filling in of the channel area between the blind shaft and the shaft in front of the port of the Galeria do Pilar. A new floor was created between the pillar and the port by the filling activities.

(A20) Possibly the installation of a mechanical drainage system, for example in the form of a water lifting wheel or bucket chain, in opencast mine A to enable a further lowering of the extraction zone.

(A21) Excavating the Galeria do Texugo in an easterly direction to prospect the mountains.

(A22) Latest date for the abandonment of opencast mine A.

[FU 11] Intentional filling of the shaft in the Galeria do Pilar between the shaft in front of the entrance of the Galeria do Pilar to the Galeria do Texugo up to the area of the pillar, where a blind shaft was constructed. Afterwards, the drainage of the opencast mine A took place through the channel, the blind shaft and the Galeria do Texugo (figs. 3.2-20a/b).

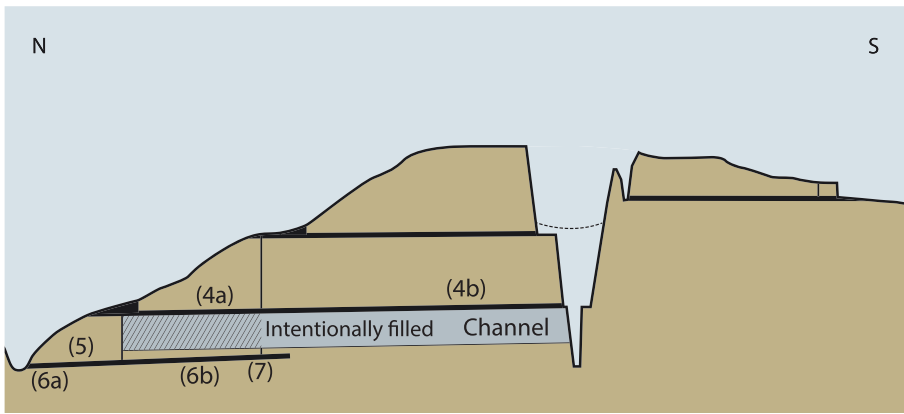


Fig. 3.2-20a/b: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, Galeria do Pilar: intentionally filled-up zone between the entrance and the blind shaft between the Galeria do Pilar and the Galeria do Texugo [FU11] (photo: R. Wahl-Clerici).

## 3.3 The Tresminas galleries

The Tresminas galleries impress both visitors and researchers alike with their dimensions. These unique underground mines, excellently preserved due to the stability of the surrounding rock, are of great importance for our understanding of Roman mining techniques (fig. 3.3-1).<sup>139</sup>

These large-chambered galleries are part of the prospecting and extraction zone of the two extensive open-cast mines Corta de Covas (fig. 3.3-2) and Corta da Ribeirinha. In contrast, the underground mine in Lagoinhos was accessed exclusively through shafts as far as currently known (fig. 3.3-3).

### Corta de Covas

- Galeria Esteves Pinto (fig. 3.3-4)
- Galeria Jürgen Wahl (fig. 3.2-10b)
- Galeria do Pilar (fig. 3.3-5)
- Galeria do Texugo

### Between Corta de Covas and Corta da Ribeirinha

- Galeria dos Alargamentos (fig. 3.3-6)

### Corta da Ribeirinha

- Galeria dos Morcegos (fig. 3.3-7)
- Galeria Buraco Seco (fig. 3.3-8)

With the exception of Galeria do Texugo, these galleries are tunnels or adits, meaning they had an opening both towards the extraction zone and on the flank of the slope. A special case is the Galeria dos Alargamentos, whose final chamber in the mountain is connected to the surface by a shaft (figs. 3.3-9, 3.3-10).

The function of the galleries differs. Those galleries planned as adits (Esteves Pinto, Jürgen Wahl, do Pilar, dos Morcegos) and in principle also the Galeria do Texugo were always used for drainage and extraction. The Burraco Seco drains the Corta da Ribeirinha to this day. The chapter on the extraction progress in the Corta de Covas deals with the various functions of the galleries and their connections among each other. So far, the information on the extraction in the Corta da Ribeirinha is sparse. The two open ports indicate that the Corta was originally divided into a western and an eastern part. The surveys of the features of the two underground mines, the spiral stairwell and the Galeria do Pastor, which meet at the junction of the western and eastern parts, have confirmed this previous assumption to be correct.

Cart tracks were cut into the floors of the Galeria Esteves Pinto, the Galeria dos Alargamentos, the Galeria do Pilar and possibly also the Galeria do Texugo<sup>140</sup>, which will have deepened with use (figs. 3.3-2, 3.3-4, 3.3-11). The intersection of the two extension axes of the Galeria dos Alargamentos presents the typical picture of a zone without pre-cut cart tracks, which gradually start further into the tunnel (fig. 3.3-12).

### Galeria Esteves Pinto

Jürgen Wahl discovered this large-chambered gallery at Tresminas in 1992. The very long port area, measuring 20.40 m, had been completely buried with slope debris and had to be uncovered first (fig. 3.2-6). This gallery provided access to the southern extraction area in the Corta de Covas. Its early date is indicated by its position and level (810 m NN).<sup>141</sup> We do not know why the visor shaft, which had been necessary for the survey and construction of the tunnel, penetrated the future level. Because of it, cart traffic could only be ensured by placing wooden fittings/planks over it, to complete the tracks cut into the floor (fig. 3.3-13).

### Galeria Jürgen Wahl

This oldest tunnel providing access and probably also drainage to the northern extraction zone of the Corta de Covas at a maximum height of 787 m above sea level, was also discovered by Jürgen Wahl in 1995. His attention was attracted at first by the conspicuous density of remains of the processing (fig. 4.0-3), such as fragments of stamp mills and millstones, as well as the penetration of the dump in front of the gallery for the shaft, which ended in the Galeria do Pilar, which had to be protected at this point by the construction of the pillar (see Galeria do Pilar). The position of the port area of the Galeria Jürgen Wahl finally resulted from the observation of a slight depression in the slope (figs. 3.2-10b, 3.3-14).

After the port area, which had been completely covered by debris, had been uncovered over a few meters, the two walls of the gallery could be identified for at least a small distance. The floor could not be uncovered yet. The

139 Wahl 1988; The mixing-up of the galleries „do Pilar“ and „do Texugo“ by Harrison in 1931, fig. 4, was further spread by other authors, cf. Quiring in 1932, fig. 2 with the wrong designation „The Arrugia of Gralheira (Pedras Salgadas) in northern Portugal“.

140 The floor of this gallery, which has not been accessible since 1988, could not be examined.

141 Wahl 1998, 60–61, fig. 4.

inside width of the gallery was 2.65 m, the length can only be guessed at on the basis of the topography and must be at least 120 m. The construction method of the gallery is still unknown.

#### *Galeria do Pilar*

The extraordinary internal dimensions and construction details of the Galeria do Pilar make it a treasure trove of knowledge on Roman mining. The port area is 4.20 m wide and the entire gallery over 250 m long (figs. 3.3-2, 3.3-5). In addition, the transition area between the gallery and the opencast mine reveals important technical details. The accumulation of debris and the levelling of the ancient waste rock now give a wrong impression of the open zone of the port on the slope side. The open zone was at least 10 m long in Roman times, including the connecting shaft to the Galeria do Texugo below. The port area of the Galeria do Pilar lies at 744 m above sea level, i. e. about 40 m lower than the Galeria Jürgen Wahl, and 31 m above the Galeria do Texugo (figs. 3.3-15, 3.3-16).

Of particular interest is the installation of the pillar, which prevented the debris from falling down through the obsolete connecting shaft to the port area of the Galeria Jürgen Wahl and the resulting obstruction when accessing the rear part of the gallery (figs. 3.3-5, 3.3-17, 3.2-12b).<sup>142</sup> This location also proves that the 23 m deep channel running along the eastern wall is younger than the construction of the pillar, because the channel was narrowed and led east of the pillar where an extension of the eastern wall offered just enough space. This extension made it possible to carry cart traffic all along the route. The traces of the wooden covers necessary to go along the channel are still visible (fig. 3.3-18). The channel itself also had to be secured with large amounts of timber, as a drop in the extension area for the installation of a capstan construction proves (fig. 3.3-19).

The structures preserved in the Galeria do Pilar in the area of the transition to opencast mining are of great interest for ancient mining. Thanks to a bridge construction, this was made accessible again in 2018 (for the first time after 1990). It then was cleared as much as possible of the debris from the opencast mine (fig. 3.3-20).<sup>143</sup>

In the connecting sector from the gallery to the opencast mine, innumerable cuts in the rock have been preserved. For the time being, it has not yet been possible to determine any relations between them, even though the majority probably served to secure the zone. In addition, the cuts of at least three different lifting constructions, two capstans were also preserved (figs. 3.2-15a/b/c). A winch was positioned closest to the surface mine (fig. 3.2-16).

Of particular interest are the traces of a capstan which was never put into operation and which was abandoned in an advanced stage of construction for reasons that cannot yet be understood. After the relatively high dome and the cuts to hold the beam had already been worked out of

the rock, the floor had to be lowered. Thus, the boundaries were determined and ditches were created in order to have as many points of attack as possible, which would mean time saved (figs. 3.3-21, 3.3-22). The abandoned capstan is about 8 m closer to the opencast mine than the one which, as the wear marks on the bottom show, was used over a longer period (figs. 3.3-23, 3.3-24).

#### *Galeria do Texugo (figs. 3.2-13b, 3.3-25)*

The construction of the Galeria do Texugo (715 m above sea level) had to meet three requirements. On the one hand, it had to be driven much deeper than the Galeria do Pilar, so that only a location slightly downhill to the east from the axis of that gallery axis was possible. On the other hand, it was the intention of the Romans to open a system here that corresponded to the shaft already sunk between the Galeria Jürgen Wahl and the Galeria do Pilar. The third prerequisite was that the channel, which had already reached a considerable depth and where the risk of collapse could not be ruled out due to a natural fissure, should be partially filled with the water draining through a blind shaft (after 175 m) between the two galleries into the Galeria do Texugo. Finally, the eastern rock was tunnelled under with a branch, a prospecting tunnel with shafts, running to the east after 199 m that was approximately 25 m long (fig. 3.3-16).<sup>144</sup>

#### *Galeria dos Alargamentos (fig. 3.3-1)*

The 157 m long Galeria dos Alargamentos, opened 791 m above sea level, is at the heart of the prospecting activities between the two opencast mines and was never connected to the Corta de Covas. It was excavated from both ends, the tunnels meeting in the middle (figs. 3.3-26, 3.3-27).<sup>145</sup>

Their main features, giving it its name, are the four regularly arranged extensions carefully cut into the northern wall. The function of these extensions has not yet been unravelled. However, it can certainly be ruled out that these were passing points for oncoming cart traffic, as there are no signs of wear and tear on the floor (figs. 3.3-6, 3.3-11, 3.3-12). In spite of the very careful finishing of the roof and walls, there are traces of a driving tunnel from which the gallery was extended on both sides. It is also interesting that the cart tracks are only present in the part driven from the slope surface.

The large, dome-shaped final chamber was first created by an extension from the shaft. Later, a construction for a capstan was built in, of which the typical round cavity and a beam hole are preserved. From this final chamber, prospecting tunnels and shafts were excavated in all directions (figs. 3.3-10, 3.3-28, 2.0-10).

<sup>142</sup> Wahl 1988, 226—229; Wahl-Clerici 2011; Wahl-Clerici 2013.

<sup>143</sup> Helfert et al. 2019.

<sup>144</sup> Wahl 1988, 229.

<sup>145</sup> Wahl 1988, 229—230; Wahl-Clerici et al. 2011; Helfert et al. 2013.



One of the most important features in the Galeria dos Alargamentos is the mine disaster in the stairwell leading to the south. The stairwell had been constructed after the gallery had been closed, because it cuts into the gallery's floor (fig. 2.1-1).

#### *Galeria dos Morcegos*

This never completed tunnel at a height of 727 m above sea level (figs. 3.3-7, 3.3-29—3.3-31) has a multiple angled route. This was probably preferred because of the topographical conditions (figs. 3.3-29, 3.3-30). Its length is about 160 m. A shorter distance would have led through a small valley bottom, in which dump material of the Corta da Ribeirinha had spread. It seems that it was preferred to avoid this by starting at a different point, accepting the added difficulty in surveying and construction. It seems to have been the plan of the Romans to use the Galeria dos Morcegos to get at the ore zone at a lower level. They had already extracted and thoroughly prospected the same ore zone at a higher level, cut through by the western port.

The full internal width of the Galeria dos Morcegos was 3.85 m, which would have allowed two lanes for cart traffic. The rock above the Galeria dos Morcegos were not stable enough in the port area, so that a reinforcement was necessary. Witnesses to this are the preserved rock cuts for anchoring the timber frames (fig. 3.3-31).

#### *Galeria do Buraco Seco*

The Galeria do Buraco Seco is 90 m long and still drains the Corta da Ribeirinha (at a height of 723 m above sea level) from mountain water and rainwater (figs. 3.3-8, 3.3-32). In order to achieve an absolutely straight tunnel, the survey probably had to be carried out from the opposite valley slope, as was done at Galeria do Pilar. It seems that the tunnel was opened exclusively for drainage purposes, as its width is too narrow for carts.



Fig. 3.3-1: *Territorium metallorum* Tresminas / Jales. Overview of the Tresminas core zone:

A — Corta de Covas, B — Corta da Ribeirinha, C — Lagoinhos 1 — Galeria Esteves Pinto, 2 — Galeria Jürgen Wahl, 3 — shaft in front of Galeria Jürgen Wahl's adit to the Galeria do Pilar, 4 — Galeria do Pilar, 5 — shaft in front of Galeria do Pilar's adit to Galeria do Texugo, 6 — Galeria do Texugo, 7 — Galeria dos Alargamentos, 8 — Galeria dos Morcegos, 9 — Galeria Buraco Seco, 10 — Spiral stairwell, 11 — Galeria do Pastor. (Template Ortofotomapa Câmara Municipal Vila Pouca de Aguiar 1:10 000, design: J. Wahl, R. Wahl-Clerici, M. Helfert, drawing: S. Mathiuet)



Fig. 3.3-2: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria do Pilar, seen from the north. The tunnel port area with cart tracks and drainage channel. The small older drainage channels are visible along the sides (photo: J. Wahl).



Fig. 3.3-3: *Territorium metallorum* Tresminas / Jales, Tresminas, Lagoinhos: port shaft (photo: J. Wahl).



*Fig. 3.3-4: **Territorium metallorum** Tresminas / Jales, Tresminas, Corta de Covas, Galeria Esteves Pinto, seen from the south, a tunnel port area with cart tracks and drainage channel (photo: J. Wahl).*



*Fig. 3.3-5: **Territorium metallorum** Tresminas/Jales, Tresminas, Corta de Covas, Galeria do Pilar: view onto the eponymous pillar with the drainage channel along the eastern side (photo: R. Wahl-Clerici).*



*Fig. 3.3-6: Territorium metallorum Tresminas/ Jales, Tresminas, Galeria dos Alargamentos: the gallery to the right, to the left one of the four extensions (photo: R. Wahl-Clerici).*



Fig. 3.3-7: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha, Galeria dos Morcegos: tunnel port area with the recesses cut into the rock at the transition from the floor to the sides for the timber props to secure the roof. Also well recognizable is the cut in the floor, in which a votive stone may have been embedded after the abandonment (photo: J. Wahl).



3.3-8: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha, Galeria do Buraco Seco: tunnel port in the open pit mine (photo: J. Wahl).



*Fig. 3.3-9: Territorium metallorum Tresminas / Jales, Tresminas, Corta de Covas: eastern slope with the twin shafts, which were inside the mountain in Roman times. To the right: riser shaft with the cuts for the risers, to the left: winding shaft. The latter pierces the end chamber of Galeria dos Alargamentos (photo: R. Wahl-Clerici).*



*Fig. 3.3-10: Territorium metallorum Tresminas / Jales, Tresminas, Galeria dos Alargamentos: extraction shaft in the end chamber (photo: R. Wahl-Clerici).*







*Fig. 3.3-11: Territorium metallorum Tresminas / Jales, Tresminas: the Galeria dos Alargamentos with one of the extensions to the right. The cart tracks in the floor do not touch any of the four extensions (photo: R. Wahl-Clerici).*

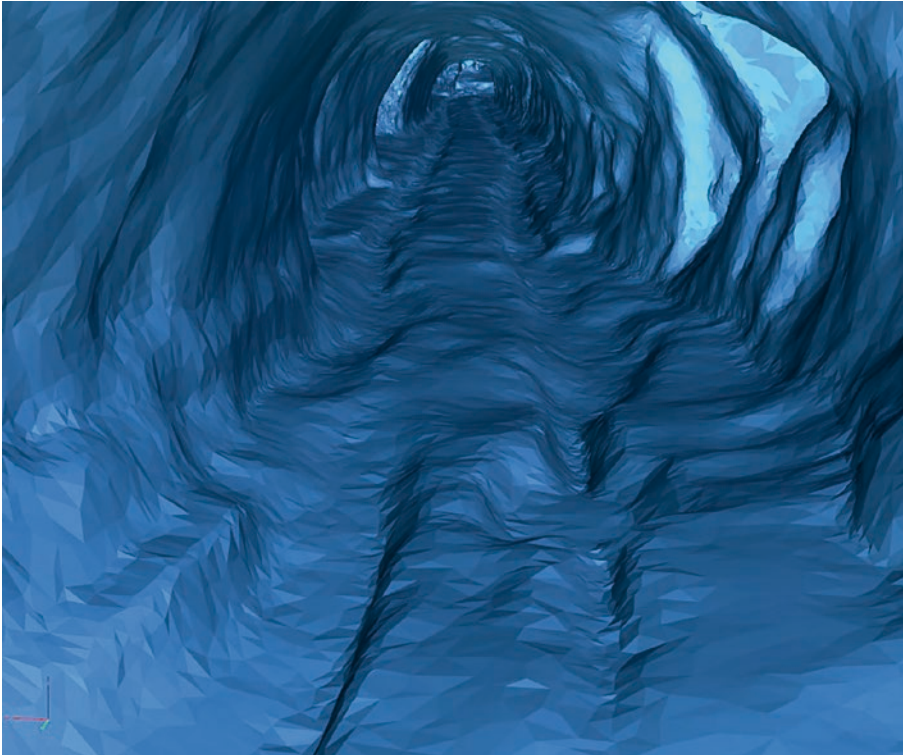


Fig. 3.3-12: **Territorium metallorum**  
Tresminas / Jales, Tresminas, Galeria dos  
Alargamentos: in some places, the cart  
tracks have been cut into the floor of the  
tunnel rather sloppily (scan and design:  
M. Helfert).



Fig. 3.3-13: **Territorium metallorum** Tresminas / Jales, Tresminas, Corta de Covas, Galeria Esteves Pinto: on the right side of the picture is the sighting shaft, with the cuts to cover the canal visible. View towards the tunnel port on the slope (photo: J. Wahl).



Fig.3.3-14: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, Galeria Jürgen Wahl: traces of the impact on the western face (photo: R. Wahl-Clerici).



Fig. 3.3-15: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, Galeria do Pilar: the tunnel port area buried by the slope debris has only been partially exposed. The fence secures the connecting shaft to Galeria do Texugo (photo: R. Wahl-Clerici).



Galeria do Texugo



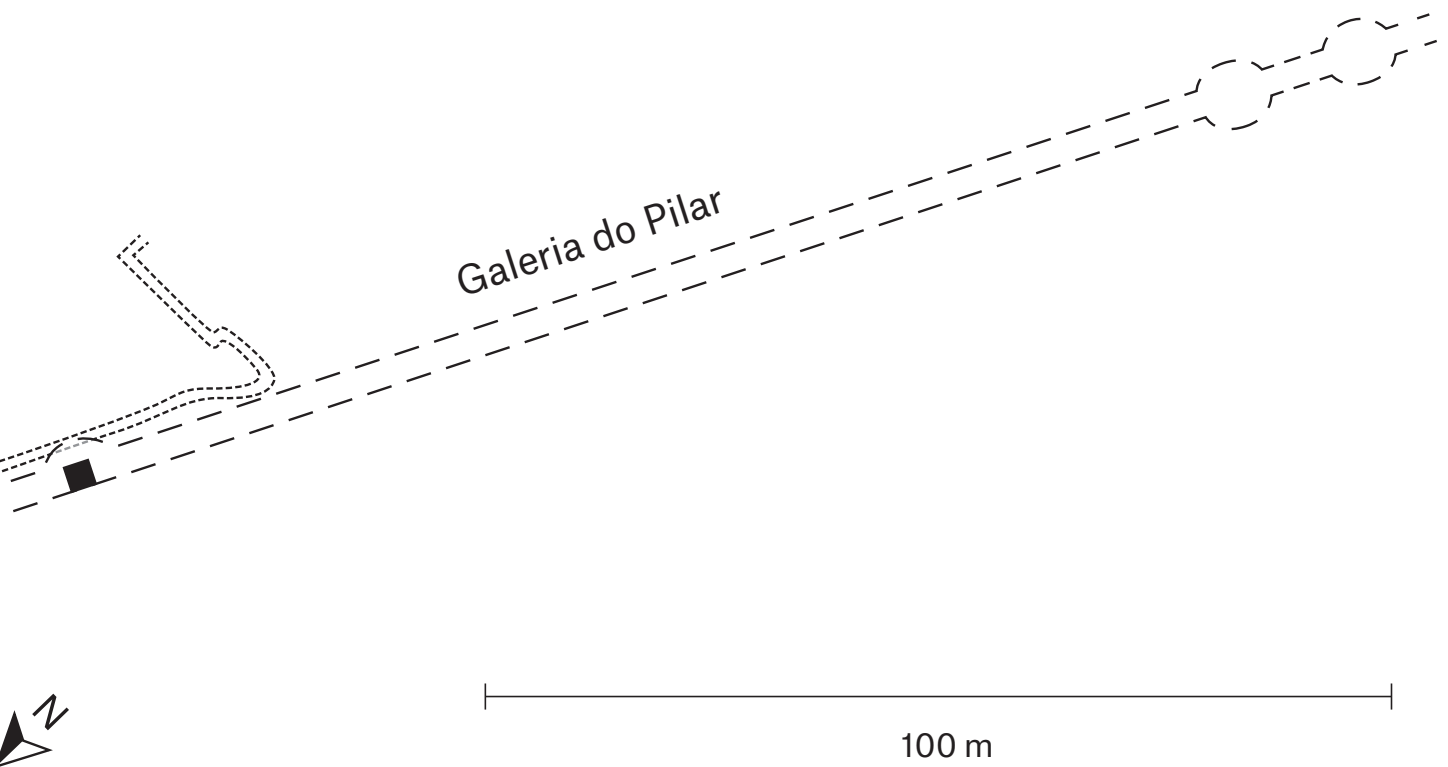


Fig. 3.3-16: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: the entrance of the Galeria do Texugo had to be built on the valley side, away from the waste rock dump of the Galeria do Pilar. This meant that the previous axis of the galleries on the northern slope of the Corta de Covas could no longer be used (template Wahl 1988, fig. 3, design: S. Mahiuet).



Fig. 3.3-17: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, Galeria do Pilar, seen from the south: to the left of the picture the eponymous pillar, and to the right the extension for the passage of transport and the drainage channel. The tunnel port is visible in the background as a bright spot (photo: C. Wahl).



Fig. 3.3-18: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, Galeria do Pilar: cuts made for the wooden cover of the drainage channel (photo: R. Wahl-Clerici).



Fig. 3.3-19: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, Galeria do Pilar: cuts for the cover of the drainage channel and remains of the positioning of the timbers in the channel in the area of the capstan (photo: R. Wahl-Clerici).



*Fig. 3.3-20: Territorium metallorum Tresminas / Jales, Tresminas, Corta de Covas, Galeria do Pilar, transition between the gallery and the open pit mine (photo: A. Wilson).*





Fig. 3.3-21: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, Galeria do Pilar, eastern faces: lowering of the floor in the part that was going to house the capstan (photo: R. Wahl-Clerici).



Fig.3.3-22: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, Galeria do Pilar: view from the south onto the narrow ditches that were first cut into the floor in order to lower the whole floor (photo: R. Wahl-Clerici).



Fig. 3.3-23: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, Galeria do Pilar, from the north: dome-like extension with cuts in the rock to attach the capstan construction. The floor has been lowered (photo: A. Wilson).

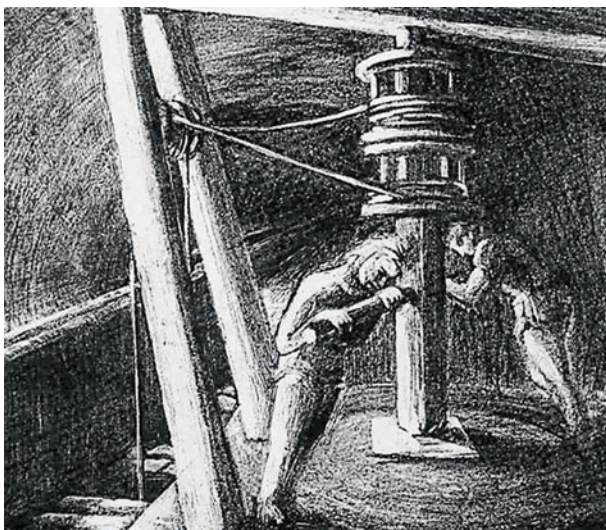


Fig. 3.3-24: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, Galeria do Pilar: reconstruction of the windlass with capstan (drawing: F. Boldt).



Fig. 3.3-25: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, Galeria do Texugo: tunnel port from the north (photo: R. Wahl-Clerici).



Fig. 3.3-26: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Alargamentos: at the point where the two tunnels meet, an unintentional extension is visible, demonstrating that the two tunnels did not meet exactly head on (Ortofotomapa 1:5000 Câmara Municipal de Vila Pouca de Aguiar; measurement, processing and presentation M. Helfert).



Fig. 3.3-27: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Alargamentos: view into the southeast corner of the crossing zone of the two branches (photo: R. Wahl-Clerici).



Fig. 3.3-28: *Territorium metallorum* Tresminas / Jales, Galeria dos Alargamentos: view from east into the prospection adit G (Fig. 2.0-10). This antique adit was enlarged in modern times (photo: R. Wahl-Clerici).

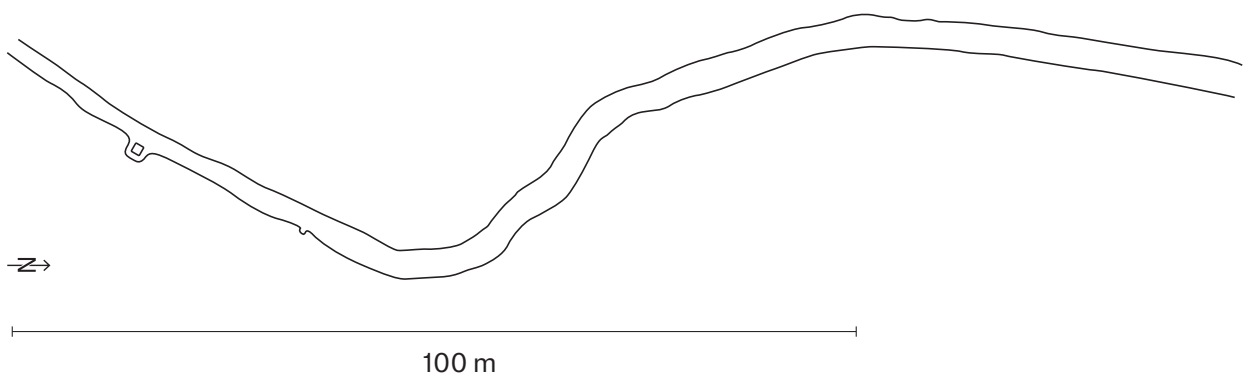


Fig. 3.3-29: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: plan of the Galeria dos Morcegos (based on documents of the Serviço de Fomento Mineiro, design: J. Wahl, S. Mathiuet).



Fig. 3.3-30: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha, Galeria dos Morcegos: zone in the area of the first change of direction from the tunnel port with target width of 3.85 m. The former working faces of the tunnel and the cuts between them are clearly visible in the roof (photo: R. Wahl-Clerici).



Fig. 3.3-31: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha, Galeria dos Morcegos: the reconstruction of the timber posts is based on the cuts in the rock of the floor (drawing: P. Moser).



Fig. 3.3-32: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: view from the north into the Galeria do Buraco Seco (photo: J. Wahl).

### 3.3.1 Constructing galleries and shafts

The construction of cavities in the mountains is always accompanied by the danger of collapse. In addition to the stability of the rock itself, the cross-section of the cavities is decisive for their stability, especially in the case of horizontal structures. When constructing a cavity, the Romans had to rely on their experience regarding the naturally given conditions. Today, rock mechanics, which deals with the statics and dynamics of solid rock, is the science by which underground cavities can be opened in a controlled manner.<sup>146</sup>

The cavities opened in Tresminas by the Romans have been preserved over the last 2000 years or so with only minor changes. In the following chapter, the various tunnels, galleries, stair shafts and shafts will be discussed in terms of their structural details against the background of the natural conditions.

#### The cross sections

The cross-sections used in the construction of tunnels can be divided into those that support and those that rather prevent the stability of the resulting cavity. The sketch fig. 3.3.1-1 shows the natural state of stress in a mass of rock. The compressive forces obviously act from above to below, which causes the underlying rock to move to the side. Consequently, the aim in tunnel construction always is to divert the rock pressure as far as possible to the side of the cavity. The sketches figs. 3.3.1-2a-d illustrate the pressure conditions.<sup>147</sup>

In contrast to this, the cross-sections of the galleries with particularly large clear widths in Treminas/Jales, namely the Galeria do Pilar with 4.20m and the Galeria dos Morcegos with 3.85 m, correspond to a rectangle that is wider than it is high (see figs. 3.3.1-2b, 3.3.1-3, 3.3.1-4, 3.3.30, 3.3.31). Although this shape is not at all ideal in terms of rock pressure, the galleries have been stable for almost 2000 years due to the stability of the rock. It seems that the rectangle was aimed at as the ideal shape for these galleries (figs. 3.3.1-3—3.3.1-6). The curvature of the working faces in the Galeria do Pilar (fig. 3.3.1-3) was probably created primarily by the technique of widening the cavity (see below).

A crevice in the Galeria do Pilar has caused part of the floor to break off into the channel, which is probably connected to the additional cavity created as a result (fig. 3.3.1-5). The roof of the entrance area of the Galeria dos Morcegos is also marked by collapse. However, this was mainly due to the fact that the rock layer above the entrance was too thin, as the roof is only stable further inside the mountain (figs. 3.3.1-6, 3.3.31).

The cross-sections of the Galeria Esteves Pinto and the Galeria do Texugo approach the ideal of a segment of a

circle (figs. 3.3.1-7, 3.2-13b).<sup>148</sup> A cart could pass through each of these. In the Galeria dos Alargamentos, the cross-sections differ between the downhill and uphill sections. The former is similar to that of Esteves Pinto and Texugo, while the latter is adapted to a flatter segment of a circle (figs. 3.3.1-6, 3.3-4, 3.3-13, 3.3-25).

Other cross-sections observed in Tresminas are either trapezoidal (see figs. 3.3.1-2c, 2.0-15, 3.3.1-9, 3.3.1-10, 2.0-17, 3.0-18) or a rectangle higher than it is wide. The latter is mainly found in relatively short tunnels and stair shafts excavated for prospecting. In the Corta de Covas, for example, only the staircase shaft between the two mining zones (southern and northern) has so far been unequivocally identified as a high rectangle. To facilitate the work, a natural cleft was exploited here at the eastern junction (fig. 3.0-7). In the Corta da Ribeirinha, the shaft of the U-shaped turning staircase was also excavated in a high rectangular shape (fig. 3.3.1-8).

Two tunnels with a more or less semi-circular roof were excavated for prospecting. One belongs to a prospecting system that was driven from the shaft between Galeria Jürgen Wahl and Galeria do Pilar before the opening of Galeria do Pilar (fig. 2.0-13). The other is part of the complex prospecting system that was opened about 100 m east of Lagoinhos (figs. 2.0-20, 2.0-21).

Of particular interest is the upper gallery, which was opened parallel to the ancient entrance area in the west of Corta da Ribeirinha and was subsequently sunk several times (fig. 3.3.1-9). Originally the cross-section of the tunnel approached a trapezoid, but in the course of the lowering of the floor, the tunnel was not widened, so that a high rectangle was created.

The tunnel underneath, which also samples that which has been left standing from north to south, is clearly trapezoidal in shape (figs. 2.0-15, 3.3.1-10). A further trapezoidal cross section can be seen in the unnamed prospecting gallery (fig. 2.0-17).

146 Katzenbach/TU Darmstadt. file:///F:/Buch\_Grafische\_Gestaltung\_2/Doppelstollen/Tunnelbau/14\_-\_Einfuehrung\_in\_die\_Felsmechanik\_11-10-06.pdf. Last view: 15.10.2018.

147 Template for the sketch: Dr. Rudolf Schindlmayr, Bergische Universität Wuppertal.

148 This cross-section is preferred in modern tunnel construction, see for instance the new railway tunnel of St. Gotthard/Switzerland (construction time 1999—2016). Here, the excavation machines opened two independent circular cavities, the floor of which was filled in and serves as track bedding. See <https://de.wikipedia.org/wiki/Gotthard-Basistunnel>.



## Advancing the galleries

Galleries and tunnels were excavated in Tresminas using various methods. The following methods have been proven:

1. Construction using the qanat method (see below), which was used on all the known tunnels of the water supply system.
2. Driving a pilot drift (small tunnel) into the correct direction and then widening it in different stages to the desired clear width and height. This has been proven for the Galeria do Pilar, the Galeria dos Alargamentos and the Galeria dos Morcegos.
3. Directly driving the gallery in the desired clear width and height. According to our current knowledge, the Galeria do Buraco Seco was constructed in this manner, as was the unnamed prospecting gallery at the eastern end of the Corta da Ribeirinha as well as the multi-levelled system of tunnels, galleries and shafts that is preserved parallel to the western entrance of Corta da Ribeirinha.

The construction method of the galleries Jürgen Wahl and Texugo is still uncertain, because they are currently only partially accessible.

Of particular interest are the different surveying methods used for the construction. A distinction can be made between the qanat method already mentioned, surveying over the mountain as well as sighting from the opposite slope.

The term qanat construction is derived from the underground accesses to the underground springs, the qanats, which were opened in dry areas of the earth. Their beginnings can be traced back to the beginning of the 1st millennium B. C. Particularly early examples can be found in Iran, where 37 000 qanats are still in use today.<sup>149</sup>

For the qanat construction method, the future course of the tunnel is staked out over the mountain at the surface. Subsequently, vertical shafts are sunk to the future floor of the tunnel at various points and these shafts are then connected to each other (fig. 3.3.1-11).<sup>150</sup> The main advantage of this method is that the distances between the individual shafts are relatively short, which means that, unlike with the opposite site method (see below), there was hardly any risk of missing the next shaft of the team tunnelling from it. Another advantage was that — depending on the depth of the shafts — the construction time for the tunnel could be considerably shortened, as there were two extraction fronts per shaft. While the cost of this method was considerable, it was obviously accepted, probably because it prevented errors in measurement that could potentially lead to major delays and additional costs.

The most famous examples of this method from Antiquity are the connecting tunnels to the Eupalinus tunnel. The Eupalinus tunnel provided the water supply to Samos

(Gr) in the 6th century B. C.<sup>151</sup> In contrast to the main tunnel, which was excavated from both ends, the qanat construction method was used for the connecting tunnels.<sup>152</sup>

In Tresminas, all the known and accessible tunnels for water supply were constructed with the qanat method.<sup>153</sup> This is easily recognizable by the typical slight depressions with the spoil dumps behind them, which run in a straight line over the mountain (fig. 3.3.1-12).

