Mining Under Empire: Exploiting the Metal Resources of Roman Dacia

Volume 1

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Abstract:

This thesis explores how the Romans managed the metal resources of Roman Dacia, and the impact that the advent of Roman rule had on mining in the province. Roman Dacia has long been a byword in the scholarly literature for its mineral wealth, but modern archaeological research on the mining remains has thus far been lacking until the excavations at Roșia Montană took place between 1999 and 2013. Through a synthesis of the archival literature and the latest results from the Roșia Montană excavations, this project demonstrates the vibrancy and diversity of mining in Dacia, arguing that the Romans were able to exploit the metal deposits of Dacia more effectively and on a larger scale than their predecessors through the application of mining technology and experience acquired elsewhere in the Empire. It illustrates how Roșia Montană was probably the foremost mining site in Dacia, but that the Romans also identified and exploited almost all the known mining regions in the province. The diversity of their methods allowed for adaptation to local circumstances both in terms of the geological and administrative needs of specific mining sites. To supplement the secondary research, ground-truthing to verify possible hydraulic-mining remains identified through satellite imagery was also undertaken. Key results of this study include establishing type-sites for hard-rock mining and hydraulic mining at Roșia Montană, and at Bucium and Pianu de Sus respectively, to aid in the identification of other similar workings in Dacia. This thesis also makes available, for the first time, the fullest treatment of the mines of Roman Dacia in English and provides a gazetteer of sites for future work.

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Introduction

The trajectory of Dacia's inclusion, development, and eventual departure from the Roman Empire offers a unique case study for mining organisation and administration at the height of Roman imperialism. It is one of the few provinces for which a fairly well-defined chronology is known: from Trajan's successful conquest in AD 106 to Aurelian's withdrawal in AD 271, Dacia was part of the Roman Empire for roughly 150 years. Within this period, the province changed from a region dominated by dispersed hillforts to an organised social and economic network of interconnected towns, forts, and secondary settlements.[1] Famous for its gold, Dacia has long been a byword amongst ancient and modern historians alike for mineral wealth—an oft-cited reason for its inclusion in the Empire.[2] The extent and manner in which these factors are interrelated, however, need to be more clearly elucidated in light of the major advances in archaeological research on Dacia.

Until now, an integrated assessment of the evidence has been difficult due to a bias in scholarly interest, as previous fieldwork focused heavily on Roman military fortifications and the *limes*, as well as major urban centres like *Ulpia Traiana Sarmizegetusa* and *Apulum*. Only in recent years has the greater emphasis on rural settlement patterns and the systematic examination of Roman mining activity addressed

1Oltean (2007).
2 Ioann. Lyd. De mag. II 28, in Iliescu et al. (1964).

the imbalance. In particular, the study of mining has benefited tremendously from excavations at Roșia Montană, the gold-producing district of *Alburnus Maior* during the Roman period.[3] Yet despite the substantial advancement in our knowledge of the underground archaeology at this key site, the surface and subterranean evidence still requires further synthesis. Moreover, the results from Roșia Montană need to be situated within a wider analytical framework that considers the related economic and socio-political networks within which the mines operated.

Whilst the numerous allusions to Dacia's reputed wealth seem reasonably justified, the archaeology offers more than mere confirmation of the literature. By examining the archaeological evidence to identify and establish type-sites for Roman mining in Dacia, this project seeks to answer two key questions:

1. How did the Romans manage Dacia's mineral resources?
2. What impact did Roman mining have on the provincial landscape?

Through a synthesis of the archival literature with the latest excavation results, this thesis explores how the diversity with which the Romans exploited the mineral resources of Dacia allowed for a flexible approach that was suited to local circumstances and arguably resulted in more efficient outcomes for the state.

1.1 Aims and objectives

The primary aim is to understand how the Romans managed Dacia's mineral resources and, by extension, how effectively they did so. Establishing the extent to which the central authorities were involved in mining activity in Dacia helps demonstrate the province's economic importance to the Roman Empire. While the overarching question of Dacia's

3 Damian (2010); Simion, Apostol and Vleja (2005); Damian (2008). See also the work of B. Cauuet, the lead excavator of the Roșia Montană underground mines.

importance to the Roman economy is not new, the most readily available synthesis remains V. Christescu's *Viaţa economica a Daciei romane*, which relies heavily on epigraphic and documentary evidence. More specific to mining in Dacia is V. Wollmann's *Mineritul metalifer, extragerea sării şi carierele de piatră în Dacia Romană*, which also tackles the subject using traditional descriptive analysis. Both volumes are by now in need of revision in light of the excavations undertaken at Roșia Montană in the last decade. Furthermore, the past 20 years has also seen increasingly sophisticated application of computing technology in archaeology, alongside a move towards regional and landscape analysis in the study of Dacia.[4] To that end, this thesis attempts to update the study of mining in Dacia by incorporating computer-based analysis of the existing evidence alongside more traditional methods. The following tasks and objectives form the groundwork for achieving the stated aims.

1. *Synthesising available archival literature to understand how Roman mining was organised and how it differed from mining in the pre-Roman period.*

   This objective is designed to contextualise the Roman evidence within the longer chronology of mining activity in the area. Although pre-Roman mineral exploitation is still poorly understood,[5] a synthesis of the Iron Age evidence provides a comparative benchmark for evaluating the scale, nature, and complexity of Roman mining against that of the Dacians in the immediate pre-conquest period. This will clarify how differences in administrative organisation and the spatial distribution of sites impacted economic activity.

4 E.g. Oltean (2007) and Wanner (2010b).
5 Oltean (2007) 104–6 .

2. *Compiling a descriptive gazetteer of known mines to identify gaps in the data sample and to gauge the level of Roman mining activity in Dacia.*

   By collating the existing written and electronic information, this database provides the starting point for future work on the Roman mines in Dacia. The dataset is by no means complete, and a purely numerical approach at quantification is currently infeasible due to the limited sample size and problems with the quality of much of the existing data.[6] However, it will at least offer a global picture of mining in the province and contextualise the evidence from Roșia Montană. By looking at the variety, type, and location of mining activity present, this data will help in explaining the patterns of exploitation in the mining landscape of the province. The final version of the gazetteer, which constitutes an appendix to the main work, is intended to provide Anglophone scholars with access to the material for further study.

3. *Applying non-intrusive techniques such as the visual analysis of satellite imagery to identify possible mining sites for further study.*

   The sample of known Roman mines in Dacia is relatively small,[7] and very little archaeological fieldwork has been undertaken at the majority of these sites. Precise geographical coordinates are also not available for most of the Roman mines in Dacia. Although it is not possible to identify underground exploitations using satellite imagery, some surface techniques such as opencast or hydraulic mining leave visible traces on the landscape when executed on a large scale and

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6 Problems with the dataset include but are not limited to: the destruction of earlier archaeological phases due to subsequent mining activity, poorly attested site evidence, and a lack of resources for conducting intensive surface survey or underground excavation.

7 Simion (2006) in Appendix D of the Cultural Heritage Baseline Report.

can be seen using software such as Google Earth™. The use of satellite imagery to identify additional mines for inclusion in the catalogue can help improve the robustness of the data sample and provide greater geographical precision to the location of some of the Dacian mines.

4. *Integrating the archaeological evidence above and below ground at Roșia Montană and situating the analysis within a wider framework of landscape archaeology.*

Given the scale and quality of the recent excavations at Roșia Montană, the site of *Alburnus Maior* remains the best case study for mining in Dacia. This objective aims to elucidate the relationship between the mining communities and their activities below ground, as well as contextualise the evidence from Roșia Montană within the regional patterns of economic activity in Dacia. Doing so provides a basis for thinking about mining as an array of interrelated industrial and socio-economic activities, first at a site-specific level and then at a province-wide level. The former helps answer questions about the efficiency and organisation of Roman mining by considering the extent to which the Romans applied their mining expertise to solving problems specific to the site of *Alburnus Maior*. From there, one can begin to think about the usefulness of extrapolating the situation at *Alburnus Maior* for use as a case study for mining in the rest of the province and for comparisons with other mining regions in the Roman Empire.

1.2 Methodology

The methodology of this thesis combines a traditional descriptive approach involving written and archival evidence from excavation results with visual analysis using remote-sensing imagery. Although mining in Dacia is a familiar sub-topic amongst Romanian scholars of Roman Dacia, much of the literature remains unavailable to Anglophone academics and in need of collation and review. Thus, the first step involved conducting a comprehensive re-evaluation of existing research in light of modern methodological standards and evidence. Where possible, archival material in Hungarian was also consulted, but the bulk of the sources are Romanian. Finally, visual interpretation of satellite imagery, supplemented by ground-truthing, has helped verify the soundness of the written sources and contribute to our archaeological understanding of hydraulic mining remains in Dacia. By combining traditional analysis with the most recently available fieldwork, this thesis offers a synthesis of the material on the mines of Roman Dacia.

1.2.1 The written sources

The use of archival material underpins current research on mining in Dacia. V. Wollmann's work is a prime example.[8] He has collated the existing written and material evidence, much of which dates to the Austro-Hungarian Empire, and expands upon the earlier work of O. Davies, who only treated the Dacian mines in passing.[9] In a sense, there is little need for yet another work that rehashes the existing archival literature.

Nonetheless, accepting the validity of Wollmann's and Davies' sources without close examination and glossing over the archival evidence as well-worn academic ground would be injudicious. For a start, an inspection of the cited sources reveals the difficulties of working with the earlier, Romanian archaeological material. The 19th-century Austro-Hungarian geological literature, while dated, remains tremendously useful for prospection owing to the limited excavation undertaken outside of Roșia Montană. Another example

8 Wollmann (1996).
9 Davies (1935) 198–208.

are the Austrian military maps of Transylvanian roads, which are often more accurate than post-World War maps for identifying Roman infrastructure in the landscape.[10] However, Austro-Hungarian material can be difficult to obtain outside Romania due to its specialist nature.[11] Strong regionalism also means that important collections are often divided and held in county museums;[12] this is also the case for excavation records and reports, which require collation from locally published journals. Reports in national academic journals achieve slightly wider dissemination outside Romania, but again, suffer from piecemeal publication. In the case of monographs, even recently published volumes that address significant gaps in the secondary literature quickly go out of print.[13] Language barriers can also hinder access to the latest research, despite a growing move amongst Romanian scholars towards publishing in English.[14]

The most pressing problem, however, remains the questionable quality of some of the excavation evidence. This is especially true for sites with ephemeral and poorly attested remains,[15] as well as those that have fallen victim to modern development.[16] Urban excavations also tend towards intermittent and fragmentary results due to the dominance of developer-led archaeology and a lack of urban archaeology as a formal disciplinary approach.[17] Owing to these problems, the written evidence needs to be examined first-hand.

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10 Fodorean (2006a) 997–8; Fodorean (2010) 469–70.
11 E.g. Pošepný (1868).
12 The wax tablets from Roșia Montană have suffered such a fate: parts of the collection are held at five museums and two libraries, all in different cities; several tablets have gone missing entirely. For details, see Ministerul Mediului (2006) 8.
13 E.g. Băeștean (2007); Fodorean (2006b); Rusu-Bolindeț (2007). Even the Alburnus Maior series is currently out of print.
14 Apart from Oltean (2007) and Găzdac (2010), there is surprisingly little overlap between British and Romanian scholars working on Dacia. Another telling example is Żmudziński (2007), discussed in greater detail in the literature review.
15 Some of the reported sites in both Davies (1935) and M. Simion's appendix in the Roșia Montană Cultural Heritage Baseline Report (2006), for example, simply note possible traces of Roman mining activity.
16 Most notably the ancient town of Ampelum, which is thought to be the likely seat of Roman mining administration in the region. See Popa et al. (1986) on results from the rescue excavations.
17 Pupeză (2010).

1.2.2 Remote sensing and aerial photographic analysis

The use of aerial photography and remotely sensed data is a growing field in Romanian archaeology, with demonstrated potential for identifying unknown rural sites and small military settlements.[18] It has also contributed to the non-intrusive investigations carried out as part of the Roșia Montană excavations.[19] Within the parameters of this project, remote sensing has been used as a prospection tool to identify mining sites mentioned in the archival and secondary literature. The aim is to enhance the soundness of the database by increasing the sample size and by providing geographical coordinates for sites that are frequently referred to by local landmarks in the secondary literature and hence difficult to locate on a map by non-residents.

The main issues with remotely sensed imagery tend to be the availability of cost-effective images in a high enough resolution for the visual identification of archaeological remains. To attain the widest range of analysis, examining a combination of old maps, aerial photographs, and satellite images would provide the best coverage. The primary source is satellite imagery from Google Earth™, which has been used to visually interpret morphologically distinct features in the landscape and locate potential surface mining activity. This technique is most useful for identifying large-scale opencasts and possible instances of hydraulic mining, as Roman workings leave very distinctive markers on the landscape.[20] Ground-truthing to verify the desk-based visual interpretation has been conducted at two sites—Vulcoi-Corabia at Bucium and the hydraulic mining works at Pianu de Sus—and cross-referenced with the available secondary literature. Although a

18 Berecki et al. (2012); Hanson and Oltean (2003); Oltean and Hanson (2001) and (2007). Cf. Bogdan-Cătăniciu (2006) 963, 967.
19 CHBR (2006) 38, 44.
20 Well-known examples include the mines at Las Médulas and on the Rio Duerna in north-western Spain; e.g. Lewis and Jones (1970); Jones and Bird (1972).

reasonable body of archaeological work exists for Bucium and Pianu, the most recent scholarship is not yet fully published and geographical coordinates are surprisingly difficult to come by. The application of visual analysis via remote sensing has played a key role in identifying Roman hydraulic mining at these two sites.

1.3 Literature review

Extensive bibliographies are available on Dacia, mining, and the Roman army, and the following literature review is by no means complete. Instead, it focusses on secondary literature from the past 20 years, providing an overview of general research trends on Dacia and Roman mining. Literature on the Roman army is subsumed under the two main subjects.

1.3.1 Roman Dacia

State of research

Several key issues characterise the current state of archaeological research on Roman Dacia.[21] Despite the sizeable body of accumulated evidence, there are crucial problems related to the quality and usage of the information available. The first is inadequate use of the archaeological evidence. There is a tendency for scholars to rely on literary sources and refer to the archaeological material only in support of their conjectures, rather than use the entire corpus in building a theory. While this may be due in the past to the dearth of evidence available for Dacia, recent publications have addressed this issue somewhat. The legacy of Austro-Hungarian and Communist rule has also substantially impacted academic

21 See Oltean (2007) Ch. 1 for full treatment of the biases and limitations of current archaeological research in Romania.

research by injecting politics into the study of history, which has resulted in a distorted historiography that has only been addressed in recent years.

In addition, Romanian fieldwork has largely concentrated on military sites and towns that attained municipal or colonial status, namely major urban sites like *Ulpia Traiana Sarmizegetusa*, *Apulum*, and *Napoca*. Rural settlements and semi-urban sites like military *vici* remain a low priority, with published information widely scattered and of varying comprehensiveness. Additional complications due to poor excavation methodology and a lack of systematic territorial coverage and recording methods further limit the reliability of the available evidence. Site location is also a problem, as the use of local place names rather than geographical coordinates has led to double-reporting, difficulties in tracing names no longer in use, and imprecisely located sites. A National SMR with bibliographic links is now available online, but geographic locations can sometimes still be imprecise; the coordinates for some excavations, for example, reference the nearest modern town rather than the exact location of the site.[22]

Geographical coverage is also considerably better in the more heavily populated western half of Transylvania, and the northern *limes* due to the fortification system. In contrast, the south is less well-studied, particularly along the *limes Transalutanus* and in the more rural, eastern half of the province. The collected papers in Nemeth's volume on the southwestern *limes* redress the imbalance somewhat by collating work on the Roman military, road networks, and the archaeological landscape in the Banat region of south-western Transylvania, while Popa examines Roman settlement patterns in Valea Hârtibaciului to the southeast.[23]

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22 The Repertoriul Arheologic National (RAN): http://ran.cimec.ro/
23 Nemeth (2011); Popa (2001).

Finally, the academic community in Romania remains relatively insular due to the poor dissemination of published work outside the country and access to older Romanian scholarship still poses a hurdle to research and international collaboration. As a result, distinct spheres have developed between Anglophone and Romanian scholars, with only the occasional overlap between the two. The most recent generation of Romanian scholars, however, is increasingly publishing their work in English and electronically, which has remedied the ease of access, as has the online curation of journal archives and county archaeological reports.

General syntheses

Most significant in English is Hanson and Haynes' JRA publication, with a selection of chapters covering key topics in the study of Roman Dacia.[24] Of these, the most important articles are the overviews to the province by the editors and leading Romanian scholar, A. Diaconescu.[25] The volume introduces the main scholarly debates on the urban development of the main towns of Roman Dacia (*Ulpia Traiana Sarmizegetusa*, *Apulum*) from military origins; the supposed but now debunked extermination of the native Dacian population after the Trajanic Wars; the probable pre-Roman origins of villas in Dacia; stylistic trends in funerary monuments of Dacia Superior; and the formation of religious and cultural identity in relation to the high level of immigration in the province. Furthermore, K Lockyear's chapter in the same volume remains the best summary available in English for the pre-Roman evidence, effectively utilising the material evidence

24 Hanson and Haynes (2004).
25 Haynes and Hanson (2004); Diaconescu (2004b).

to argue for a complex society of competing hillforts *contra* the “great king” model of Dacian society favoured by earlier Romanian scholars.[26]

Key sources for Romanian scholars include the *Istoria României* and Macrea’s synthesis of life in Roman Dacia.[27] Although succinct, Glodariu’s chapter in the 1997 edition of *Istoria* provides a fairly comprehensive summary that incorporates the archaeological as well as the historical evidence.[28] Macrea’s single-volume work remains influential, but relies heavily on the literary and written sources. Superseding Macrea are the two monographs by Gudea and Lobüscher, and Ardevan and Zerbini, both currently the most recent syntheses available, in German and Italian respectively.[29]

Population studies

A key debate in Romanian scholarship has been the issue of population continuity in both the pre- and post-Roman periods.[30] This stems in part from a historiographic legacy of Austro-Hungarian nationalism followed by Communist ideology, where the Roman contribution to demographic history was hotly contested depending on party politics. Careful analysis by L. Ellis has debunked the *terra deserta* theory of ethnic discontinuity in Dacia.[31] Despite their epigraphic invisibility, native Dacians below the stratum of the élite probably were not completely exterminated after the Roman conquest. Likewise, it was also highly unlikely that the province was entirely depopulated after Aurelian’s withdrawal. Additional papers by D. Ruscu on the literary tradition and I. Oltean examining the archaeological evidence in relation to the Roman army demonstrate the

26 Lockyear (2004).
27 Daicoviciu et al. (1960); Macrea (1969).
28 Glodariu (1997).
29 Gudea and Lobüscher (2006); Ardevan and Zerbini (2007).
30 Haynes and Hanson (2004) 27–9.
31 Ellis (1998).

differing conclusions one can draw depending on the source material.[32] Tangential treatment of the topic can also be found in Oltean's volume on Romanisation and Mihailescu-Bîrliba's monograph on immigration into Roman Dacia, which remains the most recent synthesis on onomastics and the population of Dacia Superior.[33] The current consensus generally accepts the persistence of native Dacians post-conquest, and studies such as the one by Nemeţi and Nemeţi indicate a move beyond simple identification of ethnic groups and towards a more complex understanding of Roman immigration and colonisation in the province.[34]

Romanisation

The question of Romanisation in Dacia has been a hot topic in recent years, and often studied in conjunction with the related issues of changes in land use and settlement pattern. While prominent Romanian scholars have engaged in this debate,[35] the general approach tends to favour a traditional model of top-down acculturation to Roman rule. I. Oltean's study is arguably the most successful: the monograph demonstrates how Roman rule substantially impacted the Dacian landscape by developing and diversifying settlement type and function, as well as intensifying the exploitation of natural resources.[36] However, her work deliberately excludes the Apuseni Mountains, the most extensive mining region in Roman Dacia, and geographic coverage is limited to the urbanised, western half of the province. Although the conclusion that Romanisation developed apace with urbanisation is compelling, Oltean's work needs to be supplemented by a closer look at the less-populated regions of Dacia for a fuller understanding of settlement patterns in the province. In

32 Ruscu (2004); Oltean (2009).
33 Oltean (2007); Mihailescu-Bîrliba (2011).
34 Nemeţi and Nemeţi (2010).
35 E.g. Diaconescu (2004a); Opreanu (2001).
36 Oltean (2007).

comparison, L. Chappell is less effective in his examination of the urban architecture and epigraphic remains.[37] While he rightly cautions against a Romano-centric approach to studying cultural change in Dacia, his theoretical framework suffers from an outdated and insufficiently nuanced conception of Romanisation, resulting in little new insight. Another approach is seen in Wanner's doctoral thesis, who eschews the Roman army in favour of the community as his unit of analysis.[38] Although the geographic scope is limited to north-western Transylvania, Wanner's study is innovative in its application of GIS to the evidence, through which he tracks the transformation of social relationships and perceptions of place from the pre- to post-Roman period. His is the first substantial study of this sort and demonstrates the potential of a GIS-based analysis. Wanner's geographical focus on north-western Transylvania and the Meseș Valley also offers a useful comparison to Oltean's study of the settlements of the Mureș Valley, illustrating that different parts of Dacia experienced the transition to Roman rule in a multitude of ways. Wanner thus provides a more nuanced approach to the question of Romanisation than the traditional top-down model, demonstrating that a framework of "discrepant experience" involving a multiplicity of local situations and responses may be a better explanation for Roman imperialism and cultural change in Dacia.[39]

Urban settlement

The bibliography on urban settlement in Dacia is substantial; only a selection is discussed here. Work tends to cluster around individual towns due to publications based on excavation results.[40] The best summary of the archaeological evidence is Diaconescu's

37 Chappell (2006).
38 Wanner (2010b).
39 On "discrepant experience", see e.g. Mattingly (2004).
40 Rather than list all the relevant excavation monographs, readers are directed to the work of the main excavators at each of the major sites.

chapter in the Hanson and Haynes JRA volume, whereas R. Ardevan's volume provides a synopsis of municipal life.[41] An overview of the imperial building programme has been done by C. Opreanu, whose emphasis on Roman *Sarmizegetusa* and *Apulum* is symptomatic of the bias in evidence from these two towns.[42] Work on other Dacian towns—*Napoca*, *Drobeta*, *Romula*, and *Potaissa*—is more limited in comparison, but increasing.

Ulpia Traiana Sarmizegetusa is the most extensively excavated of the urban sites, and excavation results have been published by D. Alicu, H. Daicoviciu, and I. Piso, amongst others. Most of the publications have been divided up by specialisms.[43] Piso analyses the city's hinterland and land usage, but the closest to a synthesis is Alicu and Paki on town planning and demographics, which attempts to estimate population numbers.[44] The town's most imposing monument was the amphitheatre, with a capacity of around 5,000 individuals, and population estimates range from 15,000 to 20,000 inhabitants. Based on these figures, *Ulpia Traiana Sarmizegetusa* was a sizeable city for its location in a frontier province, but befitting its status as the provincial capital.[45]

Despite being the seat of Roman administration, the study of *Apulum* is problematic as most of the Roman settlement is under the modern suburb of Partoş, Alba Iulia. Much of the information consists of scattered articles and archaeological reports,[46] although an exhibition catalogue of some rescue sites has been published by Moga and Goșa.[47] V. Moga has published most extensively on the legionary fort; inscriptions can be

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41 Diaconescu (2004b); Ardevan (1998).
42 Opreanu (2007).
43 E.g. coins, lamps, or small finds. The most recent is Găzdac and Cociș (2004) on the coins.
44 Piso (1995); Alicu and Paki (1995).
45 Cf. Wilson (2011) for estimates of city sizes elsewhere in the Roman Empire.
46 E.g. Moga, Ciobanu and Drîmbărean (2000).
47 Moga and Goșa (2008).

found in *IDR* III/5. Also noteworthy are The Apulum Project,[48] an excavation of the *colonia*'s Liber Pater sanctuary, and The Apulum Hinterland Project, which undertook field-walking and excavation at two rural sites in the environs of Alba Iulia.[49]

Work on *Porolissum* is mostly related to excavations of the fort, directed by N. Gudea, who has published several volumes on the site.[50] The American-led Porolissum Forum Project has also resulted in some publications, mostly by E. De Sena. Unfortunately, D. Tamba's study on the civilian settlements is out of print.[51]

In general, the study of urban settlement is complicated by a lack of clear distinctions between military and civil zones,[52] an issue that has been addressed by several Romanian scholars.[53]

Rural settlement

A growing body of literature is available for rural settlements, the most important of which currently derive from I. Oltean and W. Hanson's use of LiDAR and aerial survey to identify surface site remains. Their fieldwork is a much-needed revision of I. Mitrofan's and D. Tudor's earlier publications,[54] and provides a synthesis of results from aerial reconnaissance and a gazetteer of villa sites.[55]

The study of military *vici* suffers from similar problems of academic unpopularity and poor site preservation. The state of research is summarised by D. Benea, whose

48 Diaconescu, Haynes and Schäfer (2001).
49 Vințu de Jos and Oarda. Interim reports available from the Cronica Cercetârilor Arheologice din România.
50 See Gudea (2001) for a summary and select bibliography.
51 Tamba (2008).
52 Haynes and Hanson (2004) 25.
53 Bogdan-Cătăniciu (2000); Laufer (2000); Opreanu (2000).
54 Mitrofan (1973) and (1974); Tudor (1968). A full bibliography of villa sites excavated in the early 20th century is available in Mitrofan (1973).
55 Oltean and Hanson (2007). A good summary is available in Oltean (2004), but see Oltean (2007) for full treatment of rural settlements.

collation of known sites is supplemented by Oltean and Hanson's aerial surveys.[56] Of the excavated sites, a study of the *vicus* at Micia was conducted by Oltean, Rădeanu and Hanson.[57] Another welcome addition is the synthesis of the results from Cristești, one of the more fully excavated sites and an important pottery production centre.[58] In general, more fieldwork still needs to be done on rural settlement.

Infrastructure

In urban infrastructure, G. Băeștean's work on aqueducts and water management systems constitutes a new branch of inquiry. He reviews the epigraphic and material evidence for the ten main urban centres, as well as the smaller civil settlements and military camps, looking for remains of aqueducts, pipes, and distribution installations.[59] Despite an attempt at a comparative study with the rest of the Roman Empire, this volume is ultimately more useful as a catalogue than a synthesis due to the lacunose evidence from Dacia.

The study of road infrastructure has also benefited from the recent work of F. Fodorean. Using Austrian military maps, he demonstrates their usefulness in establishing the course of Roman road networks,[60] and has also tracked changes in landscape around the fort at *Acrobadara* (Ilișua) and identified road repairs during Dacia's later years.[61] On the related topic of road traffic, Mihailescu-Bîrliba, Dumitrache, and Piftor have examined the epigraphic sources for evidence of mobility and mortality on Roman roads, noting in particular the active brigandage near river routes.[62]

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56 Benea (2000); Oltean and Hanson (2001).
57 Oltean, Rădeanu and Hanson (2005).
58 Man (2011).
59 Băeștean (2007); cf. Băeștean (2004) and (2006). On the water distribution system at Apulum, see Ota and Băeștean (2010).
60 Fodorean (2006a) and (2010b).
61 Fodorean (2010a); Fodorean (2004).
62 Mihailescu-Bîrliba, Dumitrache and Piftor (2010).

The Roman army

As is the case with urban settlement, the literature on the Roman army in Dacia is sizeable. A good selection is available in the International Limes Congress publications, as well as scattered papers in the main journals *Apulum*, *Acta Musei Napocensis*, *Ephemeris Napocensis*, and *Dacia*. F. Marcu has published a well-curated catalogue of military sites, replete with useful site plans.[63] He has also worked on the garrisoning of auxiliary troops, and addressed the methodological issues of using military tile stamps to identify and date sites.[64] For individual forts, further information can typically be found as isolated excavation reports or in conjunction with studies on urban settlement for the bigger forts.

The *limes* and defensive systems of Dacia have been well-studied. Although somewhat dated, Bogdan-Cătăniciu on the organisation of the *limes* under each emperor offers a decent summary of the excavation evidence and treats the development of the forts and associated road networks as a system.[65] Work on the northern *limes* tends to centre on *Porolissum* and its role in the defence system.[66] As for the southern *limes*, the most recent volume is the one edited by E. Nemeth.[67]

Of note, recent monographs relevant to the study of the Roman economy include A. Gudea on the provisioning of the Roman army.[68] Attempts at quantification are made by calculating troop numbers and alimentary needs, and estimating production capability by looking at animal bone assemblages at several military sites. Gudea demonstrates that the Roman army played an active role as both producer and consumer of agricultural and animal products, and impacted local animal husbandry by the introduction of Roman

63 Marcu (2009).
64 Marcu (2004).
65 Bogdan-Cătăniciu (1981).
66 E.g. Gudea (1989).
67 Nemeth (2011).
68 Gudea (2009). Cf. discussions in Gudea and Gudea (2000), A.I. Gudea (2005), and N. Gudea (2005).

methods.[69] In a complementary study, N. Gudea examines food consumption needs and argues that the army in *Dacia Porolissensis* was unable to sustain itself locally, but needed to import from abroad.[70] Addressing similar questions, R. Wanner has modelled agricultural territories using GIS, combining it with data from animal bone assemblages to gauge land use in the Zalău River Valley around *Porolissum*.[71] He concludes that Roman occupation resulted in a reconfiguration of the landscape towards intensive agro-pastoral production, probably to meet garrison needs.

Numismatics

The study of numismatics is particularly well-represented, with prolific output by C. Găzdac, who edits a monograph series cataloguing coin finds from major urban and military sites.[72] Amongst these, the *Apulum* volume is particularly noteworthy as the single biggest source of civilian coin finds, despite the general lack of excavation evidence. Indeed, a key asset of Găzdac's work is an awareness of the importance of archaeological context when analysing the numismatic evidence.[73] The most important treatise, however, is Găzdac's monograph on coin circulation in Dacia, which demonstrates the introduction of a strong monetary economy that came with Roman rule and benefits from a comparative study with patterns of coin circulation in the neighbouring provinces of Moesia and Pannonia.[74]

69 While this strand of research is an exciting development, it is necessary to note that the evidence is strongly biased towards the site of Porolissum, due to the author's involvement with the excavations there.
70 N. Gudea (2005).
71 Wanner (2010a).
72 Găzdac and Cociş (2004); Găzdac and Gudea (2006); Găzdac, Călian and Alföldy-Găzdac, Á (2007a) and (2007b); Găzdac and Isac (2007); Găzdac, Suciu and Alföldy-Găzdac (2009); Găzdac, Gaiu and Marchiş (2011).
73 E.g. Găzdac and Pripon (2012).
74 Găzdac (2010).

Pottery

Key scholars working on Roman ceramics include V. Rusu-Bolindeț and A. Ardeț. Although her work centres on *Napoca*, Rusu-Bolindeț has contributed greatly to the creation of a type-series for Roman pottery in Dacia. Her main monograph demonstrates that *Napoca* was an active pottery production centre and had strong trade relations with production sites outside the province.[75] Collaborations with S. Cociș resulted in papers providing an overview of the pottery in the *vicus*, as well as an examination of cookware forms to track the process of Romanisation amongst the local population.[76]

Ardeț's work focuses instead on *amphorae*.[77] He offers a list of the types found in Dacia identified to date, and two case studies illustrating the local production of forms developed elsewhere in the empire and the possibility of an *officina* at Micăsasa. His full monograph is regrettably unavailable in the UK despite its importance to our understanding of the production and trade of *amphorae* in the province.[78] Ardeț has compiled a catalogue of all known pieces found in Dacia (including the *tituli picti*) based on existing typologies, and identified 45 types that circulated in Dacia during the 2nd to 6th centuries AD. The work of Rusu-Bolindeț and Ardeț are prime examples of an increasing emphasis in Romania on establishing local type-series and understanding the economics of ceramic production for the Roman period.

The Roman economy

The classic work on Dacia's economy is V. Christescu's *Viaţa economica a Daciei romane*.[79] Coverage of major sectors like mining, industry, and commerce are fairly

75 Rusu-Bolindeț (2007).
76 Rusu-Bolindeț and Cociș (2006) and (2005).
77 Ardeț (2004).
78 Ardeț (2006).
79 Christescu (1929).

comprehensive and in-depth; the main shortcoming is its datedness. However, it remains a useful bibliographic source for pre-20th century exploration, especially for an industry as destructive as mining. D. Benea has attempted to update Christescu's work, with some success. Although it aims to be a synthesis, the volume suffers from the diverse interests of the contributors, resulting in somewhat patchy coverage of the available evidence.[80] The most effective papers are by Benea herself, especially the last essay on Dacia's economic role in the imperial system, but the focus of the volume is largely on local production and workshops. Her general conclusion is that Dacia's workshops were able to supply the needs of the province, and levels of production were on par with western provinces such as Gallia, Germania Inferior, Raetia, and Noricum.

Although little known, the most complete, current study on the economy of Roman Dacia is by M. Żmudziński, whose substantial work builds on Christescu.[81] It benefits from being more comprehensive in its coverage of the secondary literature and systematic in its analysis, and in that sense, is more successful than Benea's volume. Methodically examining key economic topics,[82] Żmudziński draws upon the full range of available evidence to demonstrate that economic life in Roman Dacia was active, diverse, and very much integrated into the wider economy of the Roman Empire. Unfortunately, this work is available only in Polish and is out of print. Some of his other papers examine how the Roman army was active in the economic life of Dacia Porolissensis, participating in production, construction, and the organisation of mineral exploitation, and also providing a

80 Benea (2008). Mining and metallurgy are well-represented; other topics like ceramics somewhat less so. The emphasis is decidedly skewed towards craft production, with little discussion of commerce and no articles on agriculture or the monetary economy.
81 Żmudziński (2007); reviewed in Găzdac (2009). For a summarised version in English, see Żmudziński (2006b). Shorter pieces on individual aspects of Dacia's economy can be found in Żmudziński (2002), (2004a), (2004b), (2006a), and (2009).
82 These include: money, mining, agriculture, craft manufacture, transport, and trade, as well as the economic role of the army and the municipal élite.

market for local and imported goods, all of which drove villa development and the economy in this part of the province.[83] Dacia Porolissensis, he argues, was a region of vibrant economic activity. In a brief overview of the archaeological evidence for the Dacian precious-metal mines, Żmudziński notes that gold mining was one of the most important—if not the leading—sector of the economy in the province.[84] With respect to Dacia's trade contacts, Żmudziński traces the commercial relationships between Dacia and the wider empire through imports such as ceramics and food products, and the province's shift to becoming an intensive production centre for exports abroad.[85] In general, Żmudziński's work is an important contribution to our understanding of the Dacian economy and provides a rich resource for further analysis.

1.3.2 Mining in Dacia

General works

The two most recent works include those by C. Domergue, which provides an excellent overview of key topics in ancient mining ranging from the technological to the administrative aspects, and A. Hirt on the organisation of mining and quarrying in the Roman Empire.[86] Older but still useful volumes include O. Davies on mines in Europe, which has a chapter devoted to the Dacian material.[87] As one of the few summaries of the collated evidence in English, it remains one of the most widely cited sources on Dacian mines. Davies is also more reliable than R. Shepherd and J.F. Healey, both of whom are quite cursory.[88] For a synopsis of the water-lifting wheels from Dacian mines, J. Oleson's

83 Żmudziński (2002) and (2004a).
84 Żmudziński (2004b).
85 Żmudziński (2009).
86 Domergue (2008); Hirt (2010).
87 Davies (1935).
88 Shepherd (1993); Healey (1978).

handbook on Greco-Roman water-lifting devices is the typical starting point.[89] These works provide a useful general background on Roman mining, but the English-language material on the Dacian mines in particular needs updating in light of the major excavations conducted at Roșia Montană (*Alburnus Maior*) between 2000 and 2013.

Organisation and administration

A classic work on the subject is H.-C. Noeske on the administration and the gold mining population in Dacia.[90] R. Ciobanu looks specifically at the Illyrian component of the population and Hirt also has brief sections on Roșia Montană, but Hirt's work is most useful for contextualising the Dacian evidence.[91] Most notable is the work of S. Mrozek on the epigraphic evidence. He has published a selection of papers on labour contracts and the prevalence of free versus slave labour in mines, and analysed the sale prices of goods in his examination of the local economy at *Alburnus Maior*.[92] For comparative purposes, S. Dušanić's work on the neighbouring Danubian provinces touches tangentially on the Dacian evidence,[93] which is particularly useful for understanding how Rome's withdrawal from Dacia might have resulted in a shift in production to surrounding provinces in the Late Roman period.[94]

Military involvement is often discussed in relation to mining in Dacia. A few specific papers on forts and attested army presence in the mining regions include those by Moga and Mesaroș and by O. Țentea,[95] while P. Le Roux offers a general study on the

89 Oleson (1984).
90 Noeske (1977).
91 Ciobanu (1999); Hirt (2010).
92 Mrozek (1968/2004), (1977), (1989), (1971).
93 Dušanić (1977), (1989), (2004).
94 Dušanić (1995).
95 Moga and Mesaroș (1980); Țentea (2003).

relationship between the Roman army and mining.[96] There is a tendency, however, to assume military involvement with mining activity in Dacia, without necessarily questioning whether this was indeed the case.