Another method of orienting a tunnel was achieved using a sighting shaft, which in Tresminas can only be found at the Galeria Esteves Pinto. For this purpose, a shaft was sunk relatively shortly after the entrance in order to define a sight line for the orientation of the tunnel, as shown in figs. 3.3.1-13a/b.<sup>154</sup>

The measuring method using a fixed point on the opposite slope enabled a straight line to be established, as must have been the case in the Galeria do Pilar, because in this tunnel, which is over 250 m long, the light entering through the entrance can be observed from the rearmost position (figs. 3.3.1-14, 3.3.1-3, 3.3-16).

The positioning of the fixed point on the opposite slope allowed the mine surveyor to project the system connected to the Galeria Jürgen Wahl into the mountain and also the support of the measurement on a long axis. This also made it possible to construct the gallery as straight as an arrow.<sup>155</sup> However, this meant that (a) the construction was only possible from the slope and (b) that it took about twice as much time to build the gallery. In order to shorten this period, a man-sized tunnel was first driven into the rock, which was then extended either on one or on both sides (figs. 3.3.1-4, 3.3.1-5).

The construction of the Galeria do Texugo posed a special challenge, as the adit had to be connected to the shaft in front of the entrance of the Galeria do Pilar. The resulting minor difficulties could apparently be solved without

149 Grewe 1998, 33—40. Also see the lecture of Dr. Ali Ashgar Semsar Yazdi (International Center on Qanats and Historic Hydraulic Structures, Iran) WWAC Coimbra 2016.

150 The exception is the Tunnel of Claudius at the Lago Fucino (Avezzano, Italy), which is built using the qanat method but with sloping shafts. See Grewe 1998, 91—98; Cech 2017, fig. 12.

151 The main part of the Eupalinus tunnel was excavated from both sides, measuring with a geometry-based approach. See Kienast 1995, Plan 2; Grewe 1998, 58—69.

152 Grewe 1998, 55—59.

153 Aqueduct T2 (Pedroso) see Wahl-Clerici 2020, aqueduct T4 (Castanheiro Afumado e Alto da Capelinha). Uncertain: aqueduct T1 (between Tinhela-de-Baixo and the branching off from the main road to Filhagosa / Revel), aqueduct C1 (Lomba dos Corvos do Muro).

154 For the sighting shaft of the tunnel of Eupalinus on Samos; Grewe 1998, 60—62 fig. 85—86.

155 Grewe 1998, 61 fig. 85.

much effort, as the course of the gallery shows (figs. 3.3-16, 3.3.1-15).

Because of the conspicuously straight course of the Galeria do Buraco Seco (fig. 3.3-32) and the nameless gallery in the area of the ancient eastern entrance to the Corta da Ribeirinha (fig. 2.0-17), one would normally also assume that they were surveyed using a fixed point on the opposite slope. In addition, there are not sight shafts in either tunnel. However, possible positions on the opposite slope are at least 300m away, so that a survey over the mountain without a sighting shaft must be assumed (fig. 3.3.1-16).

The most difficult construction method for a tunnel was excavating it from both sides (figs. 3.3.1-17a/b).<sup>156</sup> This was the method used for the Galeria dos Alargamentos. Two branches can be distinguished here, which met almost exactly in the middle, giving the impression of an additional extension (figs. 3.3-26, 3.3-27). A particular difficulty was that one of the entrances is located at the end of a shaft about 50m deep and thus underground (figs. 3.3-9, 3.3-10). Although the survey had to be carried out across the whole mountain, a sighting shaft was not used. Under these circumstances, the construction of the Galeria dos Alargamentos can be considered a masterpiece of Roman surveying and tunnel construction.

This construction system demands extreme accuracy from the surveyors, since even small deviations lead to serious errors.<sup>157</sup> An additional complication was that the branch that started inside the mountain was 50m below the mountain surface. It was also taken into account that the gallery had a slight inclination from the slope surface. The Tresminas surveyors solved the task brilliantly, as not only did the two teams meet at the designated location, but it was also possible to guide the branch that started inside the mountain horizontally. This prevented the mountain water from constantly flowing into the large winding shaft, which was probably sunk at the same time, during the construction of the gallery. It remains to be mentioned that the two branches differ only slightly in length.

The Galeria dos Morcegos, which was also opened exclusively from the slope side, likewise shows the high level of skill of the Roman engineers. This gallery could not be routed over the shortest distance between the entrance to the slope and the one in the extraction zone, as large waste rock dumps extend into this area, and which continued to accumulate during the construction period. Modern surveying shows that at the beginning of the work, the course was directed towards the desired end point. Soon, however, a directional correction was made, followed by no less than four others, which finally achieved the original goal (fig. 3.3-29).

Using the example of the Galeria dos Morcegos, which, as we know, was never finished and never put into operation, we can also observe the Roman methods of building tunnels in Tresminas. First, a pilot drift was opened, which under certain circumstances had to be adapted sev-

eral times to the desired level (figs. 3.3.1-4, 3.3.1-18). In order to extend this tunnel, which was originally only man-sized, new advance points were set up in the eastern face of the advance (fig. 3.3.1-19). This allowed several mine workers to work simultaneously and the construction time was shortened. In the Galeria dos Morcegos, about 30 working faces, i. e. places where advance (excavation) is taking place, can be identified (fig. 3.3.1-20). Most of them were abandoned in the middle of the tunnelling. Often, the working faces can still be identified, even after the material between them has been broken out and the whole area smoothed (figs. 3.3.1-18, 3.3.1-19). In principle, this process could be repeated until the desired clearance was achieved.

In the Galeria do Pilar and the Galeria dos Alargamentos traces of three capstans could be identified. In the former, working faces can also be found, but they are found in contrary to the Galeria dos Morcegos on both side walls.

### Stairwell shafts

All the stairwell shafts known to date are between 1 and 1.20 m wide and usually have the shape of a raised rectangle (figs. 3.3.1-8, 2.0-20, 2.0-21, 2.1-3a/b—2.1-5, 2.2-1—2.2-7, 3.0-7). Since all of them were prospecting structures, they were always opened from a higher position in order to sample lower lying zones.

### The shafts

In the mining zones of Tresminas and Gralheira, most shafts have a square cross-section. This also applies to the connecting shaft between the Galeria Jürgen Wahl and the Galeria do Pilar. As this required pushing through the rubble in front of the higher gallery, it can be assumed that timber shoring was necessary. Exceptionally, an elongated rectangle is found in the old entrance shaft for ore extraction in Lagoinhos (figs. 3.3-3, 3.3.1-21). The sight shaft needed for the construction of the Galeria Esteves Pinto is further exception as it is round (fig. 3.3.1-22).

Of unknown shape are the many shafts whose entrances are buried by slope debris and material from the waste rock dumps. This applies not only to the prospecting shafts but also to the shafts of the tunnels of the water supply system, which were necessary for the qanat construction method (see the chapter Water Supply System).

<sup>156</sup> Compare Fontvieille (F), Tunnel Les Taillades. See Grewe 1998, 101—102 fig. 150—152.

<sup>157</sup> The inscription of Nonius Datus (CIL VII 2728 and 18122) is a famous example for this problem: Nonius, a veteran surveyor first surveyed the course of the underground water pipeline to Saldae (modern-day Bejaja, Algeria) and, after it had been realised that the working parties should have long since met, also undertook the correction, so that the work could be brought to its successful conclusion. See Grewe 1998, 24 and 135—139.

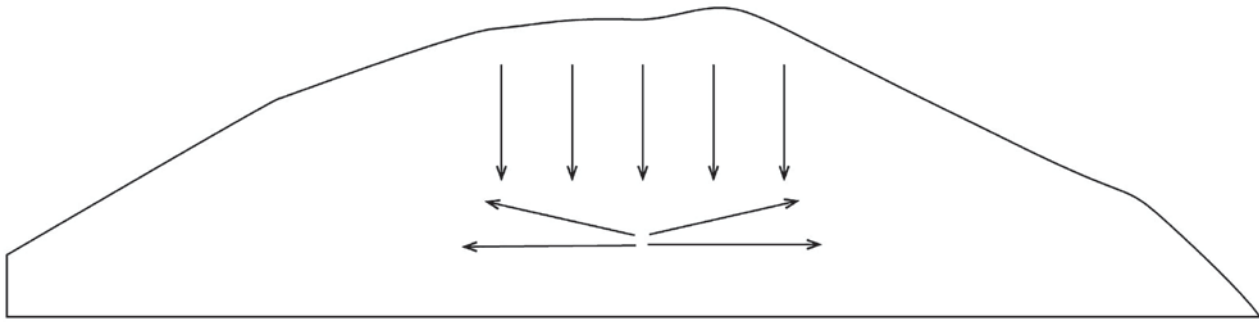


Fig. 3.3.1-1: The natural state of stress in the mountains (template R. Schindlmayr, design: R. Wahl-Clerici).

The twin shafts excavated for prospecting, which, thanks to a natural rockfall, are now visible in the eastern slope of the Corta de Covas are exceptional examples. The material removed from them was transported through the northern shaft. It pierces the end chamber of the Galeria dos Alargamentos. In the southern shaft, the holes for fixing the climbing beams are still visible; this shaft did not reach the final chamber. There must obviously have been connecting passages between the two shafts, but as far as can be seen today, these were only high enough to crawl along (fig. 3.3-9).

The sinking of a shaft also required careful surveying, as there was always a risk that the course of the shaft was not completely vertical when driving. This problem can be demonstrated in the case of the shaft connecting the mouth of the Galeria Jürgen Wahl with the Galeria do Pilar. Surveying has shown that the two entrances are topographically slightly out of alignment with each other.<sup>158</sup>

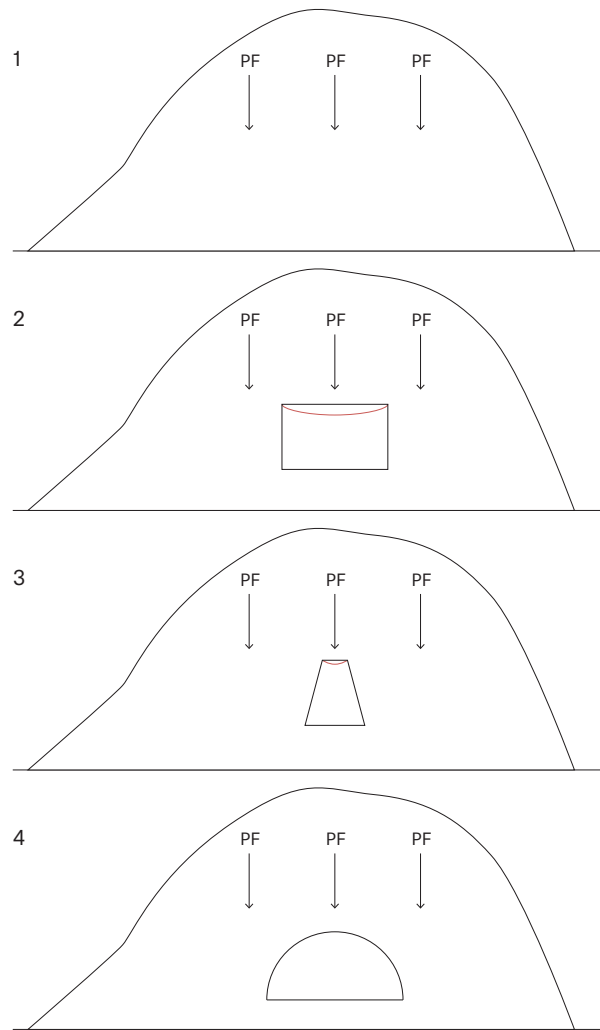


Fig. 3.3.1-2a/b/c/d

- 2a The natural pressure forces in the mountains, without disturbance.
- 2b The effect of tensile forces on a longitudinal rectangular cross-section.
- 2c The effect of tensile forces on a trapezoid cross-section.
- 2d The effect of tensile forces on a cross-section which looks like a piece of pie.

(template R. Schindlmayr, design: R. Wahl-Clerici).



Fig. 3.3.1-3: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria do Pilar: situation behind the pillar. The conspicuous irregularity of the sides was caused by the working faces, which were driven into the rock to widen the cavity. View towards the entrance on the slope (photo: R. Wahl-Clerici).



Fig. 3.3.1-4: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha, Galeria dos Morcegos: part of the tunnel below the open pit mine; after lowering the first tunnel (on the left), the adit was enlarged towards the east (photo: R. Wahl-Clerici).





*Fig. 3.3.1-5: Territorium metallorum Tresminas / Jales, Tresminas, Galeria do Pilar: collapse of the western side wall of the channel with the remains of a modern bridge to cross it. In the ceiling the first tunneling is still visible (photo: R. Wahl-Clerici).*



Fig. 3.3.1-6: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Morcegos: entrance area, with niches for lamps visible in the vertical western workforce, which were necessary during the driving of the pilot drift into the rock. The roof is only in part in its original state, as it collapsed several times (photo: R. Wahl-Clerici).



Fig. 3.3.1-7: *Territorium metallorum* Tresminas / Jales. Tresminas, Galeria Esteves Pinto: the cross section is close to the form of a segment of a circle, entrance area from the outside (photo: J. Wahl).



Fig. 3.3.1-8: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: entrance of the shaft with the U-shaped stairs (photo: R. Wahl-Clerici).





Fig. 3.3.1-9: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha, from the north: tunnel-like cut, probably for sampling the rock below the mining zones parallel to the western access to the open pit mine. The original trapezoidal cross-section and the step-by-step sinking of the floor are clearly visible (drawing: P. Moser).



Fig. 3.3.1-10: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: various stages of sampling of the rock below the mining zones parallel to the western access to the open pit (drawing: P. Moser).

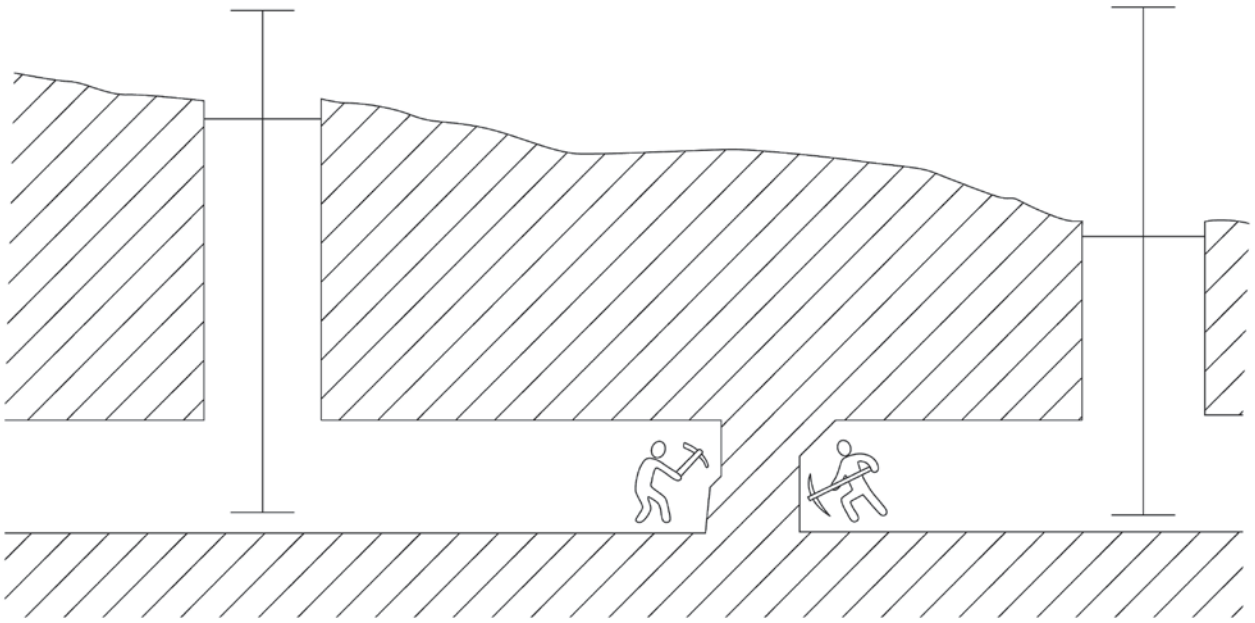


Fig. 3.3.1-11: Schematic illustration of the construction of a tunnel with the qanat method (template after Grewe 1998, fig. 27, design: S. Mathiuet).

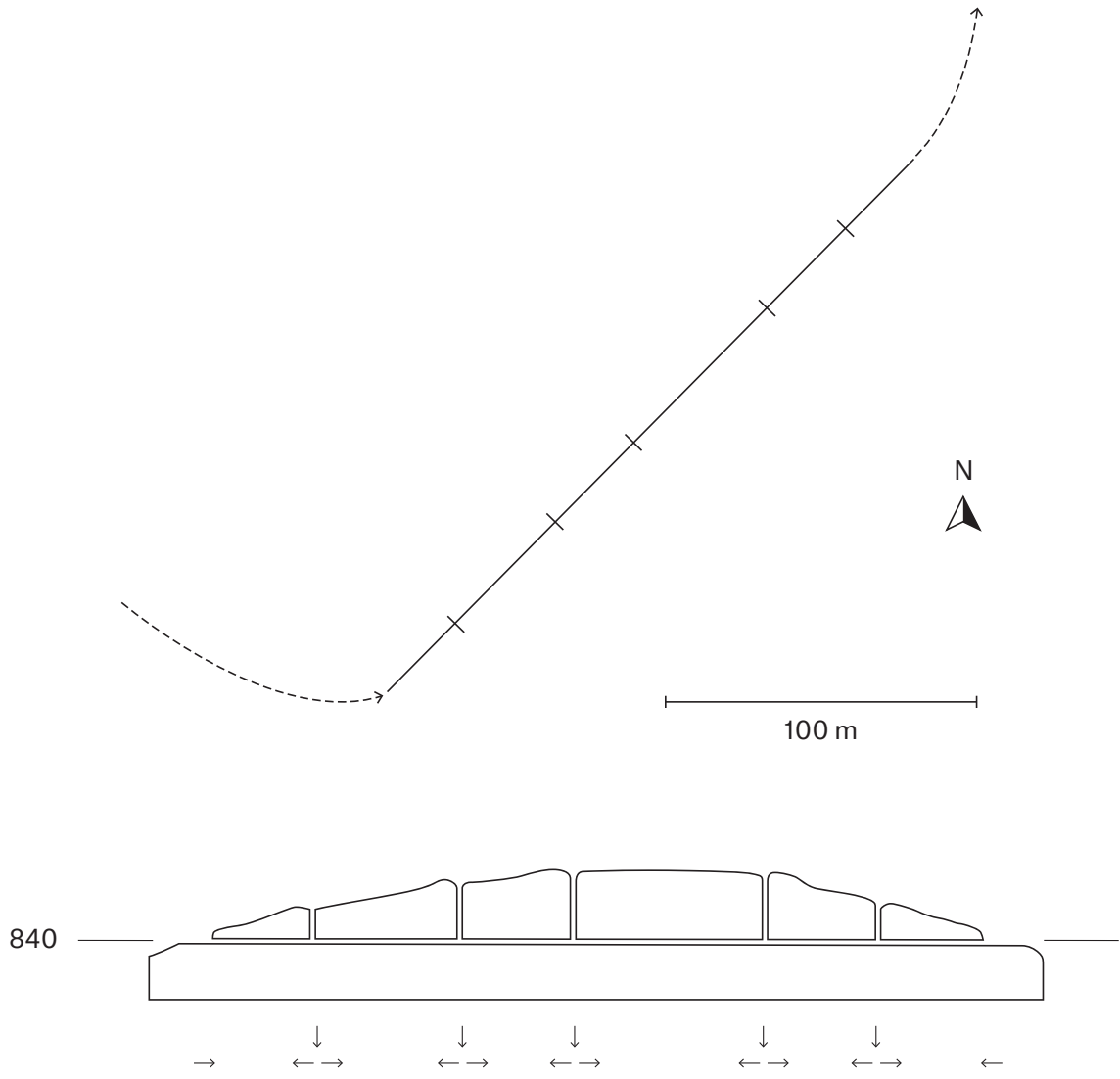


Fig. 3.3.1-12: *Territorium metallorum* Tresminas / Jales: tunnel of the aqueduct T2 (documentation J. Wahl, R. Wahl-Clerici, design: R. Wahl-Clerici, S. Mathiuet).

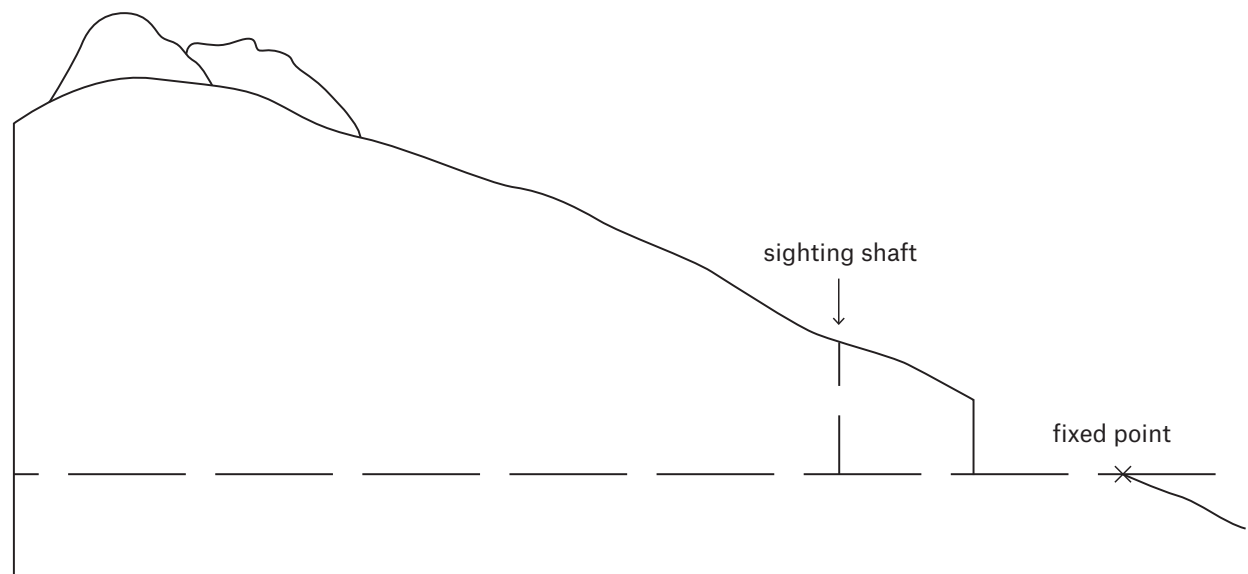
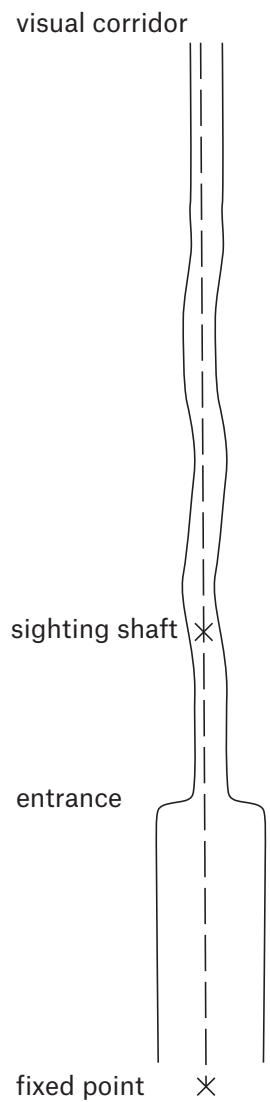


Fig. 3.3.1-13a/b  
 a) Schematic illustration (plan) of the construction of a tunnel with a sighting shaft (template after Grewe 1998, fig. 86, design: S. Mathiuet).  
 b) Schematic illustration (seen from the side) of the construction of a tunnel with a sighting shaft (template after Grewe 1998, fig. 86, design: S. Mathiuet).

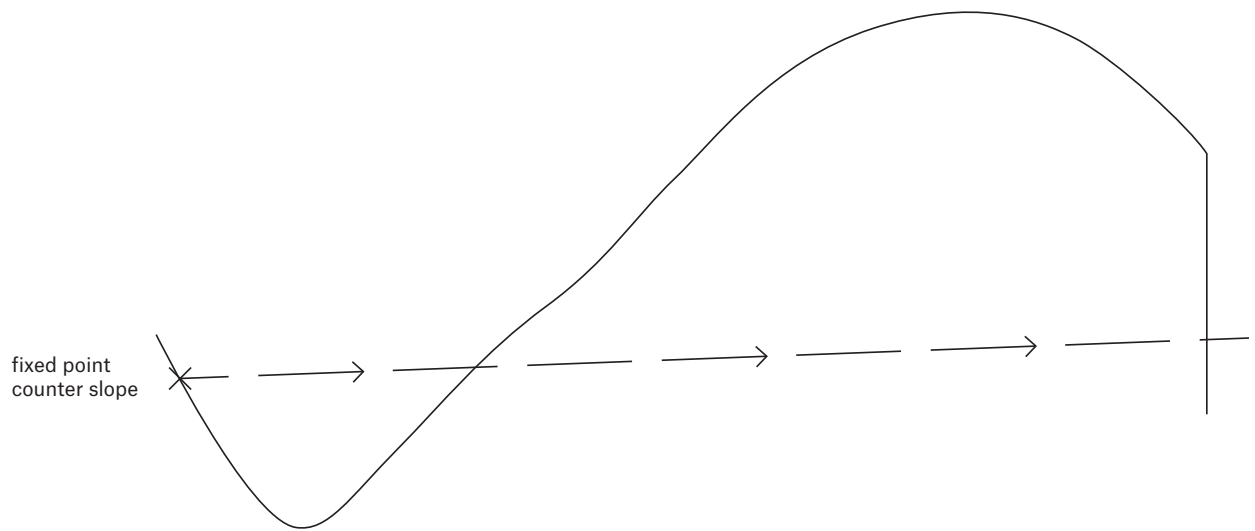


Fig. 3.3.1-14: Schematic illustration (side view) of the construction of a tunnel with a fixed point on the opposite slope. The dotted line shows the inclination of the tunnel (template after Grewe 1998, fig. 85, design: S. Mathiuet).



*Fig. 3.3.1-15: Territorium metallorum Tresminas / Jales, Tresminas, Galeria do Texugo: change of the original course of the gallery in the area of the connecting shaft in the entrance area of the Galeria do Pilar (photo: J. Wahl).*

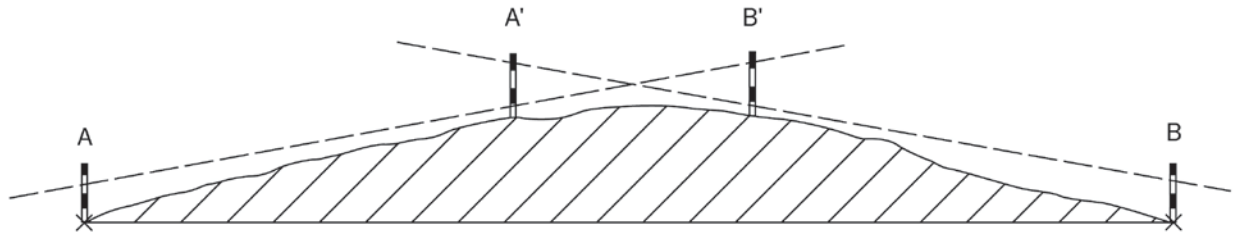


Fig. 3.3.1-16: Schematic illustration of surveying over the mountain (template Grewe 1998, fig. 26, design: S. Mathiuet).

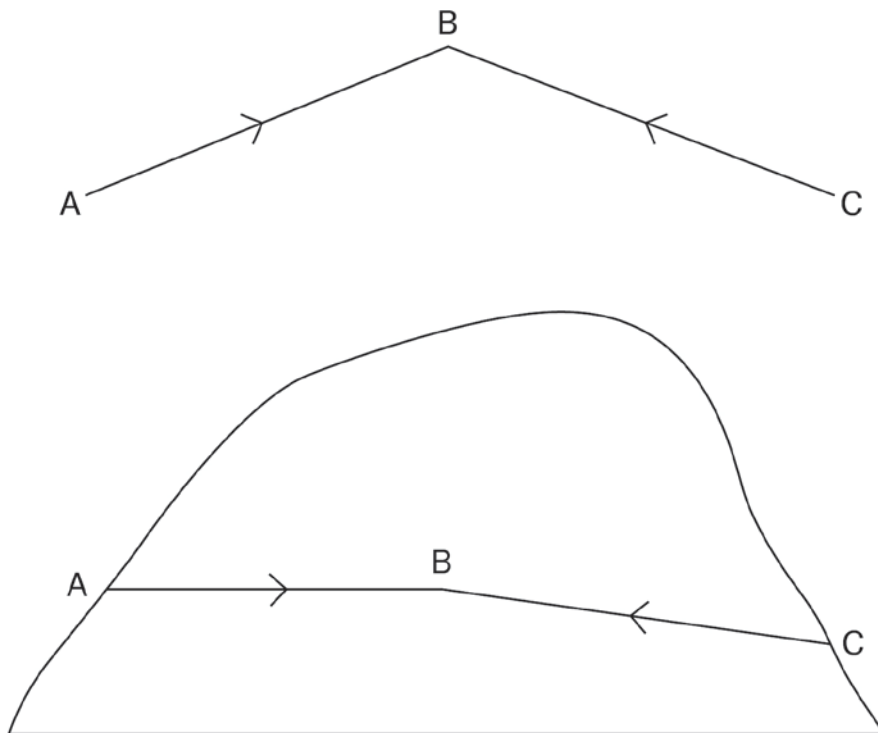


Fig. 3.3.1-17a/b: Schematic illustration of the method of excavation a tunnel from both sides. 17a = ground plan, 17b = seen from the side. Both parts of the tunnel were driven into the rock at an angle to each other, here exaggeratedly depicted, in order to increase the chance of the two parts meeting. In the Galeria dos Alargamentos, the angle is remarkably small in the horizontal plane. In the vertical plane, the tunnel that had been opened from the slope side is inclined. The tunnel section driven into the rock from inside the mountain is horizontal (template Grewe 1998, fig. 17 and 1985, 69, design: S. Mathiuet).



Fig. 3.3.1-18: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Morcegos, from the south: the tunnel had to be lowered in some places by up to 80 cm. A slight extension was driven into the western working face in the area of the prospecting shaft (photo: R. Wahl-Clerici).



Fig. 3.3.1-19: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria dos Morcegos, from the north: in the eastern working faces, both the heading face for widening the cavity and the rock left standing can be seen (photo: R. Wahl-Clerici).





Fig. 3.3.1-20: *Territorium metallorum* Tresminas/Jales, Tresminas, Galeria dos Morcegos: working face, the cutting of the rock went from the top down, as the various steps of the cuts show (photo: J. Wahl).



Fig. 3.3.1-21: *Territorium metallorum* Tresminas/Jales, Tresminas, Lagoinhos: rectangular access shaft to the extraction zone (drawing: P. Moser).



*Fig. 3.3.1-22: **Territorium metallorum** Tresminas / Jales, Tresminas, Corta de Covas, Galeria Esteves Pinto: the sight shaft required to build the gallery had been sunk deeper than the future floor (photo: J. Wahl).*

## 3.4 The waste rock dumps

The waste rock dumps in the *territorium metallorum* Tresminas/Jales are reliable indicators for the size of the extraction zones and the volume of material extracted. They also indicate tunnels and shafts that were never part of the extraction.

The waste rock dumps are especially frequent in the vicinity of the opencast mines A (Corta de Covas) (fig. 3.4-1) and B (Corta da Ribeirinha). In contrast, at excavation site C (Lagoinhos) there are only minimal waste rock dumps (fig. 3.0.1-19). Particularly conspicuous waste rock dumps can be found in front of the ports of the galleries. These accumulated with the deposition of the barren rock material removed during the construction of the galleries. This observation can be made at the Galeria dos Alargamentos and at the Galeria do Pilar (figs. 3.4-1, 3.4-2), where considerable piles of waste rock can be observed. In the case of the Galeria dos Alargamentos, the material from the prospecting tunnels supplemented the waste rock dumps from the construction (fig. 3.4-3).

The large number of shafts opened for prospecting the zone between the two open-cast mines could only be identified thanks to the waste rock dumps indicating them on the surface, since most of them are completely buried or only indicated by small depressions in the surface (fig. 3.4-4).

The waste rock dumps of the various tunnels of different aqueducts constructed in the Qanat manner are also an important indicator when attempting to trace them. The small, but conspicuous piles, which sit on the valley side of the slight depressions that mark the tunnels, are always arranged in a single line across the mountain. The depressions cannot be interpreted differently, even if neither the inflow nor the outflow has retained a segment of the channel (fig. 3.4-5).

In the mining zone, the size of the waste rock dumps and the concentrations of stamp mills and ore mills within it, provide important information on the amount of material processed there. However, the quantity of stones now present also depends on whether these had been carried off to the Roman period or later villages to be used as building material. The waste rock dumps in front of the galleries Esteves Pinto and Texugo have been distorted by agricultural activities, so that it is no longer possible to identify them without 3D laser scanning. The waste rock dumps in front of the Galeria dos Alargamentos and Galeria do Pilar also no longer have their original, hill-like form, as can be seen in Alargamentos in particular from the original course of the port in relation to the waste rock dump.

An enormous mass of waste rock dumps can be found at the southern edge of the Corta de Covas. Small mountains, which were disturbed by the road built in the 1940s rise up here (figs. 3.4-1, 3.4-6a/b). They continue in a southeasterly direction and close off the eastern slope of the open-cast mine to this day. In some places, the waste rock dump lies on top of isolated Roman houses of the settlement, because in a mining zone, mining always had priority (fig. 3.4-7).

Further waste rock dumps extend north of the Corta de Covas over the entire length of the open-cast mine and essentially over the entire flank of the slope (fig. 3.4-1). The smaller waste rock dumps east of the open pit probably contain the barren material from the sinking of the two shafts connected to the Galeria dos Alargamentos (fig. 3.4-8). They may also contain parts of the extraction from the easternmost zone of the Corta. The southern waste rock dumps were caused by the extraction in the Corta de Covas. So far it has not been possible to determine their extent even approximately.

Particularly striking are the two waste rock dumps in front of Galeria Jürgen Wahl and Galeria do Pilar (figs. 3.4-1, 3.4-2). The shaft leading into the Galeria do Pilar was driven through the former. It consists of the barren material produced by the construction and later by the extraction in the Galeria Jürgen Wahl. Ore-bearing rock was processed a little to the east of the waste rock dumps, where strikingly high concentrations of stamp mills and ore mills are located. The waste rock dumps in front of the port of the Galeria do Pilar are huge and stand out well from the surrounding area. It consists of rock transported out of the tunnel, as well as the barren parts of the processed material. Stamp mills and ore mills can still be found today in the tailings pile in front of the Galeria do Pilar, even though most of them were carried off to the village of Ribeirinha.

At the Corta da Ribeirinha, the waste rock dumps border to the north of the northern slope of the opencast mine. Numerous processing elements were identified in them. It is also significant that there is only a small waste rock dump in front of the Galeria dos Morcegos, easily explained as consisting of the barren rock from the construction. It seems that the waste rock dump in front of the Galeria do Buraco Seco was relatively large, but it is currently so densely overgrown that it is impossible to survey.

The ore vein of Gralheira is bordered by easily visible waste rock dumps (figs. 3.4-9, 3.0-27, 3.0-28, 4.0-1d). The extent to which modern work has distorted the picture in certain areas cannot yet be clearly determined.



Fig. 3.4-1: *Territorium metallorum* Tresminas/ Jales, Tresminas: the Corta de Covas from north with the waste rock dumps south and north of the extraction zone, the areas with the main waste rock dumps are colored (Google Earth, last view: 15.01.2020, design: S. Mathiuet).



Fig. 3.4-2: *Territorium metallorum* Tresminas / Jales, Tresminas, Ribeirinha valley: the distinctive dump of sterile waste rock and remains of the stamping and milling in front of the Galeria do Pilar is easily identifiable by the presence of chestnut trees (photo: R. Wahl-Clerici).