Geology and mineralogy

Information on the geology of Dacia's mining sites is widely scattered, with Ianovici and Borcoș providing the most readily accessible resource for a general overview of Romania's geological resources.[97] Ghițulescu and Socolescu's study is older, but includes a catalogue of known mines in the Apuseni Mountains, some of which may have since been destroyed during the Communist regime, and remains widely cited by Romanian scholars.[98] For the sources of alluvial gold, see Galcenco *et al*.[99]

The underlying geology for Roșia Montană and its wider geological region have already been studied in detail.[100] Concise treatment of the relationship between the mineralogy and mining activity at Roșia Montană can be found in the works of Manske *et al*. and Tămaș and Cauuet, both of which illustrate how Roman mining activity adapted to different geological conditions.[101]

Provenance studies

A series of provenance studies have been carried out, with some success. Neacșu *et al.* tried to establish the geochemical signature of gold from the Apuseni but results were inconclusive.[102] However, Baron *et al*. were able to identify a specific lead isotope signature for representative samples of Roman-period ore from Roșia Montană, which are

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96 Le Roux (1989). See also Blázquez Martínez (1989).
97 Ianovici and Borcoș (1982).
98 Ghițulescu and Socolescu (1941).
99 Galcenco et al. (1995).
100 Ciobanu et al. (2004); Leary et al. (2004); Tămaș (2007).
101 Manske et al. (2006); Tămaș and Cauuet (2009).
102 Neacșu et al. (2009).

distinct from ores found elsewhere in the Apuseni.[103] Analysis has also been done on pre-Roman objects for authentication purposes; most notably the work of Stan, Păuna, and Constantinescu and Constantinescu *et al.* on the gold bracelets from Dacian *Sarmizegetusa*,[104] and Constantinescu *et al.* on the Koson coins.[105]

For the ceramic material, Ionescu, Ghergari, and Țentea have subjected the stamped *tegulae* of *Leg. XIII Gem.* from Roșia Montană to petrographic analysis.[106] Unsurprisingly, results show that the composition of the ceramic material from Roșia Montană is like that from Alba Iulia and probably derives from the same local source.

Mining archaeology

The most current work on mining archaeology consists of the excavations at Roșia Montană led by B. Cauuet. Fieldwork results can be found in the relevant chapters of *Alburnus Maior I* by Craciun and Moga, and Cauuet *et al*.[107] Detailed information on the Cârnic Massif excavations exists, albeit in unpublished form and not publicly available.[108] Key supplementary articles on Roșia Montană include the work of H. Ciugudean, A. Sântimbreanu, and V. Wollmann.[109] However, more recent Romanian articles tend to be based on Cauuet's results. While useful as summaries, most offer little new evidence.[110]

Although the *Alburnus Maior* series has contributed greatly in advancing the fieldwork evidence, *Mineritul metalifer, extragerea sării şi carierele de piatră în Dacia Romană* remains the most complete overview available on mining in Dacia.[111]

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103 Baron et al. (2011).
104 Stan, Păuna and Constantinescu (2009); Constantinescu et al. (2008) and (2010).
105 Constantinescu et al. (2011).
106 Ionescu, Ghergari and Țentea (2006).
107 AM I (2003/2010). See also Cauuet (2005) 265–72 for a summary.
108 Cauuet (2009a) and (2009b).
109 Sântimbreanu and Wollmann (1974); Sîntimbrean (1989); Wollmann and Ciugudean (2005).
110 E.g. Timoc (2008); Ciugudean (2012).
111 Wollmann (1996).

Wollmann's volume draws largely on traditional methods of analysing the archaeological evidence, one based on texts and written sources. His collation of the then-available archaeological evidence remains a crucial source; however, the reliance on archival material dating from the 19th-century Austro-Hungarian surveys is not unproblematic.

Recent articles by Cauuet have integrated the latest archaeological evidence and gone a way towards rectifying the situation. She sheds light on mining concessions by comparing the underground spatial organisation of the mines at *Alburnus Maior* with those at *Vipasca*, Portugal,[112] and also reports on the wooden finds from the Roșia Montană mines, most notably the hydraulic drainage system found in Păru Carpeni.[113] The two most recent articles publish some of the results from the 2009 site report on Cârnic and the 2012/13 excavation season at Cătălina Monulești, but a full publication is not yet available.[114] Cauuet's work is predominantly focused on understanding the site evidence and provides critical insights into the mining techniques and technology at Roșia Montană. Nevertheless, a synthesis of mining at Roșia Montană—let alone the entire province—has yet to be written.

The mining community

The richest source of information available comes from Roșia Montana, where studies of the settlement and its associated necropoleis and sanctuaries are available. On the native makeup of the mining population itself, S. Mrozek is an oft-referenced starting point that also provides a good summary of the contractual relationships attested at *Alburnus Maior*.[115] V. Wollmann builds on the work of Mrozek and Noeske by incorporating

112 Cauuet (2004).
113 Cauuet (2008).
114 Cauuet and Tămaș (2012); Cauuet (2014).
115 Mrozek (1977). Similar work can be found in Mrozek (1968/2004), which considers the epigraphic evidence.

evidence from religious and funerary contexts.[116] More recent work has been done by H. Pundt on the formation and changes in the identity of the mining communities, which argues for a rich and cosmopolitan population at *Alburnus Maior*.[117] Onomastic studies on the origins of the miners are also quite popular.[118]

The bulk of the evidence, however, is in the *Alburnus Maior* series edited by P. Damian. Volume I contains the excavation results for the settlements, sacred spaces, and necropoleis surveyed and excavated in the 2000/01 field seasons, providing evidence for a mining society with a more monumental and complex nature than previously supposed.[119] The next two volumes are dedicated to the funerary evidence and focus on the circular funerary monument at Tăul Găuri and the Roman necropolis at Tăul Corna respectively.[120] Supplementary studies on funerary culture also include C. Ciongradi on the funerary monuments, and P. Damian and M. Simion on funerary practice.[121] These volumes provide a starting point for work on the surface finds at Roșia Montană, but as with the underground mining remains, publication of the data is still incomplete, and a site synthesis is needed.

1.4 Conclusion

Archaeology in Romania has made tremendous inroads in the past 20 years, but more still needs to be done. Mining archaeology has come to prominence both academically and in terms of public interest due to the Roșia Montană project, and illustrates the latent potential of Romania’s mines. The body of mining literature on Dacia is sizeable and

116 Wollmann (1989).
117 Pundt (2012).
118 E.g. Nemeti and Nemeti (2010); Mihailescu-Bîrliba (2010) Ch. 2.
119 AM I (2003/2010).
120 AM II (2005); AM III (2008)
121 Ciongradi (2009); Damian and Simion (2007).

growing, but largely inaccessible to Anglophone scholars and in need of revision, given the recent strides in fieldwork and the development of technological tools such as remote sensing.

More crucially, the study of mining in Dacia remains a fairly insular affair. The English-language scholarship on mining cited above addresses Roman mining more globally, treating Dacia as one province amongst many and an example of the types of mining techniques and administration employed across the Roman Empire. In contrast, Romanian scholarship focusses narrowly on Dacia, honing in on specific sites (e.g. Roșia Montană, Bucium) or particular aspects such as the epigraphic or funerary remains of mining sites, with no works that contextualise Roman mining technology and organisation in Dacia in a substantial comparative study with other provinces. An extended comparison is beyond the scope of this work. Instead, this thesis is my attempt at synthesising the available evidence for mining in Roman Dacia and identifying areas where additional research is needed. In doing so, it allows us to gauge the importance of mining to Dacia's economy and landscape, providing a foundation for future work on the economy of Roman Dacia as a whole and for comparative studies with other mining provinces.

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Metal Use and Supply in Pre-Roman Dacia

There is an assumption amongst scholars that the Roman wars in Dacia were motivated in part—if not wholly—by the lure of loot and native gold.[122] Such a claim is often justified by the efflorescence of public building during Trajan's reign, which steadily increased after AD 106.[123] Alongside this is the assumption that the primary ores mined by the Romans were important metal sources even in the pre-Roman period and that Trajan actively sought to seize the mines from the Dacians.[124] This second idea in particular is not new, and has been used to explain the speed with which the Romans initiated mining in the province after conquest.[125] While both these theories are attractive, they have not been sufficiently examined or indeed proven to be the case. A look at the literary, numismatic, and mining evidence suggests that these assumptions need to be revisited.

A few words on scope first: although the boundaries of Roman Dacia are well-defined, this is not the case for the pre-Roman period. In terms of geographical scope, the general study area will be modern Romania but excluding the Danubian basin and the Black Sea littoral as this region was part of Moesia Inferior under the Romans. Within this, the heartland of the Dacian state was located in western Transylvania in the Luncani Platform. It is here that most of the Dacian citadels can be found (*fig. 1*). In terms of

122 E.g. Hauptmann, Rehren and Pernicka (1995) 370.
123 E.g. Trajan's baths, forum, and markets in Rome, but also the harbour at Ostia; see Bennett (2001) 148 ff. This view has been most strongly espoused by Carcopino (1924) and (1934); cf. Syme (1930).
124 Baron et al. (2011); Leary et al. (2004) 89.
125 Glodariu and Iaroslavschi (1979) 110–11; Oltean (2007) 105.

chronology, the events from *c*. 300 BC onwards will be considered as this period saw the introduction of coinage through to the *floruit* of Dacian civilisation prior to the Roman conquest.

2.1 Literary evidence

Dacia has a long history in the ancient literature, even though early references are rather vague. References appear as early as Herodotus and Thucydides, who both mention the "*Getae*", a sub-set of the Thracian peoples.[126] It is not until Diodorus Siculus, writing in the 1st century BC, that the first significant anecdote appears. He recounts the story of Dromichaetes, who, having captured the Macedonian king Lysimachus, feasts his captives with vessels made of gold and silver while serving his own people using horn and wood.[127] Despite their possession of precious metal objects, much is made of the Thracians' "barbarous" way of life and their lack of cultivated produce. This story of Lysimachus' capture in 291 BC is also related by Strabo, a rough contemporary of Diodorus.[128] Strabo, who took care to differentiate between the *Getae* and the *Daci*,[129] also noted the poverty of the Getan people. While one can accept this tale as rooted in historical fact, the emphasis on the poverty and essential "otherness" of Dromichaetes' people very much reads as a literary trope. The image of the Geto-Dacians circulating in the Greco-Roman imagination was arguably in some ways a literary construct and not one to be taken at face value.

The main literary resources that actually refer to Dacian wealth are disappointingly few and contemporary accounts even fewer. Trajan's own *Commentarii de bello Dacico*

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126 Hdt. IV.93; Thuc. XCVI.2.
127 Diod. XXI.12.3–5.
128 Strab. VII.38.
129 Strab. VII.3.12, contra Plin. HN IV.25. According to Strabo, the Daci lived to the west, closer to modern Germany, whereas the Getae lived in the Pontic east. Bergquist (1989) 45 also notes how the surviving literary sources are skewed towards the Getic communities of the Danube basin as the Transylvanian tribes are underrepresented prior to the Trajanic period.

are largely lost; only one sentence survives.[130] Pliny the Younger in his letters briefly congratulates Trajan on the success of his wars over the Dacians, with no further elaboration.[131] Two tantalising extracts from the *Suda* lexicon and the *Anthologia Palatina* on Trajan's votive dedications to Zeus Kasios after defeating the *Getae* corroborate the existence of Dacian booty, but they tend not to be cited by scholars.[132] The two key accounts are thus those of Dio Cassius and John Lydus.

The story of Decebal hiding his treasures in 106 is related in Dio's *Historiae Romanae*.[133] According to Dio, Decebal diverted the course of the river Sargetia with the help of captives and concealed in the riverbed a large amount (πολὺν) of silver and gold as well as other valuable objects (τὰ τιμιώτατα), before restoring the river's flow. He also hid his robes and regalia in nearby caves. The captives were killed to prevent disclosure, but one Bicilis, a companion of the Dacian king, apparently revealed all.

The second piece of evidence, from John Lydus, cites T. Statilius Crito, Trajan's physician who accompanied the emperor in the Dacian wars.[134] Crito claims that Trajan took as booty some five million pounds of gold, twice as much of silver, and countless goblets and vessels. Along with the precious metal also came livestock, tools, and over 500,000 captive soldiers.

These two extracts are commonly cited as evidence for Dacian wealth, but their use is not unproblematic. Little mention is made of their relatively late date. Although written sometime during the late 2nd to early 3rd centuries AD, Dio's account of the Dacian wars survives only as an epitome by Xiphilinus, who lived in the 11th century. Likewise,

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130 Priscian, Institutio de arte grammatica 6.13: inde Berzobim deinde Aizi processimus. Priscian is also a late source, writing around the 6th century AD.
131 Plinius, Ep. X.14.
132 Suid. s.v. "Kasion oros"; AP VI.332.
133 Dio Cass. LXVIII.14.4–5.
134 Ioann. Lyd. De Mag. II.28.

despite the first-hand account from Crito, John the Lydian was writing in the 6th century AD. Issues of textual fidelity aside, the late date means that one cannot use these two texts as examples of Roman intelligence of Dacian wealth prior to the wars of AD 101–102 and 105–106. Although John does preface the Crito citation by noting that "the region [Scythia] … currently is and has long been rich in resources" in the ancient literature,[135] there is no sure way of identifying which literary texts, what specific part of Scythia, or what resources are being discussed. Even if the additional snippets from the *Suda* and the epigram to Hadrian in the *Anthologia Palatina* are taken into account as references to a no longer extant text,[136] they, too, are late sources from the 10th century.

Furthermore, Dio and John Lydus make no mention as to *how* the Dacians acquired their wealth. Although controversial, attempts at verifying the accuracy of Crito's figures suggest that the plunder taken by Trajan did in fact exist and was probably as fantastic as reported. J. Makkay has argued that the huge cache found in 1543, in the Strei riverbed in Hunyad (Hunedoara), was probably part of Decebal's hidden treasure.[137] The total amount of gold and silver found cannot be reconstructed for certain as the haul was confiscated and subsequently looted, but Makkay's estimate based on contemporary reports posits at least 30,000 Lysimachus coins, sheets of gold and silver, several silver vessels, two gold statuettes, and a golden dragon. The hoard was probably accumulated over a prolonged period—maybe four or more centuries. Given the region's natural mineral wealth, it is commonly assumed that the Dacians were exploiting the alluvial gold and possibly also the primary deposits.[138] Proving the existence of Decebal's treasure, however, still does not answer the question of Dacian metal exploitation. Overall, it is exceedingly difficult to

135 "…ὡς εὐδαίμων μὲν ἡ χώρα τοῖς χρήμασιν…ἐστί τε νῦν καὶ πάλαι γέγονεν".
136 Makkay (1995b) 334.
137 Makkay (1995b).
138 Makkay (1995a) 70.

sustain an argument based on the literary sources alone that the Romans conquered Dacia because they had *a priori* knowledge of its mining regions.

2.2 Numismatic evidence

The lack of literary evidence is even more startling given the numerous hoards and coin finds in the region. If the literary sources are regrettably silent, the numismatic and artefactual evidence, in contrast, provides compelling proof of Dacian wealth. But simply citing the sheer quantity of precious metal artefacts does not do the evidence justice. The finds from Romania suggest that the Dacians were familiar with the concept and use of coinage, at least at the higher levels of society. However, the function of coinage and the degree to which the region was monetised are not entirely clear and need to be studied further.[139]

Understanding how the Dacians were using coinage, and why, is crucial to answering the related question of metal exploitation. If mining provides evidence of metal supply, coin and metal use, in a sense, is indicative of demand by revealing the *need* for metal. Such studies have already been undertaken for the Roman world,[140] but not for pre-Roman Dacia. Demand has also not been adequately considered alongside the mining evidence in the most recent secondary literature on the topic. This section tries to identify how the Dacians used coins and precious metals, and what relationship this had to their metal supply.

139 See Howgego (2013) for a recent attempt.
140 E.g. Wilson (2007); Howgego (1992).

2.2.1 Coinage in Dacia: imports and copies

Coinage in Dacia is marked by successive waves of foreign issues penetrating the region, as well as local copying of adopted coins. The beginnings are unexceptional: these initially consisted of Greek coins spreading from the Black Sea colonies alongside a wider distribution of 4th-century BC coins from Macedonia, some of which penetrated as far as Transylvania.[141] This was then followed by a second series of Greek coins in the 2nd century BC, also attested in Transylvania, most notably the drachms of neighbouring Apollonia and Dyrrachium. At some point in the 3rd century BC, the locals started striking their own copies of the Greek coins. These, however, had a limited geographic distribution and ceased around the time of Burebista's reign (82–44 BC). Although unremarkable in terms of numismatic history, the region has had a protracted exposure to Greco-Roman coinage and a tradition of importing and copying coins.

What *is* exceptional is the number of numismatic finds, especially those of Roman Republican *denarii*, which was the last and most important phase of imported coinage. Excluding Italy in the 1st century BC, Dacia has the largest number of coins and hoards of all the continental European provinces.[142] One estimate puts the total number of Roman coins in Romania at around 25,000 (and probably more), with around 17,000 pieces from the intra-Carpathian region alone.[143]

These coins raise a number of questions, most of which are still largely unresolved. Specific to the coins themselves is the quantity and distribution of the hoards, and the problem of high-quality local copies nearly indistinguishable from the authentic issues. Vis-à-vis the larger question of determining coin use and its relationship to metal supply,

141 Lockyear (2004) 65.
142 Chițescu (1981) 14. Glodariu (1976) 52 notes that at least 145 Roman Republican hoards have been found in Romania, which is more than the total sum of hoards from the continental countries.
143 Roughly two-thirds of the total coins found in Romania. Crawford (1977) 117; Glodariu (1976) 51.

this means that one cannot simply point to the presence or sheer quantity of coin as evidence for monetary demand. One also needs to differentiate between the use of silver versus gold coin. Instead, it is necessary to understand how the coins may have functioned within their social, economic, and political context in Dacia.

2.2.2 Roman Republican *denarii* and silver hoards in Dacia

The date of first arrival is not clear, but Roman *denarii* definitely enter by 100 BC,[144] with a massive influx between *c*. 75 and 65 BC.[145] The date of the Republican issues does not necessarily coincide with the chronology of their spread; most of the coins were struck between *c*. 130 and 31 BC.[146] Roman Imperial issues are also attested, but they remain relatively scarce until the conquest of Dacia.[147] By the mid-1st century BC, Roman coins were effectively the functional coinage of the region.

The reasons for the considerable presence of *denarii* are variously debated,[148] but the most compelling explanation seems to be via trade and the commercial activity of local and foreign merchants. The extensive mercantile contact between Dacia and the Greco-Roman world is well-attested by the presence of large amounts of imported amphorae, ceramics, glassware, and metalware in Dacian settlements.[149] Furthermore, most of the coins are found in the Southern Carpathian part of the Dacian heartland and on trade routes running along the river valleys.[150] Tacitus relates how German tribes living near the border of the Empire preferred Roman silver coins when conducting commerce.[151] Although it is

144 Chițescu (1981) 1.
145 Lockyear (2008) 1–8; Lockyear (2004) 65.
146 Crawford (1977) 117.
147 Glodariu (1976) 50.
148 Trade and commerce: Lockyear (2008), Chițescu (1981), Glodariu (1976). Slave trade: Crawford (1977). Payment for mercenaries: Chițescu (1981).
149 Glodariu (1976).
150 Chițescu (1981) 13, 16.
151 Tac. Germ. 5.

possible that the Dacians exhibited a similar preference for Roman silver,[152] such a view is controversial and an unsatisfactory explanation for the high numbers of *denarii* in pre-Roman Dacia.

A comparison of Roman Republican *denarii* hoards versus finds of silver vessels and jewellery also reveals a marked difference in distribution (*figs. 2, 3*). While the distribution of the coins does appear clustered in areas, there is no clear bias towards Transylvania as evinced by the distribution of silverwork.[153] This suggests that the Republican *denarii* circulated fairly freely within the region. Also noteworthy is the concentration of silver finds in the western half of Transylvania, particularly around the Mureș River and its tributaries—known sources of silver-rich alluvial gold.

It is tempting to link the distribution of silver finds with settlements or even ore sources, but there is insufficient evidence to do so. Some 200 find-spots are known, with useful information on hoard content and context available for some 80 hoards.[154] These come variously from graves and settlements, but predominantly from hoards and as single finds. Some pieces were imported, such as the silver vessels from the Sîncrăieni hoard, but most were manufactured locally. However, metal sources have not been identified. Metallurgical analysis of the Stăncuța hoard, for example, which contained 34 *denarii*, 53 tetradrachms from Thasos, and 2 silver bars, revealed that one of the *denarii* and tetradrachms each shared a similar composition with one of the bars and had relatively high gold levels (>1.5%), but it is impossible to determine what was being melted down as

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152 Glodariu (1976) 50.
153 Lockyear (2004) 67.
154 Lockyear (2004) 67–69.

source material.[155] Barring further metallurgical analysis and comparative study, the significance of the silver hoard deposits is not entirely clear.

Local copying of imported coins is a vexing question, which shall only briefly be discussed here with respect to the Republican *denarii*. In general, the large number of *denarii* found in Romania is attributed in part to the presence of local replicas, but it is often difficult to distinguish between the authentic issues and the copies. These imitations vary in quality, with some virtually indistinguishable from real Republican *denarii*. In contrast, others have legends that make little sense. It may have been the case that the forgers did not understand the Latin language and were trying to replicate a legend by sight, or were uninterested in accuracy.[156] But such errors seem to be series-specific: the M. SCAVR issues (RRC 422/1a–b, 58 BC) contain many mistakes, whereas the MVSA issue (RRC 410/1–10b, 66 BC) were more carefully struck.[157] Visual analysis of the coins from the Poroschia hoard also suggests that the *denarii* were struck from dies made mechanically by imprint, which means that errors in the legend could be due to a faulty original coin or to poor die manufacture.[158] Given the existence of high-quality copies and the continued difficulty of distinguishing between originals and imitations, it seems difficult to believe that the Dacian forgers were striking coins haphazardly. Discovered hoards provide finite and select data, but preliminary estimates from statistical analysis posit that local imitations constitute around 14% to 30% of a hoard.[159] It is hazardous to extrapolate too much from these figures, but the copying of *denarii* was arguably a

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155 Lockyear (2008) 23; Lockyear (2004) 68. Note also that Stăncuța (Brăila) lies outside the Carpathians and is closer to the Black Sea littoral settlements than the main study area.
156 Chițescu (1981) 53.
157 Lockyear (2008) 10–11.
158 Lockyear (2008) 12.
159 Lockyear (2008), who revises the numbers of M. Chițescu and M. Crawford on the Breaza and Poroschia hoards.

frequent and widespread phenomenon in Dacia. The question remains why this was the case and whether the need for and production of copies would have exerted pressure on the demand for metal.

2.2.3 Coin production and the evidence for mints

Coin production in Dacia is attested by the existence of some two dozen dies, with possible evidence for centralised control of minting. The only known mint was found at *Sarmizegetusa Regia* under two Roman layers and consisted of four dies used to mint imitation Roman Republican (126 and 68 BC) and early Imperial (Tiberius) *denarii*. [160] Given the context, the dies are likely to date to immediately before the second Dacian war of AD 105–6. Copying also probably occurred right up until the time of the Dacian wars. [161] Since *Sarmizegetusa* was the seat of royal power by Decebalus' reign, it is plausible that some form of central control was exerted over coin production. However, this must be balanced against the possibility that *Sarmizegetusa* was one of several centres that minted coins.

A second set of important die finds comes from Tilişca, a defended hilltop site west of Sibiu that dominates the Secaș and Cibin river basins. Fourteen dies with three sleeve holders were found in total. Ten of these dies were used for striking Republican *denarii* types ranging from 148 to 74 BC.[162] The remaining four were made from low-quality copper alloy that quickly wore down due to the lack of resistance.[163] These dies were probably made by mechanical impression of the original coin against the die face. While Chițescu cites these dies as evidence for the lack of expertise in correctly rendering types

160 Lockyear (2008) 9; Oltean (2007) 106.
161 Lockyear (2004) 66.
162 Oltean (2007) 106.
163 Lockyear (2008) 8–9; Chițescu (1981) 14; 56.

and legends, Lockyear's hypothesis that errors may be due to the use of damaged originals rather than an inherent lack of skill should be kept in mind. With respect to the question of centralisation, it has been suggested that Tilișca stopped minting coins after 70 BC possibly in response to the centralisation of minting in the Luncani region around *Sarmizegetusa*.[164] This conclusion is based on the lack of die wear observed for the most recent coin type, which Bergquist rightly points out assumes that die—and coin—manufacture was necessarily based on using the latest issue available. Yet the presence of an imported 1st-century AD lamp indicates that the site was occupied beyond 70 BC. In short, it is not possible to determine when minting ceased at Tilișca within this period.

The die from Pecica is a somewhat unusual example, as it was found within a metalsmith's workshop and seems to be for an imitative Dacian coin rather than an imitation *denarius*.[165] The metal workshop contained evidence of bronze, iron, and silver working, demonstrating a multifaceted metallurgy. It may well have been the case that the die was brought in for recasting as it showed signs of heavy use and subsequent repair with copper. Although the coin type cannot be identified, Bergquist reports that the curved die face and deliberate slight in design indicate the production of a scyphate Dacian type. There is not, however, enough evidence to argue for Pecica as a tribal centre of economic importance in the lower Mureș valley based on the presence of a possible mint and the distribution of a local coin type.[166]

The remaining evidence for coin production is scanty and consists of three single die finds. A minting die at Ludești was for the reverse of C. Marius C.f. Capito (C.MAR.CF), which has been linked to a coin in Paris, while the one at Brașov was for

164 Bergquist (1989) 162–3.
165 Bergquist (1989) 154–4.
166 Bergquist (1989) 156, contra Crișan, the original excavator.

"Caesar".[167] The third was found in Poiana (Galați) along with an unstamped silver blank.[168] Nonetheless, the coin-dies do constitute important evidence for the production of—and by extension a local demand for—Roman-style coinage. However, there is no conclusive proof for the centralised production of copied *denarii*.

2.2.4 A demand for coins?

Why, then, were the Dacians minting coins? One explanation for the striking of local imitations is largely economic: if Roman coins were indeed accepted as currency in Dacia, as Glodariu argues, then it would follow that a certain demand existed for sufficient coin to effect commercial transactions. How great a demand, however, is difficult to judge, and one must also bear in mind alternative forms of tender such as direct commodity exchange or payment in kind. The archaeological evidence for extensive trade contact between Dacia and the Roman world lends compelling weight in favour of an economic perspective. The Dacians also seem to have been aware of metal fineness and frequently marked silver coins to check the metal.[169] This would suggest some concern for the economic value of the coins, but does not necessarily rule out their use as bullion.

In contrast to Glodariu—who potentially overstates the case for a flourishing Dacian market—M. Crawford has argued that the use of coin in Dacia had very little to do with a market economy.[170] It is also important to note that the Dacians only imitated silver denominations, but not bronze.[171] The lack of smaller denominations would have hindered the effectiveness of the coinage as daily currency, and the absence of consistent standards regarding weight and type suggests that coinages functioned only as a rough measure of

167 Lockyear (2008) 8–9.
168 Glodariu (1976) 88.
169 Chițescu (1981) 44. In contrast, there are no known marked gold coins.
170 Crawford (1977) 118.
171 Chițescu (1981) 6; Crawford (1977) 118.

value. Instead, Crawford believes that coins were used for gift payments or display, or as a form of mobile wealth—a perspective that highlights the social and symbolic value of coins beyond their economic function.

These two views need not be mutually exclusive. One need not accept the existence of a market economy to accept the influence trade and commerce might have had on the demand for coinage or the use of coins as a rough form of currency. Likewise, the symbolic function of coins also needs to be taken into consideration and may be more important than often acknowledged in the literature.

M. Chițescu offers a political explanation, but one which needs to be accepted with caution. The production of local copies probably began when the supply of imported *denarii* ceased and created a vacuum that needed to be filled. The dies found, Chițescu believes, correspond roughly to five tribal groups in Dacia that copied different *denarii* issued by different Roman moneyers.[172] Due to the lack of genuine *denarii* and the need for a universal currency for the fledgling state, Burebista intensified production until the more localised Macedonian copies were driven out of circulation. In short, the value and circulation power of Roman *denarii* helped forge the economic and political unification of the Dacian state. This argument has its problems, not least because of the overtly nationalistic tone of her conclusions. The evidence from the dies, for one, does not decisively support the existence of minting centres.[173] The relationship between Burebista and the adoption of *denarii* is also insufficiently demonstrated. As an explanation for monetary demand, it is difficult to see this as a persuasive alternative even though the presence of a centralised state would have a greater demand for metal than the other

172 Chițescu (1981) 56–7.
173 Cf. Glodariu (1976) 88.

explanations discussed.[174] Even if silver coins were functioning as a "state" currency, the amount needed is unlikely to have matched the amount needed by, for example, the Romans who came later.

On first study, Chițescu's argument has explanatory power, but what it fails to consider is that prehistoric societies functioned and operated in very different ways. This is particularly true of frontier regions like Britain and Dacia where Roman rule subsequently transformed the social and economic landscape. Metal use and demand need to be understood within the context of adoptive coinage and structured deposition rather than in purely economic terms. C. Howgego has suggested that there is a possible correlation between the adoption of coinage by Iron Age societies in the northern frontiers and the subsequent extent of the Roman Empire after annexation.[175] He argues that "the idea of coinage was borrowed and internalized to produce something new."[176] Namely, coins—and their production—facilitated the process of "becoming Roman" by allowing local communities the opportunity to participate in cultural change via the adaptation of Roman practices. For example, the choice of adopting silver rather than gold coinage in Dacia may thus be due to the established tradition of ritual deposition dominated by silverwork when coin use began in the region.[177] Likewise, the distribution of silver artefacts versus coins makes more sense within a framework of mixed function, where silver objects continued to be deposited—most notably in the Luncani heartland of Dacian civilisation—whereas silver coins circulated as part of a larger trade and economic network resulting from contact with the Greco-Roman world.

174 Cf. Preda (1973) who hypothesises that the rise of a centralised Dacian state might be related to the beginning of gold mining.
175 Howgego (2013) 21.
176 Howgego (2013) 20.
177 Howgego (2013) 25.

To return to the question of demand: it is not possible to pinpoint the exact magnitude of the demand for silver. The Dacians appear to have adopted the basic economic function of silver coinage, but there was very much a cultural and symbolic component involved with their use of silver metal. As Howgego has pointed out, the Dacians occupied a vastly different world, one which does not admit easy analysis of the sort familiar to those who study the Roman world. This is particularly true with respect to the evidence for gold.

2.2.5 Gold in Dacian society

In contrast to silver, gold appears to have played a singular role and commanded higher status in Dacian society. Mention must be made of the so-called Koson coins, the only known example of gold coins minted by the Dacians (*fig. 4*). These coins were most probably an issue of a Geto-Dacian king of a similar name (Coso-Cotiso).[178] They bear an eagle and the legend ΚΟΣΩΝ on the obverse and have been discovered in significant quantities, usually in the Strei Valley and at *Sarmizegetusa Regia*.[179] The hoard at Târsa-Luncani, for example, contained around 1,000 Koson coins, while the discovery in 1543 in the Strei riverbed consisted of 40,000 mixed Kosons and Lysimachan gold staters.[180] The Strei has been potentially identified as the ancient Sargetia River where Decebalus hid his gold during the Dacian wars, which suggests that the finds might have been a royal stockpile of sorts.[181] Given the scarcity of gold finds in Romania compared to silver, a

178 Preda (1973) 361.
179 Preda (1973) 353 ff.
180 Cojocaru et al. (2000) 185; Makkay (1995b).
181 Oltean (2007) 106.

royal monopoly on gold is a likely explanation for its rare occurrence.[182] There is also no evidence that the Koson coins circulated as currency.

The only other significant evidence for gold artefacts is the Sarmizegetusa bracelets, which were looted from the Dacian capital between 1999 and 2001 (*fig. 5*). Only 12 pieces have been recovered out of the original 24. These spiral bracelets, which weigh up to 1.2kg each, are made of solid cold-hammered gold and decorated with zoomorphic terminals.[183] Variously deposited in five separate mixed gold and silver hoards around *Sarmizegetusa*, it is unlikely that the bracelets were meant to be worn as jewellery. Taking this together with the Koson coins, it indicates that gold may have had more of a symbolic rather than active economic function. The demand for gold would have come from a very select few, who in any case were already controlling the available supply. This is not to deny their intrinsic value as stored wealth, but the distribution and type of gold artefacts found to date do not seem to suggest circulation or economic use as "currency", which stands in marked contrast to the example of Roman *denarii* discussed above. When considered in light of Howgego's analysis, the place of gold in Dacian society is perhaps unsurprising: as discussed above, Iron Age peoples adopted coinage to suit their existing cultural practices of social circulation and ritual deposition.[184] Gold and silver were adopted differently in Dacia to fulfil different but occasionally overlapping economic and social functions.

The Dacian silver and gold artefacts are indeed striking and have commanded the lion's share of attention. Nonetheless, although the Dacians unquestionably possessed the means to produce precious metal objects, it does not necessarily follow that their demand for the source metal was exceptionally high. Instead, it may well be the case that the

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182 Oltean (2007); Makkay (1995b); Bergquist (1989).
183 Constantinescu et al. (2010) 1031.
184 Howgego (2013) 27.

impressive quantity of artefacts was not driven by a great demand for gold and silver objects but the plentiful supply of easily available metal—especially alluvial gold.

2.3 Mining evidence

2.3.1 Precious metals

In order to produce precious metal objects for hoarding and Republican *denarii* for trading purposes, the Dacians needed a supply of metal—and in substantial quantities, if the reports on Decebal's treasure are indeed true. Yet the question of where the Dacians sourced their gold and silver remains largely unanswered. This is due in part to the destructive nature of mining, which tends to destroy traces of earlier activity. Also, certain forms of gold mining such as small-scale placer mining and panning leave ephemeral traces, if at all. To answer the question of precious-metal supply, this section examines evidence for both underground mining and alluvial placer mining, and then tries to assess the likeliest source of Dacian gold in light of the most recent provenance studies.

Main sources of ore

The most famous goldfields are found in the Apușeni Mountains, which contain Neogene low-sulphidation epithermal deposits rich in Au-Ag as well as some porphyry copper (*fig. 6*). The Au-Ag deposits occur variously as veins, breccias, and stockworks, as well as placer deposits.[185] The main ore-bearing districts, from south to north, are Brad–Săcărâmb, Stănija–Zlatna, and Roșia Montană–Bucium.[186] Of these, the Roșia Montană district has received the most attention, and evidence for exploitation from the Roman period onwards is substantial. The goldfield is still productive, with recent estimates valuing the contained

185 Tamaș and Cauuet (2009); Ciobanu, Găbudeanu and Cook (2004).
186 Ghițulescu and Socolescu (1941).

resource at 16.1 million ounces of gold and 73.3 of silver.[187] Another major source of primary gold can be found in the Baia Mare and Baia Borșa districts to the north, in Maramureș. It is also assumed that these mines were exploited in ancient times, but no extensive archaeological studies have been undertaken.[188]

Fluvial ores come from eroded primary deposits. As their name suggests, loosened alluvia are carried downstream by rivers from their original source and form placer deposits when found in economically significant concentrations. In Romania, placer gold in the form of Pleistocene river deposits is readily available and could have been panned from the rivers Sebeș, Strei, Pianu, Vinerea (Cugir), Apa Orașului, and Apa Sibișelului.[189] Due to differences in elevation and rock composition, the Abrud and Arieș valleys in particular see active erosion resulting in considerable deposits of gold-bearing alluvia.[190] Even today, traces of alluvial gold can be found in economically viable quantities in the Mureș, Strei, and Crișul Alb.[191] Chance finds over the centuries have also thrown up pieces weighing 5kg and up to 10 kg, with one particularly impressive 57.7 kg nugget found near the Maria mine (Brad) in 1891.[192]

In addition, lead is also present at the Șureanu Mountains or north-east of Poiana Ruscă, such as at Techereu (Tekerő) and Vălișoara (Porkura).[193] Lead-silver ingots weighing 1.4–1.7 metric tonnes in total have been found at Grădiştea, but the extraction of silver from the native lead deposits via cupellation has not been established.[194] Extraction by liquation was probably beyond the ability of Dacian metallurgists. Pieces of silver ore

187 Leary et al. (2004).
188 Baron et al. (2011) 1098.
189 Bergquist (1989) 210. Most are tributaries of the Mureș. Not all rivers are depicted due to the scale of the map.
190 CHBR (2006) 20.
191 Galcenco, Vress and Velciov (1995).
192 Makkay (1995a) 70.
193 Davies (1935) 206.
194 Bergquist (1989) 210. Most are tributaries of the Mureș River.

have also been found at a prehistoric settlement at Muncelu (Muncsel).[195] Given the presence of noteworthy amounts of copied Roman *denarii*, silver metal would have been required. It is possible that the Dacians were re-melting old coins rather than extracting the silver locally. The location of the Dacian silver mines, however, has yet to be securely identified.

Underground exploitation of primary deposits

Due to the substantial amounts of high-grade ore still available in the Roșia Montană deposit, modern commercial development has resulted in a body of archaeological work documenting the underground mining activity and related surface sites.[196] Extensive underground remains for Roman through to modern mining have been found, but there is still no firm evidence for Dacian exploitation of the primary ore deposits. In general, the pre-Roman phases—if they exist—have not been adequately studied at Roșia Montană.[197]

The excavators of Roșia Montană argue strongly in favour of prehistoric underground mining, citing carbon-14 dates from wood remains as their main source of evidence.[198] However, their use of the radiocarbon dates is problematic and requires further refinement. Furthermore, the assertion that mining at Roșia Montană is "very likely" to have occurred since the Bronze Age is not backed by archaeological evidence.[199] In their view, early workings would have begun with the surface exploitation of exposed veins that were then followed underground. Earlier authors believed that Cetate massif was also worked in the Dacian period,[200] but all traces would have since been destroyed by the large-scale open-cast mining in the modern period. Overall, in the excavators' opinion,

195 Davies (1935) 206.
196 E.g. Cauuet et al. (2010).
197 Wilson, Mattingly and Dawson (2011) 7.
198 Baron et al. (2011); Cauuet et al. (2010).
199 Cauuet et al. (2010) 456.
200 No specific names are cited by the excavators.

mining arguably had reached a high level of development three centuries before Roman conquest.

The two main pieces of evidence come from underground galleries at Țarina and Cârnic (*figs. 7*). At Țarina, a sloping timbered gallery that seemingly led to the surface was found. Radiocarbon dating of the wooden propping in 2000 returned an initial date between 50 BC and AD 80, which the authors claim could not be Roman as Trajan's conquest did not take place until AD 106.[201] Based on this, the timber propping—and the gallery—must therefore be Dacian. The first point to note is that the reported date appears to have been calibrated against an older curve. More problematic is the reporting of dates to 1σ (68% probability) rather than 2σ (95% probability). A recalibration of the reported raw date of 1965 ± 40 BP using OxCal against a 2009 atmospheric curve yielded a date of up to AD 126 instead when reported to 2σ.[202] There is a 94.5% possibility that the re-calibrated date falls within the extended date range, which indicates a 20-year overlap with the known period of Roman settlement and exploitation after Trajan's conquest in AD 106.

At Cârnic, additional wood and charcoal samples subject to carbon dating also seem to suggest that the mine was active in the Dacian period. A wooden plank dated to between the mid-3rd century to the beginning of the 1st century BC (between -265 and -90) and additional dates from the charcoal suggest similar date ranges between the 1st century AD and the Roman conquest.[203] Again, these dates suffer from the same problem as for the Țarina sample. A recalibration of the Cârnic 1 raw date of 2160 ± 50 BP against the newer IntCal13 curve does yield a date range similar to that reported by the excavators, but the probability curve actually has two major peaks, one at *c*. 350 and *c*. 200 BC, plus a smaller

201 CHBR (2006) 94; Cauuet et al. (2010) 457–8, 461.
202 Wilson, Mattingly and Dawson (2011) 44. The Țarina date was also recalibrated using the IntCal13 curve on OxCal; this is discussed in further detail below with the Cârnic 1 sample.
203 Cauuet et al. (2010) 471, 488–9.

peak at *c*. 120 BC (*fig. 8*).[204] It is not entirely clear what the results from the Cârnic sample signify, but it is important to remember that the radiocarbon date only indicates when the wood source was likely to have been felled and only provides a *terminus post quem*. While the prehistoric age of the plank sample is admittedly puzzling, one would hope for stronger, supplementary evidence to confirm a Dacian presence.

Another problem are the trapezoidal gallery openings, which typify Roman-period workings at Roșia Montană in general. Taken together with the early radiocarbon date, the excavators argue that the trapezoidal adits at Cârnic 1 therefore reflect a mining technique that the Dacians developed independently prior to the arrival of the Romans. However, this lack of observable change between the "Dacian" and Roman galleries is not so surprising if one discounts the carbon-14 date—which is, in any case, problematic—and accepts that the trapezoidal openings are probably Roman, rather than Dacian.[205] Comparative examples of Roman-period trapezoidal galleries in Serbia suggest the latter is more probably the case.

Assertions that the Romans knew about the Roșia Montană deposits and invaded the region in order to control the goldfields are extremely attractive, but still cannot be proven in light of the current evidence. Instead, it is far more likely that the Dacians used alluvial gold as their main source of metal. The trapezoidal galleries, rather than being a native Dacian invention, are best seen as a Roman import, barring more substantial evidence indicating otherwise.[206] Even the excavators admit that no Dacian ceramics or

204 See Fig. 8 results for Cârnic 1, Chamber 1, G3, US4, and Țarina vein 77. The raw dates were taken from Cauuet et al. (2010) Figure 15 and recalibrated using OxCal v.4.2.3 and the IntCal13 atmospheric curve; see also Bronk Ramsey (2009) and Reimer et al. (2013). I am grateful to Andrew Wilson for his help with the radiocarbon dates.
205 Contra Cauuet et al. (2010) 488.
206 Wilson, Mattingly and Dawson (2011) 52–3.

artefacts have been found in the mine galleries or in the associated surface sites.[207] Claims of pre-Roman exploitation of primary deposits require additional corroboration before they can be substantiated.

Surface exploitation of placer deposits

Complicating the picture, however, is the difficulty of identifying alluvial placer mining in the archaeological record. Prehistoric exploitation is likely to have used small-scale methods such as gold panning, whose remains are ephemeral and hard to trace. It is difficult, if not impossible, to assess the importance of alluvial gold in comparison to the primary deposits in the Apușeni Mountains. However, given the lack of concrete proof for underground mining—and indeed, of any trace of actual mining activity by the Dacians—exploitation of fluvial ores seems to be the most plausible explanation.

As noted above, several major rivers provided ample opportunities for gold panning. At Caraciu-Țebea, a few miles south of Baia de Arieș, three pre-Roman statues of miners were reportedly found along with a stone axe, leather sack, and many coins.[208] Possible surface exploitations could have also taken place at the gold-bearing sands at Costești, one of the major central places in the Orăştie region (*fig. 6*).[209] The Roman site of Pianu de Sus may have also been exploited in Dacian period, based on the proximity of a probable "Iron Age" tumulus, chance finds at Sălіștea-Cioara and Pianu de Jos, and two substantial hoards indicating the general wealth of the region, probably linked to gold exploitation.[210] None of this, however, is definitive.

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207 Baron et al. (2011) 1094; cf. CHBR (2006) 13.
208 Davies (1935) 203.
209 Oltean (2007) 105; Glodariu and Iaroslavschi (1979) 143.
210 Oltean (2007) 105–6.

Provenance studies

Recent research has focused on provenance studies in an attempt to answer where the Dacians sourced their gold. A series of experiments have been carried out on several Dacian gold objects, most notably the spiral bracelets and Koson (ΚΟΣΩΝ) staters from *Sarmizegetusa*. Despite the infancy of such studies in Romanian archaeology, results look promising and offer a means of circumventing the general lack of physical evidence for mining.

An early study by Hauptmann *et al*. analysed native gold samples from Roșia Montană using Wavelength Dispersive Spectroscopy (WDS) and Neutron Activation Analysis (NAA) to identify their composition.[211] The analyses revealed that the gold from Roșia Montană consistently had a high silver content ranging between 20 and 25% by weight, as well as relatively high traces of copper (Cu) and tellurium (Te). Given the technical difficulty of separating silver and gold, prehistoric objects made from gold from this area should have a similarly high silver content plus measurable copper and tellurium traces. The results were inconclusive: comparison with the earlier work of A. Hartmann revealed that only one prehistoric gold artefact from the Danubian region had measurable tellurium, and another group of objects with 25% Ag and 0.3% Cu did not have clearly detectable tellurium or tin.[212] Based on this, the authors rightly question the widely held assumption that Roșia Montană was indeed an important source of prehistoric gold in the region. Their findings also highlight the need for wider regional study to contextualise the ore samples from Roșia Montană. Other gold deposits within a 200 km distance from the Apuseni Mountains are also known in the northern Carpathians, western Balkan, and the Slovakian Ore Mountains, but these have not been analysed. The one site that has been

211 Hauptmann et al. (1995).
212 Hauptmann et al. (1995) 380; Hartmann (1970).

tested—Kremnica in Slovakia—had an ore sample with a similar compositional profile to the native gold from Roșia Montană. If this is the case, more work needs to be done establishing a baseline to allow for meaningful comparison of wider regional gold sources.

There is a small group of provenance studies on the *Sarmizegetusa* gold bracelets that were originally undertaken to establish the objects' authenticity. Although the express purpose was not an extensive regional study and the issue of metal reuse needs to be better accounted for,[213] the archaeometric results strongly point towards alluvial deposits as the most readily available source of Dacian gold.

An initial study by Constantinescu *et al*. tracked platinum group elements (PGE) using Micro-SR-XRF and micro-PIXE to identify the gold source of the bracelets. The team tested samples of both placer and primary gold to determine their geological fingerprint and then compared the measurements against the composition of the Sarmizegetusa bracelets.[214] Traces of tin (Sn) —indicative of placer gold—were identified, as well as antimony (Sb) typical of the Transylvanian deposits. Results on five of the gold bracelets revealed that they were made from native Carpathian gold, probably panned mixed with primary gold, with no attempts at refinement. Independent testing using LA-ICP-MS on the fifth bracelet also found significant traces of palladium (Pd) and platinum (Pt), known markers for placer deposits, which suggests that this bracelet was made primarily from panned gold.[215]

Further work revealed that the bracelets as a group varied in composition. Native Transylvanian gold was found to contain variable and quite high amounts of silver (from

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213 Stan et al. (2009).
214 Constantinescu et al. (2008).
215 Constantinescu et al. (2010) 1037; Constantinescu et al. (2008) 2328.

8% up to 35%), especially for primary gold;[216] very low copper levels; and trace amounts of tin for placer gold and antimony and tellurium for primary gold.[217] Due to the high amounts of silver, the bracelets could not have been made from melted monogrammed Koson coins, Lysimachus staters, or late Republican gold as the fineness of the coinage (> 95%) was much higher in composition. Tin levels also varied, which suggest that the artefacts were being made from local panned and primary gold, or a mixture of the two.[218] The most likely sources would have come from river panning and the placers at Valea Pianului near *Sarmizegetusa*, and the primary gold from surface veins, such as from Baia de Arieș and Valea Morii in the Arieș valley basin.[219] Nonetheless, the substantial dimensions of each bracelet—up to 1.2kg in weight each—indicate that the craftsmen were not limited by the amounts of raw material available.[220]

Compositional study of the Koson coins also supports the use of alluvial rather than mined primary gold by the Dacians.[221] There are two main groups of Koson coins: un-monogrammed and monogrammed. Using micro-SR XRF analysis, un-monogrammed coins were shown to be made up of 78–89% Au, 10–20% Ag, and relatively high Cu levels of 0.6–2%. The silver-rich composition plus the presence of Sn, Sb, and Te traces match the fingerprint of Transylvanian alluvial gold. Tested placer samples from Valea Pianului-Sebeș and Valea Arieșului, east and north of *Sarmizegetusa* respectively, bear this out, to the extent that the investigators were able to differentiate between coins minted from Valea

216 The relatively high amount of compositional silver is also supported by PIXE-PIGE analysis; see Bugoi et al. (2008).
217 Constantinescu et al. (2010) 1036. Cf. Stan, Păuna and Constantinescu (2009).
218 Constantinescu et al. (2010).
219 Constantinescu et al. (2012a) 401; Constantinescu et al. (2012b) 2079.
220 Constantinescu et al. (2010) 1039.
221 Constantinescu et al. (2011).

Pianului versus Valea Arieșului ores.[222] They conclude that the Dacian workshops at *Sarmizegetusa* were exploiting at least two different ore sources in their vicinity. In contrast, monogrammed Koson coins had a much higher gold content of around 90–98%, plus 1.5–9% Ag and a low Cu content of 0.1–0.5%. The high gold content indicates refinement, a practice unattested amongst the Dacian gold artefacts to date. It is probable that the monogrammed coins were made from re-melted refined gold. The similarity of composition with the alloy used in Balkan workshops for pseudo-Lysimachus staters points to the coins having been minted there,[223] but it is also possible that the Kosons were made by re-melting coins issued by the Black Sea colonies, particularly *Istros*, *Tomis*, and *Kallatis*.[224]

There have been attempts using provenance studies to identify Dacian exploitation of the primary deposits, most notably by Baron *et al.*[225] This investigation criticises the earlier studies of Hauptmann *et al.*, Bugoi *et al.*, and Constantinescu *et al.* by pointing out that the earlier samples were limited in number and mostly from objects rather than ores, and that all lacked sufficient geological and archaeological contexts.[226] Baron's study raises valid and important points.[227] However, this need not render the conclusions of the previous studies completely questionable, as the authors seem to intimate. It is necessary to note that the earlier studies had a different focus, especially the papers by Constantinescu,

222 Valea Pianului: 87–98% Au, 0.6–9% Ag, with low Ag and Cu levels due to its location far from the original primary deposit (i.e. "old" alluvial gold). Valea Arieșului: Up to 22% Ag, as well as traces of Sn and Te from the gold tellurides due to its proximity to the primary source.
223 Constantinescu et al. (2012b) 2078; Constantinescu et al. (2011) 920.
224 Cojocaru et al. (2000) 189, who used EDXRF and PAA analyses.
225 Baron et al. (2011).
226 Baron et al. (2011) 1091; cf. Baron et al. (2013). Earlier studies: Hauptmann et al. (1995); Bugoi et al. (2008); Constantinescu et al. (2008) and (2009).
227 The authors of the earlier studies were aware of shortcomings in their method: Hauptmann et al. (1995) recognised the need to analyse more samples, and Stan et al. (2009) called for a database of native Transylvanian gold.

whose aim was to identify the provenance of the *Sarmizegetusa* gold bracelets for museological and heritage-trafficking reasons, rather than archaeological ones.

Baron's project, in contrast, tries to identify whether the Dacians were already working the Roșia Montană site by comparing the sampled lead isotope signatures of primary ores against objects. So far, the study has started to establish a database using Roman-period samples to serve as a benchmark for future research. The next proposed step is to carry out analysis on Dacian Au-Ag objects as a comparison and to identify whether ore from Roșia Montană was used.

The methodology of Baron's project seems sound, and the creation of a database will no doubt prove useful for future research. One wonders, however, if the study is biased towards positively identifying Dacian-period activity at Roșia Montană. The following statement is telling, and the authors' characterisation of those who are proponents of alluvial gold exploitation is perhaps undeserved: "A certain contemptuous assertion is linked to the idea that the Barbarians could only recover gold from placers, because their mining technology was too primitive to allow them to produce gold from primary ore deposits (veins)."[228] As the following section shows, the Dacians were far from primitive and had a highly developed metalworking culture that encompassed iron as well as precious metals. Although the mining evidence is still lacking, it would be highly unlikely that the Dacians were incapable of developing or undertaking the mining of primary gold—provided there was an impetus to do so. Plentiful supplies of gold need not imply a correspondingly high level of use. If Makkay's assertion that impressive concentrations of fluvial gold were present even in the 16th century is correct,[229] then is it

228 Baron et al. (2011) 1093.
229 Makkay (1995b) 335.

not feasible that there was no pressing need on the part of the Dacians to expend effort extracting gold from the primary deposits?

Even if the project succeeds in matching lead isotope signatures with ore from Roșia Montană, there are other factors that need to be considered.[230] An example would be whether it would be possible to differentiate between ore coming from surface versus underground veins. The study differentiates between four mineralisation events and each ore sample has a different lead signature depending on its deposition source, but it is not entirely clear how the geological formations correspond with the location of the ore sample.[231] Would it be possible to differentiate between a sample found underground as opposed to on the surface or eroded out as loose ore? A related question would be how the metal came to be mined and then incorporated into an object. A hypothetical scenario, for example, could involve small-scale, local "mining" of exposed surface veins (e.g. at Cetate), with the ore subsequently being traded down to the main centres of power in the Orăştie before being wrought into an end product. This could still result in a positive identification of Roșia Montană ore in the final object, but need not indicate underground mining of the type or magnitude that many scholars assume to be the case. Furthermore, this still would not resolve the problem of re-melting and the mixing of different metal sources. Isotopic lead ratios are useful because they are unaffected by metallurgical processing and thus remain constant from ore to artefact, but the addition of different alloys or metal sources would modify the ratios.[232] Nevertheless, the creation of a lead isotope-signature database is a necessary and welcome step towards solving the question

230 As of summer 2018, no follow-up results to the 2011 paper has been published yet.
231 Baron et al. (2011) 1095.
232 Herz and Garrison (1998) 241. Bugoi et al. (2008), however, used Platinum Group Elements (PGE) rather than lead isotopes as lead is almost non-existent in ancient gold objects.

of where the Dacians acquired their gold. For the moment, the preponderance of evidence points towards the use of secondary, rather than primary, native gold.

2.3.2 Non-precious metals

While the study of gold in Dacia has benefited greatly from the Roșia Montană excavations, the Dacians also made use of other available mineral resources. Copper, lead, and tin are available in the region, and artefactual finds confirm the use of bronze, but evidence of exploitation in the landscape is surprisingly lacking.[233] Tin is available in small quantities in Piatra Semenicu in the Banat, and between Reșița and Caransebeș.[234] Ancient mining is not attested though.

Likewise, while there is evidence for copper use—and presumably exploitation—no actual mining has been identified. Slag has been found on a prehistoric site at Turdaș (Tordos), and the main copper regions are Baia de Aramă and the Banat.[235] There are pre-Roman bronzes that have impurities similar to that of copper from Baia de Aramă, but the link between metal source and object is not secure. Evidence from the Banat sites post-date the prehistoric period; most are 18th century workings. In general, very little research has been specifically undertaken on pre-Roman mining of base metals in Romania.

Iron

Of the non-precious metals exploited by the Dacians, iron is especially well-attested based on secondary evidence, but confirmation of primary ore extraction remains elusive. Even so, the plentiful evidence for a highly developed ironworking tradition, coupled with the amassed wealth in precious metal in the period prior to the Roman conquest, indicates a society proficient in metallurgy and probably its related activities.

233 Oltean (2007) 105. See above on argentiferous and auriferous lead deposits.
234 Davies (1935) 206.
235 Davies (1935) 207.

The main iron deposits are located in the Poiana Ruscă Mountains in Hunedoara, which was the centre of iron exploitation during the Roman period.[236] Based on this, Ghelari and Teliuc are sometimes cited as possible examples of Dacian mining, but without demonstrable proof.[237] Given the richness of the ores, it is highly likely that subsequent mining activity has eliminated all traces of earlier use.[238] An alternative explanation would be the use of surface ores that could be easily exploited without actual mining or via opencast techniques. These methods of surface exploitation would leave little or no trace of activity, unless smelting residue was present. In either case, it would be extremely difficult to date the remains to the Dacian period without accompanying small finds. Other sources can also be found in the Șureanu Mountains, at Dealul Negru, Steaua Mare, between Valea Mlăcii and Valea Pravățului, in the hills north- and south-west of the Strei, at Rudele, Federi, between Sipca stream and Boșorod, and at Dosul Vârtoapelor-Sub Cununi in the Orăștie Mountains.[239] Very little is known, unfortunately, about the system or method of mining due to the destructive nature of later activity.[240]

Nonetheless, the considerable exploitation of iron is implicitly indicated by the range and abundance of iron artefacts. Agricultural tools, for instance, included ploughshares, coulters, rakes, hoes, sickles, flails, spades, pruning-knives, and hooks.[241] The rake in particular demonstrates Dacian ingenuity and mastery of ironworking: it appears to be a local invention with no ancient parallel and can be found only in the immediate vicinity of Grădiştea.[242] Likewise, the diversity of blacksmith tools adapted to

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236 Wollmann (1996) 232–4.
237 Glodariu and Iaroslavschi (1979) 14, 18.
238 Oltean (2007) 104.
239 Oltean (2007) 39; Glodariu and Iaroslavschi (1979) 16–18.
240 Glodariu and Iaroslavschi (1979) 18.
241 Glodariu and Iaroslavschi (1979) 58–76.
242 Bergquist (1989) 210; Glodariu and Iaroslavschi (1979) 66.

different steps in the production process reveals the level of technological refinement the Dacians attained in ironworking.[243] To furnish the necessary range of tools for a predominantly agricultural society, a sophisticated siderurgical tradition would have been essential. The demand for iron ore would have also presumably been substantial.

The surviving evidence for ironworking mostly consists of ore reduction sites and metallurgical workshops within settlements, rather than mining sites themselves. Some proof of Dacian exploitation exists at *Sarmizegetusa Regia* (Grădiştea Muncelului), where ores from Bătrâna Hill in the Șureanu Mountains have been found near reduction kilns. This is not typical, as ores were usually reduced closer to the extraction point. Slag fragments and iron ingots were found on Tampu Hill, and ore reduction related to the exploitation of nearby resources has also been identified at Dosul Vârtoapelor-Sub Cununi, Dealul Strimbu, Federi, and Balomiru.[244] None of these sites has been systematically studied. Early attempts at provenancing have also not been successful.[245]

Metalworking workshops have been identified by the presence of tools, raw materials, kilns, and finished products associated with blacksmithing. The most secure identification occurs when several of these items are found together or in context. It may also be useful to differentiate between smithies that specialised in the primary production of iron artefacts versus those that repaired used items, as the former would require more substantial evidence for secure identification. Furthermore, the mounting pressures of the Roman wars would have favoured the development of the second type of workshop.[246]

The most complete evidence comes from the Grădiştea area. Despite the bias in archaeological activity, the concentration of related finds from Grădiştea Muncelului and

243 Oltean (2007) 105.
244 Oltean (2007) 39, 104–5; Bergquist (1989) 206–7; Glodariu and Iaroslavschi (1979) 17, 22.
245 Glodariu and Iaroslavschi (1979) 16.
246 Bergquist (1989) 204–5.

nearby sites suggests that it was the main centre of ironworking in Dacia. [247] Workshops have been found on the terraces above the religious precinct and at Căprăreaţa about one kilometre away, north-east of the sanctuaries (*fig. 9*).

The workshop at *Sarmizegetusa Regia* is noteworthy for its combined function covering the entire production process from start to finish, and dealing with both iron and bronze.[248] The aptly named "Terrace with the workshop for Bronze and Iron" held traces of rectangular buildings with iron slag, copper smelting debris, finished and unfinished bronze and iron objects, and a line of eight kilns.[249] The four circular clay kilns were probably for iron ore reduction, whereas the remaining rectangular stone kilns were for bronze working.[250] The combination of both bronze and iron metallurgy in one workshop points, perhaps, to the exigencies of war. Such pressures may also explain why the refinement of iron ore was taking place in the Dacian capital rather than where it was mined, as expected, to minimise transport costs.[251]

Terrace VIII also revealed traces of workshops which may have been related to wartime production. Eight groups of iron objects were found: one of these contained iron blooms, and the rest specialist tools for blacksmithing, carpentry, and agriculture, contained in perished boxes.[252] Amongst these finds, a knife imported from the *officina* of L. Herennius with a 1st-century AD date suggests that the workshop was active right before Trajan's conquest.[253] Furthermore, the workshop's position between the eastern wall of the fortress and the sacred precinct—rather than in the civil settlement as one

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247 Lockyear (2004) 44.
248 Oltean (2007) 105.
249 Bergquist (1989) 205.
250 Oltean (2007) 105.
251 Bergquist (1989) 205.
252 Bergquist (1989) 205.
253 Glodariu (1976) 211.

would expect—suggests that the Daco-Roman wars may have prompted the sheltered location.[254]

The remains from Căprăreaţa also indicate a smithy specialising in the primary production of iron goods, some of which may have been meant for use outside of the Dacian capital. Terraces VI and VII at Căprăreaţa produced evidence of a wooden building, along with a large number of iron tools for blacksmithing and carpentry, plus eight ploughshares and spades, four probable wheel hubs, and four unfinished artefacts.[255] A set of equipment for drawing wire was also present, but it is unclear whether the items indicate bronze working or needed repairs.[256] Of the tools found, some were seemingly unused, but—most noticeably—the blacksmith's tools were worn. The four wheel hubs are particularly striking: since much of the surrounding terrain would not have supported wheeled transport, it is possible that the hubs were meant for "export" to flatter areas such as the Mureș valley.[257] This workshop dates no earlier than the end of the 1st century AD,[258] which places its active period around the time when hostilities with Rome were starting to escalate.

Although the evidence lacks chronological resolution, some sense of scale can be gleaned from the amount of ore processed at Grădiştea. At the Căprăreaţa site, about a tonne of bloom was found on Terrace I; earlier excavation records also noted extensive slag and ironworking remains.[259] The area is also noted for its specimens of purified iron bloom (*loupes à decoupage*), numbering around a hundred and amongst the best examples

254 Glodariu and Iaroslavschi (1979) 39.
255 Bergquist (1989) 206.
256 Cf. Oltean (2007) 105.
257 Bergquist (1989) 206; Glodariu and Iaroslavschi (1979) 127–8.
258 Based on an imported unguentarium; see Glodariu (1976) 207.
259 Bergquist (1989) 205–6.

found in Europe.[260] In terms of production requirements, it has been estimated that a single workshop in Grădiștea would require about 50 tonnes of the type of ore found in Bătrâna Hill.[261] Although these numbers are admittedly sketchy, the amount of metalworking debris that has survived demonstrates the existence of an active ironworking community based at *Sarmizegetusa Regia*. This activity can be explained by the demands of daily use and repair, but the wars with Rome may have also resulted in elevated production levels.

In addition to the evidence from Grădiştea, a probable iron workshop has also been identified at Costești, where seven iron ingots were found.[262] Given the lack of corroborating finds beyond some slag and blacksmith's tools, the example at Costești may have been a workshop for emergency wartime repairs rather than for primary production.[263] Additional sites with possible evidence of metalworking based on chance finds include Ludești, Muchia Cetătii in the Cucuiș valley, and the upland site of Meleia. As noted above, the preponderance of evidence coming from Grădiştea suggests an ironworking hub centralised in and around the Dacian capital. While there are likely political and economic reasons for this—again, the Dacian wars would be a plausible one—the intensity and sophistication of metal use indicates a society entirely capable of exploiting its mineral resources, even though very few traces of mining activity remain in the archaeological record.

2.4 Conclusion

In summary, the existing literary sources do not support the assumption that the Romans had any specific knowledge of Dacian mining prior to conquest. It is hard to say more

260 Iaroslavschi and Mateescu (2010).
261 Glodariu and Iaroslavschi (1979) 19.
262 Oltean (2007) 91.
263 Bergquist (1989) 206; Glodariu and Iaroslavschi (1975) 38.

beyond the general circulation of rumours of Dacian wealth, but the evidence all dates from long after the Roman conquest when the plunder from the wars would have been publicly known and mining would have already commenced in the province.

The Dacian numismatic and precious metal finds also need to be understood in terms of both their economic and symbolic function and alongside an established practice of ritual deposition in Dacia. Without the pressures of a state-driven need to maintain a stable currency supply, the demand for precious metals by the Dacians was arguably low in comparison to the supply of metal available. Although sources of both alluvial and primary gold were plentiful in Dacia, the evidence for underground exploitation remains inconclusive, and it is more likely that the Dacians were mainly exploiting local alluvial gold to create coins and artefacts. With respect to non-precious metals, the exploitation of iron is well-attested by the range of tools and the smithing sites that have survived, even though the evidence for actual mining is deficient. The levels of development and intensity suggest that the Dacians were proficient in metalworking and in sourcing sufficient ore to meet their needs.

Barring new evidence definitively attesting the presence of Dacians underground in the mines at Roșia Montană, the assumptions laid out at the beginning need to be re-evaluated. There is evidence for the exploitation of alluvial deposits and possibly for surface workings with respect to gold, but no compelling evidence for the underground exploitation of iron. The existence of a ready supply of metal does not necessitate exploitation; rather, one also needs to consider whether a strong enough demand was present. In light of this, the annexation of Dacia and the subsequent transformation of the mining landscape under the Romans represent, in a sense, the story of a province plugged into the larger economic machinery of empire.

3

Roșia Montană: An Integrated Mining Landscape?

> … Traianus victa Dacia ex toto orbe Romano infinitas eo copias hominum transtulerat ad agros et urbes colendas. Dacia enim diuturno bello Decibali viris fuerat exhausta.
>
> … Trajan, after having conquered Dacia, transferred there an innumerable multitude of people from all over the Roman world in order to populate the countryside and cities, as Dacia had been depleted of men during the long war with Decebal.
>
> Eutropius, *Breviarium ab Urbe Condita*[264]

In the aftermath of Trajan's second war in AD 106, the Romans reputedly re-populated the *terra nova* of Dacia *ex toto orbe Romano*, with settlers from all over the empire.[265] Tantalising questions emerge from Eutropius' description of the massive re-colonisation attempt: was this population movement dictated from the upper echelons of the Roman state, as Eutropius seems to suggest? Or was it a voluntary relocation by people in search of new opportunities? Or perhaps a combination of the two?

These questions do not admit easy answers, but it might be possible to trace the hand of the state in transferring large groups of people across the empire for economic purposes. Amongst this crew of migrants was a diverse group of mining communities from neighbouring Illyria that subsequently took up residence in the key gold-bearing district of

264 Book VIII.6 of the Breviarium Historiae Romanae. Ed. F. Ruehl. Leipzig: Teubner, 1887. Translation my own.
265 Cf. Ellis (1998); Mihailescu-Bîrliba (2011), especially 13–19 on the mining population.

Alburnus Maior. Epigraphic evidence attests to the presence of the *Pirustae*, *Baridustae*, and *Sardeates*—amongst others—at *Alburnus Maior*. Although the date of their exact arrival cannot be fixed, the mass migration of a specialist mining workforce along with the swift provision of regional infrastructure testify to the organisational efficiency of the Roman Empire and its local representative: namely, the Roman army.

The speed with which the Romans started mining gold in Dacia has led scholars to presume that the army was intensely involved.[266] Comparisons with other provinces in the empire prove to be of little help, as the presence of the military is not uniformly attested across all the major mining sites in the empire.[267] To what extent this presumption of a high level of engagement is indeed the case for Dacia, however, remains difficult to judge and largely unquestioned.

The most substantial body of evidence comes from the site of Roșia Montană (*Alburnus Maior*), where extensive underground and surface workings as well as associated surface habitation and necropoleis remain intact. Together, these remains constitute a mining landscape of exceptional importance not attested elsewhere in the Roman Empire.[268] Since the material from Roșia Montană allows for a reasonably in-depth analysis not possible for other sites in Dacia, it serves as the starting point for understanding Roman mining activity and administration in the province. In addition to the mining remains, the evidence for the presence of the army will also be used to assess the level of military involvement. The results that emerge from this analysis will help contextualise Roșia Montană within the wider scope of other gold-mining sites in the region. Finally, an appraisal of the non-precious metal mines is also necessary as these

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266 Țentea (2003); cf. Christescu (1929) 23–24; Daicoviciu et al. (1960) 401; Moga (1985) 57.
267 Le Roux (1989).
268 Wilson, Mattingly and Dawson (2011).

resources were arguably the most immediately relevant to the quotidian needs of the army. The aim throughout is to understand how and why the Romans exploited the mineral landscape of Dacia the way they did.

3.1 Roșia Montană in context

The ore fields at Roșia Montană are part of a larger group of roughly 64 deposits concentrated in an area of only 900 km^2 in the Apuseni Mountains, making this area one of the most productive precious metal districts in the world.[269] Much of the historical workings centre around the low-sulphidation epithermal veins that constitute the majority of the deposit-types present, but the area exhibits great geological diversity in general. Present and future exploitation, in contrast, focus on the low-grade breccia and porphyry deposits. From north to south, the three main NW-SE striking belts are Roșia Montană-Bucium, Stănija-Zlatna, and Brad-Săcărâmb (*fig. 10*).[270]

In a sense, the Romans literally struck pay dirt in Dacia, discovering not just one but *three* highly productive mineral zones. The Roman presence is well attested in all three belts: scholars have noted this for well over a century in the mining literature.[271] Because of the preponderance of evidence from Roșia Montană however, it is easy to overlook the lacuna in our understanding of the overall chronology of which districts or deposits the Romans started working first. The answer may not be readily attainable, and it may be the case that multiple sites were discovered and worked around the same time. For the moment, it need only be noted that the Roșia Montană belt lies the farthest north of all three and it need not preclude the exploitation or importance of, say, Brad-Săcărâmb or Stănija-Zlatna

269 Ciobanu, Găbudeanu and Cook (2004) 23.
270 Tămaș and Cauuet (2009) 102; Ghițulescu and Socolescu (1941).
271 Davies (1935).

before that of Roșia Montană. The wider geological and mining context of the Apuseni district needs to be kept in mind while examining the following evidence from Roșia Montană because the site may in fact *not* be as atypical or important as it is often made out to be in the archaeological literature. While it is true that Roșia Montană provides hitherto undocumented, detailed archaeological evidence for Roman mining, comparable investigation of the other known mines in the Golden Quadrilateral may well reveal a similar level of activity.

Modern mining development cuts both ways, but archaeological research at Roșia Montană has largely benefited from the battle by Canadian outfit Gabriel Resources to secure the archaeological discharge needed to commence mining activity. A programme of intensive reassessment began in 1999 with field surveys, followed by the systematic excavation of specific sectors—both underground and on the surface—from 2000 onwards. The interdisciplinary research team of mining specialists and geologists has produced high-calibre work, the likes of which remain a rarity in contemporary Romanian archaeology. The three monographs that have been published so far reveal a rich mining landscape replete with evidence for the Roman period and beyond.[272]

There are, however, pitfalls. Coverage of the different sectors is patchy overall and limited to areas where the team had access. Factors impeding accessibility include excessive vegetation (for surface remains), flooding, safety issues, and clearance to work. Sufficient time, of course, was also an issue, and the most highly valuated ore fields took precedence in the research agenda. As a result, significantly more is known about the

272 Damian (2003); Simion, Apostol and Vleja (2005); Damian (2008). See also Wilson, Mattingly and Dawson (2011) for an independent assessment of the archaeological remains at Roșia Montană.

mining networks in the Cârnic and Cetate massifs than the Orlea-Țarina-Carpeni and Coș sectors. The Hăbad sector, although archaeologically promising, remains unstudied.[273]

Site chronology is troublesome as well. Although the excavators take pains to differentiate between "ancient" (17th-century or earlier) and "old" (medieval or earlier) workings,[274] the terminology is neither sufficiently clear nor consistently used throughout the main report published in *Alburnus Maior I*. The dating of underground galleries depends largely on ceramic finds and radiocarbon results of wooden remains from stratigraphic fill, making chronological precision difficult to establish. The reported radiocarbon dates are also not unproblematic; this will be discussed in greater detail below.[275] A dendrochronological timeline based on *in situ* samples from the drainage system at Păru Carpeni is very promising indeed, but no further results have been published since 2006.[276]

The following analysis thus makes no pretence at completeness: it is based solely on published work readily available in the public domain.[277] The last excavation season took place in 2012–2013, with exciting finds of a water wheel in the Cătălina Monulești gallery, but given the strong political opposition to the Roșia Montană Project, it remains unclear when archaeological work will resume. The current political situation surrounding the Roșia Montană Gold Mining Corporation remains precarious: repeated delays, legal

273 CHBR (2006) 98; Cauuet et al. (2003) 477. Maghiar and Olteanu (1970) and Wilson, Mattingly and Dawson (2011) make no mention of the galleries at Hăbad, and Wollmann (1996) 195 discusses only the sacred grove above-ground.
274 Cauuet et al. (2003) 471–2. "Old" workings seem to refer most frequently to Roman mining, as far as I can tell.
275 Wilson, Mattingly and Dawson (2011) 44 n. 65. Cf. the discussion in Chapter 2.
276 CHBR (2006) 98, 200.
277 Key sources not consulted or unavailable include Austro-Hungarian mining plans (e.g. František Pošepný's 19th-century maps), Minvest Deva archives, and unpublished preliminary reports by Cauuet et al. (especially the 1999 survey of alluvial deposits in the Pianu Valley). The doctoral work of D. Vleja (Universitatea din București) stems from the Roșia Montană Project and is only publicly available as a précis and remains unpublished; cf. Vleja (2011).

action, and widespread public opposition have left the archaeological research in limbo. Although the Romanian government submitted Roșia Montană for contention as a UNESCO World Heritage site in late 2016, a court case suing for damages by RMGC has resulted in government backtracking by the current regime and fresh public protests on the matter. As of June 2018, the Romanian government has withdrawn the UNESCO application for Roșia Montană, prompting fresh protests against the move.

Nonetheless, we still know more about Roșia Montană than any other mining site in Dacia. It offers a possible case study for elucidating Roman mining activity in the imperial period. While potentially illuminating, mining at Roșia Montană should not be treated as a yardstick: what works at one place was not necessarily the case elsewhere in the Roman Empire, or even at other sites within the province. The specifics of site geomorphology and the ability to adapt and implement extraction methods accordingly also play a key role in determining the nature of Roman mining in Dacia.

3.1.1 Geographical setting

Located in the southern part of the Apuseni Mountains (NW Romania), modern Roșia Montană is a commune of 16 dispersed alpine villages. The two main villages of Roșia Montană and Corna are in river valleys of the same names. Most of the known Roman remains, however, are clustered around the eponymous urban centre immediately north of the Cârnic and Cetate massifs (*figs. 11, 16*). Some mining sectors, such as Coș-Lety, closely abut the modern settlement, posing difficulties for archaeological investigation.

Roșia Montană village is protected in a bowl-shaped depression by defined peaks and steep valleys, but elevation ranges widely from the peaks of Piatra Corbului (1159 m) and Cârnic Massif (1081 m) down to the Arieș (550 m) and Abrud (577 m) valleys.[278] The average altitude is around 850 m. This difference in elevation and underlying geology results in active erosion and the sizeable deposition of gold-bearing alluvia in the Arieș and Abrud river valleys. In addition, timber resources are also plentiful and provide the necessary wood for mine propping and, before the advent of dynamite in the 17th century, sufficient fuel for fire-setting, a mining technique that required significant amounts of kindling. While soil quality is poor, agriculture at subsistence level is possible, as is herding.

Mean annual temperature is between 6–8°C, with extremes of -4°C in January and 15°C in July on average.[279] Precipitation peaks in spring, averaging between 800–1,000 mL annually, but a significant proportion occurs as winter snow. Summer is the driest season due to the higher evaporation rates. The climate is temperate continental, marked by short summers and long, cold winters lasting four to six months every year. It is not unusual for the earliest snow layer to form as soon as October and to persist until late March or April in the lower reaches of the Arieș river valley.[280] The maximum period of snow duration ranges from 168 days in the valley to over 250 days in the upper mountains. Snow depth reaches its maximum in January and February, but can also peak in April in some areas due to accumulation over the winter months.