Fig. 3.4-3: *Territorium metallorum* Tresminas / Jales, Tresminas: view from the north onto the mine dump in front of the Galeria dos Alargamentos. On the lower left side of the picture, another waste rock dump from a prospection tunnel can be identified by the accumulation of light-coloured stones (photo: R. Wahl-Clerici).



Fig. 3.4-4: *Territorium metallorum* Tresminas / Jales, Tresminas: view from the north onto two quartz heaps in the centre of the image. The tunnels or shafts crossed for prospecting the sterile quartz vein which extends from above the western end of the Corta da Ribeirinha through the valley to the north and to the next hilltop (photo: R. Wahl-Clerici).



Fig. 3.4-5: *Territorium metallorum* Tresminas / Jales, Tresminas: the barely visible dumps are part of the qanat-type construction of the channel tunnel for the water supply system (photo: Th. Schierl).





Fig. 3.4-6a: *Territorium metallorum* Tresminas / Jales, Tresminas: view from the south over waste rock dumps south of the Corta de Covas, partly cut or destroyed by the modern road (photo: R. Wahl-Clerici).



Fig. 3.4-6b: *Territorium metallorum* Tresminas / Jales, Tresminas: detail of fig. 3.4-6a (photo: R. Wahl-Clerici).





Fig. 3.4-7: *Territorium metallorum* Tresminas / Jales, Tresminas. In the background, the waste rock dumps which partially cover the houses southeast of the Corta de Covas are visible (photo: D-DAI-MAD-WIT-R-141-86-13).



Fig. 3.4-8: *Territorium metallorum* Tresminas / Jales, Tresminas: view from the south on waste rock dumps above the eastern slope of the Corta de Covas (photo: R. Wahl-Clerici).





Fig. 3.4-9: *Territorium metallorum* Tresminas / Jales, Galheira: view from the northeast onto waste rock dumps which were piled up on both sides of the extraction face (photo: R. Wahl-Clerici).

## 4.0 Treatment<sup>159</sup>

All necessary stages of ore treatment are directly dependent on the requirements on the mining site and determined by the character of the mineralisation. This essential principle is reflected by the materials and structures connected to treatment mechanisms that have been found on different mining sites in the *territorium metallorum*.

Although all three deposits (Tresminas, Gralheira and Jales) were exploited for polymetallic ore with high amounts of gold, these differ substantially in the specifics of precious metal deposition. The sites at Gralheira and Jales contained clearly defined veins that were exploited accordingly — the mineralisation at Tresminas, however, was of a more complex nature (figs. 4.0-1a/b/c/d/e).<sup>160</sup> Therefore, much more effort had to be put into the extraction and subsequent processing of the material from the latter and this effort becomes apparent in the archaeological remains on the site. As far as we know today, the ores of the Gralheira and Campo de Jales mines were conducted to the so-called ‘Forno dos Mouros’ near the river Tinhela. At Tresminas, such processing sites are distributed over a number of locations (figs. 4.0-2, 4.0-3).

This gives us the opportunity to identify not only the different stages of ore processing but also the specific sites on which these were conducted. Only the ‘Forno dos Mouros’ covered all stages of processing in one site; elsewhere, these activities took place at a number of separate locations.<sup>161</sup>

### The Mechanisms of processing

The deposits at Tresminas, Gralheira and Jales not only contain gold in granules visible to the naked eye, but also so-called ‘refractory gold’. The latter means gold that is interwoven with other minerals very closely or bound into the crystal lattices of host minerals. The grain size of the gold ranges from 3.6 millimetres down to one thousandth of a millimetre.<sup>162</sup>

Diodorus of Sicily, writing around the middle of the 1st century B. C., describes the processing, which he observed himself, very comprehensively (3,13,1-2):

Οἱ δὲ ἄνηβοι παῖδες εἰσδύμενοι διὰ τῶν ὑπονόμων εἰς τὰ κεκοιλωμένα τῆς πέτρας ἀναβάλλουσιν ἐπιπόνως τὴν ῥιπτουμένην κατὰ μικρὸν πέτραν καὶ πρὸς τὸν ἐκτὸς τοῦ στομίου τόπον εἰς ὑπαιθρον ἀποκομίζουσιν. οἱ δ’ ὑπὲρ ἔτη τριάκοντα παρὰ τούτων λαμβάνοντες ὀρισμένον μέτρον τοῦ λατομήματος ἐν ὄλμοις λιθίνοις τύπτουσι σιδηροῖς ὑπέροις,

ἄχρι ἂν ὀρόβου τὸ μέγεθος κατεργάσωνται. (2) παρὰ δὲ τούτων τὸν ὀροβίτην λίθον αἱ γυναῖκες καὶ οἱ πρεσβύτεροι τῶν ἀνδρῶν ἐκδέχονται, καὶ μύλων ἐξῆς πλειόνων ὄντων ἐπὶ τούτους ἐπιβάλλουσι, καὶ παραστάντες ἀνά τρεῖς ἢ δύο πρὸς τὴν κώπην ἀλήθουσιν, ἕως ἂν εἰς σεμιδάλεως τρόπον τὸ δοθὲν μέτρον κατεργάσωνται.

The boys there who have not yet come to maturity, entering through the tunnels into the galleries formed by the removal of the rock, laboriously gather up the rock as it is cast down piece by piece and carry it out into the open to the place outside the entrance. Then those who are above thirty years of age take this quarried stone from them and with iron pestles pound a specified amount of it in stone mortars, until they have worked it down to the size of a vetch. (2) Thereupon the women and older men receive from them the rock of this size and cast it into mills of which a number stand there in a row, and taking their places in groups of two or three at the spoke or handle of each mill they grind it until they have worked down the amount given them to the consistency of the finest flour.

After the stamping and the grinding processes Diodorus describes the ore-washing process in the Egyptian desert (3,14,1-2):

Τὸ δὲ τελευταῖον οἱ τεχνῖται παραλαβόντες τὸν ἀηλεσμένον λίθον πρὸς τὴν ὄλην ἄγουσι συντέλειαν· ἐπὶ γὰρ πλατείας σανίδος μικρὸν ἐγκεκλιμένης τρίβουσι τὴν κατεργασμένην μάρμαρον ὕδωρ ἐπιχέοντες· εἶτα τὸ μὲν γεῶδες αὐτῆς ἐκτεκόμενον διὰ τῶν ὑγρῶν καταρρεῖ κατὰ τὴν τῆς σανίδος ἔγκλισιν, τὸ δὲ χρυσίον ἔχον ἐπιτοῦ ξύλου παραμένει διὰ τὸ βάρος. (2) πολλὰκις δὲ τοῦτο ποιοῦντες, τὸ μὲν πρῶτον ταῖς χερσὶν ἐλαφρῶς τρίβουσι, μετὰ δὲ ταῦτα σπόγγοις ἀραιοῖς κούφως ἐπιθλίβοντες τὸ χαῦνον καὶ γεῶδες διὰ τούτων ἀναλαμβάνουσι, μέχρι ἂν ὅτου καθαρὸν γένηται τὸ ψῆγμα τοῦ χρυσοῦ.

In the last steps the skilled workmen receive the stone which has been ground to powder and take it off for its complete and final working; for they rub the marble

159 Bachmann 1993; Wahl 1988, 230—234; Wahl-Clerici / Wiechowski 2012; Wahl-Clerici et al. 2012b; Martins 2017.

160 Bachmann 1993; Noronha et al. 2000; Rosa 2001; Rosa / Romberger 2003.

161 Wahl-Clerici / Wiechowski 2012.

162 Wahl-Clerici / Wiechowski 2012, 328.

which has been worked down upon a broad board which is slightly inclined, pouring water over it all the while; whereupon the earthy matter in it, melted away by the action of the water, runs down the inclined board, while that which contains the gold remains on the wood because of its weight [cf. figs. 4.0-4, 4.0-5]. (2) And repeating this a number of times, they first of all rub it gently with their hands, and then lightly pressing it with sponges of loose texture they remove in this way whatever is porous and earthy, until there remains only the pure gold-dust.

Finally he describes the smelting process (3,14,3-4):

τὸ δὲ τελευταῖον ἄλλοι τεχνῖται παραλαμβάνοντες μέτρον καὶ σταθμῶν τὸ συνηγμένον εἰς κεραμεοῦς χύτρον ἐμβάλλουσι· μίξαντες δὲ κατὰ τὸ πλῆθος ἀνάλογον μολίβδου βῶλον καὶ χόνδρους ἄλων, ἔτι δὲ βραχὺ καττιτέρου, καὶ κρίθινον πίτυρον προσεμβάλλουσιν· ἀρμυστὸν δ' ἐπίθημα ποιήσαντες καὶ πηλῶ φιλοπόνως περιχρῖσαντες ὀπτῶσιν ἐν καμίνῳ πέντε ἡμέρας καὶ νύκτας ἴσας ἀδιαλείπτως· (4) ἔπειτα ἐάσαντες ψυχθῆναι τῶν μὲν ἄλλων οὐδὲν εὐρίσκουσιν ἐν τοῖς ἀγγείοις, τὸν δὲ χρυσὸν καθαρὸν λαμβάνουσιν ὀλίγης ἀπουσίας γεγεννημένης.

Then at last other skilled workmen take what has been recovered and put it by fixed measure and weight into earthen jars, mixing with it a lump of lead proportionate to the mass, lumps of salt and a little tin, and adding thereto barley bran; thereupon they put on it a close-fitting lid, and smearing it over carefully with mud they bake it in a kiln for five successive days and as many nights; (4) and at the end of this period, when they have let the jars cool off, of the other matter they find no remains in the jars, but the gold they recover in pure form, there being but little waste.

Pliny's remarks on these processes are rather brief. The relevant passage reads as follows (Natural History 33,69):

... *quod effossum est, tunditur, lavatur, uritur, molitur in farinam;*

... The substance dug out is crushed, washed, fired and ground to a soft powder.

The unrealistic sequence of stages mentioned here might be due to a flaw in the tradition of the text; it should read:

"The material is broken up, ground, washed and then roasted".<sup>163</sup>

Both authors, however, describe the stages necessary in order to obtain pure gold from deposits of the same type as those at Tresminas, Gralheira and Campo de Jales. While rather coarse-grained gold could be won by washing, re-

fractory gold demanded a much higher effort for its extraction, including roasting and smelting. The basic principles of these processes have been described by Strabo, based on the work of Polybius, on the example of silver mining at Laurion (Attica / GR).<sup>164</sup> The treatment scheme of smelting mechanisms compiled by Bachmann shows all necessary processes (fig. 4.0-6).<sup>165</sup>

Therefore the treatment differs fundamentally from the one applied on alluvial deposits such as at Las Médulas or Las Omañas (both Prov. León, E), where gold occurs as nuggets or gilt. This is the case for gold from alteration zones such as on the deposits on the Alto del Plano (Prov. Asturias, E) or within the Teleno massif (Prov. León, E). All these sites only feature a small number of ore mills or stamp mill bases, if any. This means that on these sites, there was no need to break the rock and if, only in very small quantities.

Essentially, the processing of the ore can be divided into a dry mechanical stage, a wet processing stage and a smelting stage. Stages of the dry mechanical process are collecting/sorting, stamping and grinding ore, while the ore washing is a wet processing stage. During the smelting, ore concentrations are deprived of silver and gold. The written sources do not mention a process called 'tossing extraction'; this process can only be deduced from the finds in the shafts that facilitated it. It must be assigned to the dry mechanical processes.

## Dry processing

### Collecting / Sorting

For Pliny, the collecting and sorting stage apparently was so obvious that he did not feel the need to mention it at all. During the collecting of the ore, the barren rock accumulated during mining was sorted out and discarded onto the spoil heaps of the mines at Tresminas that were located near the extraction trenches (figs. 4.0-7a/b, 3.4-9).<sup>166</sup>

### "Tossing extraction"

This is a simple but efficient way to pre-crush the ore and thus facilitate the subsequent crushing in the stamp mills.

<sup>163</sup> Rosumek 1982, 181—182; Wahl 1988, 230.

<sup>164</sup> Strabo, Geography: 3,2,10: τὴν δὲ κατεργασίαν τὴν μὲν ἄλλην ἐὼ (μακρὰ γὰρ ἐστὶ), τὴν δὲ συρτὴν βῶλον τὴν ἀργυρίτιν φησι κόπτεσθαι καὶ κοσκίνους εἰς ὕδωρ διαρτῶσθαι, κόπτεσθαι δὲ πάλιν τὰς ὑποστάσεις, καὶ πάλιν διηθουμένας ἀποχρῶμένων τῶν ὑδάτων κόπτεσθαι τὴν δὲ πέμπτην ὑπόστασιν χωνευθεῖσαν, ἀποχρῶθέντος τοῦ μολύβδου, καθαρὸν τὸν ἄργυρον ἐξάγειν.

"But as for the processes of the work, I omit all he says about it (for it is a long story) except what he says of the silver-bearing ore that is carried along in the streams, namely, that it is crushed and by means of sieves disengaged in water; then the sediment is again crushed, and again strained through (the waters meantime being poured off), and crushed; then the fifth sediment is smelted, and, after the lead has been poured off, yields the pure silver."

<sup>165</sup> Bachmann 1993, 154, note 4; also Martins 2008, 72 fig. 19.

<sup>166</sup> Agricola et al. 1950, 268.

The ore is simply tossed down a shaft onto a deeper level.<sup>167</sup> The most important evidence of this process are the shafts that connect the level of the Galeria Jürgen Wahl with the Galeria do Pilar (over 40m drop height) or the level of the Galeria do Pilar with the Galeria do Texugo (30m drop height). The material crushed in this manner was then brought out of the mine and processed further.

#### “Tundere” = Stamping

Stamping in wooden stamp mills served to crush the material even more finely with the help of the constant hammering of wooden stamps on the granite stamp mill bases (figs. 4.0-8, 4.0-9). Generally, only the bases of the stamp mills are preserved, being monolithic blocks of biotite granite, with a weight between 700 and 800 kilograms. According to their measurements of 90, 100 and 110 cm respectively, these blocks can be roughly divided into three size classes. The width and height of these blocks cannot be exactly determined due to the massive wear the blocks sustained during their use as stamp mill bases. The preserved dimensions vary between 40 and 50 cm. We can therefore reconstruct basic measurements of 3×1.5×1.5 Roman feet as a reference value for the size of the granite blocks used (figs. 4.0-10, 4.0-11).<sup>168</sup>

Generally, all the used surfaces of each base had four depressions, arranged in a fashion that always left a band of 15 to 20 cm of width free on one side. Its function must remain unclear for now, but it is imaginable that this part of the base had a part of the stamping installation built on it. Once the depressions were worn down to a point where the stamping hammers would not bite properly anymore, the stone was simply turned around and another side was used. These traces can mostly be found on three or four sides of the stamp mill bases (fig. 4.0-12).

The standardisation of the stone bases and the regularity of the traces of wear plead for an interpretation of these blocks as exchangeable parts of mechanically driven stamp mills. Four depressions per side seem to be the norm, as is demonstrated by examples found in Spain, Wales and the Kosovo which also have this number of depressions.<sup>169</sup>

The reconstruction drawing of a stamp mill from the Roman era (fig. 4.0-8) is limited to the hammers and an anvil, as one can only speculate on the details of the driving mechanism of such an installation. Examples shown in the book of the German naturalist and physician Agricola (which are about 1400 years younger) feature detailed depictions of the wooden construction for the driving of the stamp hammers (fig. 4.0-13). As such devices were built of wood in the Roman period as well, it is unlikely that additional evidence will be found in the future.

The stamp mills at Tresminas were very likely driven either by human or animal muscular power. The use of water power driven mills, which is frequently assumed, can very likely be ruled out, as there is no proof for either the supply of the high volume of water that would have been

needed or the rather high pressure that is needed to provide an installation such as a stamping mill with the necessary power.<sup>170</sup>

The number of stamp mill bases found at Tresminas exceeds that of all other mines in the Roman Empire by several hundreds (figs. 4.0-9, 4.0-14).

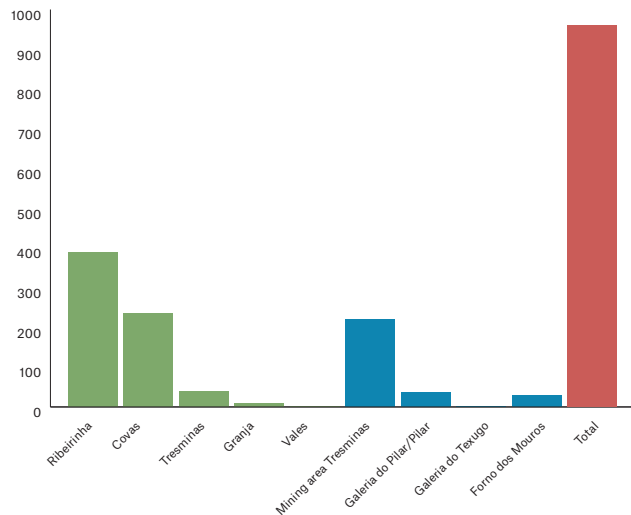


Fig. 4.0-15: *Territorium metallorum* Tresminas / Jales: distribution of the stamp mills in the modern settlements (in green) and the various find spots (in blue) within the mining zones of Tresminas and the Forno dos Mouros (recording R. Caflisch, R. Wahl-Clerici, design R. Wahl-Clerici).

167 Rosumek 1982, 80—81.

168 Wahl 1988, 230—234. A function as parts of *molae trusatiles*, as suggested by Rosumek 1982, 86—87 can be ruled out: “Das haltige Gestein wurde dadurch zermahlen, dass eine angeraute Deckplatte über die gesamte Länge des Quaders hin- und her bewegt wurde oder dass man abschnittsweise einen kleinen Stein mit der Hand kreisen liess, wodurch bei letzter Arbeitsweise mehrere muldenförmige Vertiefungen entstanden.” (The ore was crushed by moving a roughened cover plate back and forth over the entire length of the block or by circling a small stone in sections by hand, which created several trough-shaped depressions). It is very likely that for his reconstruction Rosumek referred to the Greek forward-backward mills, as found at Laurion, without taking into account the massive weight of the stamp mill bases at Tresminas. — The interpretation of Sánchez-Palencia (1979 and 1984/85), interpreting these stones as supplementary tools for gold-washing essentially follows the interpretation of Conophagos (1989, 100), who analysed stones distributed in circles that were also found at Laurion. For the time being, this interpretation revoked, as a lecture of Prof. em. Dr. G. Papadimitriou emphasised, held at the conference of the “Deutsche Wasserhistorische Gesellschaft” in Athens on 5th—17th March 2015. Daremberg/Saglio (1863, fig. 5009) had reconstructed the cisterns and ore-washing facilities in the valley of Drymos (Souriza), near Agia Triada within the territory of the Athenian silver mines at Laurion.

169 Sánchez-Palencia 1984/85: Fresnedo (Pola de Allande / Asturias / E), Cecos (Ibias / Asturias / E); García Romero 2002, 358 fig. 111, Córdoba (Córdoba / E); Burnham / Burnham 2004, 283 fig. 4.55: Dolaucothi “Carreg-Pumsaint” (Wales / UK); Domergue 1990: Las Rubias (León / E); An unreleased specimen is in the museum at León (E).

170 Wilson 2002, 23; Hirt 2010, 35.

So far, at least three fragments of quartzite stamp mill bases have been observed. Their mass and traces of wear match those of the granite blocks, although the quartzite blocks were only used from two sides, due to the inferior durability of this stone (figs. 4.0-16, 4.0-17).

A unique piece is a biotite-granite runner from a Roman mill, its surface strewn with small troughs. This stone seems to have been re-used as a crushing base for crushing ore by hand, using hammers, as depicted by Georg Agricola (figs. 4.0-18, 4.0-19).<sup>171</sup> As the original location of this stone within the mining zone at Tresminas cannot be exactly determined, two interpretations are possible. Firstly, this stone could have been used for stamping ore-bearing stone from the Galeria dos Alargamentos, as the only crushing base was discovered among a number of ore mills found at its entrance. Another possibility is that 'unofficial' miners used this method after the site had officially been abandoned.

Naturally, stamp mill bases can only be found in those mines where there was the need to crush the ore before other procedures of processing were applied. Alluvial deposits such as at Las Médulas or deposits in alteration zones such as on the Palo del Alto or on the Teleno massif have thus produced only a very small number of stamp mill bases, if any. These gold resources mainly demanded complex washing installations to extract the precious metal. The small number of mortars preserved at Pozos (León, Spain), which were partly built right into the houses, were used solely for the treatment of the ore won from the extraction trenches in and near the village (figs. 4.0-20, 4.0-21).<sup>172</sup>

#### *Molire in farinam = Grinding*

After being stamped down to more or less peaseize, the ore was ground to powder in rotating mills. This procedure corresponds to the '*molire in farinam*' mentioned by Pliny (Natural History 33,69). *Spolia* in the Roman settlement prove that discarded millstones were a welcome construction material. Attempts to determine the exact number of the preserved millstones or their fragments were given up due to their sheer number and their often fragmentary state. However, the concentrations of millstones or their fragments on several sites seem to be a good indicator of the locations of former processing sites.

The rotation mills or round mills — '*molae versatiles*' — have a diameter of two Roman feet (ca. 60 cm). This find group is almost entirely made up of disk-shaped millstones with flat or slightly conical grinding surfaces. Concentric grooves and radial gouges (cut into the stone to roughen surfaces that had become polished through use) are typical signs of wear on these millstones (figs. 4.0-23, 4.0-24).

Only a single specimen of a mill resembling the high Pompeii type was preserved at Tresminas (fig. 4.0-25). It is a runner or upper stone with very delicate cuts for the installation of the drive mechanism. In addition to this,

a sleeper stone of a mill of the same type could be identified; its mass and the quality of the stone used suggest that more than one of these mills was in operation at Tresminas (fig. 4.0-26).

With a diameter of 60 cm, the ore mills needed a lot more power for the grinding process than the grain mills with diameter of only 45 cm. Accordingly, we can safely assume that the ore mills were part of technical installations and operated by either two men or by animals.

#### **The wet processing stages of treatment<sup>173</sup>**

The dry mechanical stage was followed by wet processing stages such as washing, during which the gold was separated from lighter stone materials.

#### *Ore-washing facilities*

The installations for wet processing are among the largest monuments that are connected to the ore deposits at Tresminas. On a steep hill with a rather even slope, two parallel rows with 17 platforms in each row have been preserved. Every second platform of the western row also has a circular sedimentation basin on both sides (figs. 4.0-27a/b/c—4.0-31). It is very likely that these platforms were once the base for wooden washing tables, on which the finely ground ore sedimented according to its density.<sup>174</sup>

About 1500 years older than the washing installations at Tresminas is an example from the Nubian Desert, where a suitably inclined washing table with a basin on both the start and the end of the table was discovered. A channel leads back from the sedimentation basin to a basin below the head of the washing table, where the water had to be scooped back onto the washing table in order to enable an ore-washing circuit (figs. 4.0-4).<sup>175</sup> In the passage from Diodorus of Sicily cited above, a wooden washing board is explicitly named, over which the gold is separated from the earth with the help of water, as the gold gets stuck on the board due to its greater weight.

Such a washing board was found in the ancient mines at Seix in the French Pyrenees (Dép. Ariège). It is four metres

171 Agricola et al. 1950, 269—270.

172 Several Roman mines contain stamp mill bases with just a single, but rather deep, hole (figs. 4.0-20—4.0-22b). The examples at Pino del Oro (Province Zamora, E) indicate that the extracted ore is very likely to have been ground rather than stamped, with the grinding taking place at several locations on the site, which feature rectangular hollows in the granite. However, it is unclear whether the use of hollows in preference to stamp mill bases is connected to the poor quality of the local granite (figs. 4.0-22a/b). Sánchez Palencia et al. 2012, 200—208.

173 Wahl-Clerici 2016; Wahl-Clerici 2017.

174 Wahl 1997, 66 fig. 15.

175 Castiglioni et al. 1995, 31.175.



long, 1.10 metres wide and exceptionally thick. It was made from nine segments of wood joined together (fig. 4.0-5).<sup>176</sup>

The depiction of a washing table in the mining textbook from Schwaz (Austria) shows close similarities to the about 1700—1800 years older Nubian example (figs. 4.0-4, 4.0-32).<sup>177</sup> The hole in the tub allowed for a constant inflow of water, which needed to be neither too strong nor too weak.

Installations for the processing of ore from the mines of Attica are well preserved in Drymos (Souriza), close to Agia Triada (fig. 4.0-33).<sup>178</sup> For ore-washing, areas of 4 to a maximum of 20 m long have been defined, each supplemented by channels and sedimentation basins. On the front side of these squares, a water tank was constructed and plastered with waterproof *opus signinum*. The walls of these tanks comprised a number of small holes, set at even intervals (fig. 4.0-34). Apparently, water was carried onto the washing tables that were set in a tilted position. Eventually, the soiled water was carried to the sedimentation basins, where it remained until the dirt particles could settle; the water was then used again.<sup>179</sup>

A different type of ore-washing facility was discovered on the mining sites of deposits in alteration zones, e.g. in the Teleno massif (León, Spain) or on the Alto del Palo (Asturia, Spain). Here, particularly long vertical trenches with several steps served the settling of the gold. This is indicated by dams in the upper parts of these trenches that, assuming the availability of a water supply, were very likely connected to ore-washing processes (figs. 4.0-35, 4.0-36).<sup>180</sup>

Those facilities match the so-called *agogae* mentioned by Pliny, Natural History 33,76—78:

*fossae, per quas profluat, cavantur—agogas vocant—; hae sternuntur gradatim ulice. frutex est roris marini similis, asper aurumque retinens. latera cluduntur tabulis, ac per praeupta suspenduntur canales. ita profluens terra in mare labitur ruptusque mons diluitur, ac longe terras in mare his de causis iam promovit Hispania. (77) in priore genere quae exhauriuntur immenso labore, ne occupent puteos, in hoc rigantur. aurum arrugia quaesitum non coquitur, sed statim suum est. inveniuntur ita massae, nec non in puteis, et denas excedentes libras; palagas, alii palacurnas, iidem quod minutum est baluceum vocant. ulex siccat, uritur, et cinis eius lavatur substrato caespite herboso, (78) ut sidat aurum.*

Trenches are excavated for the water to flow through—the Greek name for them means ‘leads’; and these, which descend by steps, are floored with gorse—this is a plant resembling rosemary, which is rough and holds back the gold. The sides are closed in with planks, and the channels are carried on arches over steep pitches. Thus the earth carried along in the stream slides down into the sea and the shattered mountain is washed

away; and by this time the land of Spain owing to these causes has encroached a long way into the sea. (77) The material drawn out at such enormous labour in the former kind of mining so as not to fill up the shafts is in this latter process washed out. The gold obtained by means of an *arrugia* does not have to be melted, but is pure gold straight away. In this process nuggets are found and also in the shafts, even weighing more than ten pounds. They are called *palagae* or else *palacurnae*, and also the gold in very small grains *baluce*. The gorse is dried and burnt and its ash is washed on a bed of grassy turf (78) so that the gold is deposited on it.

Finally, the question arises as to when the well-preserved ore washing plants of Tresminas were built. Given their location, it cannot be ruled out that they were only built at a time when mining was already at an advanced stage, together with the earth dam and the C2 water pipeline. This means that older ore washing plants already existed. This is also indicated by the fact that most of the water pipes were led into the mining zone. It is most likely that these washing plants were located in the immediate vicinity of the stamp mills and the ore mills.

## Smelting

In 1993, H.-G. Bachmann developed and published a hypothetical processing and smelting system, since then further elaborated, for the ore from Tresminas and Jales (fig. 4.0-6).<sup>181</sup>

Bachmann used processing systems from the 19th century as a model, as they are known from Freiberg (Sachsen, Erzgebirge/D) or St. Andreasberg (Goslar, Harz/D). Additionally, he followed F.A. Harrison, who on the basis of slag finds assumed that the Romans used large amounts of lead for the poly-metallurgic processes.<sup>182</sup> Bachmann's studies on ore, free gold and a flotation concentrate from a lode at Jales and on slags and slack coal from the ‘Fornos Mouros’ support this hypothesis (fig. 4.0-37). His results also correlate with Pliny's comments (Natural History 33,66—78).

176 Daremberg/Saglio 1877, 1863 fig. 5010.

177 Bartels et al. 2006, vol. 1, 150.

178 Ardaillon 1897, fig. 20 and fasc. LXXVII; Daremberg/Saglio 1877, 1862—1863 with a detailed depiction of the individual washing installations fig. 5008; Conophagos 1980, 19 figs. 4—5, 20 fig. 3.

179 Daremberg/Saglio 1877, 1862—1863.

180 Bird 1972, 46 fig. 8; Those trenches were surely not dug for the sampling of the hill, as suggested by Domergue 1987, 423; Wahl-Clerici 2017, esp. figs. 6 and 7.

181 Bachmann 1993, 159; Wahl 1998, 67; See also Martins 2008, fig. 19.

182 Harrison 1931, 141.

After being stamped and ground, the pulverised ore was washed in order to extract the free gold by gravity separation. Refractory gold needed to be smelted, as is was either tightly interwoven with sulphides such as pyrite, arsenopyrite, pyrrhotite and galenite, or bonded on the atomic level to the crystal structure of pyrite or arsenopyrite. In a first step, these sulphides had to be decomposed by roasting. Roasting was also necessary to diminish the high amounts of arsenopyrite (FeAs) and pyrite (FeS<sub>2</sub>), as high contents of these substances would have been a hindrance to the next stages of smelting. Roasting led to the elimination of sulphur, arsenic, sulphur dioxide and arsenic trioxide.

Evidence for roasting processes are supplied by a slag-like sample (fig. 4.0-38 Table 1, sample W2) that was ground to a black powder; its components indicate that the sample consists of roasted and ground ore concentrate, which means that it must be residue from the roasting process.

The roasted material was then ground and put to the so-called lead smelting, together with lead and charcoal. During this stage, fluid lead-metal is generated. Lead in its fluid state has the ability to bind precious metals such as gold and silver to itself. The result of these processes is the so-called 'rich lead' in which the precious metal is concentrated. In the following stage, this material was smelted further until the molten rich lead had the desired concentration of precious metals and further processing was fruitful. The quantity of iron generated in the material during these stages was removed by adding quartz.

X-ray fluorescence analyses by Bachmann<sup>183</sup> and Wiechowski (fig. 4.0-38) and the determination of the components using a microscope and by x-ray diffraction analysis have confirmed that the slags are typical iron silicate slags with amounts of sulphide and lead. According to Harrison, the slag contained lead drops with some amounts of gold and silver.<sup>184</sup> Bachmann notes:

This material [the cinder breeze] has obviously been processed mechanically, just like the ore. Crushed and ground slags are often observed at early smelting sites. Efforts were made to separate the metal droplets trapped in the slags or other valuable materials (e.g. sulphuric copper and/or lead/stone phases) from the worthless slag silicate matrix to be rejected. . . . Nor can it be ruled out that slags were also pounded and possibly ground. Harrison points out in particular that millstones and stamp mill bases are often found in the same site 'in situ' as slags.

Bachmann emphasises the fact that both stamping and grinding processes were not only utilised for the processing of ore but also for the recycling of slags; such recycling was apparently considered worthwhile because of the lead drops (rich lead with amounts of precious metals) con-

tained in these slags. The recycled product was therefore put to lead smelting for a second cycle.<sup>185</sup>

Gold and silver were now separated from the lead and other metals. This was done via the so-called 'cupellation' process. During this heating process, lead was turned into a lead oxide, or litharge, layer. When this layer was pulled off, only the material, a gold-silver alloy remained. The litharge was put into the kiln again, along with the roasted ore to serve as aggregator for precious metals.

Pliny mentions the cupellation (Natural History 33,60):

*... ut purgetur, cum plumbo coqui.*

... for the purpose of purifying it is roasted with lead.

The lead ingot found at Campo de Jales is evidence of these processes. As the amount of lead in the vein at Jales lies at only 5.5 per cent, we can assume that the larger part of it was used for smelting on the site.

The separation of gold and silver was achieved via the process called cementation. During this process, the alloy was heated in crucibles together with common salt and additives. The gold was not damaged during this process, while the silver went into the slag — this slag could then be used to extract pure silver (with lead smelting and cupellation).

Interestingly, Pliny puts his description of the cementation process into context with gold as a cure for diseases. The relevant passage reads as follows (Natural History 33,84)

*torretur et cum salis gemino pondere, triplici misyis ac rursus cum II salis portionibus et una lapidis, quem schiston vocant. ita virus trahit rebus una crematis in fictili vase, ipsum purum et incorruptum.*

Gold is also heated with twice its weight of salt and three times its weight of copper pyrites<sup>186</sup>, and again with two portions of salt and one of the stone called 'splittable.'<sup>187</sup> Treated in this way it draws poison out, when the other substances have been burnt up with it in an earthenware crucible while it remains pure and uncorrupted itself.

<sup>183</sup> Bachmann 1993, 156.

<sup>184</sup> Harrison 1931, 141.

<sup>185</sup> It cannot be excluded that stamp mill bases found in secondary deposits or alteration zones were used in the smelting process described here.

<sup>186</sup> *misy* = weathered chalcopyrite? Fuchs et al. 1993, 24–25, 44.

<sup>187</sup> *schistos* = alum shale? Fuchs et al. 1993, 24–25, 44.



Fig. 4.0-1a: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas, from the east (photo: J. Wahl).



Fig. 4.0-1b: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha, from the west (photo: R. Wahl-Clerici).



Fig. 4.0-1c: *Territorium metallorum* Tresminas/Jales, Tresminas, from the west: extraction in the mine at Lagoinhos (photo: R. Wahl-Clerici).



Fig. 4.0-1d: *Territorium metallorum* Tresminas / Jales, Gralheira, from the east: remains of the glory hole trenches and the waste rock dump on both sides (photo: R. Wahl-Clerici).



Fig. 4.0-1e: *Territorium metallorum* Tresminas / Jales, Jales: remains of the Roman extraction at Campo de Jales southwest of Highway N212 (Google Earth, photo taken: 31.08.2013, last view: 02.07.2017).



Fig. 4.0-2: *Territorium metallorum* Tresminas / Jales, treatment zone at Forno dos Mouros, from southsoutheast (photo: J. Wahl).