The local topography, climate, and hydrology pose particular though not insurmountable challenges to mining at Roșia Montană, especially with respect to access and transport in the winter months and the increased risk of mine galleries flooding during periods of peak rainfall or the influx from snowmelt. Admittedly, continuous mineral

278 CHBR (2006) 20.
279 CHBR (2006) 21.
280 Based on contemporary estimates from local metrological stations; cf. Călinescu, Soare and Rodica (2002) 10–12.

extraction has transformed the landscape over the centuries and the environmental conditions during the Roman period are not known. However, the concept of seasonality and its implications for mining activity is insufficiently explored and could be worth further consideration given the richness of epigraphic evidence that has survived in the wax tablets.[281]

3.1.2 The wax tablets

Roșia Montană has long attracted antiquarian curiosity for its caches of wax writing tablets and its trove of epigraphic evidence since the 18th century.[282] Whilst the work of the Franco-Romanian team explicitly sought to redress the imbalance with excavated evidence, Roșia Montană still remains a pivotal site precisely because the survival of written texts enriches our interpretation of the underground galleries and their spatial organisation and administration—the two go hand in hand.

The texts themselves offer some clues to the people who lived and worked at Roșia Montană. Only 25 wax tablets are still extant (*Tables 2a and 2b*).[283] Of these, seven or eight are too lacunose or fragmentary to be useful here, but the remaining 17 contain a rich array of legal and onomastic information, including sale-purchase contracts, loans, labour contracts, a list of prices and expenditures, as well as agreements to form and dissolve associations. These texts remain a treasure trove of information on mining conditions at Roșia Montană and can also aid in establishing the chronology of exploitation, which has not been an easy task so far.

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281 This is discussed below in relation to the labour contracts and their dates.
282 CHBR (2006) 13. The collected texts of the extant wax tablets (TabCerD) can be found in IDR I; note, however, that the order and numbering of the texts differ from those given in CIL III.
283 That more were originally found is evident from editorial comments noting the destruction of tablets whilst attempting to dry them (TabCerD IV, p. 206) and the dispersal of a cache of seven sheets amongst various local residents (TabCerD XXIII, p. 253). CHBR (2006) 162 states that 29 tablets have been preserved, but the original number was probably more than 30.

Fortunately, the find locations for some of the Roșia Montană tablets are relatively secure. Between 1786 and 1855, waxed writing tablets were uncovered in various underground mines around the commune. The two mines with the largest caches are: Ohaba-Sf. Simion on the south slope of Cârnic, from which three tablets discovered in 1854 survive,[284] and Cătălina Monulești in the Lety massif, with the largest surviving cache of 11 tablets, mostly found in 1855.[285] Other find spots include galleries in Laurențiu, Igre Massif (1786); Sf. Iosif/St. Joseph, Lety Massif (1788); and Sf. Ladislau, on the north side of Cârnic (1820).[286]

The reported dates and locations for the tablets are occasionally somewhat confused,[287] and access to some galleries need to be re-established by the current excavators, but on the whole, these texts matter as archaeological finds in their own right and their value as such could be profitably explored. The known find spots offer a starting point for future work: since much of the Roman mining network still remains uncharted, the potential for finding additional sealed galleries with preserved tablets is high.[288] One possible project could involve mapping the known galleries, especially those with the larger caches, to identify whether their spatial distribution had any significance within the wider landscape, especially in relation to evidence for settlements above ground. The curious choice of hiding legal documents in a mine, even in times of crisis suggests that

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284 TabCerD II, XI, and XVIII.
285 TabCerD III, V–IX, XIV, and XVI are certain, while the attribution of TabCerD XXI, XXII, and XXV to Sf. Ecaterina/Cătălina Monulești is probable.
286 TabCerD IV, I, and XXIII, respectively. No find spots are reported for eight of the tablets (TabCerD X, XII, XIII, XV, XVII, XIX, XX, and XXIV).
287 This is true of both IDR I and especially the list of known wax tablets in CHBR (2006) Appendix G. The latter largely follows the find dates in IDR I, p. 172–174, but some of the accounts do not match up; e.g. the Sf. Ladislau tablet found in 1820 (or 1824) is variously referenced as TabCerD XXII (IDR I, p. 173), XXIII (IDR I, p. 253–4), and XXI (CHBR (2006), p. 166). This appears to be because of some confusion between the CIL III and TabCerD numbers.
288 E.g. Sf. Ladislau. The northern side of Cârnic massif, in general, has not been as thoroughly studied and requires further investigation; Wilson, Mattingly and Dawson (2011) 39.

the owner of the documents lived or worked reasonably nearby, but any further research along these avenues would require the discovery of more tablets or written documentation.

3.1.3 The geology

The local deposits at Roșia Montană can be further broken down into the following main sectors: the Cârnic and Cetate Massifs, where the most extensive mining networks have been found; Găuri; the Orlea-Țarina-Carpeni sectors; and the Coș sector on Mount Lety (*fig. 7*). Across these zones, the mineralisation at Roșia Montană exhibits considerable diversity. A region of particularly hard rock is located at Găuri on the southwestern slope of Cetate, as well as at Piatra Corbului in the south-eastern sector of Cârnic.[289] Unlike the more friable host material that constitutes much of Cetate and Cârnic, this highly silicified dacite required—for pre-modern miners—mastery of the fire-setting technique for efficient extraction of ore.

Such geological diversity has implications for mining at Roșia Montană as geological parameters determined where and how the Romans extracted the native ore. To successfully work the varied host bodies required a multiplicity of responses adapted to the situation on hand. From prospective trenching to the use of fire-setting, this adaptive response required both technological knowledge and technical knowhow on the part of the Romans, which—as we shall see—is apparent in the underground remains preserved at Roșia Montană.

289 Cauuet et al. (2003) 500, 474.

3.2 The underground mining evidence

The main auriferous zones at Roșia Montană with evidence for pre-modern mining can be grouped into the following areas, roughly moving in an anti-clockwise direction: Cârnic Massif, Cetate Massif, Orlea-Țarina-Carpeni, and the Coș-Lety and Jig-Văidoaia massifs.

3.2.1 Cârnic Massif

The Cârnic massif is located southeast of the modern village of Roșia Montană—which directly borders the northern limit of the massif—west of the open pit at Cetate, and north of Corna valley. The massif is further subdivided into several smaller sectors: Cantaliste on the northern and lowest part, and Corhuri on the southern end of the massif. To the southeast is Piatra Corbului. Cârnic Peak itself soars to some +1087 m high, but the main point of access is the road hugging the south side at around 950 m and another road on the western slope to workings at a new open pit. Due to safety reasons and the dynamiting of a drift at the 932 m level, the only accessible level to the underground mines is at 958 m.[290]

The surface workings at Cârnic are largely undated due to the difficulty of doing so, but nonetheless exhibit a diverse range of activity. Remains include waste dumps and collapsed workings, and examination of the slopes reveals drift entrances, fire-setting pits, possible open pit exploitation, exploration trenches, and ventilation openings. Roman works are mostly identifiable based on technique: vestiges of fire-setting and chisel and hammer (or pick) marks in particular provide clues of ancient extraction, but again, due to the difficulty of dating the surface remains, this is not definite. These are mostly evident as

290 NB: Numbered modern access galleries at Roșia Montană are referred to by height in meters above sea level (m.a.s.l.).

drifts on the southern slope and remnants of collapsed works in the form of safety pillars with evidence of chisel work.[291]

Admittedly scanty, the surface workings that survive at Cârnic are particularly important because any corroborating evidence from the neighbouring Cetate massif has long since been obliterated by the modern opencast mine. Despite the limited exploration confined largely to the southern exposure and the difficulty of dating anything precisely to the Roman period, the extent to which the massif has been worked suggests a certain degree of thoroughness, probably also due to long-term exploitation. One would also presume that mining began at the surface before the ore was pursued underground, which helps explain some of the diversity (and quantity) of exploitation methods observed.

Cârnic received high priority in the research programme as it was scheduled for destruction in the proposed mining project. Because of this, extensive work was undertaken, and more is known about the underground mining at Cârnic than the other sites at Roșia Montană. There are over 35 km of works in Cârnic in total.[292] Some 16 km was surveyed by the team between 2000 and 2006, of which 4 km are Roman.[293]

The underground network at Cârnic is vast, and consists of a system of intersecting drifts, vertically superposed from the 853 to the 1046 level and resulting from modern development.[294] Accessibility to the Roman remains via the surface is limited for the pre-20th-century galleries, and the main level of access is 958 for Cârnic 1.

A few sectors with known ancient workings were unexplored due to high levels of instability and reasons of security. These include Cantaliste, Corhuri, and Napoleon.[295]

291 Cauuet et al. (2003) 472–3.
292 Cauuet et al. (2003) 473. These were surveyed between 1999 and 2000.
293 CHBR (2006) 89.
294 Cauuet et al. (2003) 474.
295 Cauuet (2009a) 39–41.

Most of these galleries were opened by tools, but there is also evidence for fire-setting in Corhuri (Level 887, point 2). Another example of fire-setting was also found on the surface of Corhuri, at the foot of the massif towards level 1000, along with traces of tool-working on its north wall.[296] In general, the lack of evidence from the northern side of Cârnic is mostly due to inaccessibility to sectors such as Cantaliste where safety concerns prevented the archaeological team from carrying out full surveys.[297] The Sf. Ladislau gallery, known to be on the northern slope and the find spot of TabCerD XXIII and several other tablets in the 1820s, has also not been relocated.[298] This paucity of research here is regrettable, as the northern slopes of Cârnic lie closest to where ancient *Alburnus Maior* was presumably sited under the modern village of Roșia Montană.

Most of what is known from Cârnic is thus from the intersecting networks located towards the southern portion of the massif, and especially from the so-called "Big Network" of Cârnic 1-2-3-4-8-9-10. The Big Network consists of seven smaller networks of ancient workings and covered about 13,600 m^2. A total of about 3 km was spread out from the 921 m to the 1019 m levels, over a height of 98 m, and the system resulted from the exploitation of a complex breccia dyke body and its related branched veins.[299]

A wide variety of different gallery types is represented at Cârnic. The three major types of mining works include: exploration works (adits, both sloping and horizontal, and vertical shafts); exploitation sites (pillared chambers, benches dug on an incline, vertical and sloping shafts, and stopes); and supporting structures (circulation and ventilation

296 Cauuet (2009a) 40.
297 Cf. Wilson, Mattingly and Dawson (2011) 39, who note the surprising lack of ancient remains surveyed in the north of Cârnic.
298 CHBR (2006) 166. Only TabCerD XXIII still survives.
299 Cauuet (2014) 93.

galleries, access galleries, junctions, and drainage systems).[300] Of these, examples of each can be found at Cârnic, with the exception of drainage rooms and adits as water was not a significant problem at this site. At Cârnic 1, for example, a large exploitation chamber was found, safety pillars still intact.[301] At *dépilage* Dep 1, also in Cârnic 1, the presence of a reverse stepped ceiling is attested.[302] The stepped ceiling reveals that work was executed in successive benches, resulting in a step-like formation as excavation moved from one level to the next. There is even evidence in Cârnic 1 for a series of shafts (G6-G8-G9) arranged in a helicoidal pattern.[303]

The diversity of exploitation appears to reflect differences in the ore grade and the need for certain technologies to make exploitation possible. In Cârnic 1, for example, the miners focused on areas where horizontal and vertical veins intersected in "crosses". These crosses represented the highest-grade ore zones and as such, tended to be exploited early on.[304] In areas like Piatra Corbului (Cârnic 6–25), where the rock is more highly silicified, fire-setting was used to tackle the harder native rock. Fire-setting was a technique that involved building an immense fire that caused the rock to expand, and, when water was thrown on the super-heated rocks, caused the rock to fissure and be more easily workable.[305] This method leaves characteristically smooth and rounded walls, and can be seen, for example, in Cârnic 25.[306]

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300 Cauuet (2014) 90.
301 Cauuet et al. (2003) 483–4.
302 Cauuet et al. (2003) 482.
303 Cauuet (2004) 56, Fig. 14; Cauuet (2009a) 144. Vertical accessways are rare in Cârnic, with only one example of such a shaft known in Cârnic 5. Only three helical wells have been identified in Cârnic; Cauuet (2009a) 207.
304 Cauuet et al. (2003) 484.
305 Willies and Weisgerber (2000).
306 Cauuet (2009a) Fig. 24.

Dating the various workings at Cârnic is difficult, but this is partly due to the rock being fairly hard and thus comparatively less wood propping was found.[307] In brief, Cârnic 1 is dated to between AD 106 and the 2nd century based on the presence of Loeschcke Type X lamps. These lamps have a wide chronological and geographical distribution, and thus cannot provide a more detailed window, but the Trajanic conquest provides a *terminus post quem* of AD 106 at least. Cârnic 2, 3, 9, and 10 are all also dated to the 2nd century by the presence of Loeschcke X lamps, although Cârnic 2 does appear to have been opened after Cârnic 3. Cârnic 7, which was worked both by fire and by tools, yielded radiocarbon dates between the 2nd and the 4th century. Some evidence for later activity in the 3rd century is attested in Cârnic 1, in the pillared working chamber, and in Cârnic 6, where radiocarbon-dated wood from the galleries there returned a date window ranging from the 2nd/3rd century to the 3rd/5th century AD.[308] Despite the date range, none of these results are necessarily later than the abandonment of the province in AD 271, even though the excavators use the radiocarbon dates as evidence for continued working beyond the 2nd and 3rd centuries.

The excavation team has also proposed the possibility of pre-Roman exploitation at Cârnic, based on radiocarbon dates for a plank of wood found in the pillared exploitation chamber (Ch1) in the north-western section of Cârnic 1 (Sample Cârnic 1 – Chamber 1 G13 US4).[309] The measurement of 2160 ± 50 BP (265 to 90 BC) was initially reported to only one standard deviation (1σ); when recalibrated and reported to 2σ, the new dates range from between 365 to 90 BC (92.4% probability) and 75 to 55 BC (3.0% probability)

307 Cauuet (2008) 65.
308 Wilson, Mattingly and Dawson (2011) 38; Cauuet et al. (2003) Fig. 15.
309 This was originally misreported as coming from gallery G3.

(*Table 1*).[310] Although the date of the plank falls within the Dacian period and must represent wood felled prior to the Roman conquest, the context of the find suggests that the location of the plank is likely to be residual: the wooden fragment was reportedly found on the ancient walking surface of Ch1, but in the same stratigraphic level as a ceramic fragment with a fabric similar to the 2nd-century Roman lamps found in the nearby G1 and G2.[311] This would indicate that the piece of wood, even if it had not been reused during the Roman period, could have been redeposited in US4 from elsewhere. In addition, all of the other dates from the Cârnic wood samples are firmly Roman and dated to between the 1st and the beginning of the 3rd centuries AD.[312] The samples from elsewhere in Cârnic 1, in G1 and G2, were both from the 2nd to mid-3rd century.[313] Given that the plank of wood in question appears to be residual, the argument for pre-Roman exploitation at Cârnic is not compelling.

The mass of evidence from Cârnic has substantially improved our understanding of Roman mining at Roșia Montană. Although possible, the plausibility of a Dacian phase at Cârnic is unlikely based on the existing evidence. The remains at Cârnic also highlight some of the technological innovations introduced by the Romans, which include the use of trapezoidal gallery cross-sections and ceramic lamps for lighting. There is also evidence for types of workings not seen elsewhere; the helicoidal descending gallery is particularly noteworthy. In terms of exploitation, the Roman miners appeared to have selectively worked regions where the gold was the richest, which makes a lot of sense from an

310 See Chapter 2 for the full discussion of the problems with the radiocarbon dates reported in Cauuet et al. (2003).
311 Cauuet et al. (2003) 484; 482.
312 Cauuet (2008) 66.
313 Cauuet et al. (2003) 481.

economic perspective. These workings take a diversity of forms and were a response to the underlying geology.

Although more is known about Cârnic than elsewhere at Roșia Montană, only a small proportion of the whole massif has been explored. The missing or collapsed areas found by Pošepný have not been re-located; the northern slopes remain under-represented; and water management systems have not been adequately explored or identified. For the latter especially, it is necessary to look elsewhere in Roșia Montană for evidence, to Păru Carpeni and Cătălina Monulești.

Cârnicel

In 2000, the excavation team also explored Cârnicel, a small hill connected to the south-western extent of the Cârnic massif. Flooding and collapse prevented a full assessment, and only recent and Early Modern works were found. However, an entrance to two short galleries ending in mining faces was accidentally exposed while bulldozing on the north-western slope; the characteristic trapezoidal profile of the galleries points to Roman-period activity.[314] Not much more is known about this site.

3.2.2 Cetate Massif

Along with Cârnic, Cetate is the other main massif in the area. Located south of Roșia Montană village and west of Cârnic, Cetate has seen massive levelling due to the opening of a large opencast mine in 1972 during the communist era. The massif currently stands at 910 m—down from the original peak of 1003 m—with the base of the open pit at 890 m. Photographs taken before the modern mining works reveal a massif that was originally

314 CHBR (2006) 88, 210; Wilson, Mattingly and Dawson (2011) 39–40.

similar in shape and size to Cârnic.[315] The amount of destruction, needless to say, is vast and most of the ancient mining remains have been obliterated by the modern opencast.

Fortunately, a limited picture of earlier Roman mining at Cetate can be gleaned based on old plans and photographs pre-dating the opencast mine. Pictures of Cetate reveal surface workings consisting of four vertical open-pits of considerable size. Called the "Curțile Romane" ("Roman Courts"), these ranged from the smallest at 300 m^2 and 40 m deep to the largest at 2400 m^2 and 60 m deep (*Table 3*). Some appear to have been opened by fire, resulting in superimposed rotundas, while others appear less organised, resembling large holes piercing the massif.[316] Intensive exploitation under the communists has since annihilated these "courts" by the beginning of the 1980s; nonetheless, the impression is one of reasonably extensive surface activity during the pre-modern period.

Given the disruption caused by the modern mining, the extant surface evidence is muddled. Most of what remains are waste dumps from the modern open pit, which has especially affected Cetate's southern slopes. On the less disturbed slopes, a survey in 2001 by the French team recorded the presence of waste dumps, depressions, and access ways,[317] presumably of uncertain date. Traces of Roman activity both above and below ground can still be found in the Zeus and Găuri sectors of Cetate, and most of the archaeological research has focused there. These two areas will be discussed in greater detail separately from the main massif.

The modern underground galleries at Cetate are quite remarkable in scope, measuring more than 35 km long in an inter-crossed network of drifts. Exploration has been problematic, as access to the galleries is only practicable via three or four entrances

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315 Wilson, Mattingly and Dawson (2011) 30. Cf. Wollmann (2002c) 159 for photographs.
316 Cauuet et al. (2003) 476 and Fig. 13 on p. 497.
317 Cauuet et al. (2003) 476.

and initial assessment of the older galleries was based on old plans that were difficult to interpret. The areas closest to the opencast have also been severely affected and some exploitation points have collapsed. Surprisingly, despite the extent of the underground network, the archaeological team did not identify any ancient or pre-Early Modern (17th c.) galleries in their diagnostic survey.[318] This means that known Roman exploitation at the heart of Cetate is limited to the lost open pits. Only at Zeus and Găuri on the edge of the Cetate massif are the underground workings preserved.

Zeus

The remains at Zeus are significant as they provide evidence for surface mining that is no longer available from Cetate, as well as the possibility of some mining activity having taken place relatively early after the Roman conquest of Dacia. While neither is without their problems, mining at Zeus might offer some clues to the intensity and nature of Roman exploitation in the Cetate area.

The Zeus sector, located in the north-western part of Cetate, consists of Roman opencast and underground workings, of which 83 m was excavated.[319] These remains include several horizontal drifts (G1–G16) and two vertical *dépilages* (Dep 1 and 2) organised into three distinct zones over two levels, and centred on the exploitation of the main mineralised body, the Zeus breccia dyke (*fig. 12*).[320] In addition, these workings also provide an excellent example of Roman mining technique where galleries were opened by iron tools; namely, by hammer and chisel or by pickaxe.

The southern zone consists of the G1 drift, an isolated gallery that traversed a friable dacite spur and opened on the west onto a now-collapsed opencast. The gallery

318 Cauuet et al. (2003) 476–7.
319 CHBR (2006) 86.
320 Cauuet et al. (2003) 486.

intersects a horizontal vein at the centre, where the miners opened a *dépilage* exploiting the richest ore. The lack of drill marks suggests that this drift is an ancient one and not reworked in the modern period, although 20th-century *dépilages* crosscut the entrance and fragments of modern glazed ceramics were present in the upper layers of fill. [321]

G1 is also particularly important because of its contribution to our understanding of the chronology of the workings at Zeus. It is the only gallery at Zeus where Roman artefacts have been found. These artefacts come from the lowest stratigraphic layers and include: shards of common Roman ceramics and blown glass; a nearly intact sandstone food plate of good quality, but hard to date; iron nails; a sharpening stone; and *tegulae* and brick fragments.[322] Attempts to further refine the phasing based on two radiocarbon-dated charcoal samples suggest a starting date in the early period of Roman occupation. The Cetate-Zeus G1 US11 sample from the base of the fill was reported to 1σ as dating between the beginnings of the 1st and 2nd centuries AD (AD 5 to 145). The second sample, Cetate-Zeus G1, comes from the same intermediate layer as the Roman finds and is dated to between the early 3rd and the beginning of the 5th century AD (AD 210 to 415).[323] Reporting the dates to 2σ widens the chronological window: the first sample (G1 US11) dates between the mid-1st century BC and the early 3rd century AD when recalibrated (55 BC to AD 210), whereas the second is between the mid-2nd century and beginning of the 5th century AD (AD 140 to 405) (*Table 1*). That G1 was first filled in the 2nd century and continued accumulating fill until the 4th century, before modern intervention, is certainly a possibility based on the radiocarbon dates.[324] However, this does not preclude the likelihood that G1, like galleries elsewhere at Roșia Montană, went out of use around AD

321 Cauuet et al. (2003) 487.
322 Cauuet et al. (2003) 487; Fig. 25 profile plan of G1.
323 Reported as 1950 ± 45 BP and 1740 ± 45 BP respectively in Cauuet et al. (2003) Fig. 15.
324 Wilson, Mattingly and Dawson (2011) 30.

167 during the Marcomannic incursions as the event falls well within the dating window. B. Cauuet accepts the 2nd-century date for the entire network based on the consistent profiles of the G1 to G16 drifts and their similarity to the Cârnic research drifts examined in 2000 that were also dated to the same period.[325] However, one would hope for corroborating data from other galleries to establish that the dates for G1 are in fact true of the Zeus network as a whole.

The central zone, which can be divided into an upper and lower area, was the heart of Zeus. Here, exploitation of the richest ore in the Zeus breccia dyke was organised around *dépilages* Dep 1 and 2, along with evidence of smaller prospecting galleries. Stability was a significant problem here (e.g. G2, G3, G4, G14 *dépilage*, Dep 3)—given the friable host rock—which greatly impeded the research team's progress.

G2 and G3 were rectilinear prospecting galleries, dug from the outside of the massif inwards, and showed no signs of modern reworking. No artefacts were found in either gallery. Both galleries are close to the surface, with clearly visible entrances.[326] G4 was also a prospection gallery, as evidenced from the irregularly pockmarked walls, extensively exploring small veins and mineralised pockets. It subsequently turned into *dépilage* G14, a highly unstable site prone to collapse. These, too, were devoid of archaeological finds.[327] In general, these galleries illustrate how Roman miners may have followed visible deposits underground, while keeping the galleries close to the surface due to the fragile nature of the host body.

G5 and Dep 1 both opened from the surface, with G5 dug towards the centre before deepening into a vertical *dépilage* after 3 m. Dep 1 was a narrow and deep work (7.8 m

325 Cauuet et al. (2003) 496–7. Her tentative suggestion of an earlier 1st century BC date is unlikely and not substantiated by other evidence; see also Chapter 2.
326 Cauuet et al. (2003) 488.
327 Cauuet et al. (2003) 488–489.

long) and mainly near the surface (0.4–0.5 m max. depth) that was originally cut transversally N-S across the massif and opened as a prospecting site. On its southern end, Dep 1 turns into a vertical exploitation site 7.2 m long, with evidence for wooden propping in the form of two sets of facing niches carved into the walls.[328]

G9, like G5, began as a narrow open pit (5 m) before extending underground into a vertical exploitation that connected Dep 1 with Dep 2 (*fig. 13*). An unidentifiable ceramic fragment was found, but the radiocarbon date for charcoal in the fill indicates that the gallery was sealed during the medieval/Early Modern period and has not been disturbed by modern exploitation.[329]

Dep 2 was only partially excavated, and the sole ceramic fragment found also proved difficult to date. Taken together, Dep 1, G9, and Dep 2 constitute a sustained series of exploitation works that closely followed the mineralisation of the Zeus breccia dyke. The cumulative length of the *dépilages* was over 10 m, more than 10 m deep, and between 0.80–1.50 m wide. This long and narrow morphology is typical of Roman exploitation of vein structures, and is paralleled elsewhere at Aljustrel (*Vipasca*), in Portugal.[330] There is also evidence for a reverse-stepped ceiling in the northern part. As at Cârnic, the concern for safety is reflected in the niches for wooden reinforcements, as well as the thin platform adjoining the base of Dep 1 to the ceiling of Dep 2 in the northern sector, which was left in place to act as a horizontal pillar ensuring the stability of the massif and the workings.[331] Due to a lack of time, the excavation was not completed and it is possible that the ancient network may extend deeper beneath the two *dépilages*.

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328 Cauuet et al. (2003) 489.
329 Cauuet et al. (2003) Fig. 15. Cetate-Zeus G9 US1 is reported as 500 ± 50 BP (cal. 1385 to 1485).
330 Cauuet et al. (2003) 497.
331 Cauuet et al. (2003) 492.

The third and final sector at Zeus is the western zone, which consisted of drifts G6 to G16 that joined the western end of Dep 1 to a larger network. The intersection of two fissure systems in this zone resulted in a regular stockwork-type structure and several breccias that outcrop. As a result, the galleries opened to the surface at varying levels, riddling the west and south sides of the massif with superimposed quadrangular openings. Again, there were very few finds—so difficult to date—as well as more signs of subsequent modern disturbance than in the central zone. [332]

Most importantly, the set of drifts in the western sector is notable for the degree of professional expertise displayed: not only did the early miners focus on the intersection of breccias and veins where mineralisation was richest, the horizontal direction of exploitation also resulted in a thorough sideways attack of the massif.[333] Coupled with the main workings at *dépilages* Dep 1 and Dep 2 in the central zone, the pattern of exploitation is a fairly systematic one that worked out both the main breccia dyke vertically and the lesser ore bodies horizontally.

Mining in the Zeus sector can thus be characterised as workings fairly close to the surface, which could be ascribed to the geology, where the fragility of the host rock made deeper excavation riskier. Mining organisation and how concessions at Zeus were administered in relation to other workings at Cetate or elsewhere at Roșia Montană could also have played a role, where the smaller scale surface workings at Zeus were secondary to those at Cetate. But this is difficult to establish due to the lack of chronological precision.

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332 Cauuet et al. (2003) 493–6.
333 Cauuet et al. (2003) 495.

The frustrating lack of datable material, artefactual or otherwise, means that no gallery beyond G1 in the southern zone can be securely dated to the Roman period. Because G1 started filling up in the 2nd or early 3rd century, it may represent a gallery worked early in the Roman occupation of Dacia, in the 2nd century AD. Ascribing an early date to the entire Zeus network is very tempting indeed: coupled with the presence of numerous outcropping breccias and associated surface and exploratory workings, it could indicate an instance where Roman miners started with surface prospection before following the veins inwards, quite possibly in the early years of imperial rule. However, additional dating evidence would be needed to support this suggestion.

The signs of surface and small opencast exploitation at Zeus help ameliorate the lack of extant evidence from the Cetate opencast. Although not the same in terms of size and scale to the lost Curțile Romane, what we see at Zeus is a pattern of prospection originating from the surface followed by subsequent development into serious exploitation at deeper sites as the ancient miners followed the mineralisation. The exploration of the ore bodies was thorough, demonstrating a preferential exploitation of the richest ore where the greatest intensity of mining activity is present. There is also the possibility that the main open-air exploitation was in the main Cetate sector, while the smaller-scale workings at Zeus were satellite operations. The Zeus dacite is fairly friable, making it easier to work, but the ore grade is not as high, leading to a certain amount of economic trade-off—but presumably a worthwhile one (*Table 4*).

The open-pit and shallow surface workings, coupled with an early 2nd-century date, could suggest a possible scenario where the mines at Zeus were opened early in the exploitation of the ores at Roșia Montană. This cannot, however, be proven. In any case, even if Zeus was amongst the first areas worked, exploitation of the other deposits could not have been too far behind. The intensity and thoroughness of the mining activity observable at Zeus is clearly evident in other sectors at Roșia Montană and is testament to the efficiency and diligence of the Roman miners.

Despite its problems, Zeus is important because it provides evidence for how Roman open-pit and surface exploitation may have operated at Roșia Montană, as well as possible hints of how Roman mining could have developed from initial, surface prospection to more intensive, systematic underground exploitation.

Găuri

In contrast to Zeus, which was worked by iron tools, the ancient works at Găuri were opened by fire. Its importance lies in being one of the two places at Roșia Montană with surviving evidence of fire-setting, the other location being Piatra Corbului in the southern part of Cârnic. To put matters in perspective, fire-setting is known in less than 5% of the total workings explored so far at Roșia Montană.[334]

Situated on the south-western slope of Cetate, Găuri is a mound abundantly worked from all sides over an extended period; hence its name "Găuri", meaning "holes" in Romanian.[335] The site is vertically oriented on a S-N axis, of which two levels have been excavated, totalling 18.40 m. There may also be a possible third level.[336]

Evidence for fire-setting is present in the form of a series of superimposed openings. Exploitation by fire has been identified on both levels, but the ancient remains have suffered damage from subsequent expansion by dynamite. At Level 1, such workings are characterised by smooth and ovoid walls coloured black or red. The surface of the walls can also be cobwebbed with eggshell-like fractures and thin, flaking rocks due to the stress caused by the high incendiary temperatures and rapid cooling of this method of

334 Cauuet (2014) 90.
335 Cauuet et al. (2003) 497.
336 Cauuet et al. (2003) 499–500.

exploitation. These markers are also evident in the second level, in the smooth western wall and flaking surface, as well as the rounded cupolas in the vaulted ceiling. The cupolas, in particular, are characteristic of underground advancement by fire-setting.[337]

The geology of Găuri is a localised patch of very hard, highly silicified rock, which explains the need for fire-setting. The breccia structure here is intersected by veins, but unlike at Zeus, the fine matrix surrounding the breccia limited the vein's development and precious metal enrichment.[338] The grade of the exploited ore at Găuri is thus much lower than at Zeus—with 1 g/t of gold and 10 g/t of silver as the projected ancient limit of exploitation—and arguably represented minimal return for effort compared to elsewhere at Roșia Montană (*Table 4*).

Although generally presented in the academic literature as an example of Roman fire-setting at Roșia Montană, the ascription of a Roman date is based on comparison with similar workings at Piatra Corbului rather than local finds. The site is also cut by modern underground works at level 855. The fill of Level 1 yielded no dateable wood or artefacts and was probably modern refill from dynamited waste. Likewise, the areas most closely related to the fire-setting points identified above were also devoid of contemporaneous old waste. Charcoal and wood samples from Level 2 fill, which was unstratified, generated dates no earlier than the 15th century. But evidence for the reopening of old workings using dynamite provides at least a 17th century *terminus ante quem* for the first phase of exploitation.[339] The excavation team thus postulates that the initial opening of the halls occurred in the Roman or medieval period, with later reports taking the Roman date as

337 Cauuet et al. (2003) 499.
338 Cauuet et al. (2003) 500–1.
339 Cauuet et al. (2003) 500.

given.[340] In the absence of additional data, the exploitation at Găuri can still provide a useful point of comparison with the dated Roman workings at Piatra Corbului, but *caveat lector*.

Hăbad

The Hăbad sector—although situated on its own hill in close proximity south-west from Cetate and Găuri—is worth mentioning due to the promising nature of its remains. Two gallery entrances have been discovered thus far: the first during an archaeological excavation in 1983, along with the vestiges of a Roman road and votive altars, and the second between 1999 and 2001 when the French team reopened the La Studentu gallery.[341] Although cut with tools, La Studentu probably dates to the medieval or Renaissance period as the cross-section is distinctly different from Roman galleries.[342] The remaining drifts have not been explored and are not visible from the surface, but can be identified by the presence of waste dumps. The potential of the site is further borne out by the presence of a Roman settlement and sacred structure nearby,[343] which were most likely associated with the underground mining activity. Given that the Hăbad sector is known to have unidentified ancient works, these galleries could potentially be of Roman date and are worth further investigation.

3.2.3 Orlea-Țarina-Carpeni

The Orlea-Țarina-Carpeni area is located west of the historic centre of Roșia Montană. The contiguous Orlea and Țarina massifs lie on the north side of the valley, with Țarina

340 Cauuet (2014) 90.
341 Cauuet et al. (2003) 477, 501–2.
342 Wilson, Mattingly and Dawson (2011) 34, contra Cauuet et al. (2003) 502, who suggest that the drift may be "possibly ancient" based on the use of tools.
343 CHBR (2006) 72.

situated upstream to the east from Orlea, while Carpeni is located to the south on the opposite bank.

As with the other surveyed areas, the research conducted above-ground was hampered by the considerable mess of waste dumps both old and new; heavy vegetation; and torrential water levels. An additional problem associated with the northern sites (i.e. not the Cârnic or Cetate massifs) is the density of urbanisation along the river valley, which prevents archaeological access. As a result, the French team was unable to make full sense of the surface evidence. Nonetheless, they did identify entrances to drifts, as well as old opencasts, ditches, and collapsed pits leading to drifts in the more elevated areas.[344]

Underground, historic topographic plans were of limited use due to structural and modern disturbance: landslides blocked access; galleries had been re-walled; and redeposited waste dumps blocked galleries. Water was especially problematic: along with the Coș-Lety sector, the Orlea-Țarina-Carpeni area is situated under the water table and flooding was a significant problem.[345] At Orlea, the main drift of Sf. Cruce was flooded at the lower levels, as was Racoși, where modern works intersect the inundated ancient gallery.[346] As a result, research in this area is not as complete and future work could be undertaken by extensive surface clearance and excavation of the underground galleries from the surface.

Orlea-Țarina

Ten km of old workings are estimated at Orlea, of which 6.5 km have been surveyed. Of these, 1.5 km of the galleries date to the Roman period.[347] Țarina appears to be the more

344 Cauuet et al. (2003) 478; CHBR (2006) 93.
345 Cauuet (2014) 100.
346 Cauuet et al. (2003) 478.
347 CHBR (2006) 94.

heavily exploited of the two, even though the geological boundary between Țarina and Orlea is not particularly well-defined. Consequently, the 2005 investigations all took place within Țarina, and two of the ancient workings are in fact located on the boundary between the two, beneath the valley bottom.

Geologically, roughly 30 north-south trending veins are intersected by the east-west Crucii vein. The modern galleries are at the main Sf. Cruce level (715 m.a.s.l.) and the higher Racoși level (750 m.a.s.l.). The former is currently still accessible and was originally open to the public, granting access to the Roman mining works located at the 725 m level.[348] The Roman galleries are characterised by regular trapezoidal profiles for a 40 m long stretch, and small pockets in the walls marked places where several veins intersected and the ore was excavated. At the Racoși level, a wooden ladder of steps carved into a single tree trunk ("monoxyle") was found and radiocarbon-dated to the 2nd century AD. A ventilation adit is also known in Țarina: this was a long, narrow adit branching off and continuing parallel to the main gallery until both reached the surface via one main access.[349] This is apparently a unique occurrence and not attested elsewhere at Roșia Montană. Finally, a timbered sloping gallery leading to the surface was located. This was the gallery with the timbering fragment that was originally reported as having a radiocarbon date between 50 BC and AD 80.[350] The problems with this piece of evidence have already been discussed in the previous chapter; suffice to say, there is no reason not to believe that this portion of Țarina was Roman, albeit early in the Roman period (up to AD 126).[351]

348 CHBR (2006) 93.
349 Cauuet et al. (2014) 96.
350 Cauuet et al. (2003) Fig. 15.
351 Wilson, Mattingly and Dawson (2011) 44.

In general, the workings were distributed fairly regularly, probably due to the density of the ore distribution. More work needs to be done on the Orlea-Țarina area, as the currently researched area only consists of what was accessible from the modern mines. It is estimated that twice as many ancient remains have yet to be found.[352]

Păru Carpeni

Seven areas with ancient workings were found at Păru Carpeni. This sector is also particularly rich in timber remains, as the lower elevation of these galleries compared to Cetate and Cârnic have resulted in a very humid environment favouring the preservation of wood.

Given the significant hurdles posed by the local hydrology, water management would have been a pressing concern for ancient miners working in the northern sites at Roșia Montană. One of the most important finds from the French excavations was the water-drainage system at Păru Carpeni, where a water-lifting wheel installation has been found *in situ* and in relatively good condition (*fig. 14*).[353] The remains were found some 30 m deep in a series of four linked chambers, in a fairly good state of conservation. A piece of the planking was radiocarbon-dated, with a reported calibrated date of between the 1st and 2nd centuries AD (1 cal. BC to cal. AD 220).[354] The best evidence comes from chamber C1, where the wheel has been preserved in place, along with the supporting wooden infrastructure.[355] The shoring was still *in situ*, which dendrochronology dates the

352 CHBR (2006) 94.
353 Cauuet (2008) 65.
354 CHBR (2006) 97 gives an uncalibrated date of 1925 ± 50 BP (40 BC to AD 220). The number of standard deviations of the reported date is not clear. Cf. the dates reported in Wollmann and Ciugudean (2005) 105 for a wooden ladder found in gallery G1: 1860 ± 60 BP (cal. 2σ AD 45 to 330), with a median date of AD 145.
355 Cauuet (2008) 67–9.

wood to around AD 155, suggesting that the galleries was probably abandoned during the Marcomannic Wars.

Preliminary reconstructions of a wheel with 27 blades, radiating outwards to form compartmented buckets at the rim, find the closest parallels with the Dolaucothi wheel in terms of its rim.[356] The wheel appears to be the second in a series of four. It was held suspended by a wooden framework above a lower gallery that collected the water raised up from chamber C2 below, before lifting and emptying the water into a canal linked to chamber C3 (*fig. 15*). Wheels have also been found in two additional rooms, C3 and C4.

This installation allows the study of Dacian water wheels in their actual mining context. Although some of the wheels have not survived fully intact, the series of chambers reveal how the Romans were able to establish a linked chain of wheels and create a drainage system that effectively solved the problem of flooding at the lower levels of the mine. It also provides a useful point of comparison, not just with water wheel drainage systems found elsewhere in the empire, but also intra-site within Roșia Montană. The lack of comparable drainage installations from the Cârnic massif, where significant deep-vein mining also took place in the Roman period, is not surprising as the underlying geology was such that mine flooding was not an issue.[357] However, the most recent excavations in 2012/13 have uncovered another water wheel system—albeit a smaller set-up, consisting of two wheels—at Cătălina Monulești, and it would be worth comparing the two once the latest data have been published. Nonetheless, the presence of the drainage system at Păru Carpeni reveals a high degree of planning and management, which implies

356 Domergue (2008) 128.
357 Cauuet (2008) 67.

the amount of capital and effort that probably went into installing and maintaining the system. This will be discussed in further detail below, in the section on mining technology.

3.2.4 Coș-Lety and Jig-Văidoaia

Coș-Lety

The Coș and Lety massifs are in the north-eastern part of modern Roșia Montană, between Cârnic to the south and Văidoaia across the river to the north. The ancient network in Coș was accidentally discovered in 1855 when the modern Cătălina Monulești gallery intersected it.[358] This area in general has thus long been known in the literature as early as Pošepný for its ancient workings—most famously the water wheel installation reported in 1868—and also for the caches of wax tablets discovered in the 18th and 19th centuries in the St. Joseph mine (Lety) and in Cătălina Monulești (Coș).[359] In all, some 19 tablets have been reported. Both works are easily accessible via Roșia Montană village, which offers some indication of how closely the modern urbanisation has affected the surface archaeology in the area.

A related settlement also remains to be found, which may be located beneath the modern town; this would provide some much-needed context for the underground workings at Coș-Lety, Jig-Văidoaia, and the northern parts of Cârnic, as well as the wax tablets found in this general area.[360] A site with signs of habitation is briefly alluded to in the main excavation report published in 2003, but no more work has been published since.[361]

358 CHBR (2006) 95–96. For ease of reference, the Roman remains will also be referred to as part of Cătălina Monulești, even though the gallery itself was started in the 19th century.
359 Pošepný (1868).
360 Wilson, Mattingly and Dawson (2011) 42.
361 Cauuet et al. (2003) 479.

The entrance to Cătălina Monulești was reopened in 2001 to 2003, with further investigations taking place in 2011 to 2013. The Roman remains are accessible only from the northern part after heading 350 m south into the gallery.[362] These remains are spread out over six levels, 20 m in height, and measure some 300 m long. The galleries, which possess the typically trapezoidal-shaped profiles of Roman workings seen elsewhere at Roșia Montană, were opened with tools. The types of workings echo those seen in Cârnic: prospection galleries; descending access and communication passages with sloping bases and steps; as well as vertical exploitation chambers with wooden platforms, one of which was *in situ*.[363] The majority of the galleries and passages average 1.60 m wide by 1.80 m high—so quite large, given the context.[364] Lamp niches were also found, as were a large number of burnt wooden sticks that might have been used for lighting purposes.[365] Initial impressions seem to accord well with the mining activity observed at the larger networks in Cârnic.

The most recent excavations in 2012/13 uncovered a drainage wheel installation that may possibly be the same one discovered in 1855 by Pošepný.[366] The lead excavator certainly seems to believe so, as the location of the wheel matches the chamber Pošepný described.[367] In his 1868 report, Pošepný recounts adits opened with hammer and chisel; a wooden "monoxyle" ladder; galleries with some 40 wax tablets; and a collapsed chamber containing a water wheel about 3.30 m in diameter. Some of the finds were left behind. The modern excavators discovered two chambers that constituted the same water drainage system. One of the chambers had two wooden wheels, one positioned above the other, and

362 CHBR (2006) 96.
363 Cauuet (2014) 96.
364 Cauuet (2012).
365 Cauuet (2014) 100.
366 Wilson, Mattingly and Dawson (2011) 42.
367 Cauuet (2012).

the lower wheel still had its hub *in situ*, with its spokes still attached. The wheels have a diameter of 3.20 m and 24 buckets on the rim.[368] The buckets in the edge of the wheel rim would have scooped and deposited water in a canal in an upper gallery above where the wheel sat.

Although drainage wheels were found at Păru Carpeni in the 2005 and 2007 excavation seasons, the find at Cătălina Monulești is especially significant because of the high degree of preservation and the wheels appear to be in their original context. The chambers at Carpeni were intact, but the wheels were not, due to the fragility of the wood. The fact that the Cătălina Monulești wheels were found *in situ* is also of particular importance as it then becomes possible to reconstruct and understand how the wheels would have functioned. Possible parallels can be found with the water wheels at Dolaucothi and Santo Domingos.[369] The copper mines at Rio Tinto in Spain also had water wheels of a similar morphological character, with compartmented rims, but the literature on the wheels is confused regarding their discovery—their number, condition, and context.[370] Not all of the examples found in Spain have survived either, which makes these wheels from Roșia Montană of particular note.

Other exceptional finds include timber support frames joined by mortise and tenon joints; wooden drainage pipes; notched ladders each carved from a single tree trunk ("monoxyles"), measuring nearly 5 m in length; hods for transporting ore and sterile waste; stretchers for shifting particularly heavy loads; and ceramics, including a stoppered jug.[371] Timbering is, in general, extremely well preserved for a mining site, and there is evidence from the Cătălina Monulești adits for a variety of different propping techniques: basic

368 Cauuet (2014) 100 and Fig. 10.
369 Cf. Boon and Williams (1966).
370 Oleson (1984) 251–9.
371 Cauuet (2012); Cauuet (2014) 96 on the monoxyle.

props, half frames, full frames, and closed frames. The individual timbering elements (cap and posts) are connected by mortise and tenon joints and fitted in the adits either at spaced intervals or side by side to form fully timbered galleries. More complicated versions of these mortise-and-tenon framing systems made up of three to five pieces and wedged into the gallery walls to support the water wheels have also been found in the water drainage chambers at Cătălina Monulești. [372]

Preliminary dating based on the ceramic finds and dendrochronological analysis suggests that the mine was active between AD 150 and 180.[373] These samples appear to have been taken from the wooden supports of access galleries linking vertical exploitation sites, and thus date a second phase of working in the last third of the 2nd century AD. Dendrochronology on the "monoxyle" ladders—of which more than a dozen have been discovered, not all from Cătălina Monulești—also places the ladders in the second half of the 2nd century.[374] If these dates are accurate, then the workings at Cătălina Monulești seem to belong to a particularly crucial period of Roman mining activity in the province and around the same time as the Marcomannic Wars.

The suggestion that the Romans abandoned the mines on the advent of the Marcomanni invasion around AD 166/7 is a plausible one, on the basis that the dates from the surviving wax tablets found in Cătălina Monulești roughly correspond to the same period (*Table 2a*).[375] These nine tablets are TabCerD III, V–IX, XIV, XVI, and XXI (probable). They range in date from AD 139 (TabCerD VI) to 167 (TabCerD XIV); two are not dateable (TabCerD XVI and XXI). The latest of these, TabCerD XIV, was an agreement for a commercial partnership (*cautio societatis*) that was drawn up at Deusara

372 Cauuet (2014) 96.
373 Cauuet (2012).
374 Cauuet (2014) 96.
375 E.g. Wilson, Mattingly and Dawson (2011) 25, 37.

on 28 March 167. Although we cannot definitively discount a continued Roman presence after this date, what the tablet does indicate is that people were still operating in and around *Alburnus Maior*—and Cătălina Monulești specifically—up until at least the spring of 167.

Of all the tablets reported from Cătălina Monulești, one group is of particular interest. The tablets discovered together with TabCerD V seem to be a single cache, possibly belonging to the same owner, with the earliest one dated to AD 139 and the latest to AD 162. TabCerD V was a loan agreement that was drawn up on 20 October 162, and was found together with TabCerD VI and VIII, both of which were contracts for the purchase and sale of a female slave, dated to 17 March 139 and 16 May 142 respectively. The reported find date of 1855 for TabCerD V suggests that these tablets may have been part of the first ones found when the modern Cătălina Monulești gallery intersected the Roman works.[376] They are what remain of the 40 plus tablets, and were also apparently found with lamps, tools, pots, baskets, and more—perhaps part of a larger emergency or storage stash? Attempts to correlate tablet find spots with new knowledge of network configurations may potentially reveal more about who was involved with the mining activity at Cătălina Monulești and flesh out the evidence uncovered by the excavation team.

Unfortunately, final publication of the latest results—whilst exciting and tremendously important for our understanding of Roman water management in mines—is still awaited. Not enough information is available in the public domain for extensive analysis. It seems unlikely that the French team will be able resume their work at Cătălina Monulești to any great degree in the near future due to the political situation surrounding

376 See Sântimbreanu and Wollmann (1974) 260 for a map with the find location of the tablets.

Roșia Montană Gold Corporation, and it is hoped that the results from the 2011 to 2012/13 excavation seasons will eventually be published in full.

Jig-Văidoaia

Moving north, the Igre-Jig-Văidoaia area lies on the right bank of Roșia valley, across from Coș-Lety. The eponymous Jig and Văidoaia massifs received short shrift in the preventative archaeology programme and not much is known about the underground remains, but the surface evidence hints at undiscovered ancient mine galleries.

Only recent works are known at Jig massif, where an assessment in 2004 identified workings opened by dynamite. A test on outcropping rocks near Jig-Piciorag revealed a system of natural faults, but unexploited by ancient miners. Likewise, despite having been massively devastated by communist-era mining in the 1970s, Văidoaia also revealed signs of excavation by gunpowder.[377] There was no evidence of ancient workings using either fire or tools. This would date the mining activity here to no earlier than the 17th century.

Nonetheless, there *is* a Roman necropolis at Jig-Piciorag, south-west of Jig Massif, and it appears to be chronologically related to a nearby ore-extraction and processing site.[378] Their vicinity to the two massifs implies that ancient galleries—and probably a settlement as well—remain undiscovered,[379] as it would have been highly unlikely that the miners were transporting ores from elsewhere in Roșia Montană for processing. One might adduce as additional incentive the fragmentary inscribed altar found during the demolition of a building near Văidoaia in 1984,[380] or the wax tablet of a loan contract in Greek (TabCerD IV) found in the Laurențiu gallery at the Igre massif in 1786.[381] Despite vague

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377 CHBR (2006) 20, 93.
378 CHBR (2006) 77–78.
379 Wilson, Mattingly and Dawson (2011) 43.
380 Crăciun and Moga (2003) 39.
381 CIL III, p. 933, IV; cf. Wollmann (2002a) 31 for the location of Laurențiu-Igren.

reports of Roman mining galleries and surface exploitation in the area,[382] further investigation is clearly needed.

3.3 Related surface archaeology

The rich cultural legacy of Roșia Montană persists beyond the wealth of underground mining remains: the surface finds, too, attest an extraordinarily active mining landscape, with sites ranging in type from settlement and burial, to associated surface mining activity such as ore processing.

At least seven nuclei have been identified to date. The site types consist of:

- Habitation zones: Hop-Găuri, Hăbad-Brădoaia, Tăul Țapului, Carpeni
- Sacred zones: Hăbad-Brădoaia, Valea Nanului (Nanului Valley), Carpeni
- Necropolis: Hop-Găuri, Tăul Corna, Jig-Piciorag, Țarina, Pârâul Porcului-Tăul Secuilor
- Funerary zones: Valea Nanului, Carpeni
- Communication axes: Hop-Găuri, Hăbad-Brădoaia, Tăul Corna
- Ore-processing areas: Jig-Vădoaia, Țarina

Rather than examining each site type in turn, this section is organised geographically. It follows the main geographic locations from the mining sectors (i.e. the main massifs), roughly in a clock-wise trajectory, to better understand how each cluster of sites were interrelated (*fig. 16*). As with the underground evidence, however, the state of research is uneven across the sectors and extremely incomplete, and missing types of evidence can be extrapolated, to aid future work.

3.3.1 Cârnic Massif

Exploitation in Cârnic constituted the heart of mining at Roșia Montană across all periods.[383] Despite its centrality, expected surface remains such as habitation, burial, and

382 Crăciun and Moga (2003) 39, but neither additional information nor sources are given.

ore-processing sites associated with the underground mines at Cârnic are strikingly absent. This is, perhaps, unsurprising: the northern extent of the massif borders Roșia valley, where the limited space and density of habitation has precluded excavation in Roșia Montană's historic centre. To the west, the valley between Cetate and Cârnic has since been filled with mining waste.[384] Some possibilities may be found to the south, however, near the town of Corna and Tăul Cornei, where a necropolis has been excavated. Nonetheless, at least one major settlement and the ore-processing areas related to Cârnic's southern workings as well as the smaller neighbouring Cârnicel massif still need to be identified.[385] Given the importance of the Cârnic mining system, further work beyond the trial trenching to date is needed to address the lacuna in the archaeological record.

Corna and Tăul Cornei

The most well-known surface remains in Cârnic's vicinity is the Roman necropolis on the south side of Tăul Cornei, a manmade header pond used to drive the Late Medieval and Early Modern stamp mills in Corna Valley. Tăul Cornei is situated southeast of Cârnic's Piatra Corbului sector and at the extreme northeast of Corna village, in the upper reaches of Corna valley. The cemetery itself has been extensively excavated (95% explored), but the results await full publication and analysis.[386]

The potential of the site has long been known in the scholarly literature. Two funerary inscriptions and two funerary sphinxes indicated the potential of the site,[387] but

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383 Wilson, Mattingly and Dawson (2011) 36.
384 CHBR (2006) 21.
385 Wilson, Mattingly and Dawson (2011) 12, 40.
386 Wilson, Mattingly and Dawson (2011) 16 and 42; Crăciun and Moga (2010) 32. See AM III (2008) for the 2000–2007 excavation results.
387 Inscriptions: CIL III, 1264 = IDR III/3, 414; CIL III 1267 = IDR III/3, 419. Sphinxes: Moga and Sântimbrean (1996).

the site was not fully explored or excavated at the time.[388] Excavations in the 2000s revealed 324 cremation burials dated to the 2nd century AD.[389] The burials consisted of a mix of *in situ* cremations and secondary reburial of cremated remains (*ad ustrinam*). Despite the earlier finds of slightly more impressive funerary monuments (sphinxes), the grave goods were not particularly rich and there is no reason not to believe that the deceased were not miners or of a middling social status.

The Tăul Cornei necropolis, however, does offer one of the better ceramic assemblages found at Roșia Montană to date and the possibility of starting a local pottery typology.[390] The other necropoleis at Roșia Montană either have poor preservation or smaller assemblages, and even at the Circular Funerary Monument at Tău Găuri, the highest-status funerary structure identified to date based on its larger size and prominent location, very little pottery was found. It was also not possible to create a chronological typology due to lack of stratigraphic differentiation, unfortunately, and the forms all fall within a broad 2nd-century distribution. Analysis of the fabric does indicate that the ceramics found at Tăul Cornei were local in origin, but accurate identification is difficult due to the oxidation of the pottery remains. It would not, however, be at all surprising if the community had some form of local pottery production, especially given the miners' needs for equipment such as lamps, in addition to the usual array of tableware.

The vicinity of the Tăul Cornei necropolis to the mines at Cârnic and Cârnicel as well as the lack of other associated ore-processing sites makes it highly likely that the other sites are probably missing, rather than absent, and remain to be found.[391] Given the

388 See Craciun and Moga (2010) 32 for the excavation history on the property.
389 AM III (2008).
390 AM III (2008) 33–4.
391 Wilson, Mattingly and Dawson (2011) 40, 42.

lack of settlement evidence for Cârnic and its centrality to Roman mining at Roșia Montană, the area around Corna should be further explored for more surface remains.

3.3.2 Cetate Massif

Cetate Massif, west of Cârnic, in contrast, has suffered severe degradation of its mining evidence because exploitation took place in the form of opencast workings. However, the surface evidence is comparatively more "complete", insofar as the array of site types include habitation, funerary, and religious activity. The sites are located south of the Găuri mining galleries in the southwestern section of Cetate, and it is probable that the surface remains relate to the mining activity that took place at Găuri. To date, we know of a Roman settlement (Hăbad-Brădoaia), cremation necropolis (Hop-Găuri), "sacred areas" (presumably based on votive altar finds), and a possible communication axis connecting the Roșia and Corna valleys.[392] What remains to be discovered are the primary ore-processing sites off the southwestern slopes of Cetate. This could possibly be related to the undated waste dumps west of Cetate, which may have been worked during the Roman period.[393]

Hop-Găuri

The Hop-Găuri necropolis was located north of the Hăbad-Brădoaia sites, and consisted of 250 cremation graves, and a further 5 uncertain features that may have also been burials.[394] Dates from the grave goods indicate that the site was most active during the 2nd century AD during the reigns of Hadrian and Antoninus Pius. It is possible that the burials were of the Mala Kopašnica-Sase (MKS) type—which would indicate the presence of

392 AM I (2010) 43–76 and 78–81.
393 Wilson, Mattingly and Dawson (2011) 31, 34.
394 Wilson, Mattingly and Dawson (2011) 16, 32; AM I (2010) 185–242; AM II (2005) pl.31.

Dardanians—but the published material is unclear. Space was also at a premium at this site, as the necropolis was located on top of an extremely steep ridge.[395]

The so-called Circular Funerary Monument at Tău Găuri is in every way exceptional, both for its monumentality and its status compared to all the other funerary remains at Roșia Montana. Located 200m south of Hop-Găuri cemetery on a prominent spur, the monument is a circular stone mausoleum housing two *in situ* cremation burials of two distinct phases.[396] Two cremation graves were also found closely adjacent to the monument. Although parallels can be found with the circular mausoleum excavated at *Ulpia Traiana Sarmizegetusa*,[397] it is possible that the monument at Tău Găuri is simply a larger version of circular barrow monuments typical of Dardanian migrants elsewhere in Romania.[398] It is worth noting that the Tău Găuri mausoleum remains the highest-status funerary monument identified to date at any Roman mining site in Dacia, which would accord with the hypothesis that Roșia Montană hosted Dacia's most important gold mines and presumably also experienced higher levels of social stratification amongst community members as a result.

Hăbad-Brădoaia

These two sites southwest of Cetate produced evidence of a possible settlement at Hăbad,[399] as well as sacred areas comparable to the Nanului Valley evidence. The settlement was identified based on some vestigial buildings and two altars, but it is the sacred areas that are of particular interest. Previous excavations at Hăbad-Brădoaia in 1983 turned up some 27 votive altars, and excavations in 2001 uncovered an additional four

395 Wilson, Mattingly and Dawson (2011) 32.
396 AM II (2005).
397 Daicoviciu and Floca (1937).
398 Wilson, Mattingly and Dawson (2011) 34, see especially footnote 50.
399 AM I (2010) 117–142.

votive altars as well as two more epigraphic fragments, attesting the worship of a wide range of deities: Apollo, Diana, Janus, Jupiter Depulsor, Jupiter Optimus Maximus, Liber Pater, Mercury (Mercurius), Minerva, Neptune, the Nymphs, Silvanus, Sol, Terra Mater, and Venus.[400] In total, around 35 inscriptions and epigraphic fragments have been found. The density of these finds suggests that the sacred area—which was surrounded by stone walls—may have served as substitute temples for the local mining community.[401] Further comparisons with the evidence from Nanului Valley might help in distinguishing between the various groups of miners who lived at Roșia Montană and particularities in their religious life. The range of deities present, however, indicate what was probably a rich and varied religious life amongst the worshippers at Hăbad.

3.3.3 Nanului Valley

Situated north of Tăul Găuri and west of Cetate, the Nanului valley has produced an unusually rich number of finds of religious significance.[402] There is also a possible associated funerary zone, as four cremation graves have been found.

Three structures were found, along with 35 votive altars dedicated to an array of Latin gods like those found at Hăbad.[403] These deities included, amongst others, altars to Jupiter Optimus Maximus (IOM), Fortuna, Mercury, Apollo, Neptune, Terra Mater, Silvanus, the Nymphs, and Liber, revealing some similarities to the gods worshipped at Hăbad-Brădoaia. The dense concentration of the altars and range of divinities worshipped is highly unusual, and it is based on the altars that the area has been identified as a "sacred zone". The call for full publication of the data is certainly needed to better understand the

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400 Wollmann (1985–1986); AM I (2010) 143–84.
401 CHBR (2006) 15.
402 CCA 2001 (2002), 257, 266–272; AM I (2010) 245–368.
403 Wilson, Mattingly and Dawson (2011) 35.

religious life of the community.[404] Miners of all historical periods have been known to be highly superstitious, given the nature of their profession, and closer analysis of the finds at Nanului would help illuminate Roman beliefs.[405]

3.3.4 Orlea-Țarina-Carpeni

Orlea-Țarina-Carpeni, east of the Nanului Valley remains, is a sector of extremely high significance within Roșia Montană. Not only is there a dense network of underground mines in this area—some of which provide evidence for the installation of sophisticated water drainage systems—this is also where links to the Roman army have been found.

Carpeni Hill

Within the sector, Carpeni is of particular interest, as the bulk of the most important remains have been found here. Carpeni Hill is located slightly northwest of Cetate and north of Nanului Valley. It is here, underground at Păru Carpeni within the hill itself that two drainage systems were discovered in 2004.

On the surface, two structures with hypocausts have been excavated, and tiles with the *Leg. XIII Gemina* stamp have been found.[406] These buildings are the most prestigious architectural structures found to date, but their interpretation remains unclear. The presence of a hypocaust has led some scholars to identify the structure as a bath house,[407] but it also possible that the hypocaust and flue tiles were installed as a heating system and not necessarily for bathing.[408] Regardless of the actual function of the structure, what is fairly clear is that these two buildings were substantially higher in status and prominent in the immediate area. The stamped tiles indicate military involvement on some level,

404 Wilson, Mattingly and Dawson (2011) 11, 35–6.
405 See also Dušanić (1999).
406 CHBR (2006) 73; AM I (2010) 369–450.
407 Țentea et al. (2015).
408 Wilson, Mattingly and Dawson (2011) 36.

certainly in the construction of the building, and it is also possible that the buildings could have served as a base of operations for soldiers operating as *beneficarii consularis* at Roșia Montană. Given what appears to be capital investment in water drainage systems in the Păru Carpeni mines and the clearest traces of the presence of the army to date, this area of Roșia Montană is also arguably amongst the most notable alongside Cârnic.

A funerary zone on the north-western part of Carpeni Hill has also been identified: only eight cremation graves were excavated, but it is likely that a more extensive cemetery exists and needs to be identified. With the importance of both the underground and surface remains at Carpeni Hill, as well as the relative richness of the sector (see below), further exploration and excavation of possible graves would help us better understand the social status of those who inhabited this part of Roșia Montană.

Orlea

Located on the north side of Roșia valley next to Țarina Hill, Orlea is mainly known for its underground workings, of which 1.5 km are Roman and 5 km Early Modern.[409] More ancient workings probably remain to be found under the plentiful ancient waste dumps, as the area is riddled with old and collapsed workings. It is surprising that no Roman settlement or ore-processing site has been identified at Orlea, despite the density of the mining remains. The likelihood of workshops for ore-processing located near mine entrances is high, and such remains may possibly be sought once access points to Roman underground workings are identified.

409 CHBR (2006) 94–5.

Ţarina

Adjacent to Orlea is the Ţarina area, where a Roman cemetery, ore-processing areas, and a possible settlement have been identified.[410] The focus, however, has largely been on the Roman cemetery, where 495 burials were excavated. This is the largest cemetery found to date, both in terms of the number of graves and its surface area. The remains consisted of a mix of cremation *in situ* and *ad ustrinam*, with the latter more dominant in this cemetery compared to the others at Roșia Montană. Local pottery found amongst the funerary assemblages date the necropolis to the 2nd century AD.[411] Earlier finds also included inscribed tombstones and elaborate monuments,[412] as well as some gold jewellery and a gem, suggesting that the inhabitants in this area were possibly comparatively better off than other communities at Roșia Montană.

In addition to the cremation necropolis, a possible gold-processing area may also exist south and east of the necropolis. The evidence consists of stone grinding mortars and grinding tables for breaking ore, and a channel system, but it is unclear whether the channel was used to power stamp mills or to sort ore.[413] The settlement has not received much attention and may be under the modern town centre.

3.3.5 Coș-Lety

The Coș-Lety sector is situated in the north-eastern part of Roșia valley, between the Cârnic and Jig-Văidoaia massifs and immediately adjacent to the modern town centre. The richness of the mining evidence from Coș-Lety renders the underground network especially important, but the associated settlement evidence is disappointingly lacking.

410 CHBR (2006) 78–9; Wilson, Mattingly and Dawson (2011) 13, 44.
411 CCA 2003 (2004) 279.
412 CHBR (2006) 78. Cf. Crăciun and Moga (2010) 38–9.
413 Wilson, Mattingly and Dawson (2011) 44.

Caches of wax tablets have been found in Sf. Iosef and Cătălina Monulești.[414] Although Cătălina Monulești has yet to be fully excavated, the preliminary results from the 2012/13 campaign—when a water wheel was discovered—plus the wax tablets hint at a reasonably high level of mining activity in this area during the Roman period.[415] It is not unreasonable to assume that a settlement would have existed nearby. With the mines located in such close proximity to the modern town, suggestions that the missing settlement is probably underneath historic Roșia Montană (and possibly extending along the valley towards Țarina) seem highly plausible.[416]

3.3.6 Jig-Văidoaia

East of Țarina is Jig-Văidoaia, which overlooks the north-western part of central Roșia Montană. No Roman galleries have yet been identified in the mines in this area, but a Roman cemetery and ore-processing site are known.[417] Detailed data on the necropolis, where 34 cremation burials were excavated, have not been fully published however. The cremation burials, of which 29 were simple pits and five were stepped, appear modest, with common grave goods in a state of poor preservation. The ore-processing site is located on the slope above the necropolis and has been identified as such based on a poorly preserved structure, plus finds related to beneficiation (grinding mortars) and smelting (hearth). There are also possible traces of ore extraction as well. In general, the situation at Jig-Văidoaia is one where some surface remains have been found, but not the related

414 Sf. Iosif: TabCerD I. Cătălina Monulești: TabCerD III, V–IX, XIV, XVI; XXI, XXII, XXV (11 tablets, of which the last 3 are uncertain). Cf. CHBR (2006) Appendix G.
415 NB: The recently identified wheel might be a rediscovery of Pošepný's 1855 wheel, discussed earlier.
416 Wilson, Dawson and Mattingly (2011) 42.
417 Wilson, Mattingly and Dawson (2011) 13, 43; CHBR (2006) 77–8; CCA 2003 (2004) 262–7; CCA 2004 (2005) 297–8.

underground mines. Given that the ore-processing site at Jig-Văidoaia is only one of two found to date, this sector needs further fieldwork.

3.3.7 Alburnus Maior and missing surface evidence

Despite the breadth of the archaeological campaigns, the exact location of the main mining settlement still needs to be identified. We do know that *Alburnus Maior* was at Roșia Montană, as the wax tablets attest its existence: nine of the documents were signed there (TabCerD I, II, IV, V, IX, X XIII, XVIII, and XXII). However, the limited space along the river valley and the topography imposed by the massifs have put pressure on urban land use. The current settlement pattern consists of a nuclear core around the main square in the east and a linear settlement strung along Roșia Brook in the west.[418] As a result, it is highly likely that ancient *Alburnus Maior*, along with any possible miners' settlement for Coș-Lety, Jig-Văidoaia, and the northern workings on Cârnic, is underneath the built-up town centre.[419]

The archaeological evidence for the pattern of settlement distribution discussed above certainly suggests the presence of nucleated centres with associated sites. Where the picture is clearer is around Cetate Massif, where a nucleus consisting of a village and its cemetery, as well as a religious area and probably ore-processing facilities, are associated with mines at a near-by massif.[420] This type of nucleated settlement is also typical of historical mining in places as varied as the American West and Australia, as mining communities tend to be centred around the ore deposits that are their *raison d'être*, with facilities springing up around specific workings.[421] The presence of this type of nucleated

418 CHBR (2006) 57, 115.
419 Wilson, Mattingly and Dawson (2011) 42.
420 Wilson, Mattingly and Dawson (2011) 69.
421 E.g. Hardesty (2010).

pattern would mean that there is good reason to use the known surface remains to identify missing sites, as there is still so much unaccounted for (*Table 5*).

3.4 The mining community

Despite the progress made in documenting the surface remains at Roșia Montană, the mining community as a subject of study has received far less attention. Our understanding of the people who actually populated Roșia Montană has not advanced much further beyond the work of previous scholars, who established the strong Illyrian element amongst the mining population and posited the presence of the Roman army.[422] The most recent surface excavations largely confirm the existing view, providing a welcome contribution to the overall data available, but remain under-discussed with respect to the mining community as a specific phenomenon. Mining "settlements" and mining "communities", although related, are not one and the same, and the difficulty lies in elucidating the relationship between "settlements"—which are archaeologically visible—and "communities", which are a more abstract concept.[423] The "mining community" as understood here refers to a population brought and bound together by a common economic goal, one that lent an otherwise disparate group of individuals another layer of identity as members of a shared mining community. Characteristics of such a group may include close ethnic identification, prominent levels of superstition and religiosity, limited vertical mobility, and high horizontal mobility—aspects common to mining communities of various places and historical periods. There is limited scope at Roșia Montană for a complete synthesis of the surface evidence given the lacunae in research and publication, but it still remains the best source of information on Roman miners in Dacia.

422 E.g. Daicoviciu (1961); Wollmann (1996).
423 Knapp (1998) 13.

For such an inaccessible location, the ethnic make-up of the mining community at Roșia Montană was surprisingly heterogeneous. The wax tablets and the epigraphic evidence attest a mix of Illyrians, Greeks, and Roman citizens, all gathered in what is best described as a remote location with only marginal means of eking a living beyond the mineral wealth of the mines (*Tables 6a and 6b*). Of all the groups present, the overwhelming majority are the peregrines from Dalmatia, as revealed in the Illyrian names found on the votive altars and named in the wax tablets (e.g. Dasius, Verzo), and also partially supported by the burial practices and the distinctive technique of carving trapezoidal mining galleries. We also know that the Illyrians who immigrated to Dacia were not themselves uniform, but composed of several different groups such as the *Pirustae* and the *Sardeates*.[424] Seemingly entire separate communities from Dalmatia (rather than, say, individuals) would suggest that either the groups relocated to Roșia Montană *en masse* or settled cumulatively over time, and made some effort to assert their place of origin. This is not enough to indicate state-led or voluntary resettlement—or indeed a combination of both. But it would not have occurred were it not for the incentive of the mines, and the level of expertise evident in the mining works certainly indicates the movement of groups of people with a very specific skillset.

Individuals of Greek origin were also present at Roșia Montană, but their social position differed from the Illyrian miners. TabCerD IV, for example, is a loan agreement composed in Greek that was drawn up in *Alburnus Maior* and found in a gallery at the Sf. Laurențiu-Igren mine in north-eastern Roșia Montană. Other eastern *peregrini* at *Alburnus Maior* include Socratio, son of Socratio (*IDR* I, 40, 41), a mine leaseholder; Adiutor, the son of Macarius (*IDR* I, 40), a notary; and Memmius, son of Asclepius (*IDR* I, 41), a mine

424 Daicoviciu (1961); Ciobanu (1999).

worker. Most of the Greeks tended to be peregrines who had migrated to *Alburnus Maior*, but Iulius Macedo (*IDR* I, 32) was a Roman citizen of possible eastern or Greco-Oriental origin. Some individuals were slaves: Apalaustus (*IDR* I, 37) and Thedote from Crete (*IDR* I, 38); as were the slave owners: Bellicus, son of Alexander (*IDR* I, 37), Claudius Philetus (*IDR* I, 38), and guarantor Alexander, son of Antipatros (*IDR* I, 38). Individuals from Asia Minor are also attested at *Ampelum* (Zlatna), where there appear to be some Bithynians present (*IDR* III/3 341, 341). Although most are not miners, the Greeks seem to be migrants who moved to the mining regions for business or administrative reasons, perhaps drawn there by commercial activity or to provide auxiliary services for the mining population.

The Roman army, too, operated in the vicinity of Roșia Montană. The brick stamps and higher status buildings at Carpeni Hill provide the clearest proof that at least some individuals from the central administration were present. It is, however, uncertain whether that presence was only at the beginning when mining activity commenced in the area or extended over a longer period. Comparisons of the brick stamps of *Leg. XIII Gem*. found at Carpeni with those elsewhere suggest an early date belonging to the first half of the 2nd century AD.[425] Likewise, the army's actual role is conjecture at best. The lack of evidence for significant fortifications or encampments at Roșia Montană suggests that military personnel were probably acting in an administrative capacity as seconded officials from the provincial government or as providers of technical expertise for engineering works, rather than as wielders of brute force, but there is no way to say for certain. If the army was present as local law enforcers, it was not in a heavily militarised manner in the sense of needing to police a large slave labour population, for example. What can be said is that

425 Țentea (2003) 257.

there are signs of some social stratification amongst the mining community at Roșia Montană, with representatives of the central government such as army personnel probably commanding the highest status, but the generally modest levels of wealth seen in the funerary remains indicate a fairly even spread across the wider population.

The variety of people present at Roșia Montană can certainly be seen as a reflection of the cosmopolitan nature of Roman society,[426] but it is important to recognise that the heterogeneous nature of the group ultimately derived in large part from the economic lure of the mines. Aside from the mineral wealth, the natural resources of the surrounding area support mostly subsistence farming and transhumance. Along with the remote location and formidable mountainous terrain, it is difficult to see another compelling reason why so diverse a group of individuals would have otherwise chosen to settle at *Alburnus Maior*.

3.5 Chronology of exploitation

Although it is generally accepted that mining at Roșia Montană coincided with Roman occupation of Dacia, refining the chronology of exploitation beyond a broad 2nd-century window has been tricky. Furthermore, attempts at identifying pre-Roman and later Roman activity have turned up scanty data, and information on the post-Roman/early Medieval phase of mining at Roșia Montană is practically non-existent.

3.5.1 Pre-Roman mining

Suggestions that the Dacians worked the hard-rock deposits at Roșia Montană prior to the arrival of the Romans have yet to be definitively demonstrated but continue to attract support. This has already been discussed in detail above, but to briefly summarise the argument: the evidence for a Dacian presence rests upon radiocarbon results for two wood

426 Pundt (2012).

samples from Cârnic 1 and Țarina that seemed to date the remains to the pre-Roman period. However, when the dates were recalibrated and reported according to accepted conventions, the readjusted date range extended within the early years of Roman rule.[427] The lack of any supporting evidence for Dacian material culture at Roșia Montană both in the underground mines and on the surface also suggests minimal pre-Roman activity, if any.[428]

Although it is entirely plausible that the Dacians may have exploited the deposits—particularly the more readily accessible surface outcrops—considering the available evidence it seems most probable that the bulk of the ancient workings are Roman, rather than Dacian. In any case, the scale of Roman exploitation would likely have obliterated traces of previous use, if indeed there was any.[429] Based on this, *intensive* exploitation of the deposits at Roșia Montană commenced more or less with the advent of the Roman miners at the beginning of the 2nd century AD.[430]

3.5.2 Roman mining

Underground evidence

The extant evidence from the underground sites indicate that the mines were indeed broadly active in the 2nd century AD, as to be expected.[431] This is true of all the mining sectors with dateable finds: Cârnic 1, 2, 3, 6, 7, 9 and 10 networks (based on Loeschke X lamps and radiocarbon dates); the Zeus and Găuri sectors of Cetate (radiocarbon dates and

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427 Cf. Wilson, Mattingly and Dawson (2011) 44, n. 65. The Cârnic 1, Chamber 1 sample also encompasses a wide window and is difficult to interpret; Cauuet (2009a) 140–1.
428 CHBR (2006) 99; Cauuet (2009a) 123.
429 E.g. In the case of the Cetate opencast, where later activity would have destroyed earlier workings; cf. CHBR (2006) 83.
430 This view, of course, is subject to amendment should more solid evidence for pre-Roman mining emerge. Additional radiocarbon and dendrochronological data in Cauuet (2009a) (unpublished) for Cârnic 1 and 3.
431 For a more detailed examination of the dating evidence found in each sector, see "Chapter 3: The Underground Mining Evidence". This section is meant to be a generalised discussion contextualising the mining activity at Roșia Montană.

fire-setting techniques respectively); the Orlea-Țarina-Carpeni sector (radiocarbon and dendrochronology); and the Cătălina Monulești mine at Coș-Lety (ceramic finds and dendrochronology). The only sectors without sufficient information are at Cetate Massif itself, where the modern opencast has destroyed the Roman works, and Cârnicel and Jig-Văidoaia, which remain largely unexcavated. There is no easy way to demonstrate contemporaneous activity across all the main extraction points at Roșia Montană, but overall, the general trend points to a *floruit* in the 2nd century.