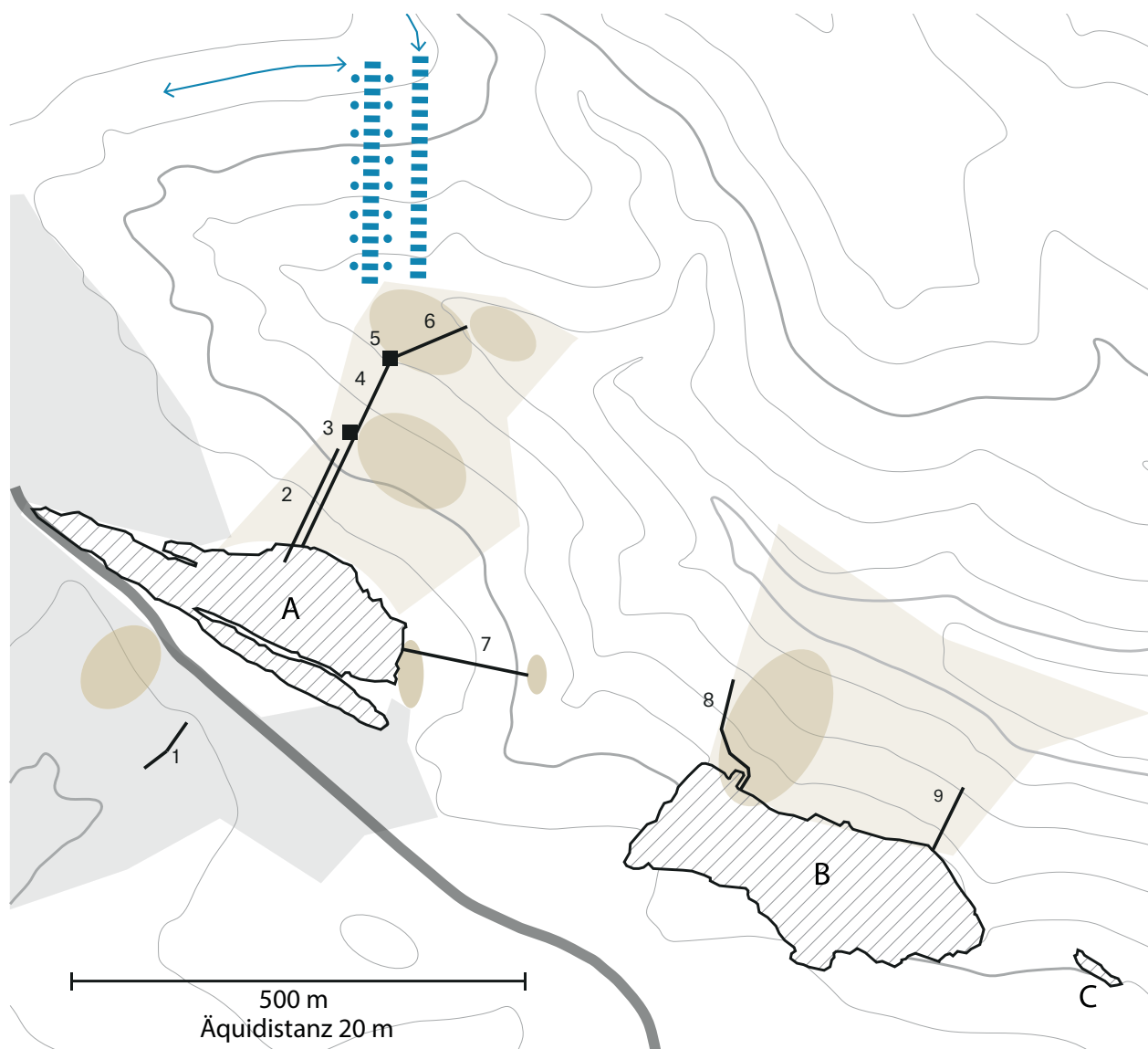


Fig. 4.0-3: *Territorium metallorum* Tresminas/ Jales, Tresminas: view over the treatment areas in the core zone.

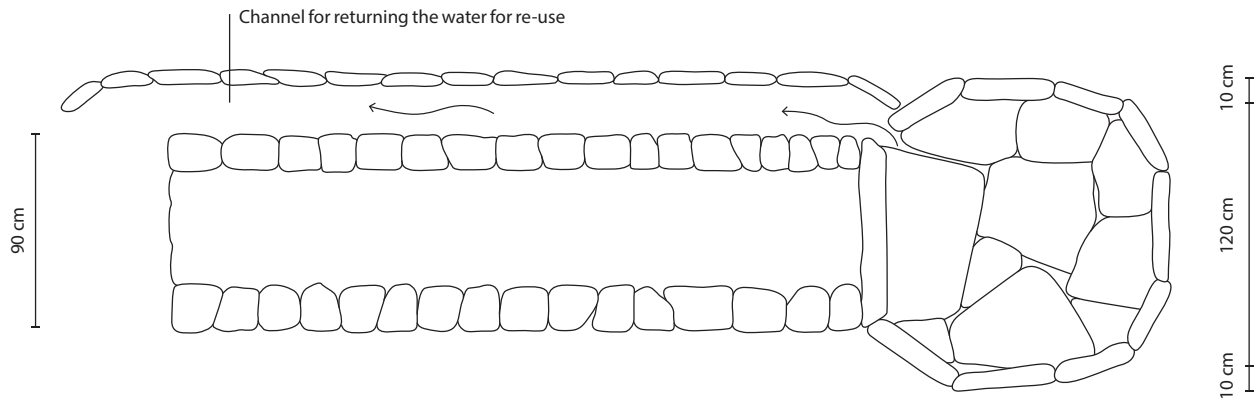
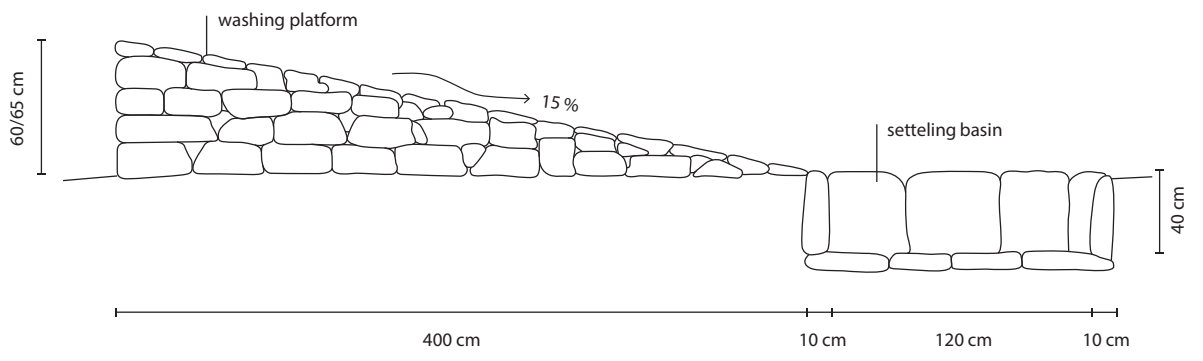
Dark shading: processing sites with high concentrations of stamp mill bases and ore mills as well as sterile material, which may have been processed.

Light shading: zones with scattered stamp mill bases and ore mills

Grey shading: settlement zone

(Documentation: R. Wahl-Clerici, A. Wiechowski, template: J. Wahl, R. Wahl-Clerici, design: R. Wahl-Clerici).





4.0-4: Nubia: ore washing platform dating to the Bronze Age (after Castilgioni et al. 1998, 175).

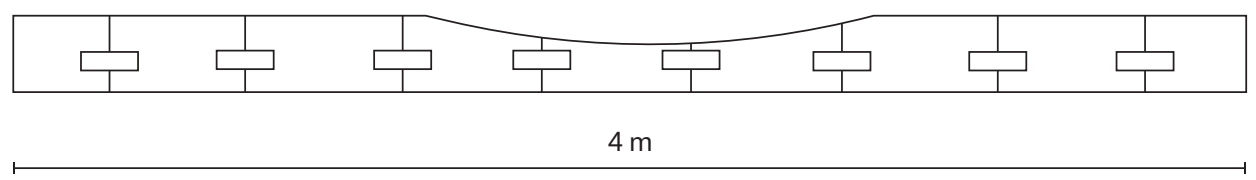


Fig. 4.0-5: Drawing of a preserved platform for ore washing from the Seix (Ariège/F) mines (after Daremberg/Saglio 1877, fig. 5010).

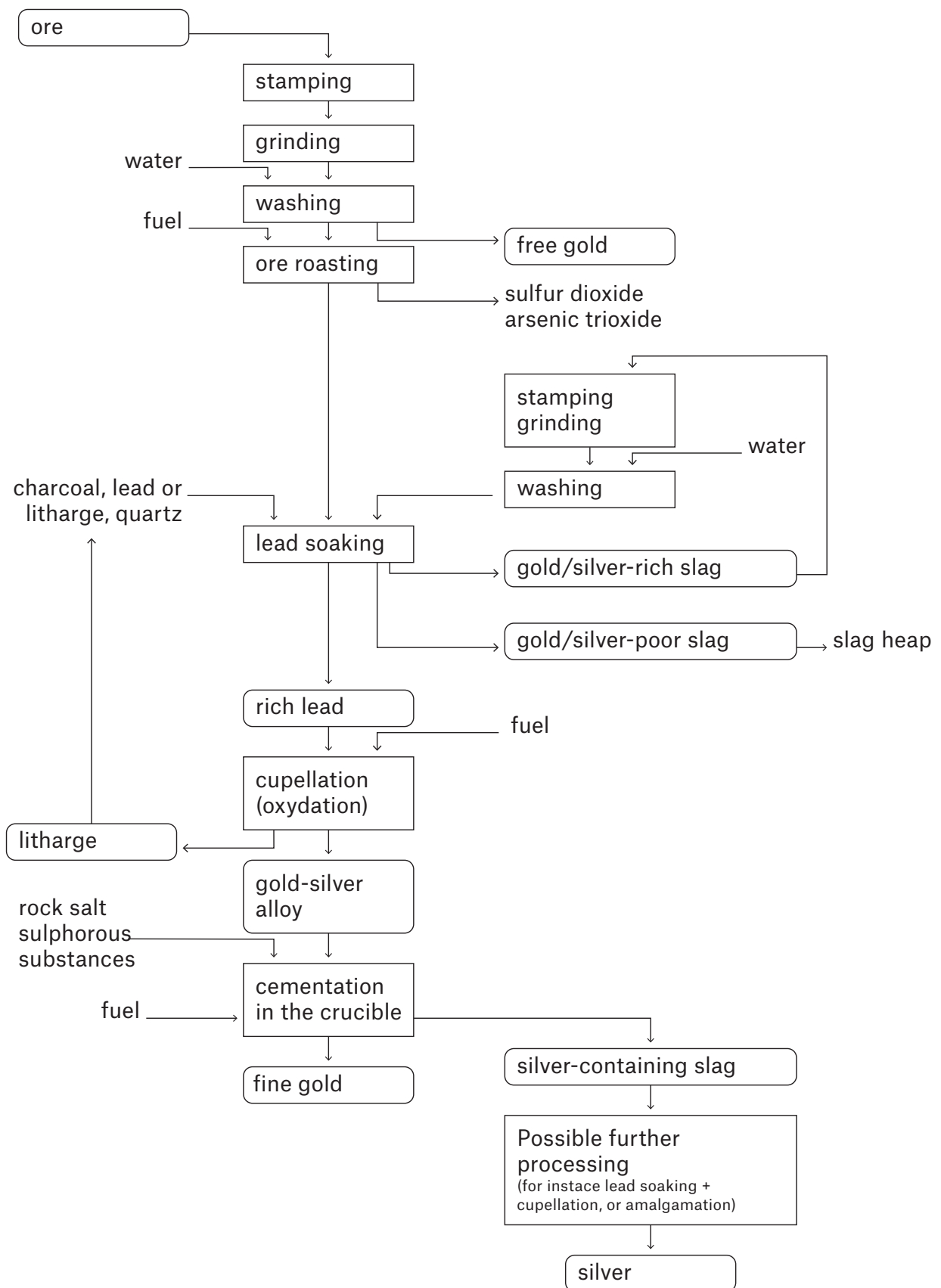


Fig. 4.0-6: Roman processing of the gold-silver ores of Tresminas and Campo de Jales. Proposal for a possible sequence of procedures (after Bachmann 1993, fig. 1).



Fig. 4.0-7a: Schwazer Bergbuch: Boys picking rock (after Bartels et al. 2006, 149).



Eine lange Klaubetafel A. Tröge B. Erzfüßchen C.

Fig. 4.0-7b: Agricola  
(after Agricola 1556/1984, 232).  
Long table A; tray B; tub C  
(after Agricola et al. 1950, 268).

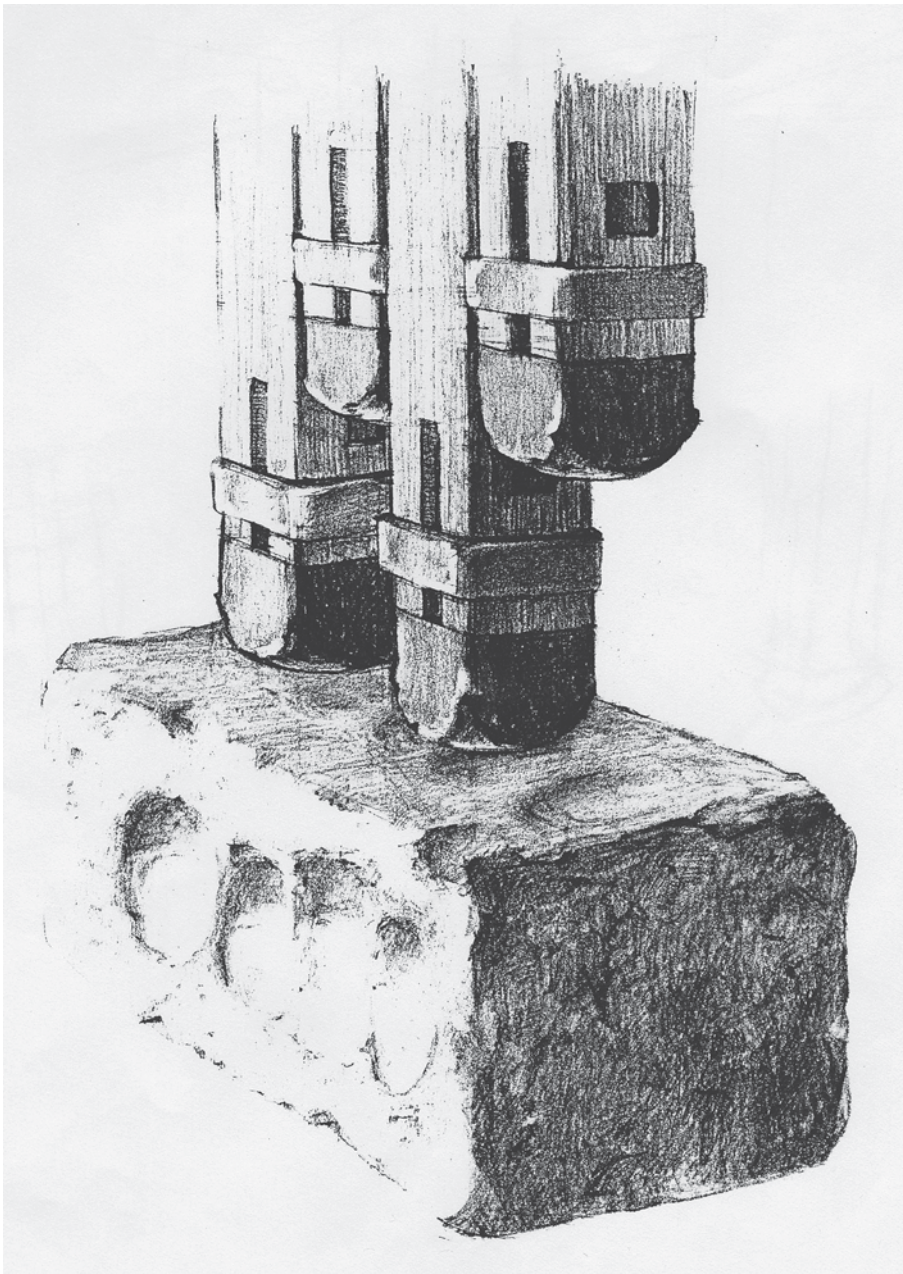


Fig. 4.0-8: *Territorium metallorum Tresminas / Jales*: mortar with stamps (template J. Wahl, design: P. Moser).



Fig. 4.0-9: *Territorium metallorum* Tresminas/Jales, Ribeirinha: use of the stamp mill bases from the extraction zone mostly as corner stones (photo: R. Wahl-Clerici).



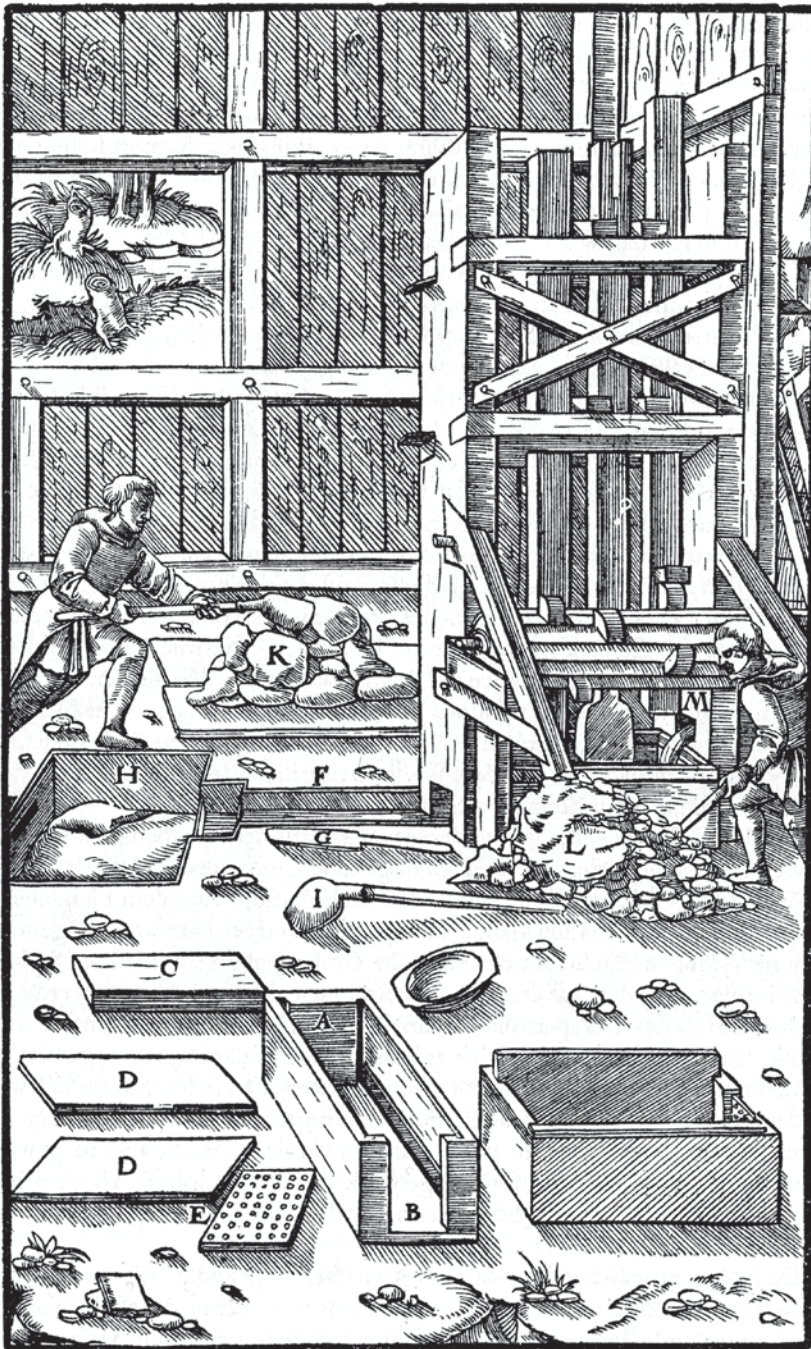
Fig. 4.0-10: *Territorium metallorum* Tresminas / Jales, Forno dos Mouros: mortar. The hollows are not regularly distributed over the area, probably because the free zone of about 15—20 cm, was used for the attachment of the stamp. The second hollow at the bottom left shows disruptions in the working process (photo: J. Wahl).



Fig. 4.0-11: *Territorium metallorum* Tresminas / Jales, Tresminas: base of a heavily worn mortar (photo: J. Wahl).



Fig. 4.0-12: *Territorium metallorum* Tresminas / Jales, Tresminas: broken mortar, used on all four sides. In the cross section, the different wear and tear is visible in the variation of the depth of the hollows (photo: R. Wahl-Clerici).



Der Pochtrog A. Die offene Seite des Pochtroges B. Der Sohlstein C. Die eiserne Pochsohle D. Das gelochte Blech E. Das Gerinne F. Die hölzerne Schaufel G. Der Sumpf H. Die eiserne Schaufel I. Ein Haufen gepochtes Erz K. Das Erz, welches gepocht werden soll L. Der Wasserzufluß M.

Fig. 4.0-13: Representation of a stamp mill (after Agricola 1556/1984, 271). Mortar A; open end of mortar B; slab of rock C; iron sole plates D; screen E; launder F; wooden shovel G; settling pit H; iron shovel I; heap of material which was settled K; ore which requires crushing L; small launder M. (after Agricola et al. 1950, 313).



Fig. 4.0-14: *Territorium metallorum* Tresminas / Jales, Ribeirinha: arch made from the reused mortars (photo: R. Wahl-Clerici).





Fig. 4.0-16: **Territorium metallorum** Tresminas / Jales: quartzite stamp mill base, used from both sides in Roman times and later re-used as a stairway in Covas (photo: R. Wahl-Clerici).



Fig. 4.0-17: **Territorium metallorum** Tresminas / Jales, Tresminas: fragment of a quartzite stamp mill base (photo: R. Wahl-Clerici).



Fig. 4.0-18: **Territorium metallorum** Tresminas / Jales, Tresminas: millstone (meta) for the crushing of the ore, later used as a mortar (photo: R. Wahl-Clerici).



*Eine Stufe Erz A. Der Quetscher B. Der eiserne Meißel C. Der Stock D. Die Schere E.*

*Fig. 4.0-19: Manual stamping (Agricola 1556/1984, 233). Masses of metal A; hammer B; chisel C; tree stumps D; iron tool similar to a pair of shears E (after Agricola et al. 1950, 269)*



*Fig. 4.0-20: Pozos (Prov. León / E): heavily used stamp mill base for at least three stamps (photo: R. Wahl-Clerici).*



*Fig. 4.0-21: Pozos (Prov. León / E): heavily used stamp mill base for a single stamp, reused in the construction of a house (photo: R. Wahl-Clerici).*



4.0-22a: Pino del Oro (Prov. Zamora/E): ore crushing area with visible hollow in the centre (photo: R. Wahl-Clerici).



Fig. 4.0-22b: Pino del Oro (Prov. Zamora/E): presumed locations for crushing the extracted ores. These ore crushing areas are distributed over a large part of the terrain (photo: R. Wahl-Clerici).



Fig. 4.0-23: *Territorium metallorum* Tresminas / Jales, Forno dos Mouros: modern wall built with millstones for ore crushing (photo: J. Wahl).



Fig. 4.0-24: *Territorium metallorum* Tresminas / Jales, Tresminas: round millstone for ore crushing with worn grooves and sharpening notches, (a) from the top, (b) fracture point with clearly visible cuts for fixing the drive mechanism (photo: R. Wahl-Clerici).



Fig. 4.0-25: *Territorium metallorum* Tresminas / Jales, Tresminas: surface find of a granite runner from a different mill-type for further milling the stamped ore (photo: R. Wahl-Clerici).



Fig. 4.0-26: *Territorium metallorum* Tresminas / Jales, Tresminas: surface find of a sleeper from a different mill-type for further milling the stamped ore (photo: R. Wahl-Clerici).



*Fig. 4.0-27a: **Territorium metallorum** Tresminas / Jales, Tresminas: view of the ore washing installations from the south. The platforms of the western row are accompanied by two settling tanks each at every second platform (photo: R. Wahl-Clerici).*

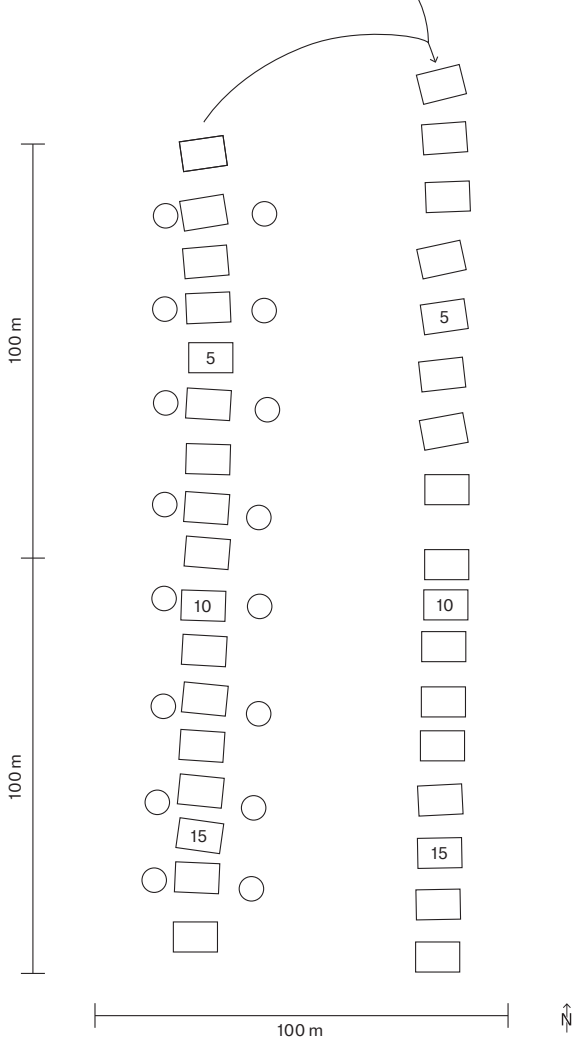


Fig. 4.0-27b: *Territorium metallorum* Tresminas / Jales, Tresminas: plan of the ore washing installations (documentation J. Wahl, R. Wahl-Clerici, design: R. Wahl-Clerici).

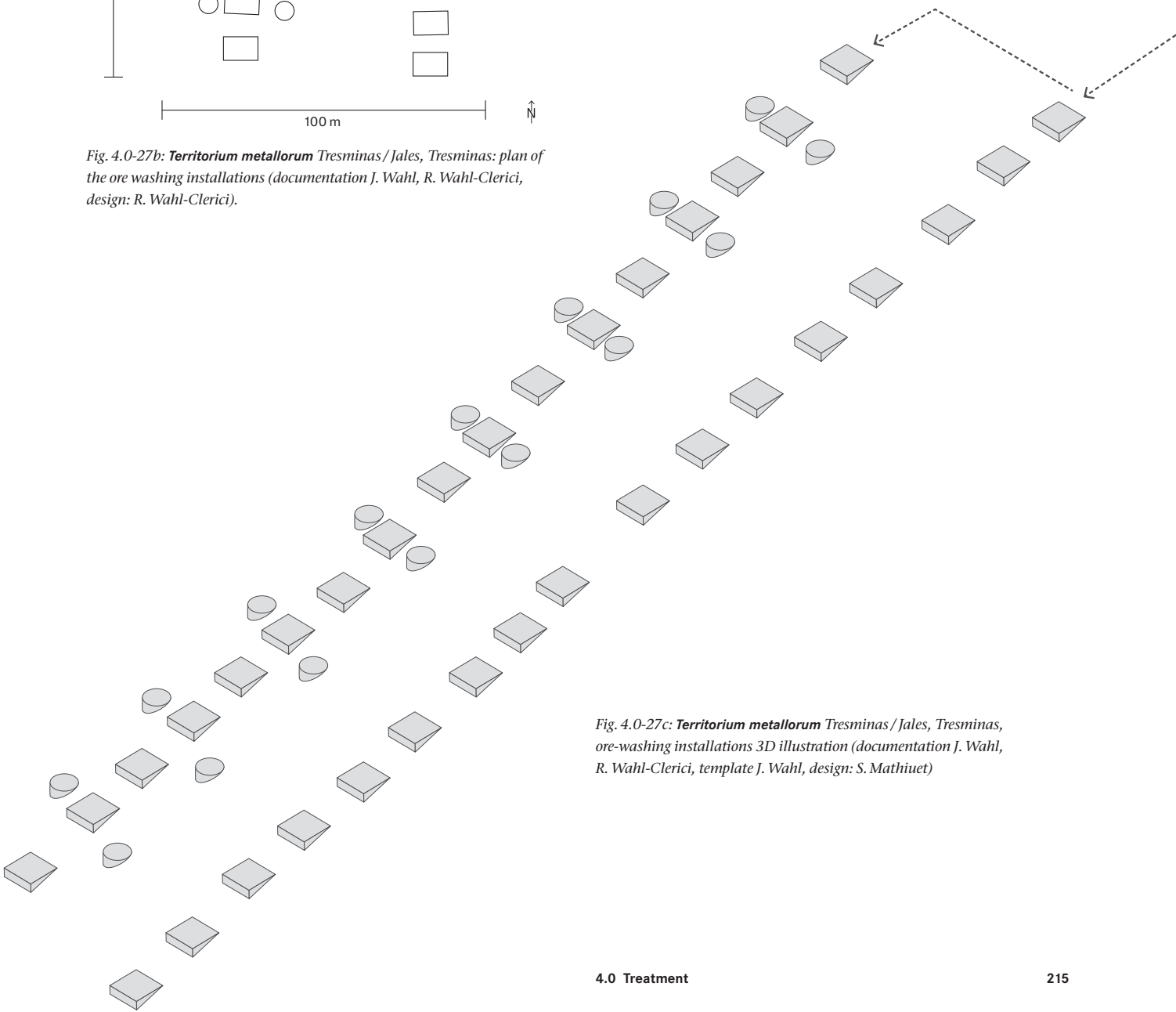


Fig. 4.0-27c: *Territorium metallorum* Tresminas / Jales, Tresminas, ore-washing installations 3D illustration (documentation J. Wahl, R. Wahl-Clerici, template J. Wahl, design: S. Mathiuet)





Fig. 4.0-28: *Territorium metallorum* Tresminas / Jales, Tresminas: platforms 1—4 (from top to bottom) of the eastern row. In the background the incision in the rock for the water supply (photo: P. Moser).

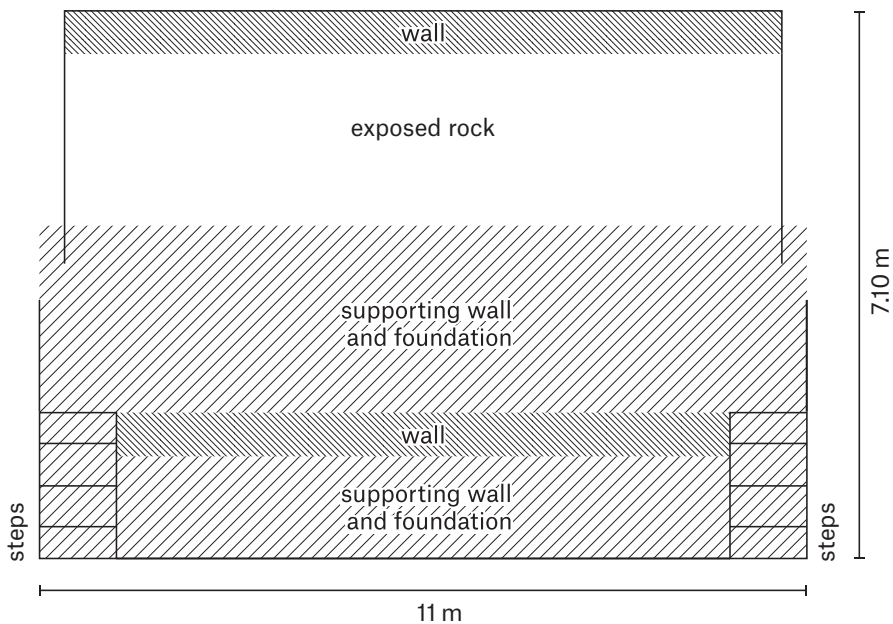


Fig. 4.0-29: *Territorium metallorum* Tresminas / Jales, Tresminas: schematic plan of an excavated ore washing platform (recording A. Wiechowski, R. Wahl-Clerici, design: R. Wahl-Clerici, S. Mathiuet).



Fig. 4.0-30: *Territorium metallorum* Tresminas / Jales, Tresminas: supporting wall for one of the platforms of the eastern row (photo: R. Wahl-Clerici).

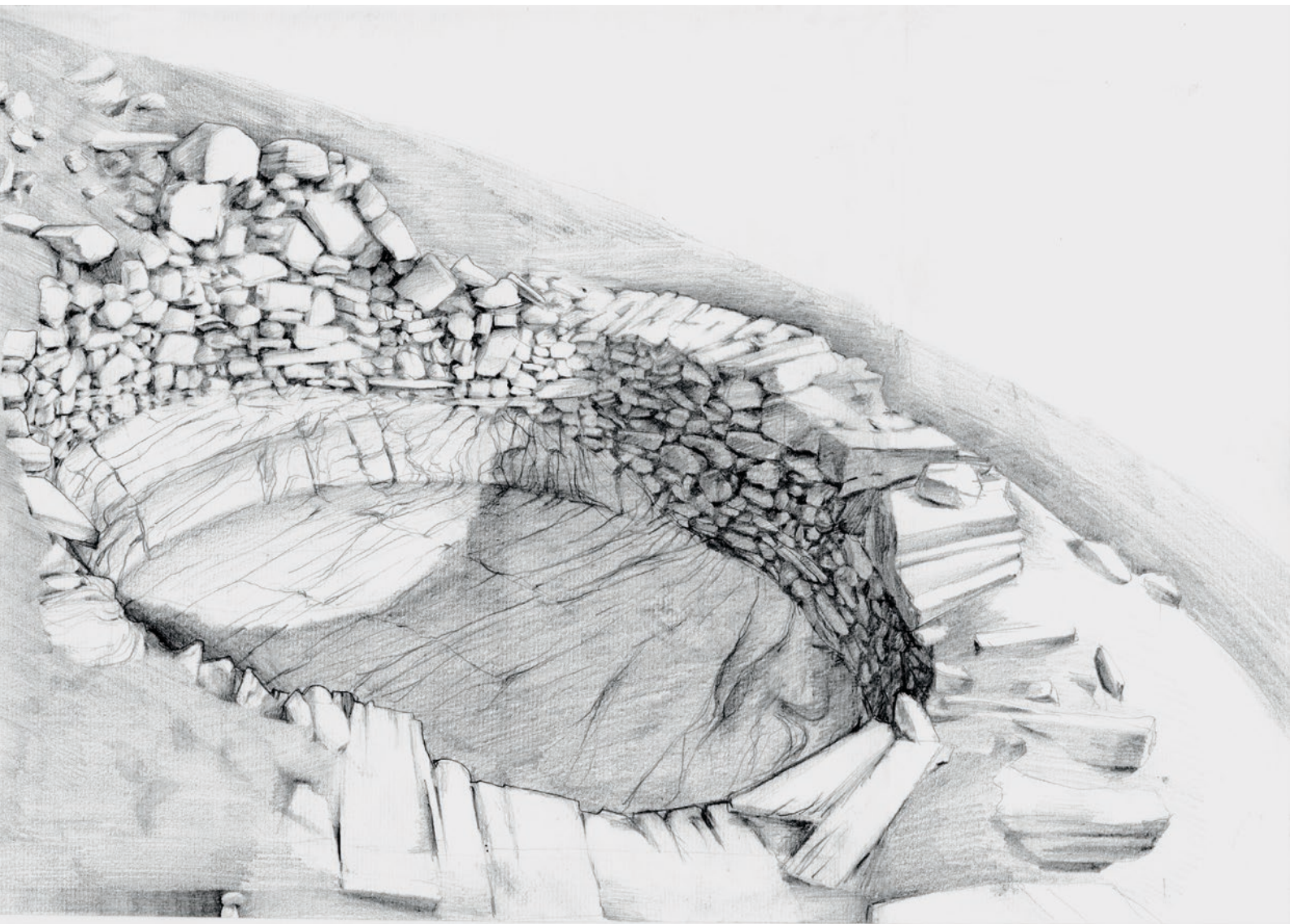


Fig. 4.0-31: *Territorium metallorum* Tresminas / Jales, Tresminas: sedimentation basin of the western row of ore washing platforms (photo: P. Moser).



Fig. 4.0-32: *Schwazer Bergbuch*: Installation for ore washing (after Bartels et al. 2006, 150).