The dating evidence is based on ceramic finds, radiocarbon dates, and dendrochronology. Most of the datable pottery were open-channelled oil lamps (*Firmalampen*) of Loeschke X type, which unfortunately has a broad chronological distribution up until the mid-Antonine period and as late as the first half of the 3rd century, and thus cannot provide further clarity.[432] The carbon-14 dates are slightly more helpful: although they only offer a probable dating window, it is possible to discern relative periods of activity, when some sectors were worked earlier or later than others. Apart from the "pre-Roman" Cârnic 1, Chamber 1 and Țarina wood samples discussed above, all the radiocarbon dates published in the first excavation report fall within the Roman occupation period.[433] Additional data from the unpublished 2009 report on Cârnic further confirms Roman activity in the massif throughout the whole of the 2nd century.[434]

These results are consistent with the dated wax tablets, which range from AD 131 (TabCerD XVIII) to 167 (TabCerD I). The latest tablet, for example, calling for the dissolution of a funerary *collegium*, was found at the Sf. Iosif mine in Lety Massif. Based on the ceramic finds and dendrochronology, we know that the Coș-Lety mines were active

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432 See Cauuet (2009a) 186–3 for discussion of the lamps found in Cârnic.
433 Data from Cauuet et al. (2003/2010) Fig. 15. See also Table 1.
434 Cauuet (2009a) 193–7.

between AD 150 and 180.[435] Furthermore the date of AD 167 dovetails with the Marcomannic invasion of Dacia, and it is probably around this time that the mines at Roșia Montană were vacated. Unfortunately, not all the wax tablets are dated, nor have they survived intact. It is, however, their usefulness in narrowing the chronological window that makes finding more tablets such a vital task.

More intriguing are the signs of later activity, beyond the 2nd century and especially after the supposed abandonment of the mines around AD 167. It is possible that the Zeus sector (Cetate Massif) was also re-worked: the radiocarbon window for the fill of one of the galleries (G1) extends as late as the 5th century, but this does not necessarily indicate actual activity, only the possibility. The fill of Zeus G1 may well have stopped accumulating after AD 167; the date is certainly within the expected dating window. The clearest evidence we have comes from Cârnic, as samples from Cârnic 1, 6, and 7 certainly seem to suggest 3rd-century activity (*Table 1*).[436] However, it is worth reiterating that the radiocarbon dates are probability windows, rather than absolute dates: the recalibrated dates for the Cârnic 1 – G2 (AD 20 to 330), Cârnic 6 – GE US3 (AD 145 to 425), and Cârnic 7 – Lev. 960 Work 14 (AD 125 to 385) samples do extend into the 3rd century, but do not preclude the possibility that work ceased earlier. There are more data available for Cârnic than for any other sectors at Roșia Montană so the picture may well be skewed, but it appears that some of the galleries in Cârnic were worked more or less throughout the better part of the Roman period in Dacia. Given the richness of the ore bodies, it is no surprise and certainly illustrates the centrality of the massif to Roman mining operations at Roșia Montană.

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435 Cauuet (2012).
436 Wilson, Mattingly and Dawson (2011) 38. CHBR (2006) 99 dates the Piatra Corbului sector (Cârnic 6–25) to between the 2nd to the end of the 3rd-century. See also p. 75 ff.

That the signs of 3rd-century activity should be at Cârnic is also unsurprising. As the largest and most important of the massifs with some of the richest deposits, it would make the most sense that if miners were to return and resume exploitation after an external shock, it would most likely be in locations where mining would still be profitable, either because of the ease of exploitation or the high economic returns. In several networks (Cârnic 1, 2, 3, and 10), works were prematurely abandoned before the ores were exhausted, suggesting that the galleries were abandoned for other reasons, probably the aforementioned Marcomannic Wars.[437] It is not unlikely that fleeing miners were aware of this and had a reason to return, even if different deposits were subsequently worked. The return to Cârnic after a hiatus is also made possible by the geology: unlike the mines on the northern bank of Roșia river which suffered from problems of drainage and flooding (Orlea-Țarina-Carpeni and Coș-Lety), Cârnic is fairly well drained and the rock is harder and more stable. It would in theory mean that the mines were more likely to still be workable after a break of months, or even years, of exploitation.

Surface activity

Dating the surface remains at Roșia Montană has proved similarly difficult, due largely to the poor preservation of structures and grave goods. Poor preservation from acidic soil conditions and the relatively lowly social status of miners, as well as the reuse of Roman material in modern buildings have all taken their toll. This is further compounded by the fact that the local pottery typology is not yet well established, and only offers broad 2nd-century dates.[438]

437 Wilson, Mattingly and Dawson (2011) 37.
438 AM III (2008) 33–4.

In general, the chronology of the surface evidence corresponds with the peak of mining activity in the 2nd century AD, as seen underground. The habitation sites at Hop-Găuri, Hăbad, Tăul Țapului, and Carpeni are all generally assumed to be "Roman" based on the presence of mining activity, as the preserved evidence is poor. The funerary assemblages from the cremation necropoleis are rather more helpful in this regard as the grave goods at Hop-Găuri, Tăul Cornei, and Pârâul Porcului-Tăul Secuilor all fall within the 2nd-century bracket as well.[439] Hop-Găuri, in particular, seems to only have been used in the 2nd century, and especially during the reigns of Hadrian and Antoninus Pius.[440] The Circular Funerary Monument, also near Hop-Găuri and the most impressive monument found thus far, has also been dated to between AD 140 and the end of the 2nd century AD.[441] Again, these dates are consistent with the other bodies of evidence examined so far. But what might be seen in the Hop-Găuri dates is a possible boom as mining activity increased. The arrival of the Marcomannic tribes may well have interrupted Roman mining at Roșia Montană during a period of particularly intense production.

But what of later activity after the invasions? Signs of 3rd-century activity are also scarce above ground, but palaeographic analysis suggests that some of the inscriptions date between the second half of the 2nd century and the start of the 3rd century AD.[442] This is by no means conclusive, but needs to be taken together with the underground evidence to provide a fuller picture.

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439 The grave goods at Jig-Piciorag are poorly preserved and of low status, and do not appear to have been datable; see CHBR (2006) 77–8.
440 CHBR (2006) 76.
441 AM II (2005) 146. CHBR (2006) 80 gives a more precise range of AD 140/144 to c. AD 180.
442 CHBR (2006) 14.

3.5.3 Post-Roman mining

Mining activity in the centuries following the Roman withdrawal around AD 275 is not well understood at Roșia Montană. Only piecemeal evidence exists as the post-Roman/early Medieval period has not been a priority in the recent excavations. One dendrochronology result from Cârnic 1 Superior was dated to the 9th–11th century, but the excavators were unable to identify corresponding mining activity.[443] On the surface, the building remains at Islaz near Balmoșești-Gura Minei on the northern slopes of Roșia valley was originally thought to be Roman based on a sizeable quantity of ceramic finds.[444] However, it is now more likely to be a fortified medieval settlement.[445] This entire area and time period, in general, needs more study before we can put the Roman-period evidence into a wider chronological context.

3.5.4 Conclusion

Although additional work is needed on the dating evidence, there is a clear need for a more nuanced understanding of the mining timeline at Roșia Montană during the Roman period, particularly one that moves away from fixating on the Marcomannic Wars as a presumed watershed moment or end date to mining activity. This is not to deny the usefulness of the wax tablets in narrowing the chronological window to between AD 131 to 167, but what they ultimately provide are dates for the documents themselves and roughly when they were hidden—and *not* dates for when the mines were in operation. Nor should the latest known date in the tablets (AD 167) be given undue significance. An external event such as the Marcomannic invasion may well provide an explanation for the caching of the tablets and, by extension, a presumed disruption in mining activity, but it should not be taken as a

443 Cauuet (2009a) 197.
444 CHBR (2006) 257; AM I (2010) 36–7.
445 Wilson, Mattingly and Dawson (2011) 45–6.

sign that the mines ceased operating entirely. Indeed, evidence from Cârnic in particular—where the geology allowed for resumption of exploitation after a hiatus of years—indicates at least some 3rd-century activity, and the continued flourishing of *Ampelum*, *Apulum*, and *Sarmizegetusa Ulpia Traiana* in the 3rd century would support a picture of resilience in Dacia in the aftermath of any such foreign incursion.

In short, the bulk of the evidence at Roșia Montană is for the 2nd century when Dacia was part of the Roman Empire. Disruptions to mining activity could be tied to external events such as the Marcomannic Wars, but suggestions that mining continued or resumed at some sites after the incursions also seem to be the case based on the limited evidence for later activity in the 3rd century. The resumption of mining activity may have been on a reduced scale, due in part to the diminished size of the work force and to physical impediments such as flooding in mines that required constant drainage to stay viable. The mines on the northern bank of Roșia river, in particular, would have been especially difficult to restart after an interruption. It is also likely that the decreased level of mining activity left remains that are difficult to distinguish from the larger-scale workings, or indeed left very few remains (if any). While it is possible to identify traces of later activity in Cârnic, to claim a "resurgence" in mining at Roșia Montană in the later 2nd and early 3rd centuries AD is perhaps slightly too optimistic based on the current evidence.[446] Nonetheless, Roman mining did continue into the 3rd century and any future studies need to take this into account.

446 CHBR (2006) 82.

4

Roman Mining Techniques and Technology

Pivotal to the Romans' success was their mastery of mining techniques, as the requisite technological knowledge (or its lack) remains a limiting factor in the extent to which mining activity can successfully take place. It is a challenge that all miners face regardless of chronological period or geographical location and is closely tied to the specificities of the underlying geology.

Unsurprisingly, remains from mining technologies are perhaps the most visible features in mining sites today,[447] and Roșia Montană is no exception. As demonstrated in the previous section, these are expressed archaeologically in the landscape as the remnants of shafts and adits, open pits, and waste-rock dumps above ground. Below ground, there are fire-set workings and water-management systems, and more generally in the form of ventilation shafts, communication and access galleries, and prospection points. Consequently, mining archaeologists tend to focus on identifying and reconstructing the technologies and techniques used, with less emphasis on the social, economic, and administrative context; such analysis is generally left to the historians.[448] A more fruitful approach would involve moving beyond simple identification and towards a realisation that mining technology does not exist in a social vacuum, but rather is effected by organisational choices and social concerns.

447 Hardesty (2010) 23.
448 An exception would be Cauuet (2004) on the spatial organisation of concessions underground and the discussion at the end of Cauuet (2014).

As scholars in an electricity-driven world, where the mining industry is now largely relegated to developing countries, it is perhaps easy to overlook the working conditions that Roman miners at *Alburnus Maior* would have faced daily and the particular challenges posed by a subterranean setting. Underground mines are cold, dangerous places, demanding much more than physical labour from miners. They require vigilance and knowledge, with technology playing a key role in ensuring economic success and worker safety. A mine in full operation would be noisy and full of activity, resounding not just with the incessant breaking of rock, but also the bustling of workers hauling waste and ore, in and out of the mine along narrow galleries barely wide enough to fit two abreast. All this exertion would take place in Stygian darkness, punctuated only by the flicker of lamp or torch light. If fire-setting operations were viable, timber would need to be hauled in, fires stoked, workers cleared, and galleries properly ventilated to prevent suffocation by smoke and fumes. If water was a problem—as is the case in parts of Roșia Montană—drainage systems would have to be installed and regularly maintained. Despite the constant effort, flooding was always a threat, as well as cave-ins if the host rock was particularly soft and waterlogged. The metals leaching out of the rocks would have also rendered the mine water acidic, requiring the use of protective leather clothing of some sort, as in more recent centuries.

Mining, therefore, is about solving rapidly shifting environmental problems on an ad hoc basis, with the additional problems associated with an underground context. The key here is technology and its skilful application, and knowledge, born from a combination of experience and technical expertise. From Roșia Montană, we have evidence that the Romans possessed the technology needed to mine the ore effectively, across a variety of geological situations. Technology was thus not a limiting factor.

Although some of the following mining methods introduced by the Romans are not novel and have analogues elsewhere, both from prehistoric mining and from elsewhere in the Empire, what is interesting is how these technologies were deployed and what it reveals about wider organisational needs. To what extent was the state involved in mining activity at Roșia Montană? The question then, is not so much the mere identification (or absence) of certain technologies, but their use within the broader context of mining administration.

4.1 Mining techniques

At its most basic, Roman miners used rudimentary, everyday tools, and the endeavour can be considered low-technology. Fire-setting as a technique for breaking hard rock is discussed separately below, but that too, in terms of tools and methods, was relatively simple. It is mainly by identifying the techniques used that the skill of the miners at Roșia Montană becomes evident.

The main tools for the primary activity of ore extraction were the hammer, chisel, and pickaxe. They would have been used to break apart the host rock as well as for prying out embedded ore. These tools were presumably made of iron, which would be comparable with Roman mining elsewhere, particularly in Iberia (e.g. Rio Tinto) where the preservation of iron is more favourable.[449]

Despite the extent and variety of Roman mining at Roșia Montană, few examples of tools survive. The finds reported by 19th-century archaeologists either lack adequate description (M. Ackner) or are atypical of the region (G. Téglàs).[450] The best extant example is a stone mining hammer (*Schrämmhammer*) of a widely attested Greco-Roman

449 Domergue (2008) 97–8.
450 Sântimbreanu and Wollmann (1974) 256–7.

type found in 1969 in the rubble of Sf. Ladislau at Cârnic, a known Roman-period gallery.[451]

The use of iron tools is thus largely identified by the traces they leave: the pointed chisel marks on gallery walls and faces, as well as the angled, quadrilateral shape of the gallery openings. One such example (of many) would be the tool marks left on the wall in G1 drift in Cârnic 1.[452] Nearly 95% of the 6+ km of ancient workings studied at Roșia Montană were opened in this manner.[453]

Other essential equipment included shovels and baskets for transporting ore and rubble, and wooden pans that could have been used for assaying. The latter is particularly intriguing, as it suggests that the miners were checking ore fineness underground, at or close to the primary site of extraction. The evidence for assaying consists of a wooden "pan" abandoned in one of the water sumps in chamber Ch5 in Cârnic 1 that was dated to the Roman period by dendrochronology.[454] The French excavation team also found a broken mortar like those from the ore-processing workshop at Piciorag, in the backfill of a stope at Cătălina Monulești. Coupled with the ore content still present in some of the preserved working faces (about 50 litres or 120 kg of extracted ore),[455] Cauuet's conclusion that Roman miners were monitoring the economic viability of ores underground is probably correct.

A characteristic feature of Roman underground mining in Romania is the trapezoidal cross-section of galleries. Their presence is amply attested at Roșia Montană

451 NB: Sântimbreanu and Wollmann report that TabCerD I was found in Sf. Ladislau in 1788, but this is at odds with CIL III and IDR I, both of which note the find spot as Sf. Iosif in Lety massif instead. TabCerD XXIII is the tablet associated with Sf. Ladislau. It is also unclear whether this is the same hammer pictured in Wollmann (2002a) 37, found in the Napoleon adit at Cârnic.
452 Cauuet et al. (2003) 481.
453 Cauuet and Tamas (2012) 224.
454 Cauuet and Tamas (2012) 225; Cauuet (2014) 100. Cf. Wilson, Mattingly and Dawson (2011) 38.
455 Cauuet (2014) 100.

and is often used as an indicator of Roman activity.[456] Dimensions varied, depending on the purpose of the gallery, and could also range in shape to more rectangular in form. Access ways and drainage galleries could also be larger in size. Some were rectangular openings around 0.85 m wide and 1.80 m high; others were trapezoids measuring 1.60 to 2.20 m (floor), 0.80 to 1.90 m (ceiling), and 1.70 to 1.85 m high, and could include a drainage channel running along the bottom.[457] But ultimately, the shape of the gallery also depended on the hardness of the rock, mineralisation, and tools used.[458] Areas with highly silicified hard rock, such as at Piatra Corbului, were worked using fire-setting instead.

It is not entirely clear why Roman miners at Roșia Montană seemed to prefer the trapezoidal shape, given the additional time and energy needed to produce regular profiles. The reason may be pragmatic: cutting a larger gallery required more effort and the removal of more rock but paid off in terms of access and stability.[459] Bigger galleries allowed for easier movement, especially when moving ore through the mine, by allowing miners to walk upright and circulate with ease. The sloping walls also helped transfer the vertical thrust from the ceiling to the floor, thus providing greater geological stability and safety for the workers.[460] This optimisation for safety would be particularly relevant in waterlogged areas, such as at Cătălina Monulești, where the combination of seeping water and friable dacite made for an especially dangerous working environment.

Trapezoidal galleries are not unique to Roșia Montană, however. They are also attested at other Roman mines in Romania; for example, Ruda-Barza and 23 August mine

456 Cauuet et al. (2003) 474; Domergue (2008) 108.
457 Sântimbreanu and Wollmann (1974) 257, Fig. 5. Cf. Wilson, Mattingly and Dawson (2011) 52: 1–1.4 m (ceiling), 1.8–2.5 m (floor), and 1.5–2 m height; and Maghiar and Olteanu (1970) 63 for average dimensions of Roman galleries in Romania.
458 Sântimbreanu and Wollmann (1974) 255.
459 Wilson, Mattingly and Dawson (2011) 26.
460 Wilson, Mattingly and Dawson (2011) 52.

at Almaş.[461] Outside of Romania, they are not well known, and few examples exist.[462] It is possible that the shape was introduced from Upper Moesia or Dalmatia, and was brought over from miners from these two neighbouring provinces.[463] This is especially relevant since the trapezoidal shape marks a departure from pre-Roman mining—which, as argued previously, is not securely identified at Roșia Montană and more probably derived from surface exploitation of alluvial deposits—and also from subsequent mining in the medieval period. Post-Roman galleries at Roșia Montană tend to be narrower and less regular, without the rectilinear shape and careful angularity of Roman galleries opened by chisel and pickaxe.[464] This helped minimise the amount of rock removed, but at the expense of easy movement. Early Modern workings opened using explosives are larger, but are likewise irregular, and identifiable by drilled bores for holding the dynamite ("shot holes").[465] If the trapezoidal shape originated in neighbouring Serbia, as has been suggested, then it would provide further evidence for a Dardanian presence at Roșia Montană, and more importantly, the introduction of a new technique from outside the province specific to the Roman period of occupation in Dacia.[466]

It is possible to see that at least some of the miners at Roșia Montană were more than subterranean quarrymen, hauling rocks out from underground, but skilled workers able to apply their technical knowhow in variable circumstances. The tools themselves were simple, but the techniques and their successful use in ore extraction much less so. In other words, it is much more about how one chose to use the available technology. We might not be able to deduce from this whether the Roman state specifically brought in or

461 Maghiar and Olteanu (1970) 67–8.
462 E.g. Kosmaj.
463 Wilson, Mattingly and Dawson (2011) 26.
464 Wilson, Mattingly and Dawson (2011) 46.
465 Cauuet et al. (2003) 471.
466 Wilson, Mattingly and Dawson (2011) 52–3.

incentivised the migration of trained labourers from neighbouring mining regions, but the skill of the miners working at Roșia Montană, together with the possible introduction of new techniques, does seem to lend credence to this hypothesis.

4.2 Fire-setting

Most of the time, tools sufficed. But areas of particularly hard rock required alternate measures, and in these instances, fire-setting was the solution. Some 5% of the identified Roman workings at Roșia Montană evidenced use of fire,[467] and all in highly silicified zones of impenetrable host rock. This technique was not new: prehistoric use of fire is attested in Europe and the Near, Middle, and Far East at both quarries and metal mines, especially in copper and silver-lead-zinc mines.[468] The Greeks tended not to use fire-setting due to fuel limitations, but the technique was commonly used in Roman mines, such as at the silver mine of Arditurri in Guipuzcoa (Spain), Dolaucothi (Wales), and Roșia Montană.[469] At its most basic, fire-setting is fundamentally straightforward, entailing the heating of rocks until they cracked and could be worked with tools. Its importance, however, lies in its relative efficiency, as one could get a decent return for the effort expended.

The main sectors at Roșia Montană where fire-setting was used are Piatra Corbului and Găuri, with some evidence on the unexplored northern slopes of Cârnic.[470] Some of the chambers opened by fire could reach spectacular proportions, and the examples from Piatra Corbului are amongst the best in the Roman world. A few workings have also been

467 Cauuet (2014) 90.
468 Willies and Weisgerber (2000) 146.
469 Domergue (2008) 110; Timberlake (1990) 50.
470 See Cârnic and Găuri in the section on underground mining evidence for more detail.

noted at Karacs-Czebe (Caraciu-Țebea) and Ruda elsewhere in Dacia,[471] but little more is known.

Although on first examination a simple technique, fire-setting may have required considerably more skill than previously supposed.[472] Factors necessary for the efficient application of fire-setting include enough fuel, water for quenching (if needed), and adequate ventilation. At Roșia Montană, Roman mastery of the technique is evident. Not only is fire-setting used where geologically appropriate—namely, on areas of hard rock—the miners also applied the requisite technical skill to successfully open workings even at fairly deep locations such as in Cârnic 7 within the massif. Mixed exploitation using both fire-setting and tools is also evident in Cârnic 7, as seen in chamber Ch14.[473] The ability to undertake such work at this level would not have been possible without a professionally skilled workforce and adequate ventilation of the mining works.

4.3 Ventilation

Good ventilation is of critical importance in underground mines, and paramount for ensuring worker health and safety even today.[474] Briefly put, poor air circulation could result in pockets of low oxygen or the accumulation of noxious gases, problems further exacerbated by the depth and size of a mine. For the Romans, ventilation was also especially necessary in areas where fire-setting was used, as the technique required adequate airflow to work.

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471 Davies (1935) 22.
472 Timberlake (1990) 52.
473 Cauuet (2009a) 166.
474 Greenberg et al. (2003). Cf. CHBR (2006) 51–2 and Cauuet (2009a) 117 on preparations needed to ventilate the lower levels of Cârnic before excavations could start.

The Romans recognised that deep mines harboured foul air that had a deleterious effect on the health of miners and could result even in death; this is well attested in the literary sources.[475] Most mines relied on natural air draughting, but there were ways to improve airflow. The most basic was the addition of ventilation shafts,[476] which brought in cooler air from outside the mine and allowed gases lighter than air to escape. If that proved insufficient, it was also possible to light a fire at one end of a ventilation shaft or drainage adit in order to start a draught and draw in fresh air.[477] Pliny, for his part, suggested sinking vent holes on either side of a particularly deep shaft or continually circulating the air by flapping linen cloths to help drive off fumes.[478] Although Pliny was writing in reference to well shafts, his advice still merits citation as the Romans seem to have applied a similar principle in their mining practice: by digging parallel galleries.

In contrast, the archaeological evidence for ventilation in mines is surprisingly scarce, its import notwithstanding. At Roșia Montană, there is a unique example in Țarina, where a narrow adit splits into two parallel galleries before converging at a common exit.[479] This is not discussed in any detail by the excavators, but presumably the two passage ways operated in a manner similar to Pliny's description above by increasing air circulation within the mine.

More generally, multiple access ways seem by far the most common means of improving airflow. Many of the larger workings at several sectors in Cârnic, for example, have two points of access, which would have had the benefit of facilitating both movement

475 E.g. Lucr. 6.808–817; Plin. Nat. XXXIII.98; Strab. 12.3.40; Thphr. De Lapidibus 52. Cf. Plin. Nat. XXXI.49 on testing foul air in a well by lowering a lit lamp.
476 Thphr. De Igne 24.
477 Thphr. De Igne 70.
478 Plin. Nat. XXXI.49.
479 Cauuet (2014) 96.

of air, as well as ore and workers.[480] This type of arrangement conveniently and efficiently solves the problem of poor ventilation while simultaneously aiding workflow. An example would be the sloping gallery G1 dug from Cârnic 2 towards the lower level of Cârnic 1, thus allowing the two networks to join up.[481] Both were large vertical workings: Cârnic 1, located near the heart of the massif some 200 m below the surface, consists of near vertical sites superimposed to a height of 50 m and extending over an area of 286 m^2 (13 m x 22 m) (*figs. 17, 18*). Cârnic 2 is closer to the surface than Cârnic 1, but still was over 35 m deep and covered 897 m^2 (23 m x 39 m). Each had three distinct levels of workings—with further subdivisions—and the two sets of sites connected at the lower level at junction G26 in Cârnic 1 via descending gallery G1 dug from Cârnic 2 (*figs. 19, 20*). A lamp medallion was also found at the base of G26, thus providing a Roman date.[482] Given the scale of Cârnic 1 and 2, it is not difficult to see both the need for managing stale air in confined workspaces deep underground and how connecting the two networks allowed for more effective communication as well as air circulation.

Another alternative form of ventilation management was the possibility of dividing existing galleries into two superimposed levels. The height of adits and sloping tunnels, which often reached 2 m, may have been tall enough to accommodate secondary ceilings made from wooden boards, fabric, or hide.[483] Remains of such installations have not been reported however, and, in any case, would be difficult to trace archaeologically, given the ephemeral nature of the materials used. Additional airing control could also be achieved by

480 Cauuet (2014) 96.
481 CHBR (2006) 90.
482 Cauuet (2009a) 147.
483 Cauuet (2014) 96.

means of rush light,[484] but this, too, is difficult to determine from the archaeological remains as wooden torches would have also been widely used for lighting.

Comparative evidence from elsewhere in Romania has not been well researched. Maghiar and Olteanu, writing more generally, seem to take the ancient literary sources at face value, citing Pliny's methods as well as Theophrastus' suggestion of maintaining a fire at the shaft entrance.[485] For fire-setting, the use of a superimposed parallel gallery and additional aeration via canvas or cloth was especially effective, as the fanning helped shift fumes and water vapour. However, archaeological examples of these methods have not been found, and the galleries from Roșia Montană still offer the best illustration.

Despite the importance of ventilation to underground mining operations, the archaeological evidence remains scanty. Nonetheless, the presence (or absence) of ventilation measures at Roșia Montană still has implications in terms of working conditions and workflow, the economic trade-off of *aérage* provision, and limitations to the application of other techniques, such as fire-setting.

Along with the ever-present dangers of collapse, ventilation is the critical safety factor in underground mining. Adequate ventilation becomes more problematic the deeper the mine runs, and large underground mines are extremely difficult to ventilate. Different portions of a mine also have varying degrees of airflow as certain parts require more fresh air than others. Noxious gases deep in mines, if not eliminated, could also contaminate other galleries. Whilst Roman mines did not run as deeply as modern ones, the problem of ventilation still had to be addressed in order to exploit deeper ore bodies.

484 CHBR (2006) 85.
485 Maghiar and Olteanu (1970) 71, 73; cf. diagrams on 78 and 80.

It is difficult to say much about health concerns in Roman mines given our inability to reconstruct in full the ancient mining experience. The problems with poor air in mines were evident to the ancient authors as illustrated above (e.g. Strabo), even if their primary concern was highlighting the negative effects on health, rather than the miners' welfare. As there is little evidence beyond the literary references, the point should not be pressed too far: but if historical and modern mining are any comparison, miners suffered lethal afflictions from their occupation, and a goodly part of the hazardous nature of the job was tied to air quality control. In addition to poisonous gases, chronic pulmonary diseases such as silicosis, "the scourge of the hard-rock miner",[486] were a perennial risk. Caused by inhaling airborne silica, this disease resulted from the breaking of quartz, a frequent component of the host rock that needed to be mined or penetrated to reach the desired ore. The silicified dacite at Roșia Montană may have resulted in respiratory problems for Roman miners toiling long-term underground. Soot, a by-product of fire-setting and the use of oil lamps and torches for lighting, would have also contributed to the poor air quality in closed mines. Providing good ventilation certainly allowed the Romans to access deep deposits. But rather less obviously, it also helped extend the working life of the miner. More than simply an improvement in working conditions, it helps to realise that the death of a miner would have still been a labour cost to bear—a cost especially dear in enterprises run on the scale of the Romans, and in an occupation chronically plagued by a shortage of workers.

The decision to open ventilation shafts was also economic, even though this is not usually addressed in the mining literature. The provision of ventilation can represent an increase in labour costs, in terms of the time and energy spent on opening another shaft or

486 Greenberg et al. (2003) 503.

gallery. Such an undertaking would be worthwhile when the problem became acute, and the richness of the ore deposits justified doing so. The depth of some of the mines at Roșia Montană, especially the big networks at Cârnic, clearly illustrate this need (*fig. 18*). For instance, the modern excavations at shaft P10 and *dépilage* D10—some of the deepest workings in Cârnic 1—needed daily ventilation to be made accessible (*fig. 21*).[487] It is not unlikely that the Roman miners also grappled with the same problem of toxic gas in their mining operations.

Even more impressively, the Romans were able to achieve this while facilitating workflow and access by creating dual-purpose galleries that allowed workers to circulate more freely within the mine. The Romans seem to have preferred sloping access ways dug from the surface rather than vertical shafts at Roșia Montană.[488] Whilst the underlying geology and the organisation of concessions in large part dictated this preference,[489] the combination of the two functions would have also indirectly affected mining costs; more specifically, the costs associated with waste rock removal in terms of time, energy, and efficiency. The vertical nature of the workings in Cârnic 1 and 2, for example, made haulage and human movement extremely laborious. Transporting ore from the depths of Cârnic 1 to the surface required long inclined slopes and stepped galleries, some of which had vertiginous inclines around 40 to 50 degrees.[490] The galleries, between 30 and 60 m long, were built large enough to enable easy movement and good ventilation, and most likely for long-term use.[491] The twin solution is perhaps merely a sign of Roman

487 Cauuet (2009a) 148.
488 Cauuet (2014) 104.
489 Cf. Cauuet (2004) on spatial layout and mining concessions.
490 Cauuet (2009a) 149.
491 Cauuet et al. (2002) 66; Cauuet (2004) 55.

practicality, but—from the perspective of economic cost-benefit—the airing *cum* transport galleries would have constituted a saving on labour costs overall.

What made the tremendous effort worthwhile was the quality of the deposits located at the heart of Cârnic Massif. The intersection of horizontal and vertical veins in "crosses" resulted in an unusually rich concentration of gold ore in Cârnic 1 and 2, and constitutes some of the highest grades at Roșia Montană. To give a rough sense of perspective: geological samples from the upper part of Cârnic 1 at level 958 contained 0.5 g/t Au and 11 g/t Ag,[492] and the breccia body in Cârnic 2, 9 g/t Au and 220 g/t Ag.[493] Grades for chamber C5, the large exploitation chamber with safety pillars at the heart of the massif in Cârnic 1, measured at superlative levels. Samples ranged from 6.03 g/t Au and 13 g/t Ag (north pillar) to 386 g/t Au and 185 g/t Ag (south pillar).[494] Deeper in Cârnic 1 Inferior, miners followed the mineralised breccia dyke downwards from *dépilage* D15 and gallery G101 to P10 and D10, the deepest points of the network (*fig. 22*). Whilst the richness of the ore is comparable between P10 (18.06 g/t Au, 93 g/t Ag) and D10 (15.15 g/t Au, 58 g/t Ag), the value drops off steeply in gallery G25 below (0.78 g/t Au, 4 g/t Ag).[495] Given the difficulties of movement and ventilation, exploitation was probably no longer economic and stopped.

Exploitation in Cârnic 2 also pursued similarly rich deposits. The focus was on the vertical Fortis vein, exploited in galleries G4 and G5, which contained high sampled values of 55 g/t Au and 43 g/t Ag (*fig. 23*). The other main source was the breccia dyke mined in the Coranda chamber in Cârnic 2 Middle. This was an intensely mineralised breccia, but consistently dominated by silver rather than gold. Sample measurements

492 Cauuet et al. (2003) 484.
493 Cauuet et al. (2003) 485.
494 Cauuet (2009a) 69.
495 Cauuet (2009a) 72–3.

ranged between 4.45 to 8.7 g/t Au and 64 to 219 Ag.[496] Cârnic 2 Inferior—made up of G1, G1bis, and G2—intersected a breccia zone only at the extremity of G1bis, and mainly contributed to circulation and ventilation.

In comparison, the ore grades at Zeus and Găuri in the Cetate massif were considerably lower (*Table 4*). Samples from two different parts of Zeus were 2.5 g/t Au and 20 g/t Ag, and 1 to 4.2 g/t Au and 3 to 42 g/t Ag respectively.[497] At Găuri, deposits opened by fire-setting in a vertical *dépilage* contained 2.20 g/t Au and 28.50 g/t Ag, with 1 g/t Au and 10 g/t Ag being the limit of extraction by the Romans.[498] These measurements are all modern, but do provide a gauge of the difference in value between the ore grades at Cârnic and elsewhere at Roșia Montană, and demonstrate why the Romans had an incentive to put in additional effort at Cârnic. The richness of the deep deposits certainly made the endeavour worthwhile, but typically only up to the point where exploitation offered tenable returns.

Lastly, inadequate ventilation also served as a limiting factor for the application of other techniques. Fire-setting is not possible without sufficient airflow. The process required fresh oxygen to maintain the fires once lit, and the copious amounts of smoke and poisonous fumes released from the burning rock also needed to be vented. Ventilation was less of a problem when the worksite was near the surface, which explains why the bulk of fire-set workings at Roșia Montană are fairly superficial. Some sites, such as G14 in Cârnic 7, were not.[499] Harnessing fire to exploit ore at such depth required knowledge, skill, and a certain degree of forethought in ensuring measures for ventilation were first in place.

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496 Cauuet (2009a) 78.
497 Cauuet et al. (2003) 487, 490.
498 Cauuet et al. (2003) 500–1.
499 Cauuet (2009a) 166.

The need for proper air circulation underground had an impact on working conditions and workflow, as well as limited the extent of mining activity. Nonetheless, ventilation was not a barrier to mining or the implementation of other necessary techniques, such as fire-setting, at Roșia Montană. Not only did the Roman miners effectively tackle the problem, they also displayed a dynamic versatility in their approach to ventilating their underground workings, and probably with ample reward for their efforts.

4.4 Mine Safety and stability

The importance of safety to underground mining cannot be over-emphasised: it is fundamental to the wellbeing of miners and to continued operation, and also one of the major cost factors in running a mine. Underground mines are more expensive to run and maintain than an opencast precisely because of the risks involved. Whereas the biggest danger in an open-air mine is a landslide, subterranean mines contend with the ever-present threat of collapse—as well as poor ventilation and flooding in select circumstances—in addition to the usual occupational hazards such as falls, broken bones, and so forth.

The ancient authors are generally silent on mining safety beyond noting the pernicious effects of poor ventilation and deploring the wretched working conditions.[500] The exception is in the case of actual mining laws; here, safety is paramount. No mining legislation has been found at Roșia Montană, but the roughly contemporaneous Hadrianic bronze tablets from *Vipasca* in Portugal provide a detailed reference to provisions for propping and support.[501] Not only were all shafts supposed to be carefully reinforced, mine

500 Again, it must be emphasised that any seeming concern for safety in the written sources and in this discussion is with respect to ensuring a mine's structural stability, rather than worker welfare per se.
501 Domergue (1983).

tenants were expected to maintain the timber propping. Touching or removing the support pillars or any malicious action that rendered the supports less stable resulted in swift retribution and deportation from the mining area.[502] At Roșia Montană, the wax tablets hint at flooding as a problem in some of the mines,[503] but the preoccupation is with minimising loss for the mine owner rather than the welfare of the worker.

Nonetheless, the overwhelming concern for safety and mine integrity is clearly evident at Roșia Montană in the archaeological remains, in its diverse range of evidence. The two greatest safety factors by far underground are ventilation and prevention of mine collapse. The focus here will be on how the Romans ensured structural integrity of the workspace and its relationship to the economics of mining operations.[504] Structural support in Roman mines could take several forms: from the shape of the gallery itself to the use of timber propping and safety pillars, both of which provided necessary support in areas of unstable rock and allowed for larger workings than otherwise possible.

4.4.1 Gallery profiles

The shape of the gallery itself was first and foremost a response to the underlying geology, but could be cut to enhance structural integrity. Indeed, the trapezoidal profile so characteristic of Roman mining at Roșia Montană maximised the transference of downward thrust from the ceiling to the walls, thus stabilising the roof.[505] This technique is also used elsewhere in Romania, where galleries were usually not reinforced, relying instead on a vaulted ceiling to distribute pressure to the sidewalls. Only if the ceiling was

502 Bruns (1909) no. 113 (p. 295). Legal action against removing mine supports was not new to the Roman period; cf. Plut. Vit. Dec. 843d where Lycurgus sued Diphilus for illegally mining out the safety pillars in the silver mines for their ore.
503 E.g. TabCerD XI on pro-rated pay when the mine was flooded.
504 See also the sections on ventilation and water management for more on safety.
505 Wilson, Mattingly and Dawson (2011) 52.

weak, was it then reinforced with a full or half frame of wood.[506] In addition to facilitating the ease of human movement, it would seem that the trapezoidal cross-section served multiple purposes particularly suited for the mining environment—perhaps enough so that the miners who practised this technique brought it with them to Roșia Montană and also elsewhere in Dacia.