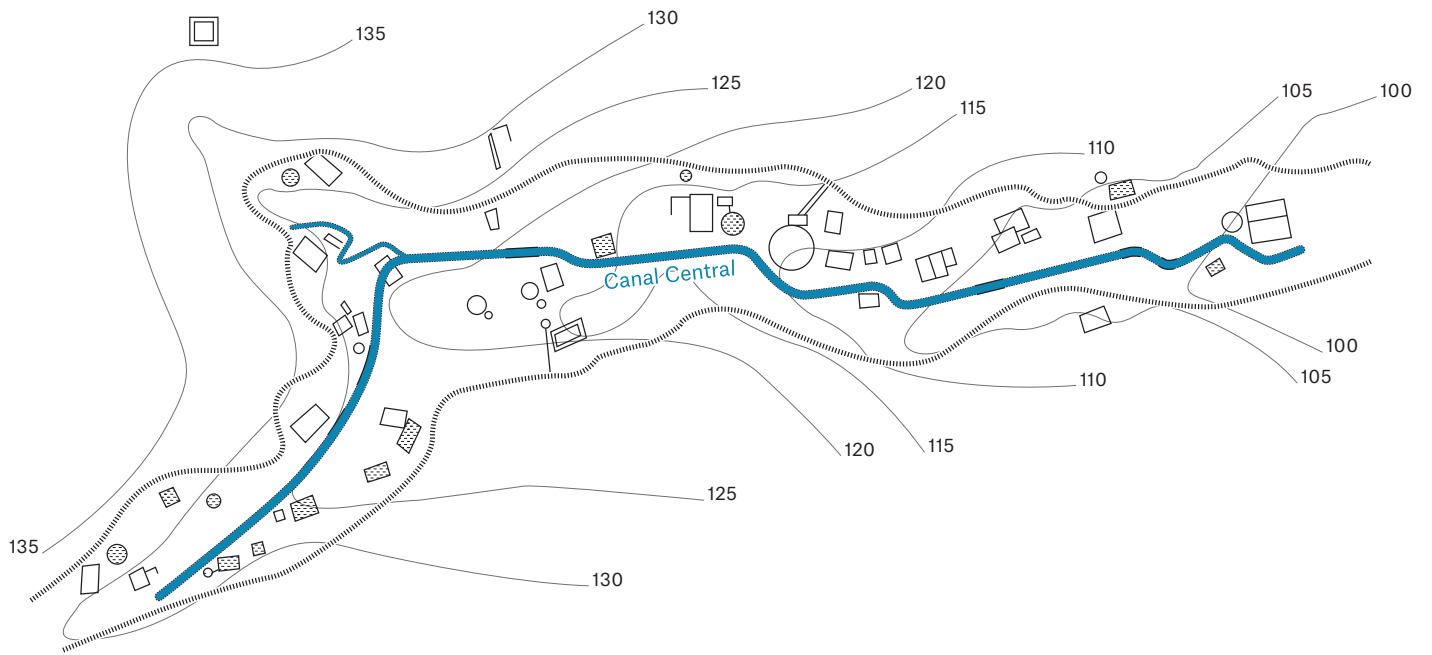


Fig. 4.0-33: Ore washing installations of the Laurion silver mines in the Drymos (Souriza), close to Agia Triada (Attica / GR) (after Daremberg / Saglio 1896, fig. 5009, design: S. Mathiuet).

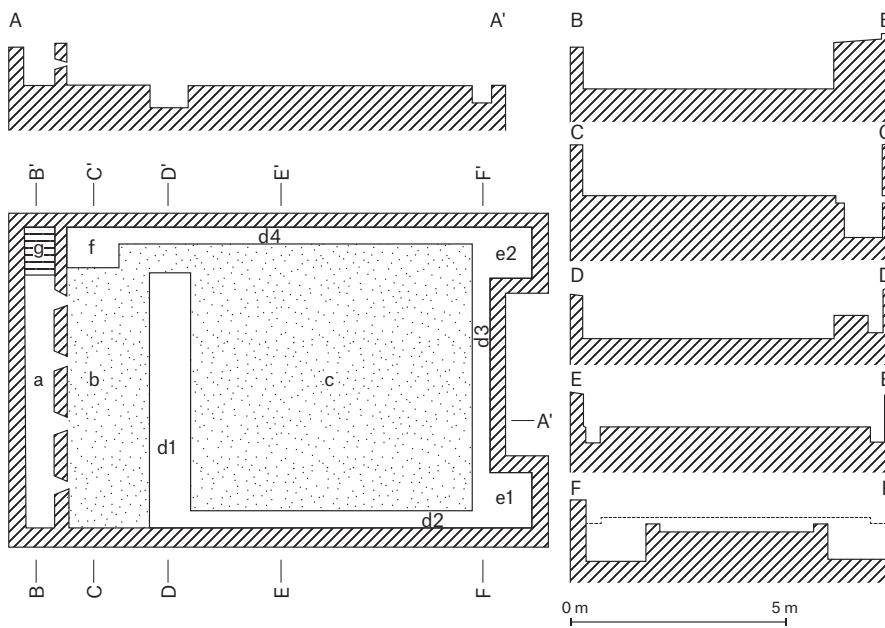


Fig. 4.0-34: Ore washing installations of the Laurion silver mines in the Drymos valley (Attica / GR): washing platform with interconnected settling tanks (after Domergue 2008, 149 fig. 92, design: S. Mathiuet).



*Fig. 4.0-35: Alto del Palo (Prov. Asturias / E): ore washing installation from above. The vegetation marks the individual steps, or rather the ledges between them (photo: R. Wahl-Clerici).*



*Fig. 4.0-36: Alto del Palo (Prov. Asturias / E): water reservoir above an ore washing installation (photo: R. Wahl-Clerici).*



Fig. 4.0-37: *Territorium metallorum* Tresminas / Jales, Forno dos Mouros: waste dump with slag from smelting ore (photo: J. Wahl).

	slack coal		lumpy slag					
	Bachmann	Sample 18	Bachmann	Sample 21	Sample W1	Sample W3	Sample W4	Sample W2
Fe <sub>2</sub> O <sub>3</sub> %	28.9	31.88	37.90	35.01	35.91	12.52	24.57	62.00
MnO	0.2	0.14	0.20	0.25	0.21	0.05	0.05	0.04
TiO <sub>2</sub>	0.4	0.37	0.30	0.58	0.58	0.74	0.58	0.05
SO <sub>3</sub>	2.3	0.54	4.00	0.69				
CaO	2.9	2.39	3.70	2.63	6.94	0.39	1.27	0.10
K <sub>2</sub> O	2.2	2.09	2.00	2.71	3.08	2.91	2.06	0.18
P <sub>2</sub> O <sub>5</sub>	0.4	0.71	0.30	0.54	0.67	0.17	0.41	0.05
Al <sub>2</sub> O <sub>3</sub>	8.8	6.99	5.80	8.13	9.34	15.19	10.6	1.09
SiO <sub>2</sub>	48.5	40.33	39.50	49.46	42.74	50.94	36.96	3.31
MgO	0.4	0.84	0.40	0.78	1.12	1.22	0.42	0.04
Na <sub>2</sub> O		1.06		0.76	0.39	0.26	0.19	0.06
ZnO	1.6	1.95	2.50	0.31	Zn 1.27	1.25	1.14	0.72
PbO	2.6	3.12	2.50	0.99	Pb 3.70	4.70	4.70	4.59
CuO	0.3	1.46	0.30	0.15	Cu 0.16	0.32	0.41	4.33
As <sub>2</sub> O <sub>3</sub>	0.1	1.4	0.10	0.02	As 0.05	0.1	0.16	0.32
Loi%		4.61		3.2	-3.38	2.94	10.58	13.36
Au ppm		7.4		5.4	1.1	13	43	2.4
Ag		188		20	52.4	255	312	550
Ba		<5		90	454	671	326	31
Ni		21		23	13	18	17	337
Co		38		20	7	6	5	38
Cr		18		22	29	72	40	12
Cs		7		11	14	20	10	<0.5
Hf		5		6	5	3	4	<0.5
Rb		100		140	211	175	129	47
Sb		500		62	537	427	846	320
Sc		6.5		7.2	8	14	10	0.5
Ta		96		290	88	21	62	2.4
Ce		350		210	58	71	46	<0.3

Fig. 4.0-38: *Territorium metallorum* Tresminas/Jales, Forno dos Mouros: XRF and neutron activation analyses on slags (table: A. Wiechowski).



## 4.1 The processing areas

Tresminas is remarkable among Roman mines, because here, we can identify both the places and the processes with which the ore was treated to extract the gold based on the finds in the treatment areas. The “Forno dos Mouros” and the ore washing plants in Tresminas can be clearly identified as former ore processing sites. In the mining zone of Tresminas, several further treatment sites have also been identified.

### The Forno dos Mouros

The “Forno dos Mouros” processing site is associated with the mining of the Gralheira deposit (fig. 4.0-2). This is already indicated by the proximity to the Galeria Minhoteira, which is originally Roman, as the processing site is located about 300m upstream, where the valley widens.<sup>188</sup> Whether all the ore mined in the deposits of Gralheira and Campo de Jales was processed at this site cannot be determined with certainty, especially as the appearance of the entire area is much changed today as a result of 20th century mining.

At Forno dos Mouros, the processes of stamping, grinding, and smelting can be demonstrated on the basis of the remains preserved (figs. 4.1-1, 4.0-23, 4.0-37). Evidence of the washing of the already dry-processed ore and the renewed breaking up of rich slags is provided not only by the investigations by Bachmann (discussed above in the context of ore processing), but also by the aqueduct that carried the water from the Rio Peliteira into the area.

High arsenic and lead contents (up to 1.3 wt.% and 0.3 wt.% respectively) were identified in the zone located below Forno dos Mouros and in the field along the river, which have been interpreted as processing residues (fig. 4.1-2). These were presumably caused in part by the smelting smoke produced during ore roasting. The abnormally high arsenic contents are further evidence that Forno dos Mouros was a former processing and smelting site.<sup>189</sup>

### The processing sites in the Tresminas extraction zone

Several processing stations can be identified in Tresminas (fig. 4.0-3). The ore washing plants, which extend over the whole hillside on the other side of the valley on the northern slope of Corta de Covas (figs. 4.0-27a/b/c—4.0-31, 4.1-3,

3.4-2) are conspicuous. Even though the vestiges of the dry-mechanical treatment processes are distributed over the entire mining zone, noticeable concentrations of finds indicate that stamping and grinding took place in at least seven areas. The localization of smelting sites is more difficult. In one of the processing sites at Tresminas, pieces of a silver-rich slag were also found. In these, the silver contained is a result of cementation, which indicates that further processing at the same site must have been heat-intensive. Interestingly, remains of a channel with a maximum width of 45 cm which cannot be assigned to any of the main aqueducts were also found in the vicinity of this processing zone. It is very likely that this canal was also connected to the processing work.

Processing sites are thus characterized by various features and finds, which may be traces or remains of the installations necessary for the processing, such as stamp mills and ore mills, but also the waste from processing, such as slag.

This allows the following indicators to be defined for identifying a processing area:

- Conspicuous concentration of stamp mill bases and ore mills or their fragments (figs. 4.0-3, 4.0-24, 4.1-1, 4.1-4—4.1-6).
- Conspicuous accumulation of waste products generated by the latter processes (e.g. finely crushed rock material in the dump in front of the entrance of the Galeria do Pilar) (fig. 3.4-2).
- Remains of specific treatment processes (e.g. the ore washing plants in Tresminas or the pile of slag breeze at Forno dos Mouros) (figs. 4.0-27a/b/c—4.0-31).
- Water supply installations (fig. 4.1-3).
- Finds of pieces of slag that could only have been produced by a smelting process (e.g. Forno dos Mouros, slag containing silver from Tresminas).

With regard to the first two points, it must be mentioned that the concentrations of mortars and millstones alone is not sufficient to determine processing sites, since most of the reusable remains were transported to the surrounding villages in the post-Roman periods as building material (see figs. 4.0-9, 4.0-14). Not only the presence but also the posi-

<sup>188</sup> The Galeria Minhoteira, which is originally Roman, was re-used in the 1990s in order to test the deposit and was extended and provided with side-tunnels for this purpose.

<sup>189</sup> Wahl-Clerici / Wiechowski 2012, 335.

tion of the stones in relation to the extraction site is crucial for the definition of a processing site. For example, there are only four or five ore millstones in the entrance area of the Galeria dos Alargamentos, but their position is sufficient to assume a former processing site here. A small number of mills was apparently sufficient for the small amount of ore that had to be sampled at this site (fig. 4.1-4).<sup>190</sup>

Of particular interest is also the concentration of stamp mill bases and ore mills located in the entrance area of the Galeria Jürgen Wahl, because this confirms the importance of this tunnel, which lead into the open-cast mine (fig. 4.1-5).<sup>191</sup> In addition, aqueduct T4 seems to end in this area, which indicates that washing installations were present here at a relatively early stage of mining, i. e. probably up to the middle of the 1st century. However, it has not yet been possible to prove this archaeologically. This is possibly connected to the waste rock dumps in the area and their slippage, which may have covered the remains. This would also mean that the ore washing installations on the slope north of Corta de Covas are younger.

Another processing site, possibly related to an early access to the southern extraction zone of the Corta de Covas, can be determined with the help of the combination of stamp mill bases, ore mills, water supply and silver-bearing slag found at the site (fig. 4.0-3).

Four niches cut into the northern slope of the Corta da Ribeirinha are also of particular interest, because in the dump below these, stamp mill bases and ore mill fragments are concentrated, so that the conclusion that these are also former processing sites is not too far-fetched (fig. 4.1-6). These finds indicate that the ore was processed as close as possible to the extraction site. The three stamp mill bases originally found within the Corta da Ribeirinha as well as the isolated fragments of stamp mill bases and ore mills found above the present path also indicate this.

190 It is possible that the round mill re-used as a stamp mill base also originated from the entrance area of the Galeria dos Alargamentos, see fig. 4.0-19.

191 A thorough inspection of the dumps by A. Wiechowski and the author revealed over 300 fragments of ore mills and stamp mill bases on the surface of the dumps just east of and below the entrance. Some of these had been recently used in the former terrace walls.



Fig. 4.1-1: *Territorium metallorum* Tresminas / Jales, Forno dos Mouros: modern mill building, built reusing Roman mortars and millstones (photo: R. Wahl-Clerici).

Trace elements	Sample 1	Sample 2	Sample 3
As	590	1300	800
Cu	60		
Pb	482	601	348
Zn	297	456	246
Ag	2.3	2	1.7
Ni	43	25	20
V	66	1	1
Be	8	510	
Sn	7	2	10
Au	342	982	343
Co	8.3	9	13
Mo	4	1	1
Sb	5.7	0.4	7.7
W	13	32	4

Fig. 4.1-2: *Territorium metallorum* Tresminas / Jales, Forno dos Mouros: some trace element contents from two field samples in alluvial deposits (1 and 2) and a sediment sample (3) from the Forno dos Mouros. Data in ppm, Au in ppb (table: A. Wiechowski).

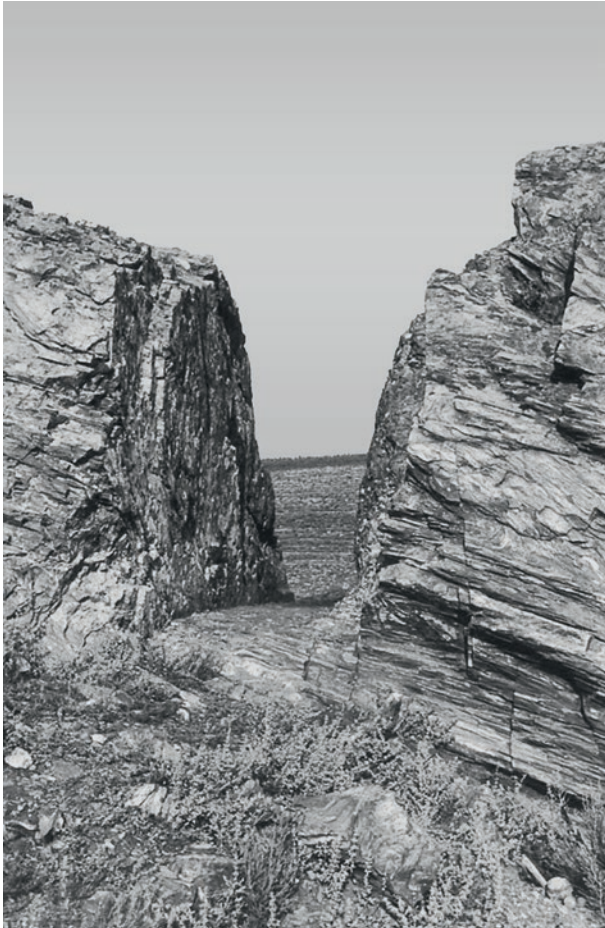


Fig. 4.1-3: *Territorium metallorum* Tresminas / Jales, Tresminas: rock cut above the ore washing installation for aquaeduct C2 (photo: J. Wahl).



Fig. 4.1-4: *Territorium metallorum* Tresminas / Jales, Tresminas: entrance area of the Galeria dos Alargamentos. The millstones have been moved; they originally were outside of the Galeria (photo: R. Wahl-Clerici).



Fig. 4.1-5: *Territorium metallorum* Tresminas / Jales, Tresminas: heavily worn stamp mill bases which were reworked in the post-Roman period in the processing site near the Galeria Jürgen Wahl (photo: R. Wahl-Clerici).

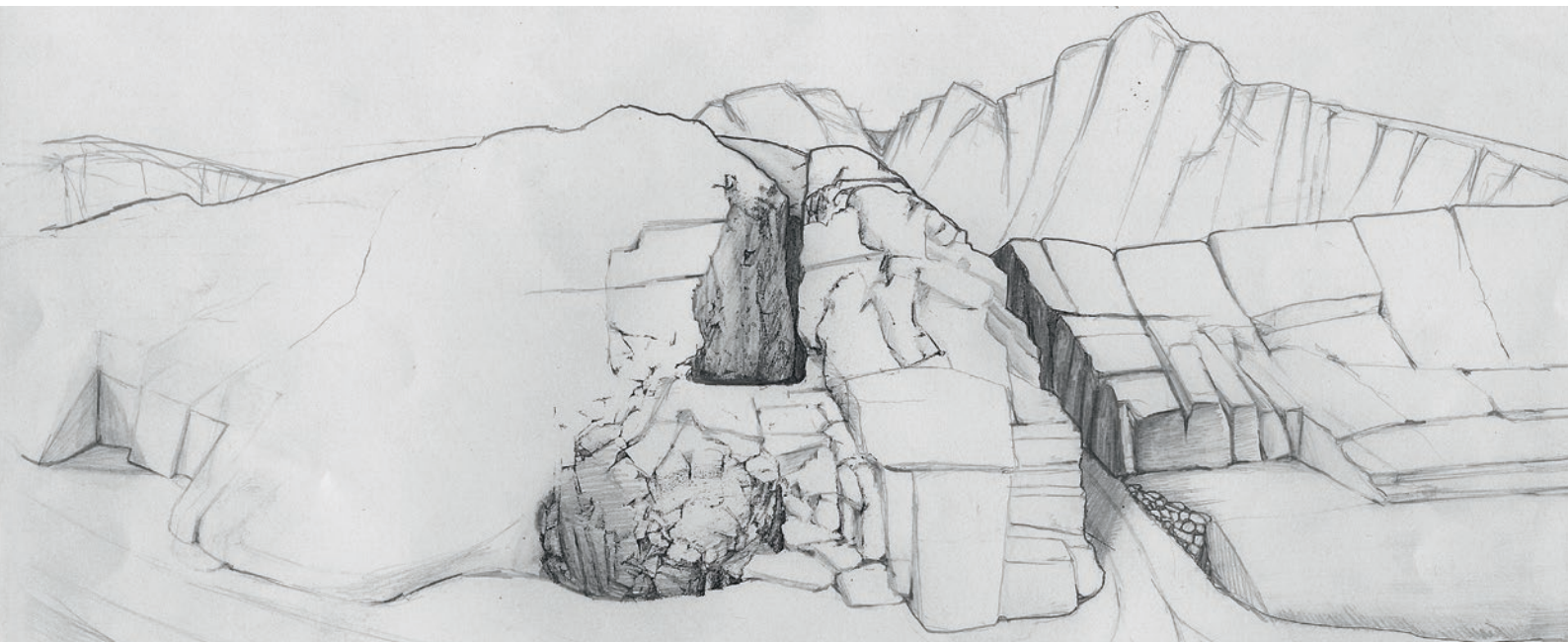


Fig. 4.1-6: *Territorium metallorum* Tresminas / Jales, Tresminas: western entrance area to the Corta da Ribeirinha, with the processing areas cut into the mountain (photo: P. Moser).

## 4.2 The gold contents in the Tresminas, Jales and Gralheira deposits<sup>192</sup>

As the Romans must be presumed to have used their impressive technical possibilities to exploit all the areas containing the profitable ore, it is impossible to know the exact content of gold in the extracted rock at the Tresminas, Gralheira and Jales deposits. However, the question on the amount of gold in the minable veins of these deposits should nevertheless be posed. The basis for such considerations is provided by the surveys carried out repeatedly during the 20th century by Portuguese state institutions such as the Serviço de Fomento Mineiro (today Laboratório Nacional de Energia e Geologia), but also by private companies, most of which were internationally active and specialized in the explorations of mineral deposits.<sup>193</sup> The research of Diogo Rosa is of particular importance for this topic, as he dealt with the gold in the deposits of Tresminas, Gralheira and Campo de Jales in his dissertation, that means in a scientific and not an economic context.<sup>194</sup>

The results available help to draw conclusions about the precious metal content in the extracted rock. At the same time, it should be noted that we can never be certain that mining in certain zones was abandoned solely because of the low precious metal content. Structural changes around A. D. 200 led to significant changes in the Roman economy, which in turn did not remain without effect on the state-organized precious metal extraction.

In connection with a list he published on gold mined in the Roman period, Domergue soberly states that “les quantités produites ont été faibles, eu égard aux statistiques acutelles”.<sup>195</sup> He relies on the limited figures published to date on the total yield (20 tons of gold in Tresminas and 4.7 tons in Las Médulas<sup>196</sup>) and then refers to the difference between Pliny’s statement (Natural History 34,78) that the Asturian, Callaecian and Lusitanian mines produced 20 000 pounds of gold a year (that is just over 6500 kg), and that in no other part of the world has this yield lasted for so many centuries.<sup>197</sup>

*vicena milia pondo ad hunc modum annis singulis Asturiam atque Callaeciam et Lusitaniam praestare quidam prodiderunt, ita ut plurimum Asturia gignat. neque in alia terrarum parte tot saeculis perseverat haec fertilitas.*

According to some accounts Asturia and Callaecia and Lusitania produce in this way 20 000 lbs. weight of gold a year, Asturia supplying the largest amount. Nor has there been in any other part of the world such a continuous production of gold for so many centuries.

In fact, in the previous text Pliny makes explicit reference to gold extracted from alluvial deposits, indicating that gold extracted from primary deposits in the *territorium metallorum* Tresminas/Jales may have been recorded separately.

These few figures alone make it clear that the determination of the quantities of gold extracted is based on assumptions that are by no means certain. Since the written sources do not provide us with sufficient information, we have to base our calculations on four aspects:

- Gold content per tonne of ore
- Fineness
- Mining volume
- Relationship between ore and sterile overburden

### Gold content per tonne of material extracted

In 1993, Bachmann published information on the gold content in Tresminas, Gralheira and Jales as part of his investigations into the processing and smelting of gold-bearing ores. He relies on information from Frank A.

<sup>192</sup> Wahl-Clerici, Considerations on the Profitability of Roman Gold Mining in the Northwest of the Iberian Peninsula during the 1st and 2nd Centuries A. D.

<sup>193</sup> Compiled in Martins/Martins 2017.

<sup>194</sup> Rosa 2009.

<sup>195</sup> Domergue 2008, 209–210, (Translation:) The quantities produced were small when compared to the current statistics of gold production. — Gold production in 2016: 3260,1 tons of newly extracted gold from mines and 1297 tons from recycling (according to <https://www.solit-kapital.de/goldangebot> last accessed 29.04.2018). The information on the recycling of gold on the same site is: “41 mobile telephones contain the same amount of gold as one ton of gold ore.” — Also see <https://www.gold.de/artikel/wie-viel-gold-im-handyl/> (last accessed 29.04.2018): one mobile phone contains 0,024 g gold. — We can conclude that the gold content assumed in the first website is 1 g per ton gold ore.

<sup>196</sup> Bachmann 1993, 154; Sánchez Palencia 2000, 157 and 188. Sánchez Palencia calculates 190 tons for the entire northwest of Spain, based on an assumption of 50 mg Au/m<sup>3</sup> of extracted material. With a specific weight of 2.25 tons of compacted gravel/m<sup>3</sup> this results in an average yield of 0.022 g/ton of extracted material.

<sup>197</sup> Pliny’s reference to the fact that production in Italy, which was even richer in metals, had long since ceased as a result of an old ban imposed by the forefathers is probably a tribute to his patriotism.

Harrison, published in Mining Magazine in 1931.<sup>198</sup> During the soundings of the latter in the ore veins of Jales and Gralheira, high contents of 25 to 75 g Au/ton were determined and average values of approx. 15 g Au/ton were calculated.<sup>199</sup> Further on in his text, Bachmann assumes a concentration of approx. 10 g Au/ton.<sup>200</sup> This amount is essentially based on the reports by Jones (1938) and Reynolds (1965), the latter in turn relying on a lost report from the 1930s written by mining engineer Skelton. They all cite an average value of 10.8 g Au/ton, although it is not clear from the publications mentioned whether this figure refers to all three mineralisations of the *territorium metallorum* Tresminas/Jales (that is, Tresminas, Gralheira and Jales) or only to one of them.<sup>201</sup> More recent studies on the gold mineralisation in northern Portugal show values between 2.05 g and 22.8 g Au/ton in the silicified shale of Tresminas.<sup>202</sup>

In the plans of the Tresminas exploration carried out by Serviço de Fomento Mineiro in the 1970s and 80s, both the gold and silver grades and the sample sizes are recorded. The numbered sampling points, wellmarked in red, can still be unambiguously identified today, so that a precise and unequivocal spatial allocation of the specific precious metal contents is possible (figs. 4.2-1, 4.2-2). In the course of the aforementioned investigations, it transpired that only a small number of the samples contained any gold at all.

#### Corta de Covas

In the area of the fire sites, a uniquely high content of 33.25 g Au/ton was found in one sample (fig. 4.2-3). Subsequently, 4 further values between 0.02 and 1.12 g Au/ton were found. Probes taken in the Galeria do Pilar, which were drilled downwards into the rock behind the cuts for the incorporation of the capstan construction, and thus sampled the zones under the Roman mining, also yielded values of 22.4 g and 20.4 g Au/ton. Gold grades between 0.5 g and 4.8 g and between 0.0 g and 6.6 g Au/ton were measured in the rock from the subsequent samples.<sup>203</sup>

#### Corta da Ribeirinha

Rock from probe drilling in the Corta da Ribeirinha area returned significantly lower values (2.0 g, 2.7 g and 3.0 g Au/ton) and most samples only yielded the merest traces of gold. A higher proportion of gold (11.6 g Au/ton) was found in a survey starting from the Galeria dos Morcegos.

The Galeria Cardoso Pinto, which was only opened in the 20th century, and the adjacent areas in the Corta da Ribeirinha were also sampled intensively. Thanks to the dense sampling, possible concentrations could be detected, as similar values are often grouped spatially. For example, 40.7 g, 18.8 g, 9.0 g and 3.6 g Au/ton or also 25.4 g, 1.2 g and 0.9 g Au/ton were measured at neighbouring locations. All in all, gold was detected in 25 of the 116 samples.<sup>204</sup>

The quartz vein, which closes the Corta in the west and can be followed from the southern ridge through the valley and over the adjoining northern slope, had been sampled several times and turned out to be completely sterile.

#### Lagoinhos<sup>205</sup>

In Lagoinhos, 48 samples were collected from the upper portion of the underground mine, 38 of which contained only traces of gold. In the remaining 10 samples, the two values of 27.7 g and 12.3 g Au/ton respectively are conspicuous. All other examined gold grades range from 0.8 g to 3.6 g Au/ton. Here, too, there is a certain tendency towards a spatial concentration of specific gold grades (figs. 4.2-1, 4.2-2, 3.0.1-6).

#### Gralheira

Only a few values are accessible to us for this deposit, but these are quite high. On their website, the St. Elias Mines, for example, publish information on contents between 8 g and the extremely high concentration of 130 g Au/ton. Harrison reports values such as 77.8 g, 42 g, 28 g and 24 g Au/ton. A compilation by Martins/Martins (2017) showed values between 3.2 g and 143.0 g Au/ton with clearly varying concentrations along the ore vein.<sup>206</sup> Rosa calculated a reserve of 5.8 tons of gold at a grade of 6.1 g/ton to a depth of 180 m for the Gralheira vein.<sup>207</sup>

198 Harrison's calculation was based on the non-metric system. 1 long ton = 1016.05 kg. The difference of less than 2% is meaningless in this context. — Quiring adopted Harrison's data in his publication „The History of Gold“ 1948, 128—130.

199 Jones 1938 still states a value of 98 g Au/ton in his report. Since the designation of origin of the sample is not clear, the value cannot be excluded.

200 Bachmann 2013, 153.

201 Jones 1938; D. G. Reynolds, Tres Minas Property. December 1965.

202 Noronha et al. 2000, 213 Tab. 1.; Due to the consistent consideration of all samples, the mean values given by Machado/Barbosa/Dória/Ribeiro 2006, 1033 for the gold content of 0.8242 g Au/ton in the Corta de Covas and 0.5361 g Au/ton in the Corta da Ribeirinha are clearly below the values given here.

203 Dias Carvalho 1979, 143—144 fig. 2; Martins 2017, Tab. 2: Teores de ouro e prata no minério de algumas explorações no ano de 1936: Corta de Covas. 11.8 g Au/ton, 67.9 g Ag/ton.

204 Martins 2017, Tab. 2: Teores de ouro e prata no minério de algumas explorações no ano de 1936: Corta da Ribeirinha: 4.1 g Au/ton, 16.9 g Ag/t.

205 Wahl-Clerici et al. 2017.

206 Martins/Martins 2017, 160; figs. 8—9 with the distribution of the assayed values. Values of 2.0—140.0 g/ton gold are reported for the Gralheira deposit by the Kernow Resources & Developments Ltd. (KRD). See file:///C:/Users/regul/Desktop/4.2%20in%20Bearbeitung/postt809.html, downloaded 12th November 2019.

207 Rosa 2001, 9: He states therefore that these are relatively small reserves, which at the low gold price of 1998 are hardly worth the effort of mining. — The price of gold 1997/98: 262 Euro/Ounce, 16.05.2020: 1582 Euro/Ounce, in other words, the price of gold has increased approximately six-fold over this period.



## Campo de Jales

A plan with a schematic representation of the gold grades from the modern Campo de Jales mine, in which the extent of Roman mining is marked by a dashed line, shows the distribution of the ore grades (fig. 4.2-4). The zones with more than 7 g Au/ton are substantial, but account for only about 40% of the ore volume. In a few areas 5–7 g Au/ton were present. The 12.98 g Au/ton from the modern mine of Jales should therefore roughly correspond to the values of the rock mined in Roman times.<sup>208</sup>

## Result

As mentioned earlier, all samples from the Tresminas mining zones inevitably originate from the areas no longer exploited. Whether the abandonment of the mines had to do with the decline in profitable gold grades or was due to historical events can no longer be clearly determined today.

Isolated, strikingly high values are referred to as the nugget effect. With the very irregular distribution of gold in the deposit, this means that the samples analysed are not representative, as gold grains accidentally present in the samples can distort the picture significantly.<sup>209</sup>

## The fineness

In addition to the size and gold content of a deposit, the proportions of gold and other valuable metals are also important. This fineness was already known in ancient times. Pliny writes about it (Natural History 33,80):

*Omni auro inest argentum vario pondere, aliubi decuma parte, aliubi octava. in uno tantum Callaeciae metallo, quod vocant Albucrenense, tricentima sexta portio invenitur; ideo ceteris praestat. ubicumque quinta argenti portio est, electrum vocatur; scobes hae reperiuntur in canaliensi.*

All gold contains silver in various proportions, a tenth part in some cases, an eighth in others. In one mine only, that of Callaecia called the Albucren mine, the proportion of silver found is one thirty-sixth, and consequently this one is more valuable than all the others. Wherever the proportion of silver is one-fifth, the ore is called electrum; grains of this are found in ‘channelled’ gold.<sup>210</sup>

Rosa was able to demonstrate this strikingly high gold grade in the Tresminas deposit. Fig. 48 of his 2001 dissertation “Metallogenesis of the Jales Gold district, northern Portugal”, illustrates a histogram showing the various grades of gold fineness in the deposits of Campo de Jales (560–840), Gralheira (600–760) and Tresminas (900–940).<sup>211</sup>

## The volume of extraction

In addition to these values, the volume of rock extracted from the mines is decisive for the calculation of the total yield. For Tresminas, Harrison names a mass of 20 million tons.<sup>212</sup> Since the basis of his calculation, the sketch he published of the Corta de Covas mining area in Tresminas, is wrong in several aspects, this volume must be questioned.<sup>213</sup> Thus his cross-section A through the Corta de Covas shows a complete extraction of the northern area at least up to the level of the Galeria do Pilar, whereby the unmarked position could also be the lower Galeria do Texugo (fig. 4.2-5).

However, the current appearance of the Corta de Covas is based to a large extent on natural rockfalls and the deepest mining took place only in a relatively small zone, as documented by the Serviço de Fomento Mineiro (figs. 4.2-6a). In addition, Harrison assumed two mining zones in the southern part instead of one long one. Furthermore, the assumption of the height of the original mountains does not correspond to the known conditions. On the basis of these criteria, the volume of mining in Tresminas must be reduced to a maximum of 8–10 million tons, i. e. at best to half the tonnage assumed by Harrison.

The differences in the deposits of Tresminas, Gralheira and Jales are of course also reflected in the volume produced. Although, according to current knowledge, as little waste rock as possible was mined in Tresminas, a much higher volume had to be processed in order to extract the gold, which is not visible to the naked eye in silicified shale in the concentration zones (figs. 4.2-2, 4.2-3, 4.2-6, 4.2-7). The situation is different for the ore veins of Jales and Gralheira. In following the ore vein, only just enough waste rock was mined here to make enough space to allow

208 See [www.steliasmines.com/storage/news\\_releases/Sli-News-2009-01-Jales-Drill-Hole-FINDAL.pdf](http://www.steliasmines.com/storage/news_releases/Sli-News-2009-01-Jales-Drill-Hole-FINDAL.pdf). Downloaded 2nd March 2017. This website also mentions the Jales Extension deposit, located between the Jales and Gralheira veins, which suggests that it was a single deposit system. — See also Dias de Carvalho 1979, 143 — Martins/Martins 2017, 165 fig. 12: The Mina de Jales produced 23.5 g Au/ton with an average grade of 12.9 g Au/ton. — Kernow Resources & Development Ltd. (KRD) indicates an average grade of 12.9 g/t gold for the Campo de Jales mine during the 20th century mining period. file:///C:/Users/regul/Desktop/4.2%20in%20Bearbeitung/postt809.html. Last view: 12.11.2019.

209 Wahl-Clerici et al. 2017, 4.

210 Pliny continues the passage with the remark that artificial electrum was also produced with a ratio of 3–4 parts gold to 1 part silver for better processing. See König/Winkler 1984, 152–153.

211 Whether the high fineness of the gold in the deposit of Tresminas is sufficient as a basis for an interpretation of the site as the *metallum Albucrenense* cannot be said at the current state of research on the gold deposits in the northwest of the Iberian Peninsula; Rodríguez Colmenero 1999.

212 Harrison 1931, 142.

213 Harrison 1931, 144 fig. 4.

the mine to be worked (figs. 4.2-2, 3.0-26—3.0-28, 3.0-30, 3.0-32). Characteristic of this are the elongated glory holes with the various traces of work and the tailing piles heaped up at the sides.

The plans already mentioned showing the now largely destroyed Roman mining zones, indicate a volume of around half a million tons of mined rock. Not enough information is currently available to determine the total volume of rock extracted for Gralheira.

The diversity of the deposits and thus of the mining is reflected not only in the size of the mining zones but also in the tailing piles and the preserved monuments of the processing. This becomes quite clear with the processing sites, of which only the Forno dos Mouros with around 30 stamp mills is known in the area of Jales and Gralheira.<sup>214</sup> On the other hand, several processing sites have been identified in the Tresminas zone, where around 1000 stamp mills were documented. These figures confirm the difference between the volumes extracted and processed in the various deposits.