4.4.2 Wooden propping

The use of timber supports is well attested at mines throughout the Roman Empire,[507] and various types have also been found at Roșia Montană. The need for propping was dependent on the geology and is most frequently seen in areas with softer rock. As such, most of the evidence comes from Țarina and Păru Carpeni, where the host rock is a more friable volcanic sediment, as compared to the dacite of Cârnic, which is highly silicified at points and quite hard. Examples of wood propping from Cârnic are thus comparatively rare. It is also worth reiterating that the evidence is dependent on preservation. As with most of the wood found at Roșia Montană, the wetter conditions on the northern bank of the river both necessitated and favoured its use and preservation. In the absence of wooden remains, the presence of propping has also been deduced by notches in gallery walls where the beams would have fit.[508]

One of the examples we do have from Cârnic is the long gallery G2 in Cârnic 3, where the wooden remains found in the gallery indicate the need to ensure safety and access, as this particular gallery was dug into friable dacite.[509] In general, however, the

506 Maghiar and Olteanu (1970) 63.
507 Domergue (2008) 112–3.
508 E.g. In the Zeus sector of Cetate Massif, where the wood is not preserved due to the lack of moisture and proximity of the sites to the surface, but notches in the wall indicate that the beams were jammed horizontally into the holes and forced against the wall on the other side; CHBR (2006) 87.
509 Cauuet (2009a) 80.

stability of the galleries in Cârnic was aided by their trapezoidal shape, the hardness of the rock, and the lack of drainage problems, and thus did not require shoring up to the same extent as some of the other mines.

In contrast to Cârnic, a wide variety of timber frame systems can be seen at Cătălina Monulești (Coș-Lety) and Păru Carpeni—where most of the wooden remains have been found—as well as a few examples from Orlea-Țarina. The sheer range of examples illustrates the richness of mining carpentry at Roșia Montană, and points to the presence of skilled woodworkers in the community.

Mortise and tenon jointing is typical of the propping remains found in Cătălina Monulești.[510] The timbering used in the adits took a variety of forms, from simple two-timber props (i.e. cap and one post), to half frames, frames, and closed frames. These frames were spaced in intervals or as needed, or could even be placed contiguously to make fully timbered adits.[511] At Păru Carpeni, there is a unique example of super-imposed trapezoidal adits over at least four levels, positioned directly above another, with wooden propping used to consolidate the floors and ceilings in between.[512] Although an unusual case, this type of vertical working would not have been possible without the use of additional supports to stabilise the adits. The remains found in the water drainage chambers at Păru Carpeni and Cătălina Monulești are even more impressive and will be discussed in greater detail in the section on water management. All that needs to be noted here is that amongst the wooden finds, in addition to the remains of the water wheels

510 CHBR (2006) 96. Cf. Maghiar and Olteanu (1970) 70, which illustrates the mortise and tenon joint of wooden side and top pieces from "1 Mai" mine.
511 Cauuet (2014) 96 and Fig. 7.
512 Cauuet (2014) 93.

themselves, provisions were made for reinforcing the upper gallery, to ensure the functionality and stability of the chamber.[513]

The galleries at Țarina were also often shored with wood because of the underlying dacite, and used the same method of mortise and tenon jointing.[514] A timbered sloping gallery leading from the surface to a shallow-depth mining work is known at Țarina.[515] Despite the controversial pre-Roman radiocarbon date (as discussed earlier), there is no reason not to believe that the timbering is Roman. At Orlea, the Roman Gallery (+725m) originally had wooden props but has since deteriorated.[516] Examples that have survived, particularly the armature in gallery +729.497m in the ore-rich Sf. Cruce zone, reveal the high quality of Roman mining carpentry. Here, buttressing was needed due to the softness of the rock, and consisted of a three-sided frame made of fir to support the sidewalls and ceiling.[517] Despite not being new, the quality of the wooden fittings at Roșia Montană have been such that they appear to be Renaissance or Early Modern, leading Wollmann and Ciugudean to submit a sample from Orlea for radiocarbon dating. The results indicate that the wood is Roman: BP 1910 ± 60 (cal. 2-σ 20 BC–AD 245).[518]

What is clear is the quality of the carpentry skills attested. The types of propping used reveal adaptability to particular situations, such as the use of a half or full frame as appropriate. The regularity of some of the propping dimensions, especially for timber-lined galleries, suggests that some of these fittings may have been standardised to a certain extent. This would have allowed for the ready production of propping with greater

513 Cauuet (2008) 70, Fig. 12.
514 Cauuet (2008) 67.
515 CHBR (2006) 94.
516 CHBR (2006) 94.
517 Wollmann and Ciugudean (2005) 106–7; cf. Pl. V 1 and 2, which are mis-referenced as Pl. VI in the article.
518 Wollmann and Ciugudean (2005) 107.

efficiency, but would have only worked if gallery dimensions were also similarly standardised. At a site with as much mining activity as Roșia Montană, it would have made sense to have a group of dedicated woodworkers providing this auxiliary—but crucial—service. Mine safety depended heavily on the security of its supporting infrastructure, and it is telling that the provisions at Roșia Montană were not just varied and adaptable, but of extremely high quality.

4.4.3 Safety pillars

In the case of larger, chamber-shaped workings that exploited a particularly substantial ore body, concessions needed to be made between safety and completely mining out the ore. Working chambers required the use of support pillars, which were left in place to bear the weight of the roof as the ore was excavated.

As galleries were opened along veins and breccia zones, exploitation expanded on a horizontal plane, with pillared chambers resulting in areas of richer ore and short galleries in poor areas.[519] To dig the large chambers, the miners drove galleries in a radiating star shape, before knocking through the adjoining walls whilst leaving behind some support pillars for the roof.[520] This technique appears to be unique to Roșia Montană,[521] where traces of these different galleries are still visible. Exploitation could also expand across two to three levels with safety pillars maintained in between each level, and access made possible via short stopes or stepped slopes.[522] This method of working strikes a compromise between mining out the ore as thoroughly as possible—thus the resulting large chambers—whilst necessarily leaving some ore unmined in the pillars to

519 Cauuet et al. (2002) 65.
520 Wilson, Mattingly and Dawson (2011) 57.
521 Wilson, Mattingly and Dawson (2013) 16.
522 Cauuet (2009a) 207; Cauuet (2014) 93.

maintain the viability of the working site. One could argue that the economic benefit of leaving the pillars in place outweighed the costs.

All the best examples of pillared working chambers come from Cârnic, where the size of some of the rooms attained impressive proportions. Cârnic 3, for example, had three sets of pillared chambers where ancient miners exploited a large area of ore, leaving the zone too dangerous to explore now.[523] But the two most spectacular examples at Roșia Montană are probably those in the Cârnic 1 and 5 networks. The main ore extraction point in the Cârnic 1 network was chamber C5, which focussed on a highly mineralised breccia body and its intersections. This area in general was extremely rich; sample 504 from the intersection of the breccia and a sub-vertical vein measured 113 g/t Au and 174 g/t Ag.[524] Samples from the standing pillars in C5 also suggest systematically elevated ore grades: 386 g/t Au and 185 g/t Ag (sample 1945, southern pillar) and 6.03 g/t Au and 13 g/t Ag (sample 1968, northern pillar) (*Cf. Table 4*). These geological results illustrate not just the richness of the deposits, but reveal the concern that the Romans had for safety and the stability of their underground workings. A radiocarbon date from the pillared chamber also suggests some later Roman activity in the 3rd-century AD,[525] perhaps hinting at the longevity of the work zone.

In Cârnic 5, site 19 exploited a rich vein consisting of hard quartz, whereas the walls were friable dacite. Samples of vein grades taken from the pillars separating the upper and lower levels of the site place the value at 123 g/t Au and 145 g/t Ag.[526] One of the samples (796) can be considered representative as the safety pillar was originally part

523 Cauuet et al. (2002) 41 ff.; Cauuet (2009a) 81.
524 Cauuet (2009a) 69.
525 Wilson, Mattingly and Dawson (2011) 38, presuming that the "pillared working chamber" refers to Chamber C5.
526 Cauuet et al. (2002) 53; cf. Fig. 199. See also Cauuet (2009a) 91–2.

of the ore body itself.[527] As with chamber C5, geological analysis indicates efficient exploitation of the most valuable ore.[528]

Again and again, the concern for safety is palpable, even at the expense of not extracting all of the highest grade ore.[529] This concern for mine safety is evident elsewhere in Roman mining as well: the *Vipasca* mining laws, for example, unequivocally banish individuals who illegally mine supporting pillars left for safety reasons.[530] On a more human level, the care accorded to structural stability is unsurprising as it behoves both the miners and mine operators to ensure safety. For the miners, presumably self-interest played a role, given their inherently dangerous occupation. That the hazards of their profession may have been a source of concern is hinted at in the richness of the miners' pantheon attested at Roșia Montană. The variety of deities worshipped at the sacred areas in Nanului Valley and Hăbad suggests a particularly active religious life, and the veneration of gods like Terra Mater (Earth), Sol (gold), and Diana (silver) reveals a preoccupation with deities associated with mining.

One can also argue that it was also in the mine operators' interest to ensure worker safety as it would have affected their bottom line. The death (or loss) of a worker would still be a labour cost, especially in a labour-intensive activity like mining where bodies are usually in short supply. Moreover, at a site like Roșia Montană, the relative cost would also be higher as the workers were highly skilled. At the organisational level, a collapse could result in the mine shutting down, which at best would cost the operator time and effort in re-opening the mine, or at worst a cessation of all exploitation. That ore-rich pillars were left standing to ensure long-term security indicates a decision valuing the

527 Cauuet (2009a) 93–4.
528 Cauuet (2009a) 91.
529 Cauuet et al. (2003) 485; Cauuet (2009a) 66.
530 Domergue (2008) 111.

longevity of the mine and long-term output over quick economic return. The richness and nature of the deposits at Cârnic certainly seem to support this view and offer a context against which such pragmatic decisions could be made.

4.5 Lighting

Adequate light was crucial for subterranean mining and its importance cannot be overestimated. Even with modern electric lighting and high-powered headlamps, the sudden failure of one's light source underground is a forceful reminder of human impotence in the absence of light.

4.5.1 Types of lighting used in mining

Several types of lighting were used in mines: wooden torches were the most basic light source, but lamps have also been found. Fire-setting, too, could be a possible source of light, but given the high temperatures and fumes released, and that the light would in any case be secondary to the main objective of breaking rock, it will not be considered here. The Romans are known to have used lamps at Sotiel Coronada in Spain, where niches about 5 cm deep were found near the roof of adits, some with traces of clay for affixing the lamps.[531]

The evidence from Dacia is similar. Clay lamps have been found at various mines in Dacia, with examples from Roșia Montană, Zlatna, and Vulcoi-Corabia. In appearance, these lamps are round or oval with a fuel reservoir in the back and orifices for refilling the reservoir and a spout for the wick. Known types could have two (*lucerna bilychnis*), three (*lucerna trilychnis*) or multiple nozzles (*lucerna polilychnis*). Many of these were stamped

531 Davies (1935) 22–3.

with the workshop of manufacture,[532] and most, such as the one found in 12 Apostoli at Ruda, were made locally in Dacia.[533]

The relative scarcity of lamps in a mining context could possibly be due in part to a preference for torches, but it is more likely that lamps have not survived due to the poor preservation conditions. The highly acidic waters of some of the galleries at Roșia Montană, for example, are not ideal for the survival of ceramics. The excavators at Tăul Cornei faced a similar problem where lamps found in the necropolis were affected by the acidic conditions of the local soil.[534]

Iron and bronze, which are already prone to corrosion, are even less likely to survive in such adverse conditions. Bronze lamps mounted on chains next to the mine exit were found at 12 Apostoli, but this is one of the few known examples.[535] Few iron lamps are known in Dacia; again, due to poor preservation and lack of academic interest. Examples are available for surface contexts but references to iron lamps in mining contexts are at best vague or conjectural.[536] The known lamps were generally simple in form, even more so than their bronze and clay counterparts, and could easily be made by any competent blacksmith. The Dacian examples have an open reservoir with a built-in handle that could be used for suspending the lamp, and tallow was probably the main fuel source as it was easier to procure and cheaper than oil. Furthermore, the deep basin suggests reasonable lighting capacity. The chronology for these lamps is not precise and most date broadly to the 1st to 3rd century AD. Given their ease of manufacture and lighting

532 Téglàs (1909).
533 Maghiar and Olteanu (1970) 73, 76.
534 Mining activity is known to cause Acid Mine Drainage (AMD), where metals leached into the water system render the surrounding soil more acidic. This has adversely affected the survival of some of the surface finds.
535 Maghiar and Olteanu (1970) 76.
536 Regep-Vlascici (2008) lists a total of 14 examples, of which 12 were locally produced in military workshops or related vici, and only one from a rural context.

capability, Regep-Vlascici may well be right that the surprising lack of iron lamps in Dacian mines is due to lack of research rather than lack of use. It is also telling that similar lamps have been used by miners with minor modifications into the modern period.[537] This is one area in which future work on mines less plagued by wet conditions could help clarify.

4.5.2 Evidence for lighting at Roșia Montană

The evidence for lighting at Roșia Montană is not hugely plentiful, but the identification of lamp niches as well as the chance preservation of clay lamps and wooden torches has helped illuminate our knowledge of lamp use in underground mining. The wooden torches are especially interesting and could be the subject of additional work.

Most of the identifiable lamps found at Roșia Montană are of the Loeschke X type. The lamps are morphologically similar to those found elsewhere in Dacian mines, but tend to be quite simple, with one body opening above the reservoir. The number of lamps found is small relative to the size of the Cârnic network. Only two complete lamps were recovered, out of a corpus of 67 different examples in total. The size of the lamps ranged from small (5 cm in diameter) to slightly larger ones (6–7 cm diameter).[538] The lamps have helped establish a broad chronological date for the galleries in which they have been found. These have been mostly dated to the 2nd and 3rd centuries AD based on the production and circulation of the Loeschke X type, so well within the period of known Roman activity at Roșia Montană. Unfortunately, as is the case with using surface lamp finds for dating purposes, the long timespan is too imprecise to be of much further use.

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537 Regep-Vlascici (2008) 353.
538 Cauuet (2009) 17–8.

Many examples of lamp niches exist in galleries all over Roșia Montană, with most of the evidence coming from Cârnic. The niches found at Roșia Montană were carved directly into the walls, roughly in the shape of small domed nooks with a flat bottom for siting the lamp. Most of these were sited around shoulder height or higher, such as the ones in *dépilage* D11, Cârnic 1 Superior near the ceiling.[539] Placement of the niches near the ceiling or slightly elevated helped illuminate the space below: in exploitation chamber C1, Cârnic 1 Middle, a niche by the ceiling about 1 m above the base of the shaft lit the whole area.[540] Natural geodes could also be used as niches too, as seen in gallery G3, Cârnic 1 Middle.[541] One of the most spectacular examples, however, has to be the descending gallery G31 in Cârnic 2 Superior, which runs for 70 m with a denivelation of 30 m and has 125 steps and 20 lamp niches.[542]

Although the lamp niches have reasonably flat bottoms, the question of how the lamps remained in place had not, until now, been adequately answered. A particularly fortuitous find was a lump of clay bearing the imprint of a lamp base, still stuck to the bottom of a lamp niche, which was discovered in the aforementioned gallery G31.[543] Also discovered in another niche in the same gallery was a lump with four fingerprints of an ancient miner still imprinted upon its surface.[544] Although Davies noted the use of clay as adhesive in his brief résumé on lighting in mines, the example from Cârnic 2 is one of the only surviving archaeological samples known.

The relative rarity of ceramic finds underground, plus their usefulness for broad dating purposes, has resulted in the clay lamps garnering most of the attention, but wooden

539 Cauuet (2009a) 128; Cauuet (2009b) Fig. 169.
540 Cauuet (2009a) 140.
541 Cauuet (2009a) 144.
542 Cauuet (2009a) 151; Cauuet (2009b) Fig. 435–446.
543 Cauuet (2009b) Fig. 446; Wilson, Mattingly and Dawson (2011) 54–5.
544 Cauuet (2009b) Fig. 445.

torches were probably more commonly used. For one, the raw materials for torches were more readily available and in plentiful supply, furnished by the local forests. In the galleries, the use of wooden sticks as torches can be identified as such by their burnt extremities and relatively small size. Given that mining required free hands for pickaxing and ore extraction, it is likely that miners held the torches in their mouth or with their teeth to illuminate their immediate work area. The exceptional preservation of wood in waterlogged galleries at Roșia Montană has revealed large caches of discarded "torches". Examples of these have been found at Cătălina Monulești, such as in G2, an unfinished gallery. Dimensions vary in length and width starting from approximately 20–35 cm by 1–2 cm, but most of the sticks were not large or heavy at all. Some examples also bear teeth marks indicating how they might have been used, but it is also possible that the burnt wooden sticks were used to light lamps.[545]

The unrelenting darkness of the galleries would have posed a considerable obstacle to the Roman miners. This would be further compounded by the extremely damp conditions in some of the mines under the water table, which present difficulties in keeping a light alive. It is possible that the main galleries were illuminated by oil lamps—as evidenced by the lamp niches—with additional lighting of the immediate workspace supplemented by wooden torches and more lamps (personal ones?), but this is by no means certain.

Although the Romans were innovative in introducing the use of lamps underground in the Dacian mines, they were not the first to use ceramic lamps in this context as the Greeks did so as well.[546] But what is remarkable is not the introduction of lighting

545 Personal observation; this material on lighting in Cătălina Monulești remains unpublished.
546 Davies (1935) 22.

technology, but the conditions in which Roman mining took place, especially when compounded with the difficulty of orienting oneself underground. What the lighting conditions in the mines underscore is the achievement of the Romans: that they were able to exploit, assay, and organise the works on the level and scale that they did, in what must have been crepuscular gloom.

4.6 Water management

Successful water management is perhaps most illustrative of the Romans' skill in underground mining in Dacia. This is especially true of deeper mines that went underneath the water table; in these instances, measures for drainage were necessary for productivity as well as mine safety. It is in this respect that the Roman mining at Roșia Montană deviates from pre-Roman mining in the province as the Romans employed their technological expertise in water management to extract ore at depths inaccessible to earlier miners. The implications for the economics of mine management are also profound, as the presence of sophisticated drainage systems raises questions regarding capital investment and the trade-off between the cost of such installations against an increase in output and possibly efficiency. The installation of complicated mine-drainage systems arguably required technical knowledge and managerial oversight on a higher level than small-scale exploitation would entail. This section explores, more specifically, the extent to which the state was involved in water management, either in disseminating the necessary technological knowledge or in organising the more extensive drainage systems seen in some of the underground mines in Dacia.

Roman water management in mines ranged from simple in form to more complex methods involving mechanical drainage devices. The level of need depended on the amount of surface water run-off and the height of the water table, as well as the underlying geology, and varied from mine to mine. One fairly basic type of mine drainage would be wooden pipes, such as the example from a mine in Stănija, near ancient *Ampelum*, with a Roman date quite likely based on the dimensions of the pipe segment (one *gradus* long, with an inner diameter between four to five *digiti*).[547] The pipes tapered at one end to ensure a watertight seal when joined together. An even simpler method was the use of discharge channels dug along the base of a gallery wall and water collection pits. Although not well-documented at most of the other underground mines in Dacia, traces of drainage channels were found cut into a Roman gallery at O Adam (Adamul Vechi) mine in Țebea.[548] At Roșia Montană, channels and sumps were also identified in Cârnic 1 and Cătălina Monulești.[549] For mines like Cârnic with less friable rock and better natural drainage, these basic methods sufficed. To date, the excavators of the massif only found provision for water management in Cârnic 1, which consisted of a horizontal gallery with a channel along one wall.[550] Furthermore, the two wells at the deepest point of the Cârnic 1 network—including one of the rare helical workings—ended with a flat base: the lack of arrangements for evacuating water suggests that excess water drained away through natural fissures in the rock and could be managed with relatively simple means at Cârnic.

At the other end of the spectrum, complex devices found in mining contexts include water screws, force pumps, bucket-chain machines, and water-lifting wheels.[551] The water wheel, in particular, has spurred academic research in Romania, as the Dacian mines have provided several spectacular examples to date. Much emphasis has surrounded the (re)discoveries of the Roman water wheels, but one needs to remember that mines

547 Kalcyk (1984) 5; Rosumek (1982) 106–7. Cf. Maghiar and Olteanu (1970) 55: the pipe is probably the same one found by Maghiar in 1931 in Dealul Ungurului, with a length of 750 mm and a diameter ranging between 80 to 100 mm and 70 mm on the tapered end.
548 Maghiar and Olteanu (1970) 56; Wollmann (1996) 133.
549Cauuet (2014) 93.
550 Cauuet (2009a) 122.
551 Davies (1935) 24–8; Oleson (1984).

could also be drained very simply using sumps, channels, draining tunnels, and pipes. The use of mechanical devices would probably be most practical in mines where the returns exceeded the effort involved in installing and maintaining a complex drainage system.

4.6.1 Water wheels in Dacia

Six sites in Dacia have reported evidence of water wheels: Brad, Bucium, Zlatna, Fizeș, Botiz, and Roșia Montană (Verespatak).[552] The Dacian water wheels are all similar in type, with compartmented rims for scooping up water and driven either by hand or treading. Information on the wheels from Brad (Ana-Erbstollen mine), Bucium (Sf. Petru și Pavel mine), Zlatna (Stănija mine), Fizeș, and Botiz is perfunctory, rendering the Roșia Montană wheels particularly important. The other wheels were found in fragments and are roughly dated to the 2nd or 3rd centuries based on the period of Roman imperial occupation. Apart from the Roșia Montană examples, many of the extant remains are now lost or poorly documented, and what has survived tends to be the thicker hub pieces.

Brad

The second-best example of water wheels in Dacia comes from Brad, Ruda-Barza, where the evidence suggests that the arrangement of wheels found in the mines at Roșia Montană is not unique. Two wheel hubs similar in type to the Roșia Montană examples were discovered in 1892 at Ana-Erbstollen in a Roman gallery that exploited the Michaeli (Mihai) lode (*fig. 42*).[553] Although only one hub has survived, the presence of several sumps in the gallery indicates that the wheels were arranged in a series and used for mine drainage. The original installation consisted of 25 pairs of wheels, and a reconstruction in

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552 Oleson (1984) 179. For the Fizeș hub, see Wollmann (1996) 118.
553 Oleson (1984) 196; Maghiar and Olteanu (1970) 71.

1905 by J. Bauer estimated that each wheel had around 26 spokes and was 2.90 m in diameter.[554] The series of wheels lifted the water from the base gallery that was 45 m below the present level, to a drainage gallery at 650 m that ran parallel to the "Roman Steps" and sloped towards Ruda Valley, where the water was evacuated.[555] Radiocarbon dating of the hub gave a date of 2000 ± 60 BP, or 150 BC to AD 130 when reported to 2σ (95% probability). Despite the authors' surprise at the median date of 15 BC, they understandably reject the pre-Roman date in favour of a Roman one, placing the wheel in the first decades of the 2nd century AD.[556]

There is little additional information about the local geology, but observations by Maghiar and Olteanu regarding the state of the surrounding bedrock indicates that mining conditions were difficult. Due to the moisture and friability of the rock, the Romans appear to have bypassed the neighbouring veins of Sofia and Magdana, leaving them unworked, the metal content of the ore notwithstanding.[557] The ore in the Michaeli lode appears to have been rich, containing up to 30 g/t of gold.[558] Although not as elevated as the highest levels observed in the large working chamber C5 in Cârnic 1 at 386 g/t, the ore grade at Michaeli falls within a comparable range to the other samples from C5 at 6.03, 26, and 43.2 g/t respectively, and is certainly higher than the cut-off point of ancient exploitation of less than 1% g/t (*Table 4*). Despite the increased difficulties caused by the waterlogged mining conditions, the Michaeli deposit was presumably worth the expense and effort of erecting a series of water-drainage wheels—as well as the long accessway known today as the "Roman Steps"—to extract the gold at Ruda-Barza.

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554 Wollmann (1996) 117, Pl. XXXVII. Cf. Bauer (1904) 291–2.
555 Wollmann and Ciugudean (2005) 102.
556 Wollmann and Ciugudean (2005) 103–4.
557 Maghiar and Olteanu (1970) 57; Wollmann and Ciugudean (2005) 102–3.
558 Maghiar and Olteanu (1970) 57.

Bucium

The wheel fragments from Bucium come from the only securely identified Roman underground working at Sf. Petru și Pavel on the northern slopes of Corabia. In either 1929 or 1930, N. Maghiar discovered the wheel hub in a sump along with some of its spokes, as well as a wooden gutter for carrying away the discharged water.[559] The current whereabouts of the remains are unknown, but Maghiar's illustrations indicate a wheel identical in form to the other known wheels, with a solid hub measuring 85 cm long and 33 cm thick in the middle, tapering to terminations on both ends measuring 10 cm thick, with sockets for 26 spokes. The accompanying wooden gutter measured 20 cm wide in profile, with an inner depth of 9 cm.[560]

Given the currently inundated state of the mine, the need for drainage wheels during the Roman period is patent. Far more is known about the surface mining that occurred on the other side of the massif from Sf. Petru și Pavel, on the southern slopes of Vulcoi-Corabia, where Roman mining activity at Bucium appears to have been active.[561] It is unclear to what degree or how the underground and surface mines are related, if at all. Further fieldwork investigating the interior of Sf. Petru și Pavel is necessary to identify the original location of the water wheel and to ascertain the importance of the find and the underground workings at Bucium.

559 Maghiar and Olteanu (1970) 70 n. 32, 72, 76; Oleson (1984) 196–7; Wollmann (1996) 118. Wollmann reports that Maghiar found the gutter affixed to the upper edge of the gallery armature and disputes this arrangement, arguing that water brought to the level of a gallery linked to the outside could be drained simply by a gutter running along the gallery floor, rather than lifted another level by a water wheel. Although Wollmann is correct with respect to the placement of the gutter along the gallery floor, I have not been able to identify Wollmann's reference in Maghiar and Olteanu concerning the location of the Bucium gutter, which was reported as found in the sump, unless Wollmann is referring to the description on p. 67 that describes the drainage of mines more generally.
560 Oleson (1984) appears to have misreported the dimensions of the gutter as 0.90 m wide and 0.16 m deep.
561 See Chapter 5.

Zlatna

One of the more significant finds from Zlatna are the water wheel fragments from Stănija, yet not much detail is available at all in the secondary literature. Oleson's information was gleaned second-hand from Wollmann, and what we do know is extremely tenuous. The fragments of the purported Stănija wheel discovered in the 1930s were similar to the ones from Roșia Montană, and it is on this basis that Oleson surmises a Roman provenance, with the date based on the period of imperial occupation in the province.[562] Wollmann himself was unable to trace the wheel remains or identify any further information,[563] and no other source besides Oleson mentions a water wheel at Stănija.

Fizeș

Almost all of what is known about the Fizeș wheel comes from Wollmann, who reports a hub from the inventory of the county museum of Deva identical in construction to that of the Roșia Montană wheels but having 26 spokes instead of 24.[564] The hub measured 67.6 cm long, with a diameter of 24.8 cm. There is some confusion regarding the origin of the hub: Boroneanț notes that a wooden double-wheel for water drainage similar to the Spanish wheels was found in a gallery at the Băița-Crăciunești gold mine, and the *CHBR* attributes Fizeș as the possible origin of a wooden double-wheel—presumably the same double-wheel mentioned by Boroneanț—in its entry for Băița.[565] There is no reason not to believe Wollmann about the wheel's origin; even if the hub was not found at Fizeș proper, Băița was an active gold-mining site in the Roman period, and the wheel could have come

562 Oleson (1984) 282.
563 Wollmann (1996) 118 n. 55.
564 Wollmann (1996) 118.
565 Boroneanț (2000) 125–6; CHBR (2006) 133. I was unable to access G. Téglàs (1889) Tanulmanyok a romaiak daciai aranybanyaszatarol, Budapest, p. 38–40 to verify Boroneanț's reference. Boroneanț also appears to have incorrectly cited his other source, Macrea (1969) 302, who makes no mention of a wheel from Fizeș, but a wooden double-wheel from Ruda instead. Although only one hub has been found, the assumption that the Fizeș wheel was a double-wheel probably stems from this error, or from comparisons with the arrangement of wheels at Ruda-Brad or Roșia Montană.

from one of the neighbouring underground mines within the commune. A mining settlement is thought to have been at Fizeș between the Cornet and Sfredel hills, and the water wheel may give some indication of the possible importance of the mining operations at Fizeș.

Botiz

The wheel from Botiz is a problematic case, perhaps more so than it would first appear. Not much information is known about the wheel remains. According to Oleson, a wooden hub made of oak—which he identifies as coming from a mine drainage wheel—was found at Botiz. The solid hub had radial slots for the mortised spokes and tapering ends at either side for the axle.[566] The 28 spokes is the highest number of those found in Romania to date, compared to 26 for the wheels from Brad and Bucium, and 24 for Pošepný's wheel from Orlea, Roșia Montană.[567] The overall shape is similar to the hubs found at Ana-Erbstollen in Brad and Sf. Petru și Pavel at Bucium, where the wheels were used to drain underground mines.[568] The dating of the remains to the second or third century AD is based on the chronology of Roman mining in the province. Neither the morphology nor proposed chronology is particularly unusual, as both are in line with the known examples of water wheels in Dacian mines.

The problem with the Botiz wheel is the find spot, which is not at all secure.[569] One possibility is that Botiz was recorded incorrectly. It is tempting to identify Botiz as Băița,

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566 Oleson's measurements are slightly off. The diagram in Cibinium (1966) 107, pl. I has a total length of 0.69 m, compared to Oleson's reported length of 0.67 m and 0.23 m thickness for the hub.
567 Wollmann (1996) 118; Oleson (1984) 196–7, 277–8. Cauuet (2008) and Cauuet and Tamaș (2012) do not give a number for the wheels discovered in Păru Carpeni, Roșia Montană, but the reconstructions depict 27 spokes.
568 Cf. Sântimbreanu and Wollmann (1974) 262, Fig. 11.
569 According to Oleson's sources, the find spot of Botiz seems to be taken from Römer in Rumänien (1969) 143, E11, which provides no further bibliography. Neither Cibinium (1966) nor Sântimbreanu and Wollmann (1974) give a find location. I was unable to access Weisgerber (1979).

as the site is also known as Boița or Boicza, and was an important gold-mining centre during the Roman period. Doing so would then place all the water-wheel finds within the context of the Golden Quadrilateral, where gold mining in Roman Dacia was most developed.

Working under the assumption that the wheel did come from Botiz, attempts to trace the location of the site have been difficult as it is not listed as a known mining site in any of the main sources. Of two possible villages named Botiz, one is in Satu Mare county, outside the general areas where Roman mining was active and outside of Roman Dacia itself. This leaves Batiz, a village to the north of Călan in Hunedoara, where there *is* evidence for Roman mining activity at the iron-mining sites to the west.[570] However, there are no known underground gold mines nearby that the wheel could have come from.

Wollmann, who has also identified Botiz as modern Batiz, is most likely correct that the hub is a misreported find. The museum records the source as a gold mine belonging to the donor, one J.F. Zeibig,[571] president of the Banking Consortium at Sibiu that had acquired the First Transylvanian Gold-Mining Company at the beginning of the 20th century. On that basis, the museum curator believed that it was possible that the remains are the same as the installation discovered in Orlea in 1858 and subsequently acquired by Pošepný in 1868. Demonstrating that the hub originally came from Orlea would be difficult, but Wollmann's assertion remains the most plausible explanation. Although Wollmann's work postdates Oleson's by over a decade, clarification on the Botiz wheel has not appeared in the English-language scholarly literature.

570 Of the two towns named "Batiz" in the 19th-century Hungarian encyclopaedia A Pallas nagy lexikona, the first is modern Botiz in Szatmár county (Satu Mare), and the second a town in Hunyad (Hunedoara) that acquired the name Batiz from the eponymous family due to a property dispute. The village is also depicted in the map of Hunyad in the Harta Iosefină a Transilvaniei (Josephinische Landesaufnahme) (1769–1773) p. 199.
571 Wollmann (1996) 118, n. 53.

Apart from perhaps the example from Ana-Erbstollen mine in Ruda, there is in fact little information on the water wheels of Dacia. The regrettable lack of detail on the other wheels means that the examples from Roșia Montană constitute our best source of information, especially regarding the actual arrangement of the wheels, where the drainage installations have been found *in situ*.

4.6.2 The water wheels of Roșia Montană

Not surprisingly, the find spots for the water-lifting wheels at Roșia Montană concentrate in the northern banks of the valley, where the underlying geology (soft, friable rock) and the water table are most problematic for underground mining. The two areas of note are Păru Carpeni and Cătălina Monulești, where wheels have been identified. Elsewhere, such as at Cârnic, where the rock is more stable, drainage methods were simpler and involved channels, tunnels, and water collection pits rather than mechanical devices.

As noted earlier, four water-wheel chambers arranged in a series were excavated at Păru Carpeni in 2004, with some of the wheels and wooden suspension propping found *in situ* (*fig. 14*).[572] Although examples have been found elsewhere in the Empire, such as in Spain and Wales, the Păru Carpeni discovery is the only one still intact. What it shows is the amount of organisation needed to plan, execute, and maintain a properly drained mine. In addition to constructing and installing the wheels inside the mine, some planning must have been involved in laying out the drainage chambers in succession, as well as the financial impetus for erecting the system. Oversight of the operation of the wheels would also be required to some degree, as flooding of the lower chambers would make it extremely difficult to drain and restart an inundated mine.

572 CHBR (2006) 199–200; Cauuet (2008). See also section 3.2.3 in this thesis.

The wheel at Cătălina Monulești was first discovered in 1855 and described by Pošepný in 1868, and the recent find by the French team in 2012 may well be a rediscovery of the same wheel.[573] The archaeological campaign ended before excavation of the wheel finished, and results have not yet been published in full, but hopefully future work will clarify the rather confused account provided by Pošepný and others.[574] Provisionally, it seems that at least 25 pairs of wheels were set up in a series to drain a 75 m deep shaft. Davies accepts Pošepný's 25 pairs, but Oleson rightly points out that while 50 wheels is possible, Pošepný's numbers have yet to be verified. Further excavation is clearly needed to answer this question, but if the evidence from Păru Carpeni is any indication, the Romans were certainly capable of organising complex drainage systems at Roșia Montană and elsewhere, as the evidence from Ruda-Barza seems to suggest. The question remains, however, as to who was involved in setting up and managing these systems.

Due to the complexity of the endeavour, it is rather tempting to assume that the Roman central authorities played an influential role in organising or constructing the drainage chambers. This is certainly possible: the Roman army would have the technical expertise to construct such mechanical devices, as well as the means. The presence of the army associated with the surface finds at Carpeni Hill could support this view, but it is also possible that the army was present mostly in an administrative or supporting role. The miners at Roșia Montană were highly skilled professionals as evident from their tunnelling expertise, and the community may have had a dedicated team of woodworkers providing auxiliary services for mine infrastructure. The quality of the wood propping found in the

573 See the section on the Coș-Lety underground mining evidence.
574 See Oleson (1984) 276–9 for a summary. The wheel is incorrectly reported as being found in both Mt. Orla (Orlea) and Katelin Monulesti (Cătălina Monulești); this may be a result of conflation between the Păru Carpeni and Cătălina Monulești wheels.

galleries at Roșia Montană indicates the presence of skilled carpenters; whether these woodworkers were specialists or also miners cannot be ascertained, but they would have had the requisite carpentry skills to make the individual pieces needed for a water-lifting wheel. It is thus entirely possible that the drainage systems were not entirely state-directed (if at all), but an investment on the part of the mine lessees to increase the productivity and longevity of their mines.

One possible scenario could involve an engineer—possibly from the army—providing instructions for building the water-lifting devices, with local woodworkers making the individual components that were then assembled and installed inside the mines. The unassembled wheels could also be transported to other nearby mines and constructed there as needed, eliminating the need for extensive state involvement with respect to providing technical expertise once the initial instructions had been conveyed. The morphological similarities between the Dacian water wheels within the province certainly suggests a generic template or method for building these wheels. The parallels between the Păru Carpeni and Cătălina Monulești wheels and the one from Dolaucothi in Wales could indicate the transference of knowledge by means of the army, as we know, for example, that the army was based at the Pumsaint fort and involved with the gold mining at Dolaucothi.[575] But the fundamental point is that the state's involvement in the actual management of the mines at Carpeni and Cătălina Monulești need not have been heavy-handed as a result, even if they did provide some form of technical or administrative assistance. The multi-wheel drainage systems represent an investment to be sure, but with a corps of trained carpenters present and already providing much needed gallery infrastructure, commissioning a series of water wheels would not have constituted a great

575 See Burnham and Burnham (2004) 6–8, 329 on the Dolaucothi excavations.

difficulty from a technical standpoint under this scenario. With regards to expense, installing a mine-drainage system would still have been an outlay, but one with reduced costs if the skilled labour for both carpentry and mining were readily available to build the wheels and drainage chambers respectively—which they were.

There is no way of conclusively identifying who supervised the mines with water wheels at Roșia Montană. But if there is indeed a relationship between the underground mining works and the provision of engineering expertise by the army, this might help explain why the presence of the Roman army has largely been found near the mines where water management was particularly crucial. Cârnic, which had better natural drainage, did not need the same water management as the mines of Orlea-Țarina, Carpeni, or Coș-Lety, and lacked a strong army presence. Coupled with the rich deposits, Cârnic would have been a particularly attractive site for exploitation, as the extensive mining networks indicate. However, the Romans were clearly capable of working the deposits on the northern banks of Roșia Valley, where skill in water management was key to their success.

4.7 Hydraulic mining and gold washing

Mining in Roman Dacia was not limited to the underground, hard-rock mines, despite the overwhelming attention paid to the admittedly impressive remains of Roșia Montană. The Romans had mastered the application of water technology in mining in the two centuries prior to their annexation of Dacia and evidence of their proficiency still marks the landscape where large-scale hydraulic exploitation occurred, most notably in north-western Spain, such as the sites along the Sil and Duerna valleys.[576] The suitability of hydraulic-mining techniques is largely dependent on the local geology. However, these

576 Domergue (1990) 35 ff., 510; Lewis and Jones (1970); Jones and Bird (1972).

methods could be applied in different geological contexts and at various points in the mining process. The erosive power of water could be used to work placer, alluvial, and hard-rock mines, and could also be harnessed for prospection to clear overburden or for washing ore out of waste rock. Considering that technological expertise was clearly not a barrier for the Romans, we can reasonably expect to find evidence for the use of water power in Dacian mines where viable, especially at alluvial deposits.