## The relationship between ore and sterile overburden

In his study of the gold contents in the *territorium metallorum* Tresminas /Jales, Bachmann assumes a hypothetical ratio of 10:1 (overburden to ore) in relation to the total material mined.<sup>215</sup> This pure estimate may be true for the Jales and Gralheira veins, but it is more difficult to transfer to the Tresminas veins due to the unique and complex deposit conditions. Thorough fieldwork helped to make the Romans' approach more comprehensible. It became clear that the mining zones could be restricted quite specifically to the gold-bearing areas, i. e. to the zones of silicified slate, so that not too much overburden was produced here either. Since the tailing piles in Tresminas have not yet been sufficiently surveyed, their volume could only be calculated approximately. It is therefore difficult to determine the relationship between the ore mined and the overburden. In addition, a large part of the processed material was deposited in the valleys after stamping, grinding and washing. Despite all these reservations, we also base the calculation of the total quantity of gold on the estimated ore to overburden value in the range of 1:10.

## Results

If we assume a maximum mining volume in Tresminas, Gralheira and Jales of 10 million tons, with a ratio of ore to overburden of 1:10 and a content of approx. 10g Au/ton in the ore, this results in a total recovery of 10000kg raw gold.

Calculated over a period of 150 to 200 years of operation, an average annual production of 50—67 kg could be expected. The use of moulds comparable to those from Magdalensberg resulted in an annual production of around 9—12 small and 3.5—4.5 large bars respectively.<sup>216</sup> This would correspond to an average annual production between 6100 and 8200 aurei of 8.19 grams.

214 Harrison 1931, 140 mentions several places where there is said to have been a significant amount of gold-bearing slag. However, his data are unspecific and do not help with a renewed identification of these smelting places.

215 Bachmann 1993, 154.

216 Gostencnik 2016, 28—32: The imperial gold foundry and the moulds for ingot discovered: the inscriptions on the moulds clearly indicate that the gold was the possession of Emperor Caligula. The small mould made it possible to cast a bar weighing 5.615 kg = 17 Roman pounds and the large one 14.538 kg ≈ 44 Roman pounds. In this context, the 15 gold bars of Sirmium (Sremska Mitrovica, Serbia), which weighed between 248g and 500g, should also be mentioned. The three emperors are Gratian (359—383), Valens (328—378) and Valentinian II (419—455). See also Kenner 1888, 19—46. After Speidel 1996, 75—76, the calculated pay of 8 million HS for the Vindonissa fort (Switzerland) would have meant 8.1 ton silver coins or 656 kg gold coins per year. See also Wahl-Clerici (in print), Considerations on the Profitability of Roman Gold Mining in the Northwest of the Iberian Peninsula during the 1st and 2nd Centuries A. D.

### Samplings with gold and silver contents

Sample	146	147	150	155	156	160	161	165	173	174
Length in m	0.3	0.4	0.45	0.45	0.35	0.55	0.35	0.5	0.3	0.7
Content g/T Au	1.4	27.7	3.2	0.8	1.8	0.9	3.6	1.9	1.6	12.3
Content g/T Ag	0.2	6.8	2.1	3.9	2.3	3.5	4.4	0.9	2.7	3.8

Fig. 4.2-1: *Territorium metallorum* Tresminas/Jales, Tresminas, Lagoinhos: list of samples containing gold on the basis of the information provided by the SFM 1985.



Fig. 4.2-2: *Territorium metallorum* Tresminas/Jales, Tresminas, Lagoinhos: view into the mining zone inside the mountain of Lagoinhos. It is visible that the abandonment took place in stages. Sample 174 was taken from the deepest step. The southeastern face has broken away at the bottom (photo: R. Wahl-Clerici).

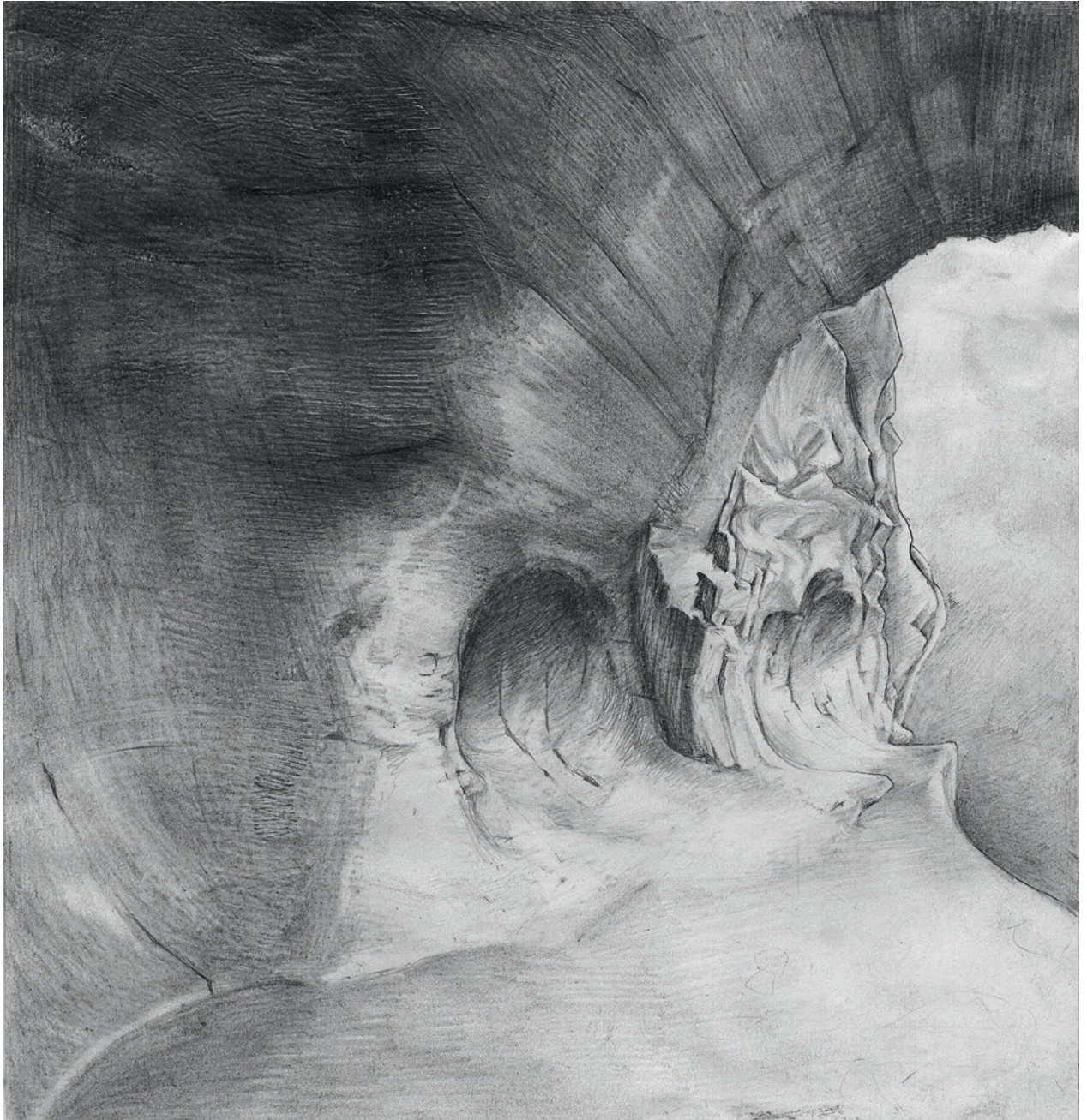


Fig. 4.2-3: *Territorium metallorum* Tresminas/Jales. Tresminas, Corta de Covas: range of fireplaces with the highest gold content in Tresminas (drawing: P. Moser).

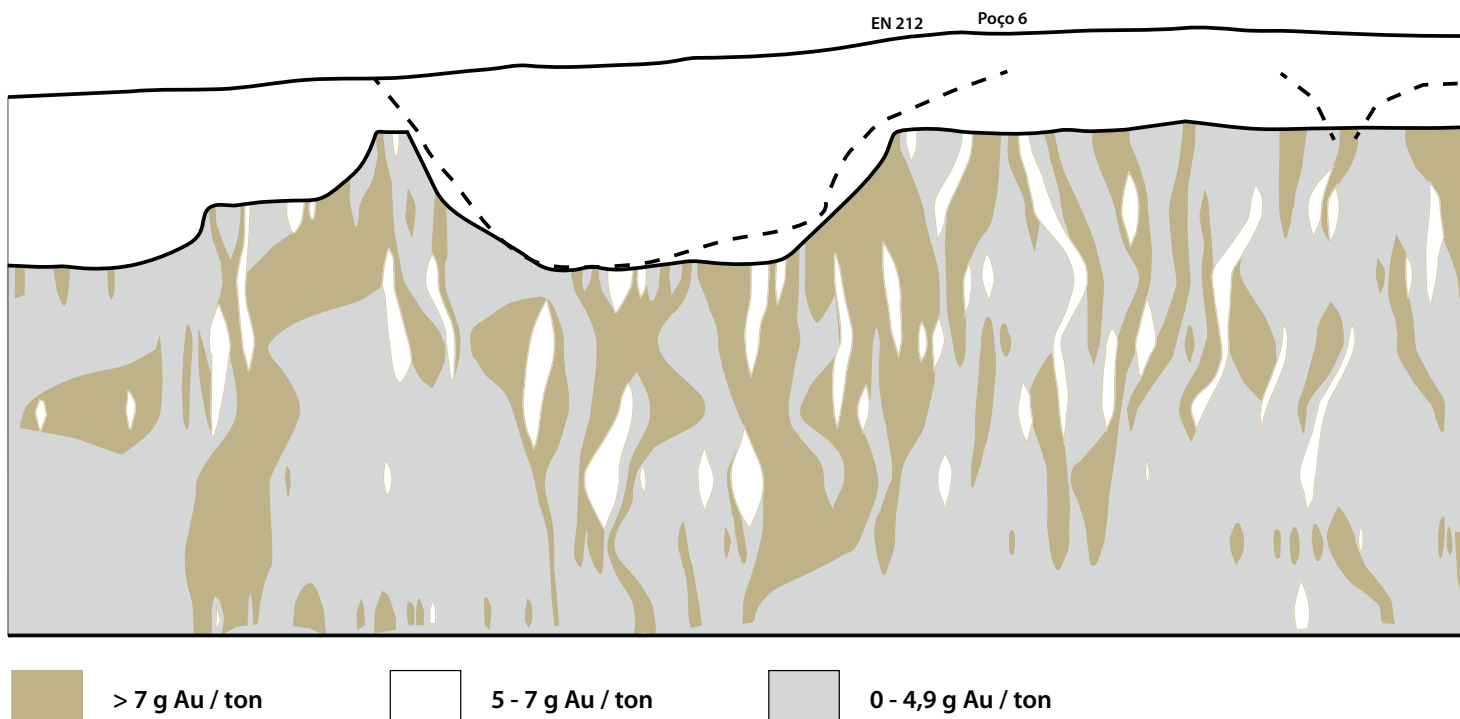
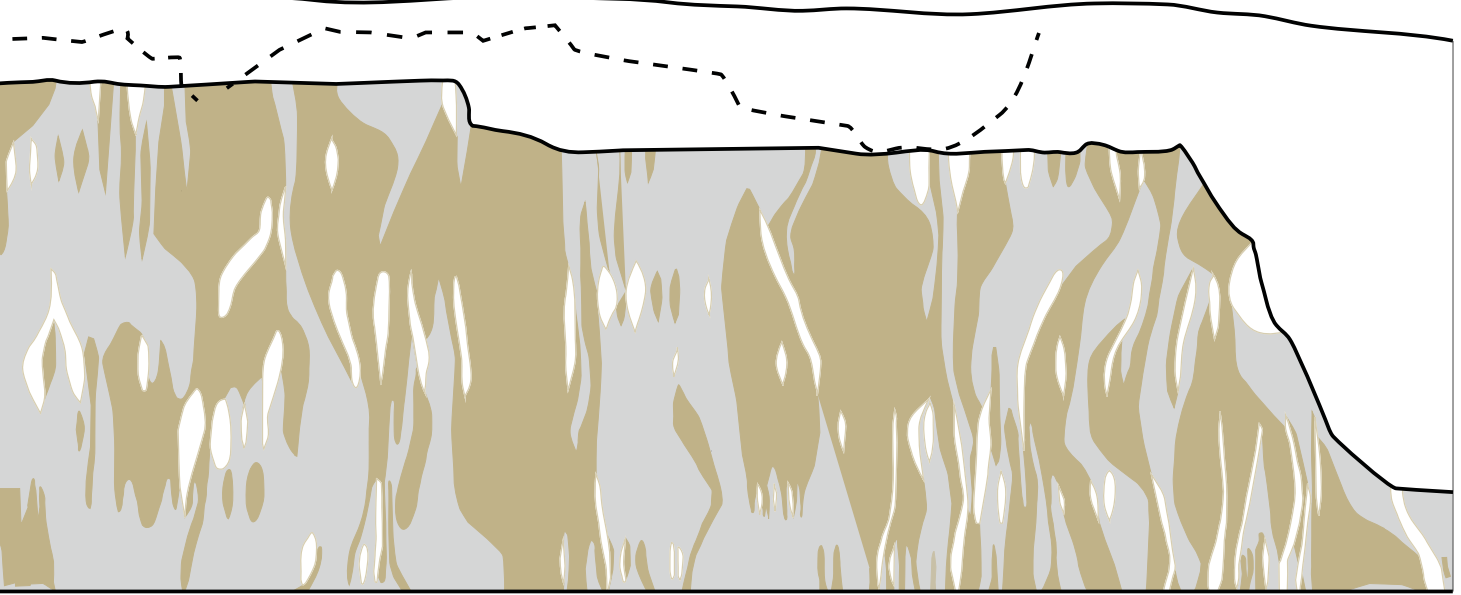


Fig. 4.2-4: *Territorium metallorum* Tresminas / Jales, Jales: longitudinal section of the Campo de Jales vein with gold concentrations inscribed. The dotted line approximately marks the boundary of Roman mining (original: *Elementos fornecidos por Minas de Jalles Ltda.*, design: R. Wahl-Clerici).

Sta Barbara



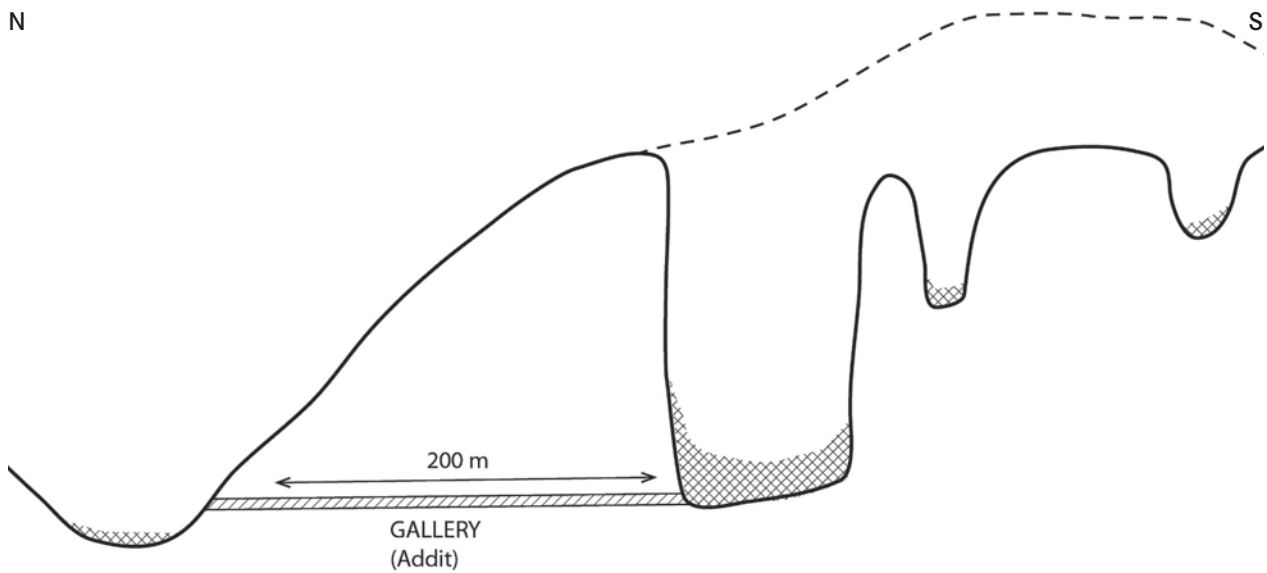


Fig. 4.2-5: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: section through the Corta de Covas after Harrison 1931 (design: R. Wahl-Clerici).

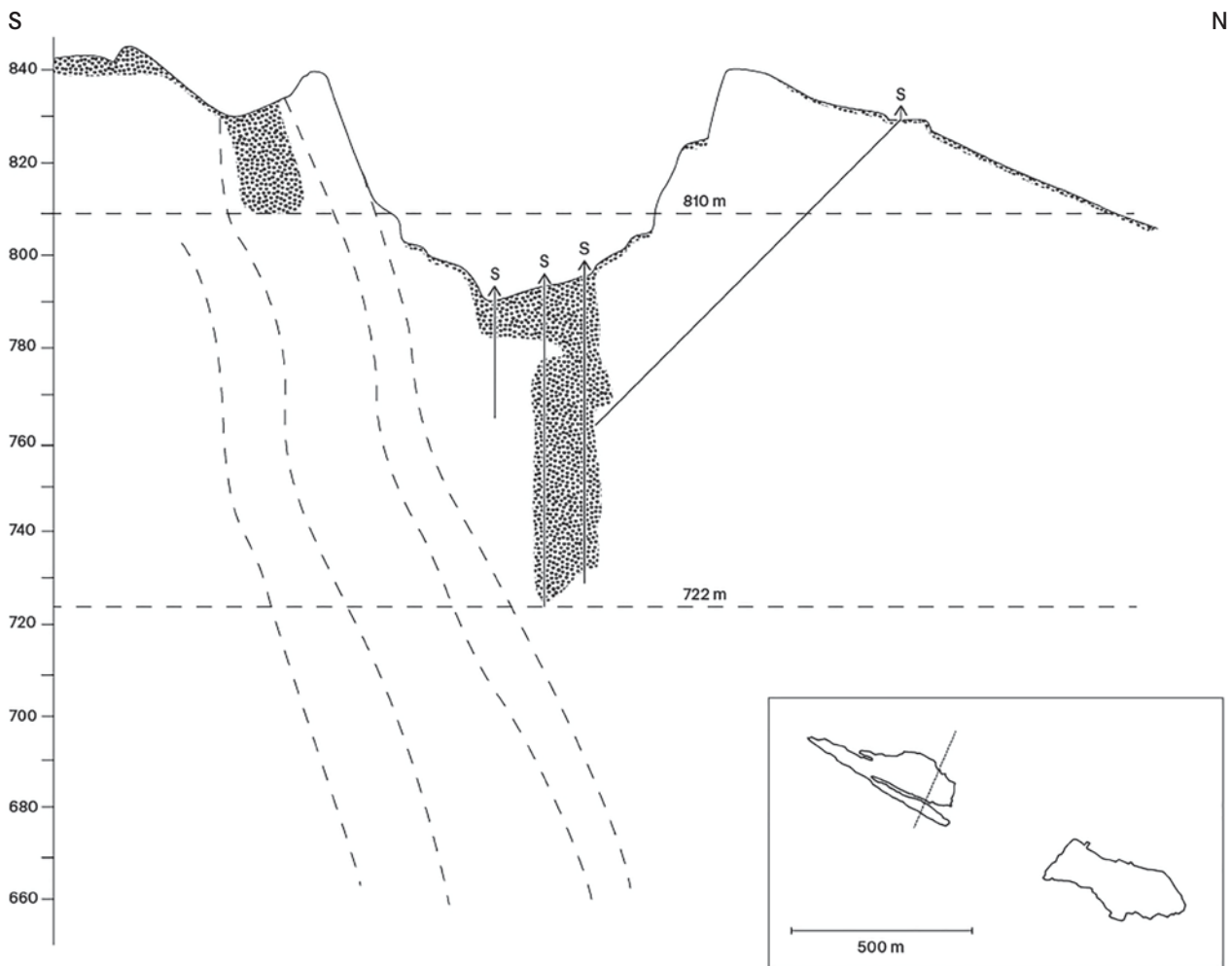


Fig. 4.2-6: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta de Covas: north-south-section through the Corta at the lowest point sounded (S = sondage). The depth of the southern mining zone was adapted to the level of the Galeria Esteves Pinto. Lower right: position of the sondage (after Direcção geral de geologia e minas, Serviço de Fomento Mineiro, Divisão de Prospecção de Minérios Metálicos, SFM-SPE-1987-88, design: R. Wahl-Clerici, S. Mathiuet).



Fig. 4.2-7: *Territorium metallorum* Tresminas / Jales, Tresminas, Corta da Ribeirinha: glory-hole in the western part (photo: R. Wahl-Clerici).



## 5.0 Water Engineering and Water Usage within the *territorium metallorum* Tresminas / Jales<sup>217</sup>

Water engineering and use within a mining territory are based on completely different needs than those of for instance a Roman town. While urban centres needed a constant supply of fresh water for daily use in all areas of life, mining districts mainly needed water for industrial purposes (figs. 5.0-1, 4.0-27a/b/c—4.0-31). At the same time, the residents of mining districts such as at Tresminas were supplied with water for their personal use. Still, in mining districts we cannot find impressive buildings like an aqueduct bridge across a valley or lavishly decorated *nymphaea*, buildings typical for and present in abundance in Roman cities, as the example of Sagalassos (Provinz Burdur/TR) shows (fig. 5.0-2).<sup>218</sup>

While the Tresminas water supply system was unadorned, it was elaborately built and characterised by its practicality and high efficiency. This also applies to the systems in the other mining areas in the northwest of the Iberian Peninsula. Water engineering was never a cheap endeavour, but water engineering in combination with prestigious building projects generated horrendous costs (fig. 5.0-4).<sup>219</sup> Water supply for industrial purposes needed to be as cheap as possible, as the costly investment was only risked so as to ensure a constant production process.

Mining zones and settlement areas within Tresminas were situated in locations high up in the mountains, as were a large part of the processing sites, where natural water supply was always scarce. On the other hand, the major streams in the area — the Tinhela, the Peliteira and the Curros with its tributaries — carried water all year round and were therefore used to supply the mining district with water, with the consequence that the system of water supply pipes had to be laid out over a large area and in a complex manner due to the very hilly landscape (fig. 5.0-3).

The water supply system consists of different components. Inside the *territorium metallorum* at Tresminas/Jales, numerous different elements of this system are preserved in various versions. Essentially, these can be differentiated into installations for water storage, water supply, water use and installations connected to problems of wastewater management specific for a mining zone.

These installations might be listed as follows:

### 1 Water storage

- Hydrographic basins
- Dams and water reservoirs
- Weirs
- Basins

### 2 Water supply

- Aqueducts, including tunnel systems

### 3 Water uses

- for ore processing and smelting
- for craftsmen's workshops
- for the settlement, both high quality water for drinking and water of lesser quality for animals and washing, etc. was necessary

### 4 Wastewater

- Mountain water
- Industrial wastewater
- Wastewater from the settlements

## 1 Water storage<sup>220</sup>

### Hydrographic basins (fig. 5.0-5)

In a hydrographic basin, water from the adjacent area accumulates and is collected in a water-storage facility and then fed into one or more channels. Within the mining zone at Tresminas, three different basin systems were discovered;

217 The whole system of water-supply has been investigated by Jürgen Wahl and Regula Wahl-Clerici since 1988; a monograph on this topic is forthcoming. Wahl 2003; Wahl-Clerici 2016.

218 Daily water consumption was calculated for the 2nd century A. D. in the city of Rome at about 100—150 litres and 250 litres in Pergamum (Ausbüttel 2005, 116). Numerous aqueducts are preserved on the Iberian Peninsula, for instance in Mérida, Tarragona, Segovia, etc.

219 The *Aqua Marcia* in Rom cost 45 million *denarii* in 144 B. C. Hadrian's aqueduct to Alexandria Troas in the province Asia cost 7 million *drachmae*. Non-Imperial donations to finance the aqueducts are well known, for instance in Aspendos in Pamphylia (Province Antalya/TR): 8 million HS = 80 000 *aurei*. For the decision on a project as important and financially exhausting as the construction of an aqueduct, the Roman town of Colonia Iulia Genetiva (Urso, Osuna, Province Sevilla/E) decreed that two thirds of the local decuriones had to be present for the vote. See Ausbüttel 2005, 116—117. In order to reduce costs and shorten the construction time, aqueducts in Rome were built one above the other whenever possible. For example, the *Aqua Tepula* was put on top of the *Aqua Marcia* and above that, the *Aqua Julia*, see Aicher 1995, fig. 22.

220 Wahl-Clerici 2017.

these are closely connected to the three main streams in the area:

- Tinhela-system (1)
- Curros-system (2)
- Peliteira-system (3)

With the help of these systems, the Romans were able to use the natural water sources available most efficiently for the mining industry. The former were mainly concentrated in the relatively flat highlands of the Serra da Padrela, whose relatively marshy soils even today are mainly wooded by trees that require an abundant supply of water, such as birches and alders.<sup>221</sup>

#### (a) River Dams and Barrages with Water Reservoirs

Within the *territorium metallorum* Tresminas/Jales, two large earthfill dams are preserved in large parts (figs. 5.0-6, 5.0-7). These are the dams at Outeiro (figs. 5.0-8, 5.0-9) and Sainça (fig. 5.0-10), which have been documented since the times of Jerónimo Contador de Argote. The unfinished rockfill dam (figs. 5.0-11, 5.0-12) which dams up the river Peliteira above Campo de Jales is less well known, as is the no longer existent earthfill dam of Tazém (fig. 5.0-13), which collected the water of the Ribeira de Frades. Its former position can be clearly determined thanks to the existing rock carvings for the directly adjoining channel C2, which channelled the water to the washing facilities of Tresminas.

The earthfill dam at Outeiro has a width of 65 metres at the base and its maximum height can be reconstructed at 21 m. Its crest is 150 metres long. This dam is among the highest Roman dams and amazes its visitors even now.<sup>222</sup>

The earthfill dam at Sainça has a width of 40 metres at the base and had an original maximum height of 12 metres. Its crest is 170 metres long.<sup>223</sup>

For each of the structures, a natural rock was chosen as the ideal foundation, reducing the construction efforts. The same labour-saving choice of site for the construction of the dams also applies to the (now completely destroyed) earth fill dam of Tazém and the rock fill dam on the upper reaches of the Rio Peliteira.

The reddish, highly loamy soil available in the area was used to build the earth fill dams. It was extracted in Roman times near the Outeiro dam (fig. 6.0-28). Similar deposits, both larger and smaller, are found in large numbers in the slate zone of the mining district (fig. 5.0-14). When in contact with water, this loamy material forms a closed, water-repellent surface, which meant that it was not necessary to cover the dam with protective stone slabs on the waterside. This also explains why no capstones could not be found for the dam. The dam body on the Rio Peliteira lies in the granite region, which is why granite boulders were used here (fig. 5.0-12).

The dam walls were constructed less conspicuously. We know of a dam collecting the water of the Ribeiro do Muro below the village of Vilarelho (figs. 5.0-15, 5.0-16)

and another collecting the water of the Rio Peliteira about 150m above its mouth into the Rio Tinhela. In the construction of the latter, a valley narrowing into a natural cataract was exploited. Here too, the former position can mainly be identified by the preserved workings in the rock for the main outlet (fig. 5.0-17).<sup>224</sup>

The Vilarelho dam is still preserved up to about 2/3 of its former height, which can be traced by the positions of important, undestroyed elements of the dam together with the actual structure. The positions of bottom outlet, the main outlet for the canal and the overflow can still be determined today (fig. 5.0-18).

In the unfinished rockfill dam on the Rio Peliteira, the bottom outlet and the adjoining drainage channel are preserved, both of which would have been covered had the construction had continued. With the help of a carefully worked stone block with a closable hole, the amount of water discharged could be regulated as required at the beginning of the channel (fig. 5.0-19).

The water was fed into the aqueduct through the main drain. At the Vilarelho dam, the aqueduct had conspicuous carvings in the rock, into which a wooden construction was probably placed to regulate the water flow. Other traces also preserved are the probable position of the overflow. This example shows how complex the additional introduction of water into an existing aqueduct was. Three such examples have been found in the water supply system of Tresminas, with the one of Vilarelho being the best preserved.

In the often very narrow valleys surrounding the *territorium metallorum*, most of the channels were fed from weirs, as this allowed the discharge to be positioned at the desired height regardless of the topography. The preserved structures near Sevivas on the Ribeiro de Sevivas (figs. 5.0-20, 5.0-21) and in the Vale Curtinhas below Tinhela de Baixo on the Rio Tinhela (fig. 5.0-22), testify to the fact that limited water storage was also carried out here, as the quantity to be discharged could be regulated more easily and sufficient water was always available.<sup>225</sup> At the transition from the river to the channel, a sluice was installed to regulate the discharge. When there was an overflow, the water drained off via the wall to the lower level of the river (fig. 5.0-23).

#### The Basin in the Settlement

The large basin preserved on the fringe of the settlement at Tresminas was also part of the water storage installations (figs. 5.0-24, 5.0-25). In this sedimentation basin, the drinking water was freed from impurities that could not

221 A birch needs up to 100 l water a day in the hot climate of the region.

222 Wahl 2003, 497.

223 Wahl 2003, 498.

224 Wahl-Clerici / Wiechowski 2012, 334 fig. 12.

225 Wahl-Clerici 2020.

be avoided due to the open pipes. Today, the basin is filled up with material that has been washed in and accumulated during the period of use up to the crown of the outer wall, with the wall preserved only slightly higher in some sections. This material, which is mostly fine and loamy, is interspersed with many small stones and remarkably hard.

Fragments of *opus signinum* were observed in the settlement area to the east of the building, indicating that the main water distributor, the *nymphaeum*, of the settlement probably stood there.

## 2 Water Supply

Aqueducts ensured the water supply from the storage and the feed into the channel to the point of use. The aqueducts consisted of open channels, rock openings and tunnels (figs. 5.0-3, 5.0-26—5.0-28).

So far, no less than twelve aqueducts have been identified in Tresminas. Seven of these lead the water from the Rio Tinhela from the west towards the mining zone (T0—T6). Another four (C1—C4) carry the water from the east to Tresminas. In addition, an aqueduct was built to supply the Forno dos Mouros treatment zone (fig. 5.0-17).

Due to several factors, the state of conservation of the aqueducts varies considerably from section to section. In particularly steep areas, often the only remnants preserved of the aqueduct are the traces of worked rock (figs. 5.0-28—5.0-35a/b). In addition, agriculture and forestry have destroyed large parts of the aqueducts. Until the end of the 20th century, the inhabitants of the surrounding area also used the walls of the channels as easily obtainable building material. Thanks to decades of systematic research and documentation of all the remains that could be found, it has been possible to trace the course of the twelve aqueducts despite these problems, and even strands that were far apart could be identified as belonging together (fig. 5.0-3).

It has also been possible to determine the position of the feed of all aqueducts, at least through back projection of the height at the beginning of the aqueduct, even if it is not always possible to identify the structure. In addition, by measuring the absolute height of preserved sections, it has been possible to identify strands that were sometimes far apart as belonging together. It is more difficult to identify the destination of the individual aqueducts and thus to determine the intended use of the water. This applies to the majority of the channels with the exception of two channels, C2 (fig. 5.0-34a/b, 4.1-3), which carried water to the ore washing facilities and the channel that carried water to the “Forno dos Mouros” treatment area (fig. 5.0-17).

## 3 Water Use

The water in a mining district was used for many purposes. The basic requirement was always a sufficient supply for washing the gold from the stamped and ground ore.<sup>226</sup> We know that the large ore washing facilities north of the Corta de Covas (fig. 5.0-1) apparently replaced older installations, which were located either at the open accesses to the mining zones or at the hillside entrances of the tunnels. It is still unclear whether the water was also used to drive the stamp and ore mills or whether human or animal muscle power was preferred. It is also possible that the water was only used to moisten the stamped and/or ground material (fig. 4.0-13).

It is possible that after firing it, the miners sprinkled the rock with water in order to break it up, even though vinegar was preferred for this purpose, according to Pliny, Natural History 33,71:

“[...] *hos igne et aceto rumpunt* [...]”

“[...] which are burst asunder by means of fire and vinegar [...]”

The use of water to wash away the crushed rock in the Tresminas, Gralheira and Campo de Jales deposits can be excluded. This assumption is that the rock (with the gold it contained), was undercut and subsequently collapsed in a manner similar to the method employed at Las Médulas, a technique that is described by Pliny, Natural History 33,66 as *ruina montium*. Afterwards, the extracted material is supposed to have been washed out by the flow of water through the tunnels. This hypothesis has already been refuted for Tresminas, Gralheira and Jales.<sup>227</sup>

Water also formed an essential resource for the blacksmiths and other craftsmen in the *territorium metallorum* Tresminas/Jales. The *lex metallis dicta* from Vipasca (Aljustrel/Portugal) mentions ropemakers, tanneries and fullers' workshops, which were probably connected to the mining activities there.<sup>228</sup>

The location of the settlement of Tresminas demanded a constant supply of water for daily use, as there are no perennial streams in the direct vicinity (figs. 5.0-24, 5.0-25). This applied to both the water for drinking water as well as the water for the bathhouses. The fact that a bath was part of the miners' everyday life is demonstrated by the ruins of a bathhouse on the edge of the Las Rubias mining zone in the Teleno massif, the Vipasca tablets (which mention a bath for the miners) and, finally, the bath in the settlement

226 The publication of trace analyses of the remains of the treated material inside the ore washing basin of the *territorium metallorum* Tresminas/Jales is currently in preparation.

227 Wahl-Clerici 2013, 43—44; Also see Domergue 1970, 162—163.

228 See the Vipasca tablets: Edmondson 1987, 244—254.

belonging to the quarries in the eastern desert of Egypt, where water was a precious commodity and therefore rationed.<sup>229</sup>

## 4 Wastewater

According to current knowledge, the wastewater produced by the treatment process was only discharged into a sewer at Forno dos Mouros. In the settlement, there were several smaller and one large sewer. It seems that these were built both for the craftsmen's workshops and for the residential part of the settlement.

### Mining

One of the biggest problems in mining is the mountain water, the natural water flow in the mountain, which in the opencast mines was supplemented by rainwater. These waters must always be drained off, as otherwise extraction is no longer possible. Mechanical installations for this task dating to the Roman period have been preserved, especially in the south of the Iberian Peninsula. They include water-lifting wheels, pumps, Archimedean screws and scoops, with the individual elements often used in various combinations.<sup>230</sup>

Pliny already mentions the problem and the simplest manner of solving it (Natural History 33,97):

*... ad MD passus iam cavato monte, per quod spatium aquatini stantes noctibus diebusque egerunt aquas lucernarum mensura amnemque faciunt.*

... the tunnelling having been carried a mile and a half into the mountain. Along the whole of this distance watermen are posted who all night and day in spells measured by lanterns bale out the water and make a stream.

Inside the mining zone at Tresminas the mountain water was, if possible, drained through the galleries and the channels in their floors and transported to the surface (figs. 5.0-36, 3.3-4). This method was still 'state of the art' in mines up to the later 19th century A.D., when mechanisation brought industrial pumping stations.<sup>231</sup>

Theoretically, the lifting device driven by a capstan, one of which had been installed in the Galeria do Pilar, could have been used not only for lifting ore, but also for transporting water away from the deeper sectors towards the channel. Due to the challenging topography, such installations had to be applied in the southern part of the Campo de Jales vein.<sup>232</sup> There are some indications for the existence of a water-lifting wheel, but as the documentation of the evidence is unclear and debatable, it must remain a hypothesis.<sup>233</sup> Whether the

bronze vessel from the collection of the Minas de Jales Ltda. (formerly Campo de Jales, today in the Museu Municipal Padre José Rafael Rodrigues de Vila Pouca de Aguiar) had once been part of a bucket wheel is unclear due to the lack of information on its find context and its rather unspecific shape (fig. 5.0-37).<sup>234</sup>

### Treatment

Although the quantities of water required for the processing of the ore (see chapter Processing) were not particularly large, they had to be available at all times. However, with the exception of a small construction in the area of Forno dos Mouros, which is largely covered by slope debris (fig. 5.0-38), there are no traces of sewers. It must be assumed that the wastewater was simply allowed to run down the slope.

### Settlement

The polluted wastewater created by the various crafts and additional wastewater from the settlement was collected in small channels, such as they frequently occur in Roman settlements (fig. 5.0-39). Only one rather wide channel (70 cm wide, with a depth of about 1 m) is noteworthy; it cuts through the southern part of the settlement and is fed by small channels carrying water from the vicinity (fig. 5.0-40). As it has only been partly excavated until now, we can neither determine its course nor the destination of the wastewater.

229 For the Roman bath on the edge of the mining zone at las Rubias on the Teleno massif, see Domergue 2012, figs. 19–23, Dieulafait 2011. For the Vipasca tablets see Edmondson 1987, 244–254. In the Eastern Egyptian desert: For the bath buildings see Peacock/Maxfield 1997, 122–134 and Hirt 2010, 217–218: The water was supplied from the springs and the natural subterranean cisterns under military supervision. Hirt 2010, 168–169 emphasizes that the water was strictly rationed according to rank, with the military always being allocated more than the civilians. — Hirt 2010, 208–209: The largest known allocation was 1 *keramion* = 6.5 l per day. Legionaries, horsemen, veterinarians and architects received 5.4 l. Most workers had to be satisfied with 3.25 l and inferior persons with only 2.16 l. Whether these quantities contained only water for consumption or also water for bathing purposes is beyond our knowledge.

230 Oleson 1984; Domergue 2008, 122–130.

231 The Rothschnöberger-Tunnel (construction time 1844–1882) carried mountain water from the Erzgebirge over 50.9 kilometres and with an incline of 0.033% into the Triebisch river, which enters into the Elbe near Meissen 12 kilometres to the north of this point (Saxony/D).

232 Older inhabitants of the village of Cidadelhã (Freguesia Alfarela de Jales, Concelho Vila Pouca de Aguiar) give account of a 'mina' (a mine or tunnel) by which the northern mining sector of Jales was apparently drained.

233 Oleson 1984, 228–229: Minas dos Mouros (Portugal). According to the current state of research this structure should be the Galeria do Pilar with its channel along the eastern working face, although the descriptions by Harrison (1931) and Davies (1933) do not quite match the actual conditions.

234 Vitruvius, De architectura 10,4,4: bronze vessels, each containing about 3.28 l (Fensterbusch 1964, 483).

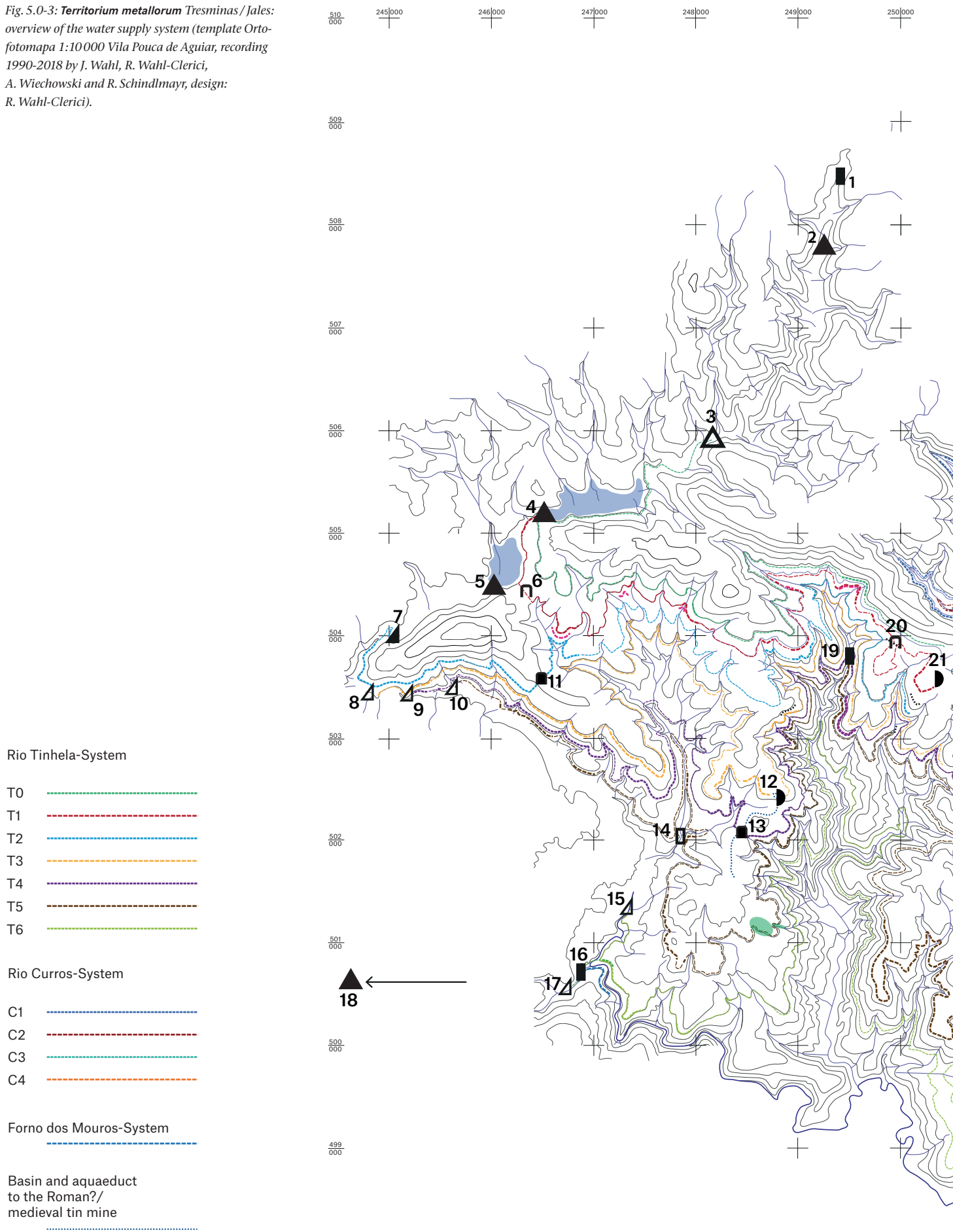


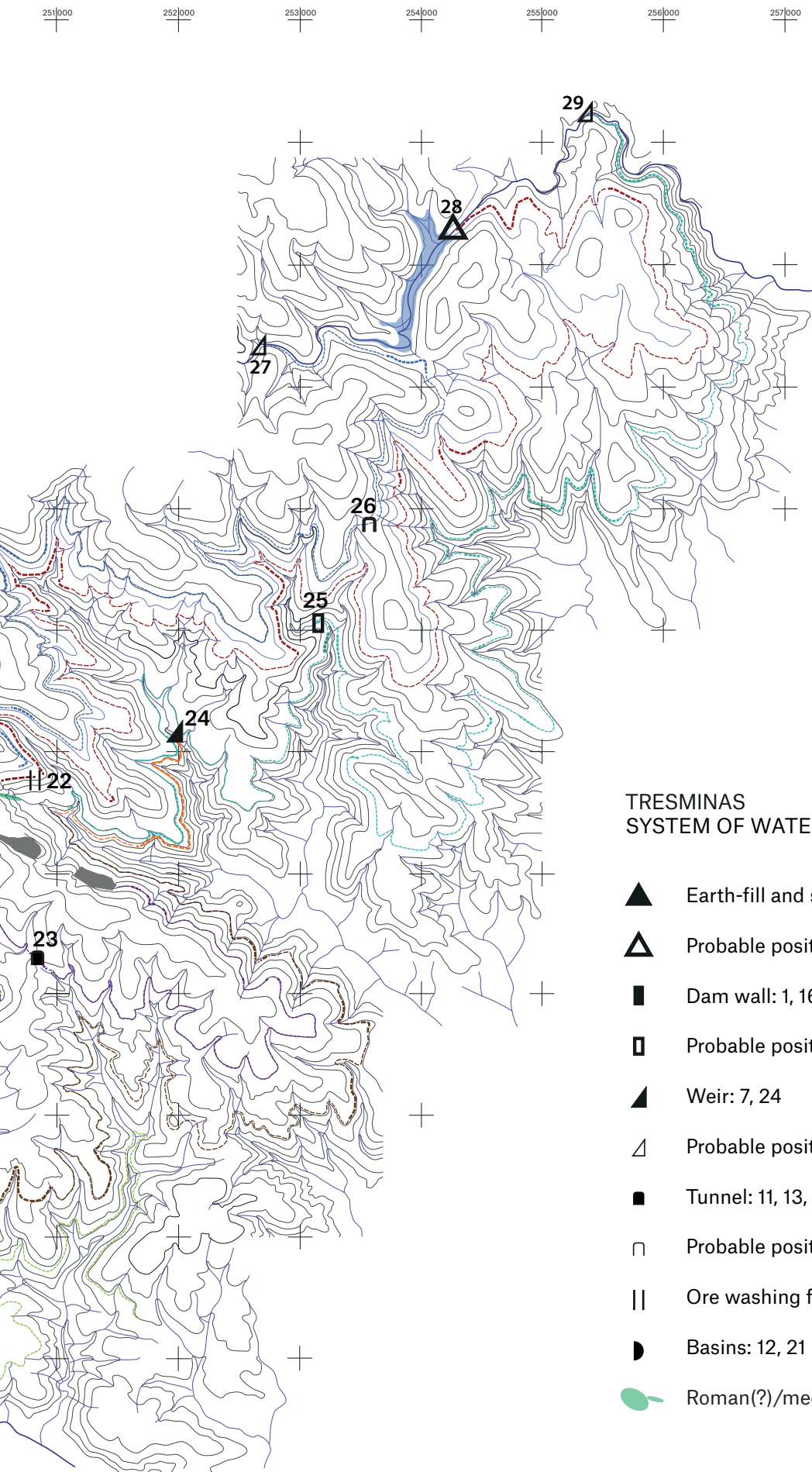
*Fig. 5.0-1: **Territorium metallorum** Tresminas / Jales, Tresminas: platforms 5 to 10 of the western row of the ore-washing installations, the platforms 6, 8, and 10 are completed with sedimentation basins on each side (Photo: R. Wahl-Clerici).*



*Fig. 5.0-2: Sagalassos (Prov. Burdur / TR): Nymphaeum (photo: R. Wahl-Clerici).*

Fig. 5.0-3: *Territorium metallorum Tresminas/Jales*: overview of the water supply system (template Ortofotomapa 1:10 000 Vila Pouca de Aguiar, recording 1990-2018 by J. Wahl, R. Wahl-Clerici, A. Wiechowski and R. Schindlmayr, design: R. Wahl-Clerici).





TRESMINAS  
SYSTEM OF WATER-SUPPLY - GENERAL MAP

- ▲ Earth-fill and stone-fill dam conserved: 2, 4, 5, 18
- △ Probable position of a earth-fill dam: 3, 28
- Dam wall: 1, 16, 19
- Probable position of a dam wall: 14, 25
- ▲ Weir: 7, 24
- △ Probable position of a weir: 8, 9, 10, 15, 17, 27, 29
- Tunnel: 11, 13, 23
- Probable position of a tunnel: 6, 20, 26
- || Ore washing facilities: 22
- Basins: 12, 21
- Roman(?)/medieval tin mines





*Fig. 5.0-4: Aspendos (Prov. Antalya/TR); aqueduct (photo: R. Wahl-Clerici).*

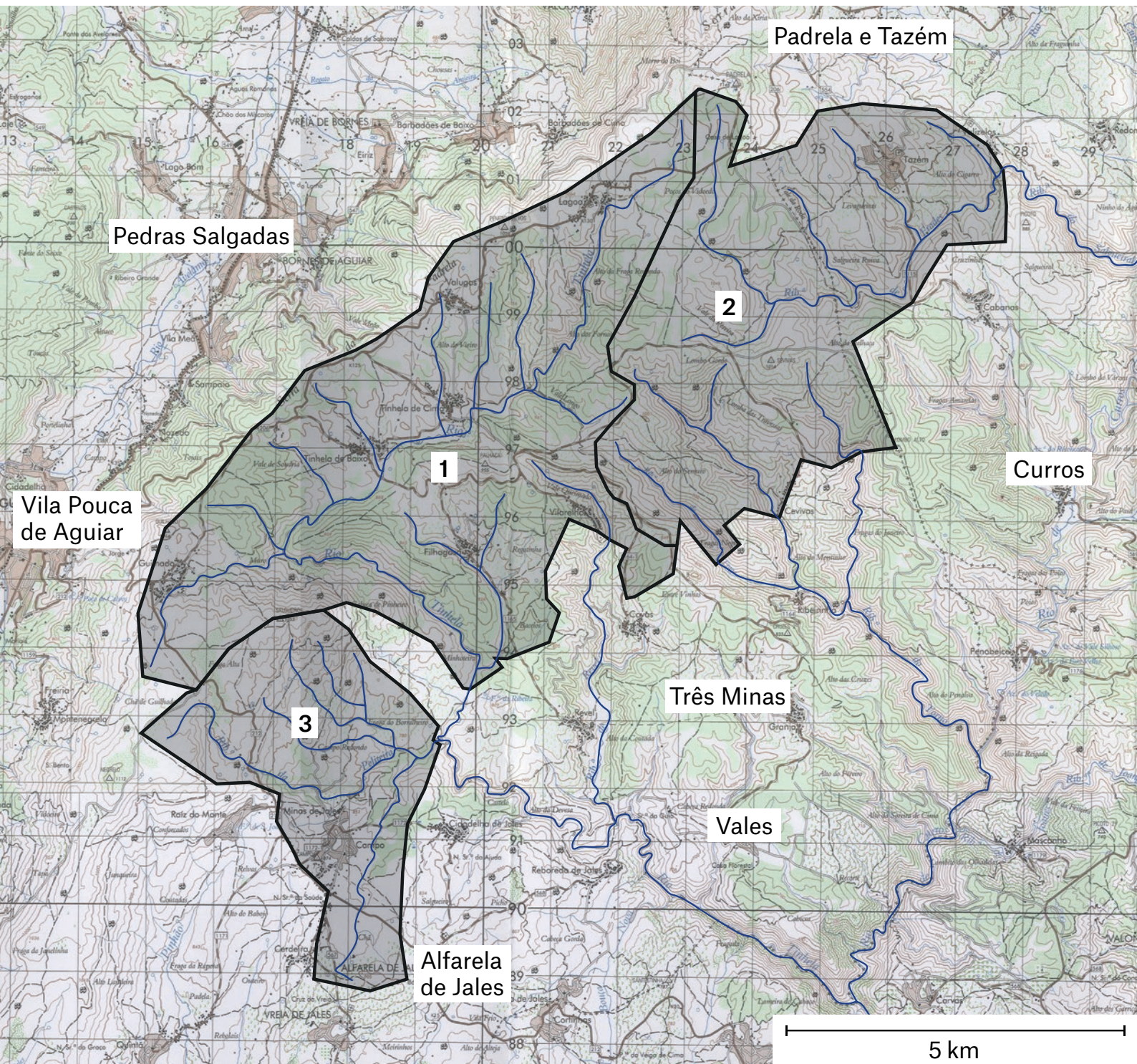


Fig. 5.0-5: *Territorium metallorum* Tresminas/Jales: overview across the hydrographical basins. The water from the Rio Tinhela and from the high-lying western tributaries of the Rio Curros was channelled into the mining zone of Tresminas, while the water from the Ribeiro da Peliteira and its tributaries went mostly to the Forno dos Mouros treatment zone (template Carta Militar de Portugal, Instituto Geográfico do Exército Folhas 6-D e 10-B 1:50000, design: R. Wahl-Clerici).



Fig. 5.0-6: *Territorium metallorum* Tresminas / Jales: schematic overview of the Outeiro and Sainça dams and their highest possible water level (template Google Earth, 14.12.2015, inclination with viewing height of 1.19 km, design: R. Wahl-Clerici).

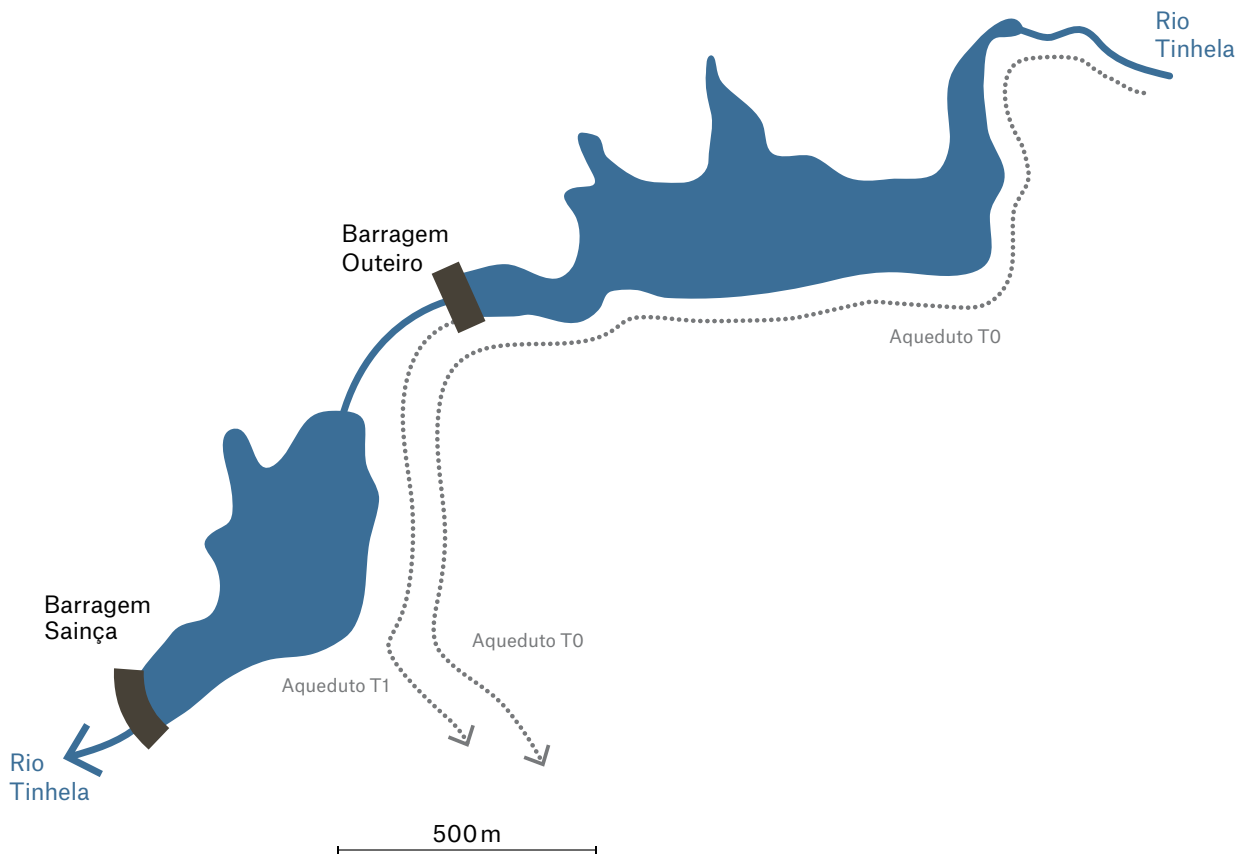


Fig. 5.0-7: *Territorium metallorum* Tresminas / Jales: the reservoirs at Outeiro and in the Sainça field at maximum capacity (template Ortophomapa 1:10000 Vila Pouca de Aguiar, documentation and design: J. Wahl and R. Wahl-Clerici).



Fig. 5.0-8: *Territorium metallorum* Tresminas / Jales, from the west: Outeiro earth fill dam. Both preserved wings are recognizable (photo: J. Wahl).



5.0-9: *Territorium metallorum* Tresminas / Jales from the west: Outeiro earth fill dam. In the foreground, the rock used as base is visible (photo: R. Wahl-Clerici).



5.0-10: *Territorium metallorum* Tresminas / Jales, from the westsouthwest: Outeiro earth fill dam, with rock base and heaped earth (photo: J. Wahl).



Fig. 5.0-11: *Territorium metallorum* Tresminas / Jales, from the north: rockfill dam on the upper reaches of the Ribeiro da Peliteira. The top of the wall can be seen near the wide wall, approximately in the middle of the picture. For the continuation south of the Ribeiro da Peliteira, a hill was raised (photo: R. Wahl-Clerici).



Fig. 5.0-12: *Territorium metallorum* Tresminas / Jales: detail on the southern side of the rockfill dam on the upper reaches of the Ribeiro da Peliteira (photo: R. Wahl-Clerici).



Fig. 5.0-13: *Territorium metallorum* Tresminas / Jales, from the southwest: view of the position of the former dam at the Ribeira de Frades between Tazém and Cabanas (freg. Carazedo de Montenegro, conc. Valpaços). In the foreground the area of the former reservoir (photo: C. Wahl).



Fig. 5.0-14: *Territorium metallorum* Tresminas / Jales: pit on the road from Tinhela de Baixo to Tresminas, where the typical reddish, loamy material that was used to build the earth fill dams, is visible (photo: R. Wahl-Clerici).



Fig. 5.0-15: *Territorium metallorum* Tresminas / Jales: dam at Ribeiro do Muro southeast of Vilarelho. The wall is covered by the vegetation, however, incisions in the rock are well visible (photo: R. Wahl-Clerici).



Fig. 5.0-16: *Territorium metallorum* Tresminas / Jales: detail of the outlet-construction of the dam at the Ribeiro do Muro, southeast of Vilarelho (photo: R. Wahl-Clerici).





Fig. 5.0-17: *Territorium metallorum* Tresminas/Jales, from the northwest: foundations of the dam at Ribeiro da Peliteira, shortly before the passing into Rio Tinhela. The aqueduct that was fed by the reservoir led the water to the Forno dos Mouros treatment zone. The range pole marks the main outlet (photo: R. Wahl-Clerici).

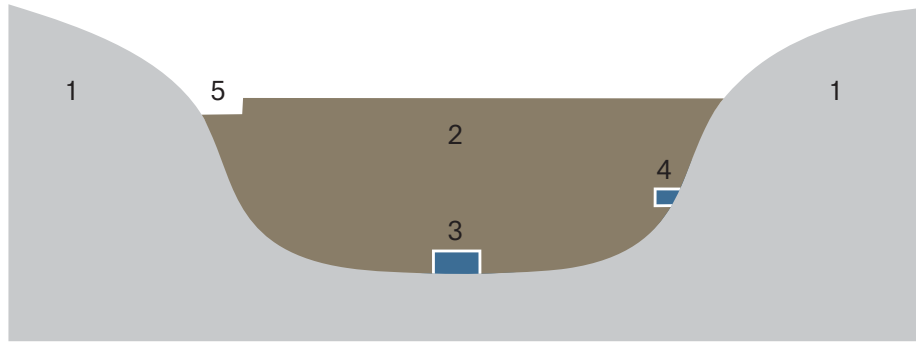


Fig. 5.0-18: Schematic view of the reservoir and the discharges: 1 = underground, 2 = dam, 3 = bottom outlet, 4 = main outlet, 5 = overflow (template R. Wahl-Clerici, design: S. Mathiuet).



Fig. 5.0-19: *Territorium metallorum* Tresminas / Jales: rockfill dam on the upper reaches of the Ribeiro da Peliteira with the bottom outlet with the regulating stone, as seen from the valley (photo: R. Wahl-Clerici).



*Fig. 5.0-20: **Territorium metallorum** Tresminas / Jales: Sevivas weir, the C4 aqueduct to the mining zone of Tresminas was fed from here. The cuts in the large rock mark the beginning of the channel (photo: R. Wahl-Clerici).*



*Fig. 5.0-21: Territorium metallorum Tresminas / Jales: Sevivas weir, the measuring stick indicates the level of the C4-aquaeduct (photo: R. Wahl-Clerici).*



*Fig. 5.0-22: Territorium metallorum Tresminas / Jales: weir of the Rio Tinhela in the Vale Curtinha. View from the valley, from the west. The bottom outlet is hidden under the large transverse boulder (photo: R. Wahl-Clerici).*



*Fig. 5.0-23: Territorium metallorum Tresminas / Jales: weir of the Rio Tinhela in the Vale Curtinhas. View from the north into the reservoir area with the protecting granite slabs, the outlet is marked by the worked rock-part in face of the granite-slabs (photo: R. Wahl-Clerici).*



Fig. 5.0-24: *Territorium metallorum* Tresminas / Jales, Tresminas: outer wall of the settling tank in the settlement area (photo: R. Wahl-Clerici).



Fig. 5.0-25: *Territorium metallorum* Tresminas / Jales, Tresminas: view into a section of the water tank of the settlement area. The very hard material is interspersed with small stones (photo: R. Wahl-Clerici).



Fig. 5.0-26: *Territorium metallorum* Tresminas / Jales: the marked ridge in the slope shows the course of the aqueduct C4, which continues in the rock cut in figs. 5.0-27a/b/c, 5.0-28 (photo: J. Wahl).



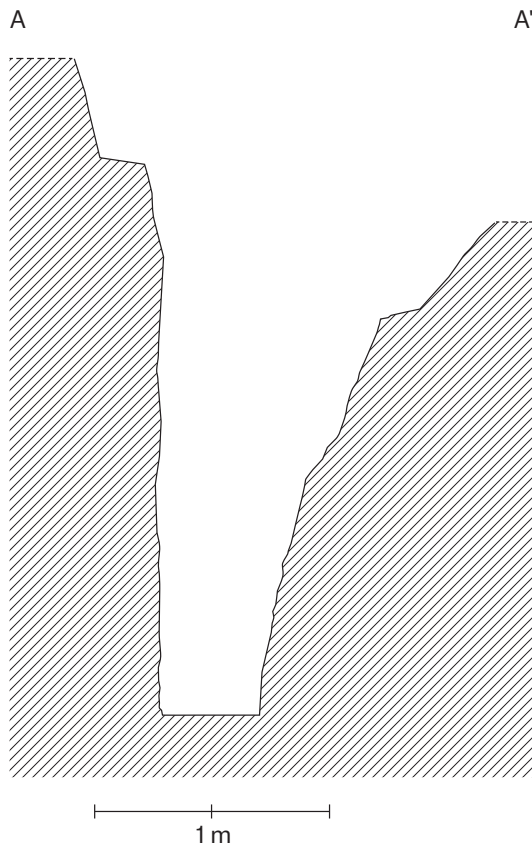
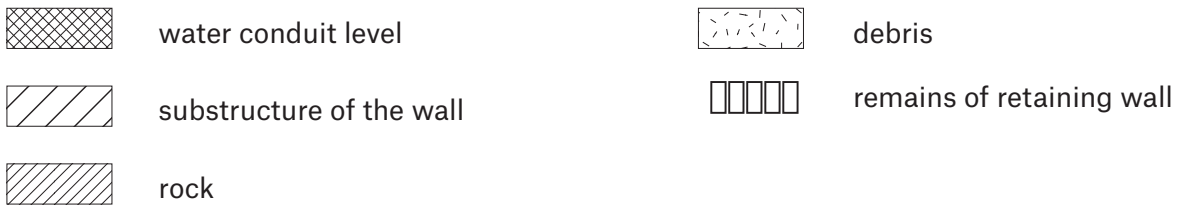
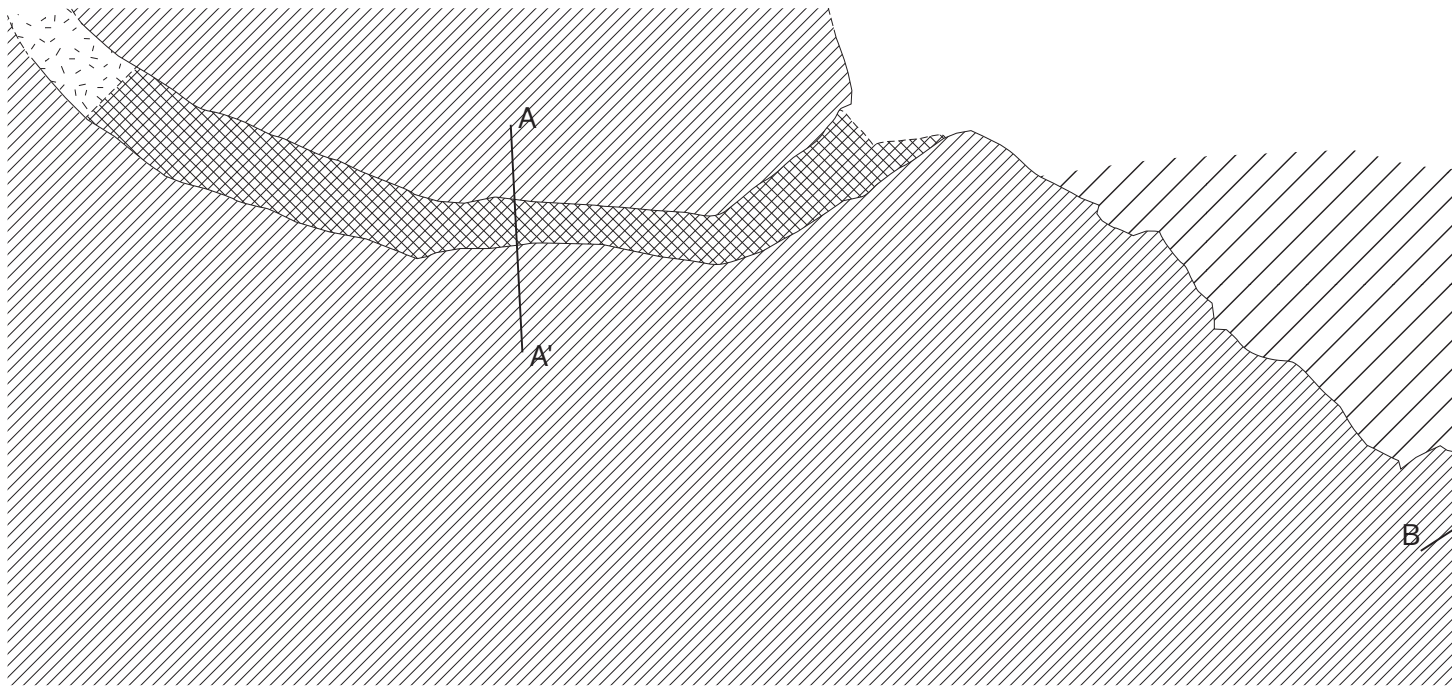


Fig. 5.0-27b: *Territorium metallorum* Tresminas / Jales: cross section A — A' of the rock cut of the aqueduct C4 above Ribeirinha (documentation: E. Andenmatten 2000, design: R. Wahl-Clerici 2013).

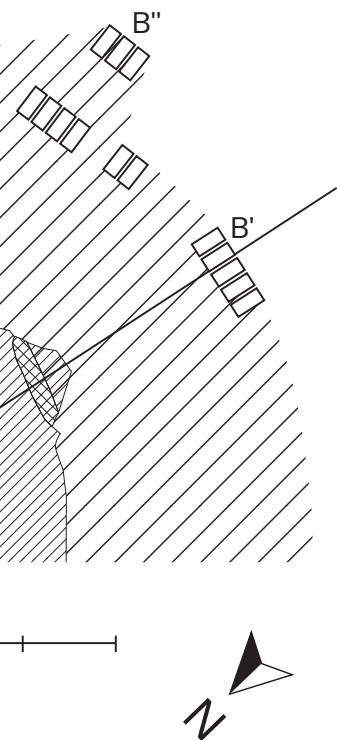


Fig. 5.0-27a: *Territorium metallorum* Tresminas / Jales: plan of the rock cut of the aqueduct C4 above Ribeirinha (documentation: Andenmatten 2000, design: Wahl-Clerici 2013).

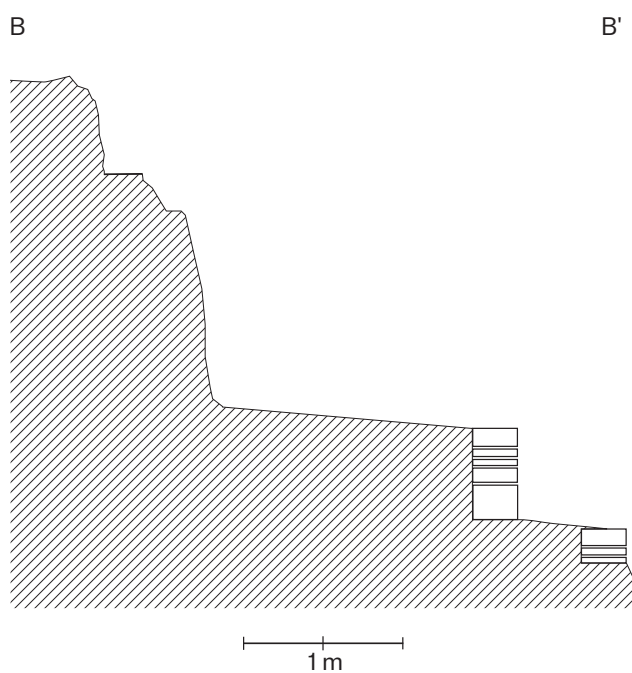


Fig. 5.0-27c: *Territorium metallorum* Tresminas / Jales: cross section B — B' of the rock cut of the aqueduct C4 above Ribeirinha (documentation: Andenmatten 2000, design: Wahl-Clerici 2013).



*Fig. 5.0-28: **Territorium metallorum** Tresminas / Jales: view towards the south with rock cut of the aqueduct C4 above Ribeirinha (photo: R. Wahl-Clerici).*



Fig. 5.0-29: *Territorium metallorum* Tresminas / Jales: rock carvings for the aqueduct C4 in the Ribeirinha valley (photo: J. Wahl).

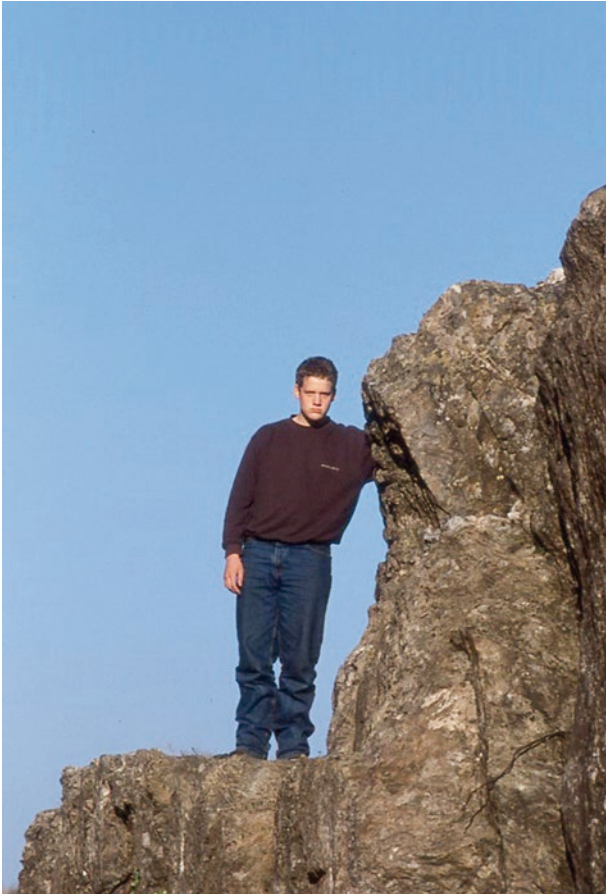


Fig. 5.0-30: *Territorium metallorum* Tresminas / Jales; rock incisions of the aqueduct T2 (photo: R. Wahl-Clerici).

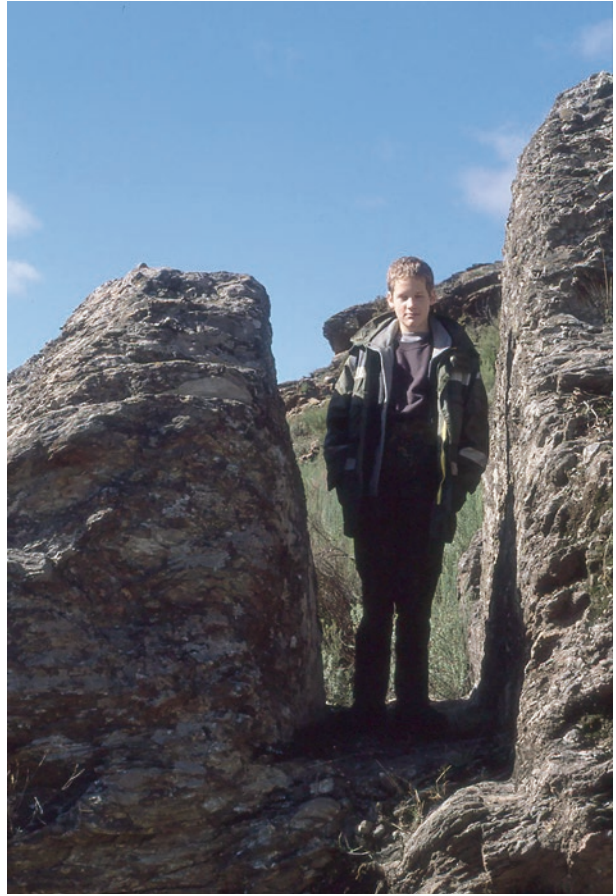


Fig. 5.0-31: *Territorium metallorum* Tresminas / Jales; Fragas Amarelas rock cut, made for the aqueduct C3 near Cabanas (Freg. Carrazedo de Montenegro, Conc. Valpaços) (photo: R. Wahl-Clerici).



Fig. 5.0-32: *Territorium metallorum* Tresminas / Jales, Fragas Cortadas; rock incisions of the aqueduct C3 (photo: R. Wahl-Clerici).



Fig. 5.0-33: *Territorium metallorum* Tresminas / Jales: the aqueduct T6 in the Rio Tinhela valley, opposite the Forno dos Mouros treatment zone (photo: R. Wahl-Clerici).



Fig. 5.0-34: *Territorium metallorum* Tresminas / Jales, Vilarelho: junction of two construction lots on the aqueduct T1 (photo: R. Wahl-Clerici).



Fig. 5.0-35a/b: *Territorium metallorum* Tresminas/Jales, Sevilas, Vale do Ribeiro do Cão: part of channel C2 was completely cut into the rock. Well preserved are the carvings in the rock made to position the stones of the accompanying wall (photos: J. Wahl).



Fig. 5.0-36: *Territorium metallorum* Tresminas / Jales, Tresminas, Galeria do Pilar, from the south: drainage channel on the eastern working face (photo: R. Wahl-Clerici).





Fig. 5.0-37: *Territorium metallorum* Tresminas / Jales, Campo de Jales: bronze vessel, probably part of a water-lifting machine (Museo Municipal de Vila Pouca de Aguiar, photo: J. Wahl).



Fig. 5.0-38 *Territorium metallorum* Tresminas / Jales, Forno dos Mouros: drainage channel (photo: R. Wahl-Clerici).



Fig. 5.0-39: *Territorium metallorum* Tresminas / Jales, Tresminas: small drainage channel in the settlement, covered with millstones of the ore-processing (D-DAI-MAD-WAHL-KB-81-86-24).



Fig. 5.0-40: *Territorium metallorum* Tresminas / Jales, Tresminas: drainage channel in the settlement (photo: R. Wahl-Clerici).

## 6.0 The quarries

The territorium metallorum Tresminas/Jales is rich in high quality rock, as demonstrated by the granite quarrying in the Concelho of Vila Pouca de Aguiar, which is still profitable today.<sup>235</sup> In Antiquity rock was quarried here at various locations and earth was also extracted. This was often carried out in the immediate vicinity of the building site, in order to reduce costs and effort. A local extraction of construction material can not only be proven for the construction of the bridge “Ponte do Arco” but also in connection with the construction of the ore washing installations of Tresminas and other buildings on the site.

Granite (biotite-granite and two-mica granite), schist and highly loamy earth were used as building materials (figs. 6.0-1, 6.0-2). It is crucial to not only identify the extraction sites, but also the use of the material in order to be certain that the material was used for the building of installations connected to mining. When proceeding in this manner, the origin of many of the end products found in the mining zones (e. g. stamp mill bases, ore mills or altars) can be determined, which in turn allows conclusions to be drawn about the organisation of the mine. For some objects, however, a more precise determination of the origin is only possible through geochemical investigation.

### Granite quarries

In the case of the granites, it can be assumed that it was mainly the blocks created by weathering which were lying around openly that were used for quarrying (fig. 6.0-3). Occasionally, traces of quarrying can also be detected on the bedrock or on blocks that are still half covered by earth (figs. 6.0-4—6.0-7).

The workplaces in the granite quarries are distributed over their entire zone and are mainly characterised by the absence of granite blocks, a conspicuous accumulation of rock cuttings and the possible presence of discarded work stones (figs. 6.0-8a/b).

### Biotite granite

The biotite granite, which is both hard and pressure-resistant, is located in the valley of Vila Pouca de Aguiar. The excellent quality of the rock has led to it being quarried from Roman times onwards until today. In addition to the modern quarries, which stand out even on Google Earth, there are many older quarrying zones where the rock was mined with the same methods as in Roman times. The few

preserved traces of undisputedly Roman date prove at least that extraction took place above the church of São Martinho de Bornes (Freg. Bornes, Vila Pouca de Aguiar), i. e. in the biotite granite zone closest to Tresminas (fig. 6.0-4).

The biotite granite was probably used exclusively for the production of stamp mill bases and ore mills.<sup>236</sup> Large accumulations of these were found near the places where the dry mechanical processing was carried out. Ore mills are found quite often as *spolia* in the Roman mining settlement, while stamp mill bases were only used as fragments. However, the majority of the latter were transported to the modern *aldeias* (villages) of Riberinha, Covas or Tresminas, located near the mining zones (figs. 6.0-9a/b). In Roman times, the name-giving pillar in the Galeria do Pilar was also constructed using at least 36 stamp mill bases (fig. 6.0-10). Finally, a solitary stamp mill base was found in the Galeria do Texugo (fig. 3.2-13b).

Another important site is the processing zone “Forno dos Mouros” in the area of the ore deposits of Gralheira and Campo de Jales (fig. 6.0-2). Most of the Roman granite objects in this zone were discovered integrated as *spolia* into the construction of the modern mill below the processing zone (fig. 4.1-1).

We can state the following with respect to the biotite granite:

- The biotite granite used in the mining zones of Tresminas and Gralheira/Jales was extracted in as close proximity as possible, i. e. near the transition zone to the slate zone, high above the valley floor of Vila Pouca de Aguiar.
- According to current knowledge, biotite granite was used exclusively for the production of stamp mill bases and ore mills.
- This raises the question: were the quarries and objects exclusively owned by the state?
- If so, it is possible that the objects were released from state ownership at the end of their original use. This is suggested by the distribution of these objects in the former settlement area — with the disclaimer that the

<sup>235</sup> Sousa 2013; The Concelho (district) of Vila Pouca de Aguiar, in which the Roman *territorium metallorum* Tresminas/Jales is located, is also named “Capital de Granito” (granite capital); The origin of the granite used to clad the outer wall of the Celtiberian Castro dos Mouros (Cidadelhã, Freg. Alfarela de Jales, Conc. Vila Pouca de Aguiar), located in a slate zone, is not known (fig. 2.0-3).

<sup>236</sup> So far, three quartzite stamp mill bases have been identified, probably all from the area south of the oldest mining zone P1 of Corta de Covas. All ore mills are made of biotite-granite.

archaeologically investigated settlement area is too small to draw reliable conclusions about the general occurrence of such objects.

### The two-mica granite

The two-mica granite was not suitable for the production of ore mills and was used exclusively for grain mills, inscribed stones and construction elements (figs. 6.0-11, 6.0-12a/b). The most extensive and varied production of different objects can be found in the quarry of Fonte da Ribeira, which is located in a granite zone that penetrates deeply into the slate zone.<sup>237</sup> Other quarries could mainly be identified by the rock used directly on site.

The work stones discarded in the Fonte da Ribeira quarry in various stages of processing allow us to outline the production of the round mills step by step (figs. 6.0-13a/b).

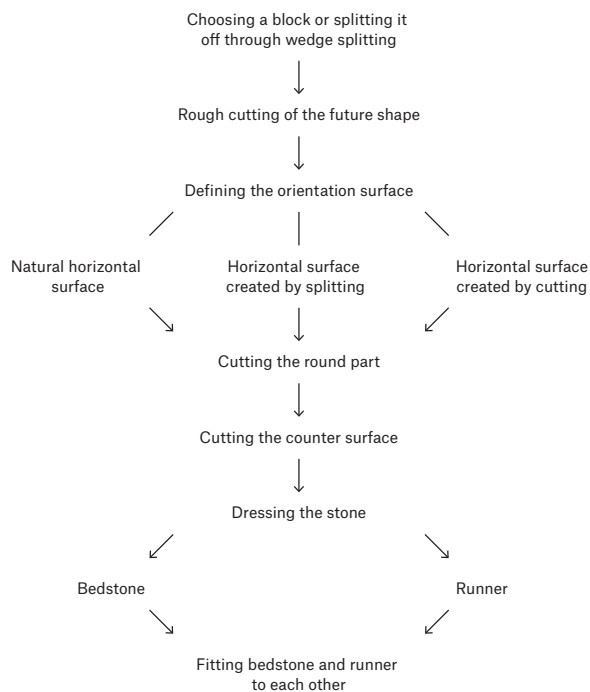


Fig. 6.0-14a: Schematic representation of the steps required to produce a millstone of two mica granite in the Fonte da Ribeira quarry (template R. Wahl-Clerici, design: S. Mathiuet).

First, a suitable block was selected or obtained by splitting. It had to be larger than the future millstone by about 15–20 cm in at least two dimensions (figs. 6.0-3, 6.0-7). It was then roughly cut into a round. It is difficult to be sure which of the blocks lying around in the quarry may have been abandoned after this step, as they could in principle also have been prepared for other objects such as building components.

For the further working of the millstone, the orientation surface had to be determined. This could already exist naturally (fig. 6.0-15) or could be obtained by splitting (fig. 6.0-16) or by dressing (fig. 6.0-17) the rock. In the fol-

lowing step, the stone was worked into a completely round disk. The stone in fig. 6.0-18 proves that the orientation surface did not have to be worked out very carefully for the following steps.

At least two discarded blocks demonstrate the dressing of the other side of the stone. For this purpose, the superfluous stone was worked off all around the future millstone. The two specimens still found in the quarry would have had to be discarded due to the miniscule natural fissures, which only became apparent during this step (figs. 6.0-13a/b, 6.0-19a/b).

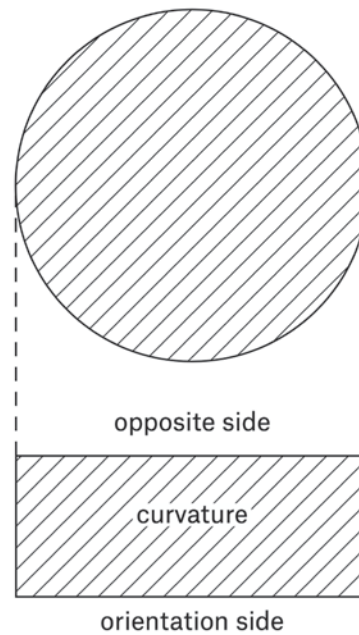


Fig. 6.0-14b: Diagram showing the designations of the orientation surface, the counter surface and the rounding (photo: R. Wahl-Clerici).

It is possible that the decision whether to create a *meta*, a sleeper / lower stone, or a *catillus*, a runner / upper stone, had to be made at this point, that is, before the counter surface was dressed. For a *catillus*, a disk had to be constructed that was as perfect as possible in order to optimally position and cut out the central hole (figs. 6.0-20a/b/c). The losses during this delicate process were high (figs. 6.0-21, 6.0-22). The future *meta* — sleepers — did not have to be prepared so carefully (figs. 6.0-23a/b/c). The adaptation of *meta* and *catillus* to each other probably took place when they were first installed at the site of use.

237 Wahl-Clerici et al. 2015; Wahl-Clerici, The millstone production in the Roman quarry at Fonte da Ribeira, *territorium metallorum Tresminas/Jales*. In: N. Alonso, T. Anderson, L. Jaccotey, Querns and Mills in Mediterranean Antiquity: Tradition and Innovation during the First Millennium BC, EAA meeting Barcelona 2018, Collection Collège de France “Techniques and Economies in the Ancient Mediterranean”. In print.

### *Ponte do Arco*

For the construction of the Ponte do Arco, which was part of the connecting road to the south towards the Douro, the boulders created by weathering and lying around on the surface were mainly used, as the conspicuous absence of such blocks on the neighbouring rock formation shows. Actual traces of quarrying have been preserved in only two places (fig.6.0-24). This is an observation characteristic for the building of larger structures in the area of granite zones.<sup>238</sup>

## The schist quarries

The local schist was the most frequently used building material in the Roman mining territory of Tresminas. In principle, all buildings were built of schist, including the amphitheatre, the water tank at the edge of the settlement and the ore washing facilities.

The two quarries on the southern edge of the Roman mining settlement are still visible today (figs.6.0-25—6.0-27). Presumably the stones for the buildings in the settlement were quarried here. We can assume this to have been the case despite the absence of the walls in the settlements, as the stones of the Roman buildings, whether from the settlement or from the aqueducts, were systematically removed and reused in the field walls and buildings of the nearby villages of later periods.

Both quarries are elongated incisions in the surface of the slope. The dimensions of quarry 2 can no longer be determined with certainty, as post-Roman agricultural work has partially changed the contours. For the same reason, the bottom of the quarry zones was not determinable. Distinct traces of mining have only been preserved at quarry 1.

- Quarry 1: length max. 90 m, width (top) 24.30 m, width (bottom) ca. 17 m, currently visible depth ca. 4 m; total volume at least 2700 m<sup>3</sup>
- Quarry 2: length max. 51 m, width max. 24 m, height max. 2 m; total volume at least 1500 m<sup>3</sup>

## The Outeiro earth extraction pit on the Rio Tinhela

About 250m south of the large earth dam of Outeiro (figs. 5.0-7—5.0-9), a depression in the slope has been identified as a material extraction pit. It is a long and irregular pit of approximately rectangular shape (L max. 46 m, W max. 30m, with a maximum depth of ca. 7 m in the highest part, see fig. 6.0-28). From this pit, highly loamy earth used for the construction of the earth dams and for sealing the water pipes was extracted. Calculation of the volume of the nearby dam at Outeiro shows that the

volume extracted from this pit alone was by no means sufficient for the construction of the dam, which is no less than almost 21 m high, approx. 150m long and approx. 65 m wide at its base. We must assume that further pits with similar material were also exploited. However, these have largely disappeared.

## Results

The numerous quarries in the *territorium metallorum* Tresminas/Jales cover the entire demand for stone material. A distinction can be made between the quarries where a specific material was extracted for a specialist use, such as that the biotite granite used for the mortars and ore mills, and the two-mica granite used for the grain mills, inscription stones, building elements, etc. In contrast, the two schist quarries south of the mining settlement of Tresminas, were used to extract material used for less specific building material, used in houses, etc.

While granite quarries are well known from elsewhere in the Roman Empire, both the schist quarries and the earth extraction pit near the Outeiro dam seem to be objects that have not been thus far observed or recorded. We must assume that blocks of rock lying on site or rock cut out for foundations were also incorporated into the constructions. This can be observed, for example, at the amphitheatre or at the ore washing facilities.

<sup>238</sup> For example, at the Alcantarilla dam south of Toledo (E). Arenillas Parra / Barahona Oviedo 2009.

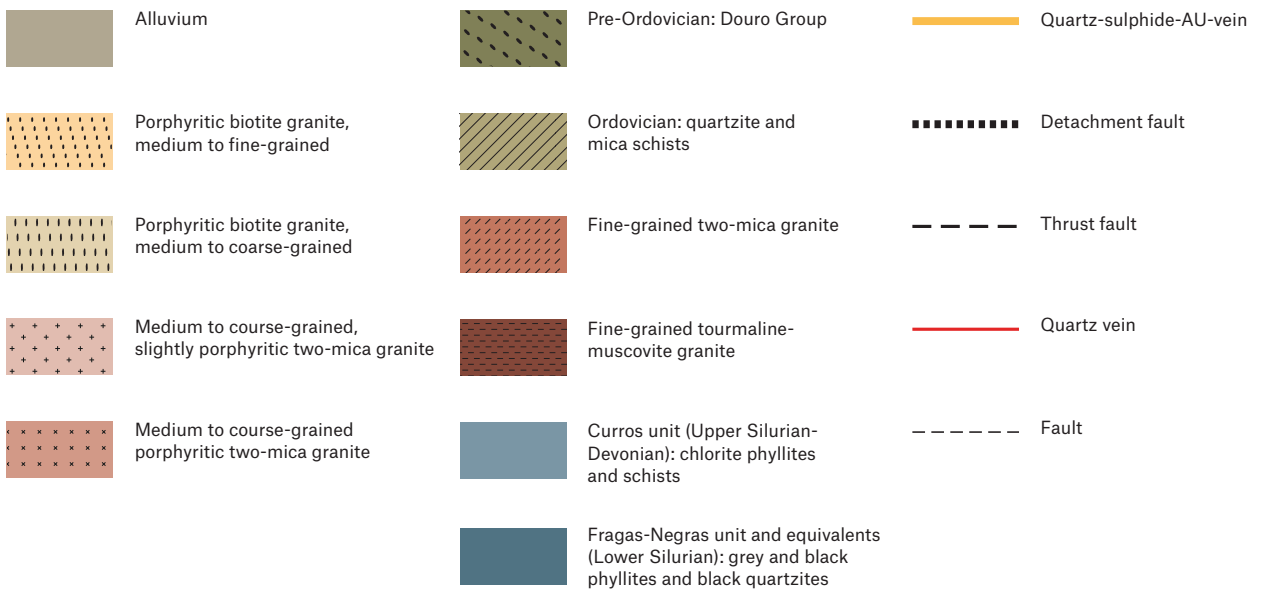
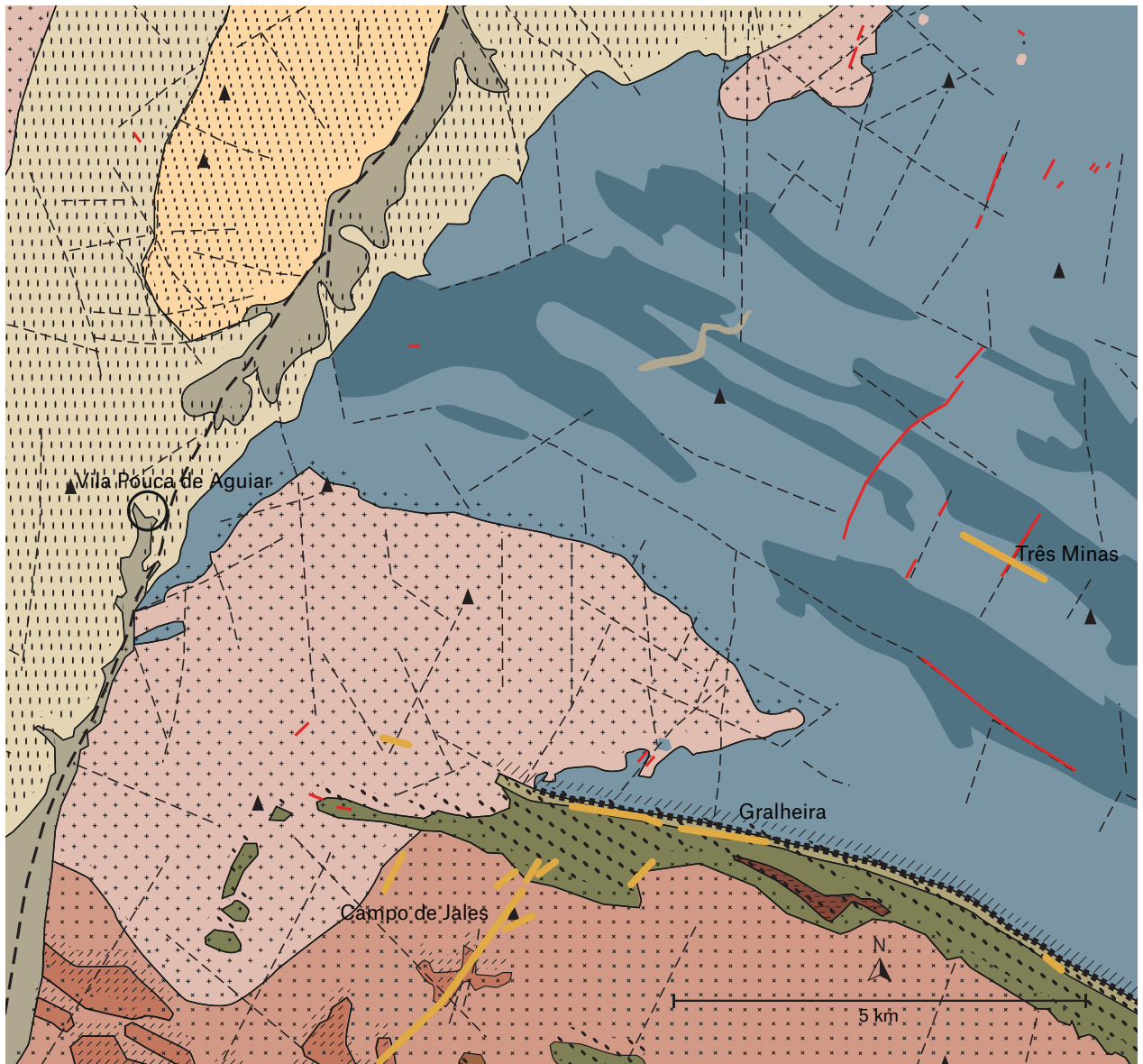


Fig. 6.0-1: Geological map of the Vila Pouca de Aguiar region (after Sousa Oliveira 2013, 16 and Rosa / Romberger 2003, 647, re-worked by R. Wahl-Clerici).

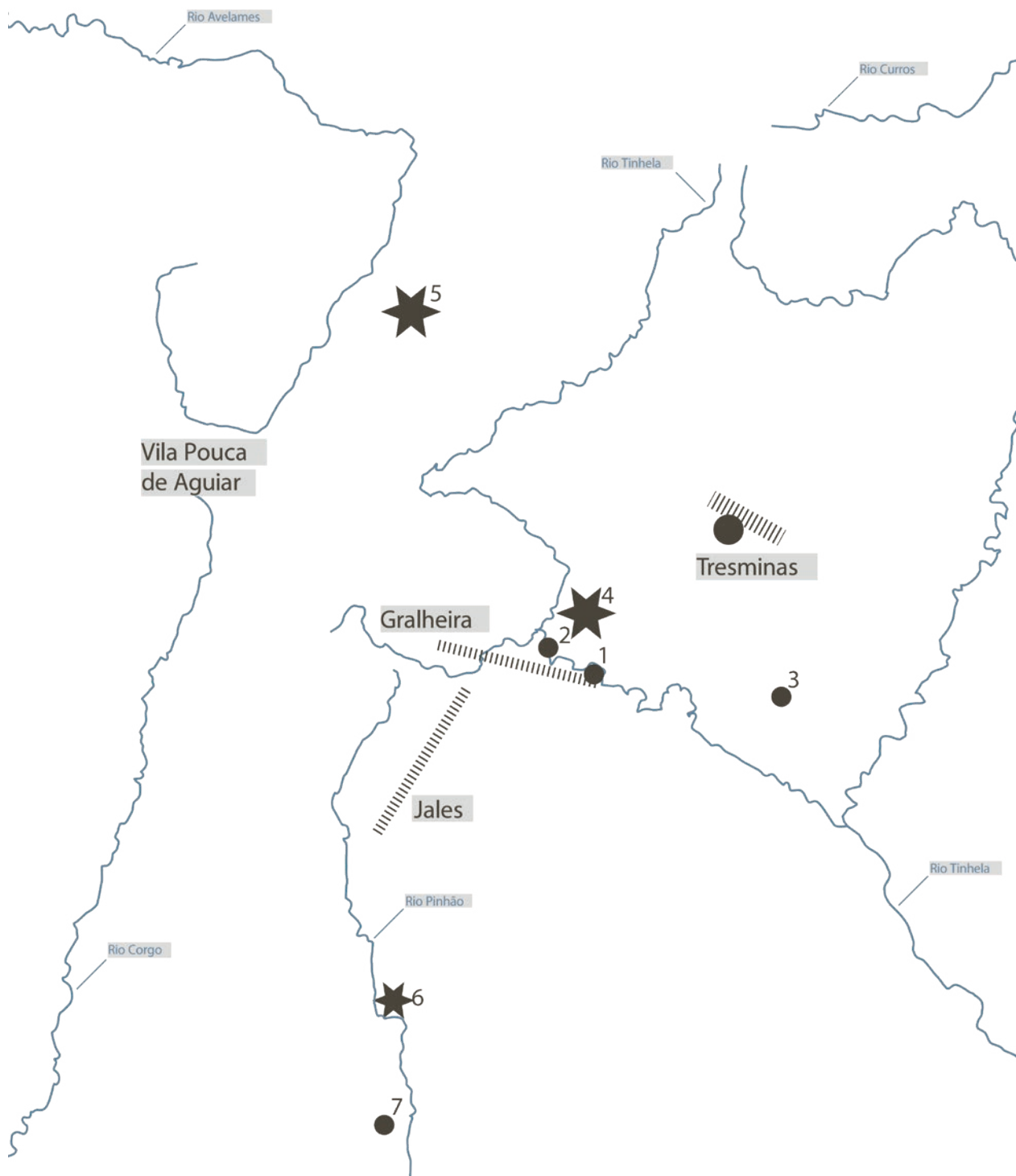


Fig. 6.0-2: *Territorium metallorum* Tresminas/Jales: Stars: 4 Quarry of Fonte da Ribeira, 5 Quarry of São Martinho de Bornes, 6 Quarry of the Ponte do Arco-Bridge. 1 Castelo dos Mouros, 2 Forno dos Mouros, 3 Farm of Vales, 7 Ponte da Cheira (template Carta Militar de Portugal 1:50 000 [folhas 6-2 e 10-1], design: R. Wahl-Clerici and S. Mathiuet).



Fig. 6.0-3: *Territorium metallorum* Tresminas / Jales, Fonte da Ribeira quarry: the area is littered with granite blocks of varying size (photo: R. Wahl-Clerici).





Fig. 6.0-4: *Territorium metallorum* Tresminas / Jales: Roman quarry above the church São Martinho de Bornes (Freg. Bornes, Vila Pouca de Aguiar) with remains showing the preparatory work for lifting and splitting (photo: J. Wahl).



Fig. 6.0-5: *Territorium metallorum* Tresminas / Jales, Fonte da Ribeira quarry: preparatory work for lifting (photo: R. Wahl-Clerici).



Fig. 6.0-6: *Territorium metallorum* Tresminas / Jales, Fonte da Ribeira quarry: block prepared for splitting off for an elongated object, largely covered with earth (photo: R. Wahl-Clerici).



Fig. 6.0-7: *Territorium metallorum* Tresminas / Jales, Fonte da Ribeira quarry: block prepared for splitting, from which parts have already been split off at the front and side (photo: R. Wahl-Clerici).



Fig. 6.0-8a: *Territorium metallorum* Tresminas / Jales, Fonte da Ribeira quarry: workplace with the typical sharp-edged offcuts. On the right in the background a block prepared for splitting (photo: R. Wahl-Clerici).



Fig. 6.0-8b: *Territorium metallorum* Tresminas / Jales, Fonte da Ribeira quarry: workplace characterised by the absence of granite blocks (photo: R. Wahl-Clerici).



Fig. 6.0-9a: *Territorium metallorum* Tresminas / Jales, Ribeirinha (village): reused stamp-mills (photo: R. Wahl-Clerici).



Fig. 6.0-9b: *Territorium metallorum* Tresminas / Jales, Tresminas (village): idealised reconstruction of a prehistoric tomb, using a medieval sarcophagus and roman mortars (photo: R. Wahl-Clerici).



Fig. 6.0-10: *Territorium metallorum* Tresminas / Jales, Corta de Covas, Galeria do Pilar, looking towards the entrance: the pillar was built with at least 36 re-used stamp mill bases from biotite granite (photo: R. Wahl-Clerici).



Fig. 6.0-11: *Territorium metallorum* Tresminas / Jales, Fonte da Ribeira quarry: incomplete column base or capital, diameter 50 cm, H max. 23 cm (photo: R. Wahl-Clerici).



Fig. 6.0-12a/b: *Territorium metallorum* Tresminas / Jales: column with capital, originally re-used in a farm building in Covas, today in Tresminas (freg. Tresminas, conc. Vila Pouca de Aguiar / P), height of the column 116 cm (photo: R. Wahl-Clerici).



Fig. 6.0-13a/b: *Territorium metallorum* Tresminas / Jales, Fonte da Ribeira quarry: worked stone, only about half preserved, with the orientating surface and rounding finished. The stone broke during the dressing of the other side of the stone and shows well-preserved traces of dressing. Diameter 45 cm, H max. 29 cm, projected height in the end 16—17.5 cm (photo: R. Wahl-Clerici).



Fig. 6.0-15: *Territorium metallorum* Tresminas / Jales, Fonte da Ribeira quarry: roughly cut stone with naturally flat orientation surface. Diameter min. 47 cm, H min. 34 cm (photo: R. Wahl-Clerici).



Fig. 6.0-16: *Territorium metallorum* Tresminas / Jales, Fonte da Ribeira quarry: by using an aplite dike, a straight surface could be created on this block (photo: R. Wahl-Clerici).



Fig. 6.0-17: *Territorium metallorum* Tresminas / Jales, Fonte da Ribeira quarry: roughly cut stone, measurements of the exposed part 49 cm × 54 cm; height min. 33 cm (photo: R. Wahl-Clerici).



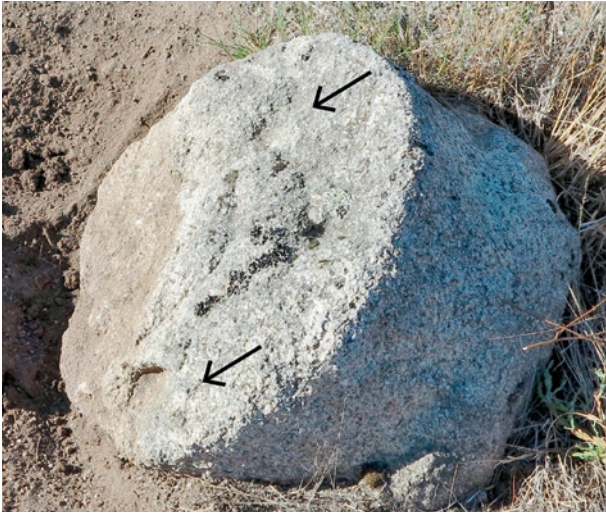


Fig. 6.0-18: *Territorium metallorum* Tresminas / Jales, Fonte da Ribeira quarry: millstone blank with a combination of a wedged and cut orientation surface and a carefully trimmed rounding. The arrows point to the remains of the two preserved wedge pockets: diameter 45—46 cm, worked height min. 14 cm, max. 33 cm (photo: R. Wahl-Clerici).



Fig. 6.0-19a/b: *Territorium metallorum* Tresminas / Jales, Fonte da Ribeira quarry: the stone had to be discarded during straightening of the opposite side due to the fissures. Diameter 42 cm, H max. 38 cm, projected height at the end 19 cm (photo a: R. Wahl-Clerici, photo b: T. Schierl).



Fig. 6.0-20a/b/c: **Territorium metallorum** Tresminas / Jales, Fonte da Ribeira quarry: worked stone with neatly finished orientation surface and rounding with central markings. The counter surface was not further worked, as the stone became unusable due to a fault. A triangular wedge-shaped pocket is preserved in the unworked part. Diameter worked part 40 cm, H max. 31 cm, projected height at the end 14.5 cm, wedge pocket L 10 cm, T 6 cm. Width cannot be determined (photo: R. Wahl-Clerici).



Fig. 6.0-21: **Territorium metallorum** Tresminas / Jales, Fonte da Ribeira quarry: runner with incorrectly positioned central hole, broken in two halves. Diameter max. 42,5 cm, diameter central hole min. 7,5 cm, max. 10,5 cm, H max. 19 cm (photo: R. Wahl-Clerici).



Fig. 6.0-22: **Territorium metallorum** Tresminas / Jales, Fonte da Ribeira quarry: fragment of a catillus (runner). Diameter max. 40 cm, diameter central hole preserved 9 cm, H 9 cm (photo: R. Wahl-Clerici).



6.0-23a/b/c: *Territorium metallorum* Tresminas / Jales, Tresminas: Meta (sleeper/lower stone) with clear traces of use, found in the mining settlement. The area that served as a support on the ground is only roughly hewn. In the area of the central hole, traces of fractures are visible which either led to the stone being discarded or were caused by a more recent impact. Diameter max. 41 cm, H max. 9 cm (photo: R. Wahl-Clerici).



Fig. 6.0-24: *Territorium metallorum* Tresminas / Jales, Ponte do Arco from the north: a boulder with wedge pockets is visible in the middle of the picture (photo: R. Wahl-Clerici).



Fig. 6.0-25: *Territorium metallorum* Tresminas / Jales, Tresminas: location of the schist quarries 1 and 2 south of the mine settlement, marked by crosses (template Ortofotmapa 1:5000, page 7531, Vila Pouca de Aguiar, design: R. Wahl-Clerici).



*Fig. 6.0-26: **Territorium metallorum** Tresminas / Jales, Tresminas: view from the southwest into the schist quarry 1 south of the mine settlement (photo: R. Wahl-Clerici).*



Fig. 6.0-27: *Territorium metallorum* Tresminas / Jales, Tresminas: cutting traces above the northern slope of schist quarry 1 (photo: R. Wahl-Clerici).



Fig. 6.0-28: *Territorium metallorum* Tresminas / Jales, Outeiro: view into the earth extraction pit (photo: R. Wahl-Clerici).





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The reconstruction of Roman mining activities in a primary deposit during the 1st and 2nd centuries AD has been made possible thanks to the excellent preservation of ancient mining and the prerequisite accompanying industries in the *territorium metallorum* Tresminas /Jales. Decades of on-site research and careful documentation of the monuments and traces of mining have facilitated the understanding of the work processes presented in this volume: prospection, excavation and processing. Within this framework, prospecting not only served the discovery of deposits as reported by ancient sources, but it accompanied the miners' daily work and was an essential element of the mining process.

The mining itself has left traces that enable us to both follow and understand the progress of mining over time. The planning and execution that become visible as a result of this allow us to infer a central organisation. The fantastic extensive high galleries of Tresminas, whose dimensions and state of preservation still impress visitors and researchers today are a further example of this. Finds that were abandoned, never completed or destroyed in ancient times are particularly helpful in understanding the mining process.

The complex processing of the gold-bearing ores has left behind in Tresminas around 1 000 stamp mills, countless rock-grinding mills and enormous ore washing structures. In addition, the water management system associated with mining and settlement is discussed. An important part of the industrial complex was also the local stone quarrying for the production of stamp mills, rock-grinding and grain mills. A summary of the historical context of the *territorium metallorum* Tresminas /Jales is presented in the introduction.