There are indeed a handful of examples in Dacia where the Romans employed mining methods that involved the use of water in surface exploitation. Out of 91 sites with reported traces of Roman mining, about 25 have possible signs of hydraulic mining, gold washing, or water infrastructure of some sort.[577] These figures are in no way exact, but do offer a starting point for reassessing the incidence of hydraulic mining in the province, contra the prevailing emphasis on the underground mines. However, to do so, it is necessary first to define what constitutes hydraulic mining and to differentiate instances of its use from the more general term "gold washing".

Hydraulic mining is understood here as hushing, which is the erosion of overburden by the sudden release of water from a reservoir to expose ore-bearing rock, or ground sluicing of alluvial deposits. This method can be used either for prospection or clearance, and can be applied to both hard-rock and alluvial mines. Instances of hydraulic mining at hard-rock and alluvial deposits can be found in Dacia, indicating that Roman miners were adept at its use in a variety of geological settings.

Gold washing, in contrast, is the more general and problematic term, and admittedly can sometimes be used to describe hydraulic mining methods in the sense of

577 See Appendix 2. These numbers include both precious and non-precious metal mines, as well as entries with unconfirmed or possible mining activity.

“using water to wash out (i.e. erode) ore”. The basic definition is the act or process of washing auriferous soil for gold. What it means here is either: the use of riffle boxes, troughs, or similar structures to separate out the heavier ore from the lighter gangue, which is then washed away by water; or the digging of pits into the riverbank that are used to wash gold out of alluvia (“river-bed mining”). Although some infrastructure can be used to aid in gold washing, the use of the phrase “gold-washing installations” in the current secondary sources is not at all clear. The evidence for these two methods of gold washing thus largely consists of piles of gravel, usually in dumps by the river. What is not included in this definition are gold panning on a small scale with handheld implements, even though it probably also occurred concurrently, and the use of water in ore processing, which belongs in its own category.

Unfortunately, the subject of Roman hydraulic mining is a particularly muddied field in the secondary literature on the Dacian mines. The earlier literature—where there appears to be some awareness of hydraulic mining as a distinct mining method from gold washing—is sometimes clearer than the most recent work from the past two decades. M. Macrea defines gold washing as the collection of gold from river sand, after the method described by Strabo in *Turdetania*, Spain.[578] Most of the evidence in Dacia consists of sand or gravel mounds remaining on river banks, not just in the Apuseni (the Arieș, Crișul Alb, and Ampoiul basins), but possibly also along the Jiu (Petroșani, Iscroni, Uricani) and in the Banat (Turnu Rueni, Borlova, Bolvașnița, Berzovia, Dognecea). This would seem to indicate that “gold washing” at these sites refers to the digging of pits on the river’s edge or other methods of washing alluvial river gold such as the use of troughs, rather than larger scale processes like hushing.

578 Macrea (1969) 301; cf. Strabo III.2.8.

Hydraulic exploitation is not unknown in the Romanian secondary literature, despite the lack of analysis by current scholars. V. Christescu differentiates the use of hydraulic methods—which he considers a type of mining—from the extraction of gold from river sand ("scoaterea aurului din nisipul aurifer").[579] Furthermore, he also makes some attempt to distinguish the washing of crushed ore that is part of the beneficiation process, which could sometimes require the provision of water, as seen at Boița (Băița).[580] Both of these activities are different from hydraulic exploitation ("exploatarea hidraulică"). However, Christescu's understanding of hydraulic mining is not entirely correct: in describing the washing of ore out of collapsed debris, Christescu paraphrases the second half of Pliny's description of *ruina montium*.[581] In this process, water was channelled using canals (*corrugi*) over long distances on a level slope to the mountain heights, filtered through stones, and impounded in reservoirs. The sudden release of the reservoir water created strong flows for washing the gold ore out of the mining debris. After recovery of the gold, the waste water and gangue were then carried away in other channels called *agogae* to the nearest river. He cites as evidence cuts in the hillside—called "jeugă" by locals—that led water from the peaks for hundreds of meters, such as at Piatra Seacă near Almașu Mare, and the reservoir at Corabia in Bucium[582] Based on this, it appears

579 Christescu (1929) 12, 20.
580 Christescu (1929) 19: "The grinding of the ores was done with the hammers and mills, which ground everything; then washed. At Boița, it was given to the stone mills, to the stones that ground the ore [...] The washing of gold (spălarea aurului) is seen after the provision of water conduits (conductelor de ăpa)"; cf. Téglàs (1883) 144. NB: Although translated here as "water conduits", the term can variously refer to water pipes, water-channelling ditches, or even aqueducts.
581 Pliny NH XXXIII.21.74–77. Cf. Téglàs (1890) 12–3. There is no evidence, as far as I can tell, of ruina montium being used in Dacia.
582 Christescu (1929) 19: Christescu mentions the reservoir at Vulcoi–Corabia but does not appear to have realised that the Ieruga opencast was hydraulically mined. I have not been able to track down the etymology of "jeugă", but one wonders if it is related to the Greek ἀγωγαί (agogae) as suggested by A.I. Wilson (May 2018, personal communication). Téglàs (1893), writing in Hungarian, uses "jeruga", or Romanian for "canal, channel"; cf. Preston (1993) 92, 272. "Iarúga" and its cognates are loanwords in Old Russian, Serbo-Croat, and the Slavic languages probably derived from Turkic roots (e.g. jar-yq), meaning "defile, ditch, channel, or watercourse"; cf. Menges (1951) 76–7.

hydraulic exploitation—to Christescu at least—is a method applied to hard-rock deposits. Even though he does acknowledge that alluvial deposits could be exploited with water, the hydraulic workings at Pianu de Sus are listed by Christescu as one of the Roman gold washeries ("spălătorii de aur").[583]

The most recent scholarship from the past 20 years has not directly addressed the lack of clarity surrounding gold washing and hydraulic mining in Dacia and, in some cases, has inadvertently compounded the confusion for Anglophone scholars. Leaving aside the matter of insufficient fieldwork and ground truthing, the two key problems with the literature lie in translation and definition.

The most widely available dataset in English is M. Simion's catalogue of mines in the *Cultural Heritage Baseline Report* commissioned by RMGC.[584] Hydraulic mining is not mentioned as such, and gold washing—with a few exceptions—is generically translated from the source material without further explanation as to what is meant by this term.[585] One of Simion's main sources is V. Boroneanț, and some of her entries appear to be translations of Boroneanț's original entries in Romanian, with literal renditions of "gold washing" or the exploitation of gold "through washing" into English.[586] The same appears to have been the case with records from the *TIR*, Simion's other key source, which uses the German "Goldwäscherei" to describe the remains.[587] Ultimately, most of the available modern sources fail to specify what is denoted by "gold washing", and the lack of

583 Christescu (1929) 12–3, 19 n. 3. Christescu's understanding of hydraulic exploitation as applied to alluvial deposits seems based on Strabo III.3.8–9, which actually describes the process of gold washing using pits or installations instead.
584 CHBR (2006) Appendix D.
585 Cf. the language used in CHBR (2006) Tables 5-1 to 5-5.
586 E.g. Surduc: "exploatării aurului prin spălare", Boroneanț (2000) 124. Note, however, that Boroneanț does seem to try to indicate the washing of gold sand in particular, which is not always reflected in Simion's work.
587 Cf. the use of similar terms in an earlier source, Marțian (1909): gold-washing remains are generically described as "Spüren alter Goldwäschereien".

deviation in terminology likely reflects an uncertainty on the part of modern scholars themselves, or acceptance of some widely understood meaning of the term in Romanian that has failed to translate with sufficient clarity into the English-language scholarship on mining.

In addition to the language barrier, there is a problem with definitions and imprecision, as "gold washing" appears to be an umbrella phrase that encapsulates a wide variety of activities. These range from the exploitation of river gold—whether by panning or installations on riverbanks—to large-scale hydraulic mining applied to alluvial or hard-rock deposits. The activity at Petroșani, for instance, probably refers to the washing of gold sand from the river ("Aici se spăla nisipul aurifer").[588] In contrast, the site of Pianu de Sus is simply described as an alluvial gold-washing centre ("centrul pentru spălarea aurului aluvionar"), even though its significant system of canals and reservoirs indicate that the "gold washing" taking place at Pianu de Sus is better described as the hydraulic method of ground sluicing or even hushing.[589] Even more confusingly, some ore-processing procedures also seem to fall under "gold washing": these include the use of water to separate out gold from gangue via gravity, or the washing of crushed ore during the beneficiation process. There is clearly scope for a more precise approach to hydraulic mining and gold washing in the Dacian mines, so that we can identify the use of these methods in Dacia and move beyond the current focus on the underground mining remains and Roșia Montană.[590]

588 Boroneanț (2000) 125.
589 Wollmann (1996) 149–50.
590 See 5.2 for an analysis of possible hydraulic-mining and gold-washing sites.

4.8 Conclusion

Despite the need for further archaeological research, there is a coherence to the evidence that clearly demonstrates the skill, knowledge, and proficiency of the Roman miners in Dacia. The study of mining technology and techniques in this case is not so much a question of innovation, but rather one of competence and application. Roșia Montană in particular reveals how Roman mining could very much be a professional endeavour, one that required a proficient workforce to succeed in extracting ore at the scale witnessed. Although the other Dacian mines are not well researched in comparison, corroborating evidence such as the reported water wheels at Ruda—also an underground mining site in the Golden Quadrilateral—suggests that Roșia Montană is probably not a unique, only a larger and better studied site than the other gold mines in Dacia.

5

The Mines of Roman Dacia

Due to the depth of research undertaken there, it is sometimes easy to forget that Roșia Montană was one of several gold-mining hubs in Dacia, especially since the secondary literature tends to emphasise the unique nature of the findings—this thesis included. Nonetheless, despite the wealth of evidence, the site needs to be contextualised against the other known gold mines in Dacia. It is unclear to what extent Roșia Montană is in fact typical of mining in the rest of the province—especially with respect to scale and intensity—even considering differences in geology and mining technique. To do so, the first portion of the analysis focuses on the hard-rock mines in the immediate vicinity of Roșia Montană: namely, the goldfields within the Golden Quadrilateral. This helps situate the evidence from Roșia Montană alongside comparable gold mines on a regional level. Next, reports of gold-washing sites will be assessed, in an attempt to disambiguate the evidence and identify the application of hydraulic mining methods in the province. Finally, an examination of the remaining known gold and non-precious metal sites in Dacia will illustrate the differences between mining in the Golden Quadrilateral and the rest of the province.

Although Dacia is best known for its gold, this chapter also examines Roman exploitation of non-precious metals as economically important iron and copper deposits are present in the region. Iron was a crucial metal for everyday use—particularly by the Roman army—which presumably would have been important in a militarised frontier province like Dacia, as was copper. Though the non-precious metal mines are not directly comparable to the gold mines *per se*, they are necessary for an overall understanding of

Roman metal-resource management as well as the chronology of mining in the province. The primary aim is to provide a systematic review of the currently known Roman mining sites in order to identify possible patterns of Roman mining activity in Dacia.

5.1 Gold-mining sites in Dacia

5.1.1 The Golden Quadrilateral

The so-called "Golden Quadrilateral" is an exceptionally dense concentration of gold-bearing deposits in the South Apuseni Mountains, with its vertices defined by the mines of Baia de Arieș (north), Zlatna (east), Săcărâmb (south), and Baia de Criș (west). The area's importance stems not just from the remarkable geological wealth, but also the zone's arguable centrality to Roman gold mining in Dacia. In terms of its geology, the mines in the Golden Quadrilateral exploited deposits most similar to those at Roșia Montană, and we would expect to see the Romans applying similar methods here. The principal ore-bearing districts with evidence of Roman activity fall into three general groups, going from north to south: Roșia Montană-Bucium, Stănija-Zlatna, and Brad-Săcărâmb (*fig. 10*). Beginning with Bucium, given its relative proximity to Roșia Montană, the discussion will cover each group in turn, as listed above.[591]

Geology

The geology of the Golden Quadrilateral is complex and cannot be discussed in full here, but the main point is that there are some differences across the three gold belts. The region is host to numerous epithermal and mesothermal Ag-Au, Cu-Au, and Cu, Au, Ag, and base

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591 NB: Unless expressly noted otherwise, the use of "district" in this chapter denotes modern mining districts in a geological sense, rather than Roman mining administrative districts.

metal deposits associated with volcanic activity, with gold mining mostly taking place in the high-grade epithermal veins found in the three belts.[592] These Au-Ag epithermal veins are the most relevant primary deposits with respect to Roman-period exploitation. It is also worth noting that Neogene volcanic activity also occurred in two additional isolated areas: Baia de Arieș in the north-eastern corner of the Golden Quadrilateral, and along the Mureș valley to the south.[593]

There are two metallogenetic types in the Golden Quadrilateral—calc-alkaline andesitic (CAM) and sub-alkaline rhyodacitic (SRM)—both of which generate low-sulphidation Au epithermal deposits.[594] The Roșia Montană-Bucium belt is more complex than the other two, as both CAM- (Roșia Poieni, Bucium Tarnița, Vulcoi-Corabia) and SRM-type environments (Roșia Montană, Bucium Rodu, Frasin) exist. The Zlatna-Stănija belt, in contrast, contains mostly CAM-type structures, except for the Fața Băii deposit (SRM-type). Brad-Săcărâmb has similar characteristics to Zlatna-Stănija, with mainly CAM-type andesitic structures (Barza, Troița-Bolcana, Coranda-Hondol), but a few SRM-type patterns are also present (Măgura Ţebii, Băiţa-Crăciuneşti, Săcărâmb).

The two ore-generating types form different deposits.[595] The CAM-type deposits take the shape of open-space veins, although stockworks are also common. SRM-type deposits are more complex, resulting in breccia pipe and stockwork formations, subordinate vein systems, and massive sulphide veins, with minor replacement ore bodies. What this means is that the Golden Quadrilateral is unique in possessing both world-class gold deposits such as Roșia Montană, as well extremely rich, smaller concentrations of

592 Eldorado Gold (2014) Section 7.
593 Tamaș et al. (2006).
594 See Vlad and Orlandea (2004) for a full explanation of the metallogenesis of the Golden Quadrilateral.
595 Vlad and Orlandea (2004) Table 1. Cf. Tamaș et al. (2006) Figure 2.

deposits in places like Barza and Săcărâmb.[596] Of all the gold deposits in the Golden Quadrilateral, Roșia Montană is the largest and most important. It would be interesting to see the degree to which the richness of the ore bodies corresponds with the archaeological evidence and the expected level of Roman activity. Based on geology alone, Roșia Montană should display the highest levels of exploitation.

Of the Roman sites known in the Golden Quadrilateral (*Aurariae Dacicae*), almost all are associated with gold mining (*figs. 24, 25*). Even at Abrud, the only *castellum* in the immediate region, there is evidence for a settlement and mining activity, as well as a necropolis in the vicinity.[597] The location of these sites are not simply distributed along the local tributaries and drainage basins of the Southern Apuseni, but in fact adheres closely to the underlying geology and falls along the three distinct NW-SE striking gold belts mentioned above. This is not a surprising observation, given the *raison d'être* for most mining towns. However, the lack of other settlements in the region suggests that the Romans penetrated the Golden Quadrilateral specifically for one reason: the gold.

State of research

Although the region is well-known historically for Roman mining activity, modern coverage is poor compared to Roșia Montană, with a dearth of archaeological research at the other sites. Most of what is known are collations of earlier Austro-Hungarian accounts and chance finds in the area, supplemented by small-scale or early 20th-century excavation reports where available.[598] Records of such findings, in addition to being dated, are largely

596 Udubasa et al. (2001).
597 Popa (2002) s.v. "Abrud".
598 E.g. Davies (1935) is the earliest in English, but coverage is brief. Later work, such as the CHBR (2006), draw heavily on the same sources, with little new information added. The best resources are probably Wollmann (1996) and RepAB (1995), the latter of which collects the material from the secondary sources in

unverified, with questionable reliability. Significant finds such as the water wheels of Ruda-Brad and Bucium, for example, have not received further investigation, despite their importance to our understanding of Roman water management in underground mines. Although there is now newer evidence for water wheels from the Roșia Montană excavations, there is still a need for additional examples from elsewhere in the province so the wheels can be studied more systematically.[599]

Excavation evidence, in general, is piecemeal and limited. The mining sites have not garnered much interest—or funding—beyond the developer-led archaeology at Roșia Montană. Of the three districts, rescue excavations were carried out in Zlatna in the 1980's but in the modern town, with no recent work on the mining remains.[600] A search of the *Cronica Cercetărilor Arheologice din România*, the online database of archaeological work carried out annually in Romania, reveals no new excavations in Zlatna, three records for Bucium, and one for Brad.[601] To date, the most significant project is the Bucium Valley Research Programme led by Horia Ciugudean, with fieldwork begun in 2003.[602] Unfortunately, the programme's current status is not entirely clear, nor have there been further publications beyond Ciugudean's 2012 article.

There is a pressing need for further archaeological study in the Golden Quadrilateral. As with Roșia Montană, these mining sites face an uncertain future, either through neglect or threat of development. Whilst public attention has centred on Roșia

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one place, but only for Alba county. Popa (2002), which summarises the earlier findings for known Roman settlements in Dacia, has been used to supplement the RepAB (1995).

599 The main specialist study on water-lifting devices remains Oleson (1984), which pre-dates the Roșia Montană excavations.

600 Popa, Moga and Ciobanu (1986).

601 The database covers excavation reports from 1983 to 2017 and can be found at http://cronica.cimec.ro/CercetariARH.asp. Entry IDs: 3077 and 3329 (Bucium), 3604 (Bucium Șasa), and 740 (Brad).

602 The project website is available at http://www.buciumland.ro/index.php, but is dated 2005 and does not appear to have been updated recently. Images from the 2017 field season are available from the project's social media account (https://www.facebook.com/Ancient-gold-mining-in-Transylvania-the-Bucium-valley-project-1162901410421664/), archived at http://archive.is/FxPY0. See also Ciugudean (2010), (2012).

Montană in the battle for heritage and environmental preservation, mining conglomerates have been seeking permits for sites elsewhere in the region, where it is in their interest to maintain a low profile given the ongoing legal disputes (*fig. 26*). Gabriel Resources, the Canadian parent company of RMGC, for example, has also applied for exploitation licenses at neighbouring Bucium. The proposed area covers Rodu-Frasin and Vulcoi-Corabia: two key areas with Roman mining remains at Bucium, and arguably the next most important archaeological site in the Golden Quadrilateral after Roșia Montană. Other companies with vested mining interests include Carpathian Gold (Rovina Valley Project) and European Goldfields/Eldorado Gold (Certej Project), both seeking to exploit sites in the Brad district to the south.[603] Of the two, the Certej Project is of greater concern as several Au-Ag deposits known to have been exploited during the Roman period fall within the license's remit (e.g. Hondol, Măgura, Săcărâmb, Băiţa-Crăciuneşti).[604] Even more troubling, feasibility reports by Eldorado Gold downplay pre-modern mining activity as "artisanal", "small-scale", and "rudimentary", with no further detail given to any remains pre-dating the 18th century.[605] The modern open pit, which ceased operation in 2006, is located north-east of modern Hondol and situated above underground workings.[606] This is the main area that Eldorado Gold is seeking to develop. The Hondol and Săcărâmb mines constitute the same complex, and Roman gold extraction reportedly took place at Coranda Hill (the modern opencast), at the edge of the town.[607] We simply do not know enough

603 Carpathian Gold Inc. (2012); European Goldfields Limited (2009); Eldorado Gold (2014) and (2016). European Goldfields was originally part of Gabriel Resources prior to company restructuring in 2000.
604 The Rovina deposit is a porphyry copper-gold deposit similar to Roșia Poieni (north of Roșia Montană) and is considered sub-economic for pre-modern exploitation.
605 Eldorado Gold (2016) 6-1.
606 Eldorado Gold (2016) 5-2, 6-2. It is unclear in the plan on 6-2 which works are "historic"—one assumes the underground galleries, given the development at Săcărâmb—and what the approximate dates of the workings are.
607 Tudor (1968) 191; Boroneanț (2000) 128; CHBR (2006) 137.

about the Roman presence at Săcărâmb to rule out the very real possibility that the Certej Project will destroy any extant evidence.

Although not directly affected by the proposed modern mining projects, the remains from Ruda-Barza, southeast of Brad, hint at the wealth of evidence yet to be found: water-wheel fragments as well as the so-called "Roman Steps" ("*Treptele romane*") are known from the Roman galleries there.[608] These reports require further verification, but such finds suggest that Roman-period activity was likely far from rudimentary for its time, if the results from Roșia Montană are any indication. Roșia Montană is an important site, to be sure, but it is clearly by no means the only one worth investigating or preserving when the mining archaeology of the entire region is under threat.

5.1.2 The Roșia Montană-Bucium belt

The next most important centre for mining activity in the Golden Quadrilateral after Roșia Montană is Bucium, located on the south-eastern end of the same gold belt. Like Roșia Montană, modern Bucium is a commune of dispersed alpine settlements, consisting of 30 settlements scattered along the valleys, hills, and on the slopes of the Detunata and Vulcoi-Corabia mountains.[609] There are three main epithermal Au-Ag occurrences and one of porphyry copper-gold (Bucium-Tarnița).[610] Roman activity has been identified at the two adjacent northern Au-Ag deposits of Rodu and Frasin, and at Vulcoi-Corabia in the south, with the most detailed evidence coming from the latter (*fig. 27*).

Much of what we know comes from Mount Corabia and was reported in the late 19th century by the Austro-Hungarians, followed by excavations of the cemetery in the

608 The site, however, does appear to fall within the concession granted to European Goldfields; see European Goldfields (2009) Figure 9-1.
609 NB: All six of the major villages in the commune can appear with "Bucium" prepended in the full name (e.g. Bucium-Sat). References to the village of Bucium here is to Bucium Șasa.
610Data from http://www.gabrielresources.com/site/bucium.aspx. Archived at http://archive.is/ZoAsu.

1930s by O. Floca.[611] Although N. Maghiar's discovery of a wheel fragment in Sf. Petru și Pavel mine in 1929/30 is significant, there has been no further investigation.[612] Initial research carried out by Gabriel Munteanu in the wake of Roșia Montană seemed promising, and we await a fuller publication on Bucium.[613] The most recent surface fieldwork is H. Ciugudean's Bucium Valley project. Even though the results have not been published in full, Ciugudean has at least verified the existence of hydraulic mining remains on Vulcoi-Corabia as well as the location of the underground Sf. Petru și Pavel mine.[614] This data is further supplemented by site records in the Repertoriul Arheologic Național (RAN), especially for the excavations at Frasin and Rodu.[615] Limited archaeological information is also available from the Universitatea de Vară Bucium (Summer University of Bucium) on the vestiges of later mining and architectural remains in the landscape.[616] It appears that the Summer University programme, also directed by Ciugudean, has superseded the Bucium Valley project. In addition to publishing a series of reports, the programme's umbrella organisation, RPER, has helped establish an ethnographical mining museum at Bucium-Poieni and will hopefully continue their research in the commune.[617]

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611 Floca (1936–1940).
612 Maghiar and Olteanu (1970) 70 n. 32, 76. Both Wollmann (1996) and Oleson (1984) cite Maghiar and Olteanu (1970), but neither appear to have found additional information about the wheel.
613 Munteanu (2014). As Gabriel Resources had applied for exploitation permits at Bucium, it is possible that developer-funded archaeological work was originally undertaken by Munteanu under the supervision of B. Cauuet, PI of the underground excavations at Roșia Montană.
614 Ciugudean (2010), (2012).
615 RAN Codes 3468.01 to 3468.04.
616 See http://rper.ro/. The summer education programme is run by the Rencontres du Patrimoine Europe-Roumanie Association (RPER) under the auspices of the Romanian Academy. Exploration of the archaeological landscape of Boteș and Vulcoi–Corabia is included, but as part of the programme's wider agenda of education and preservation of Bucium's cultural patrimony.
617 The mining museum was established in 2017 by the Baia Domnilor Association. See http://www.baiadomnilor.ro/.

Vulcoi-Corabia

Although the mines of Bucium are frequently referenced in the secondary literature as if they belong to a single site, the two gold deposits with evidence of Roman activity—Rodu-Frasin and Vulcoi-Corabia—are some 5 km apart. The most well-known remains are at Mount Corabia (1351 m) corresponding with what usually constitutes "Roman mining at Bucium" in scholarly references.[618] Located south and south-east of the modern town of Bucium on the mountainous massifs between the Ampoi and Arieş basins, the Vulcoi-Corabia remains constitute the most important evidence of Roman mining in Dacia after Roșia Montană. Though not as extensive in size and scope as some of the individual sites at Roșia Montană, the range of activities found on Corabia encompasses the whole gamut expected of an established mining base: exploitation points, ore-processing areas, and miners' settlements and cemeteries. Even more importantly, the mines at Vulcoi-Corabia have largely escaped the impact of later human intervention in the post-Roman and modern periods and remain relatively intact.[619]

Roman exploitation at Corabia centred around two mines near Vulcoi peak, Gaura Perii and Ieruga, both of which are reasonably substantial opencast mines (*fig. 28*). Although not as extensive as the modern opencast that has obliterated the Roman remains at Cetate, Roșia Montană, both Gaura Perii and Ieruga are visible from the air. Modern surface investigation, however, is impeded by the encroaching trees, and details are best seen in earlier images of the two mines (*figs. 30 and 31*).

Gaura Perii, the smaller of the two mines, is cut into the southwest slope of Corabia. Ieruga is the largest of all the mines in the area. Exploitation started at the top of the

618 Popa (2002) and RepAB (1995), both of which have summarised the earlier Hungarian and excavation reports, form the basis for the following synthesis of the surface evidence at Vulcoi–Corabia, with additional references as needed.
619 RPER (2014) 21, nr. 21.

mountain, at 1349 m, and pursued a quartz vein downwards. At the deeper levels of the mine, the Roman miners drove a large adit measuring over 600 m long and 40 m deep.[620] The long trenches cut into the slope of the eastern edge of Ieruga, leading to a small pond—what Ciugudean calls "ore treatment areas"—are remains left from the application of hydraulic mining techniques. The opencasts were excavated using iron tools, as some faces bear the traces of pickaxe markings. Although Ciugudean postulates the application of fire-setting, he found no evidence of its use. Several mortars and grinding stones found in the area roughly date both the workings to the 2nd to 3rd century.

The opencasts at Vulcoi-Corabia are fairly sizeable, and a comparison to the known Roman workings from Cetate at Roșia Montană indicate that the larger of the two mines, Ieruga, could come close in size. The approximate extent of Ieruga at the bottom, as noted by Ciugudean in his field surveys, is at least 600 m long by 40 m deep. The four so-called "Roman Courts" at Cetate, in comparison, ranged from around 300 m^2 and 40 m deep, to 2400 m^2 and 60 m deep (*Table 3*). Although these numbers are not exact and the Cetate opencasts are pit workings opened by hand versus the vertical, v-shaped trenches at Vulcoi-Corabia, the size of Ieruga falls in the mid to upper range of the Cetate opencasts. Ieruga is larger than Court 3 at 600 m^2 by 50 m, and possibly even Court 2 at 1200 m^2 by 50 m, taking into account that the measurements for Ieruga are approximated from the adit driven at its base. Although it is difficult to date how long the two Bucium mines were in use, the size of Ieruga indicates that mining was probably intense in scale, if not also in duration.

Although Ieruga and Gaura Perii are the only workings large enough to still be easily observable today, the vicinity of the two mines is riddled with the remains of numerous

620 Ciugudean (2010) 264–5.

smaller opencasts and dumps spread out over a large area. Mining took the form of long trenches, starting as opencasts at outcropping veins, and measured between 10 to 100 m long, 5 to 40 m wide, and 3 to 15 m deep.[621] Possible underground galleries may exist, but are difficult to identify due to collapse and the infilling of waste material.[622] Geological analysis of the Corabia-Ieruga vein in the early 1980s also revealed that at least 30% of the gold present is in the form of free gold, as grains, flakes, or nests.[623] The relative richness of the backfill in some of the old galleries registered at several grams per tonne and consisted of microscopic and nearly invisible free grains, suggesting that ancient miners likely targeted clay-dominated ore—probably high-grade—with visible free gold. Unfortunately, there is not enough chronological clarity to ascertain when these other mines were active. Nonetheless, the evidence suggests that mining at Vulcoi-Corabia was probably even more extensive than what has been studied thus far, and hints at fairly high levels of activity in the Roman period.

Vulcoi-Corabia is also notable for its hydraulic mining remains. The hydraulic mining evidence consists of the channels cut into the landscape perpendicularly to the Ieruga opencast, and the various water conduits and reservoirs still visible on the slopes of Poduri for extracting and processing the gold ore (*figs. 28, 29*). Although these remains are frequently cited as proof of the importance of Bucium as a Roman mining site in Dacia, the wider implications of the use of hydraulic mining have not been fully explored, nor assessed against the other methods of mining seen in Dacia. The hydraulic remains and their use will be discussed in greater detail below.[624] For the moment, what needs to be

621 Ciugudean (2010) 264–5.
622 Ciugudean (2012) 225.
623 Ciugudean (2010) 263.
624 See 6.2.

noted is the scale of the operation and the investment of effort involved, which supports the general picture of an intensely worked site.

In addition to the mining remains, the other surface finds at Vulcoi-Corabia and its environs for housing suggests the presence of an active mining community, one large enough to have aggregated into a mining settlement, and permanent enough to have left behind traces of inhabitation. Some of the miners appear to have lived in close proximity to their workplace: signs of miners' dwellings, plus the residue of unprocessed ore, were reported in the vicinity of the channels and reservoirs associated with the hydraulic exploitation.[625] The stone mortars and grinding stones found on south-east slope of Vulcoi-Corabia suggest the widespread processing of ore both close to the source and where workers lived.[626] As well as the miners' dwellings amidst the mine workings on Vulcoi, a settlement was also found at the foot of the mountain. The array of finds in the settlement comprise a variety of objects expected of a mining community. These include tools, ore-crushing equipment, a lamp with a FESTI stamp,[627] and a votive altar dedicated to Zeus Kimistenos.[628] The stone altar, which was dedicated by Myron, who was a miner or a mining official, indicates a Greek element to the mining population.

Funerary remains associated with the mining activity are also known (*fig. 37*). Several groups of graves found on the Boteș and Poduri hills form what can legitimately be considered necropoleis. Excavations on the burials were first carried out in the late 19th century by B. Lukács (2 tumuli) and G. Téglàs (42 tumuli), and then by O. Floca in 1938

625 Popa (2002) s.v. Bucium.
626 Ciugudean (2012) 232, Plates VIII, X, and XI.
627 CIL III, 8076, 15.
628 Popa (2002); RepAB (1995) 65.

(6 tumuli).[629] Ciugudean also reports the presence of ancient opencasts on top of Boteș, along with the burial mounds.[630] This could reflect a possible lack of space, as the surface remains cover a fairly wide area across the southern slopes of Vulcoi-Corabia, but there is not enough information to draw any conclusions.

The tumuli were about 6 m in diameter and 1 m high, with an average distance of 3 to 4 m between each tumulus. Some had a ring of stones at their base. Within these tumuli were cremation tombs, with rectangular pits oriented E-W. Signs of burning indicate that cremation took place *in situ*, either in the pit or above, and some were done *ad ustrinum*. There were also a few brick-lined inhumation graves, typical of Roman custom. Tomb inventory was also fairly typical, and comparable to assemblages such as those found at the Roșia Montană settlements: various ceramics (pots, jugs, cups), terra sigillata, glass vessels and beads, lamps,[631] fibula, a metal mirror, bone objects, spikes, and iron nails.[632] Coins from Trajan, Hadrian, and Antoninus Pius place the date of these burials to the expected height of Roman mining in the province. Several funerary monuments were also found, with decorative reliefs of stars and medallions, as well as fragments of a funerary inscription.[633] There are no structures like the large Circular Funerary Monument at Roșia Montană, however, which seems to indicate a modest level of wealth amongst the inhabitants of Vulcoi. Overall, the similarity of the evidence at Vulcoi-Corabia to the remains at Roșia Montană indicate that the cremation graves belonged mostly to miners, who probably came from Illyria and Dalmatia. Although there are few clues to the overall longevity of the Vulcoi-Corabia site, the presence of these necropoleis suggests an

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629 Floca (1936–1940). The location and boundaries of the cemeteries excavated by the Hungarians were difficult to identify, even by Floca.
630 Ciugudean (2010) 263.
631 Some lamps were stamped: FOAR = CIL III, 8076, 14.
632 Floca (1936–1940); Popa (2002); RepAB (1995) 65.
633 CIL III, 7831.

established mining community that achieved a level of permanence. The need for multiples necropoleis also seems to indicate the presence of a large workforce, which would have been necessary based on the level of activity indicated by the mining remains.[634]

Despite its extremely remote mountain location, Vulcoi-Corabia was also fairly well connected. Remains of a Roman road have been identified in several places in Bucium and the southern slope of Corabia, and take the form of paved road fragments.[635] This would seem to suggest a certain amount of effort to connect the site to the wider region, as indicated by roads leading west to Abrud and south to *Ampelum* (*fig. 28*). Coupled with the signs of a dynamic mining community and the sizeable exploitation of the gold deposits, the need to ensure access to and from Vulcoi-Corabia further reinforces the site's importance within the group of Roman gold mines in the Golden Quadrilateral.

In terms of chronology, the activity in the Vulcoi-Corabia area dates broadly to the Roman period in Dacia. There is insufficient information to link the activity in and around Corabia to specific events such as the Marcomannic invasions or the Antonine Plague, as many of the small finds fall within a broad chronological window. The clay lamps found in the Poduri and Boteș cemeteries date to the mid-2nd century AD, a finding corroborated by the bronze coinage found amongst the grave goods of one of the burials.[636] In addition to the coins of Trajan, Hadrian, and Antoninus Pius mentioned above, a hoard was also discovered in the 1870s–80s on Negrileasa Hill, east of Corabia, of which eight coins dated to between AD 116 to 167.[637] These dates are in keeping with the burgeoning of mining activity at Roșia Montană. Much more work is needed to refine our understanding

634 Wollmann (1996) 141.
635 RepAB (1995) 65; RPER (2014) 21, nr. 21.
636 Floca (1936–1940) 172.
637 These eight coins were in the possession of B. Lukács, who excavated the surface remains along with G. Téglàs. The remainder was scattered to private individuals, whereabouts unknown.

of the site chronology at Corabia, but the general premise of a speedy start to mining soon after the Roman conquest in AD 106, followed by an external shock leading to a decline in activity in the late mid-2nd century could probably apply to the mines of Bucium as well. The piles of partially exploited ores left behind on Vulcoi-Corabia could possibly be related to the sudden abandonment or depopulation of the site, but more supporting evidence is needed to demonstrate this.[638]

The question of pre-Roman mining at Bucium, however, is still a matter of some debate. Ciugudean is a proponent for mining activity as early as the Bronze Age.[639] He argues that the road linking Zlatna and Bucium has much earlier precedents and is related to the Early Bronze Age barrows along the Morile, a tributary of the Ampoi, and that the alignment between the two in the local topography channelled the traffic along specific routes. This constituted a "Golden Corridor" along the Ampoi valley that was part of a larger trade network connecting the Transylvanian mines to the elite consumers of neighbouring regions. These ancient miners, Ciugudean believes, not only exploited the river gold of the Ampoi and its tributaries, but also worked the hard-rock deposits of Vulcoi-Corabia. Accordingly, the Roman mining seen at Bucium and neighbouring Roșia Montană was nothing more than a reorganisation and enlargement of earlier mining activity, based on the application of improved technology.

The key contention here is whether the available evidence for opencast mining at Bucium points to any degree of prehistoric exploitation.[640] Firstly the presence of Bronze Age barrows in the general vicinity of the mines does not necessarily mean that the two existed or were worked in the same period. The presence of opencast mining is undeniable

638 RepAB (1995) 65.
639 Ciugudean (2012).
640 See Chapter 2 for the argument against significant pre-Roman mining at Roșia Montană.

at Vulcoi-Corabia and it is certainly true that such workings are difficult to date to a specific chronological window, but the associated surface remains demonstrably point to Roman activity. Whilst it is certainly conceivable that small-scale surface exploitation may have taken place on outcropping veins before subsequent Roman mining destroyed all traces, there are very few signs of Dacian activity in general. The discovery of a silver tetradrachm of Phillip II of Macedonia as well as what seem to be traces that are Dacian in origin is intriguing, but inconclusive.[641] Other evidence of pre-Roman activity include the four Bronze Age gold rings found at Vulcoi, and the hoard of coins from Thasos dating to the Iron Age period discovered elsewhere in the northern part of the commune.[642] Again, these do indicate the presence of pre-Roman peoples, but is insufficient evidence to argue decisively for pre-Roman mining—of any significant level—in the Vulcoi-Corabia area. At the moment, the surest dating we have for the levels of activity seen at Vulcoi-Corabia is from the Roman period.

Citera Slăveșoi: the Sf. Petru și Pavel gallery

In addition to the surface mining activity, underground exploitation also took place at Bucium. The main example is Sf. Petru și Pavel (1351 m), part of the Baia Domnilor group of underground works on the northern slopes of Vulcoi overlooking Bucium Valley, and on the opposite side of the hill to the Vulcoi-Corabia surface workings on the southern slopes (*fig. 28*).[643] Baia Domnilor was worked in the 19th century and is famous for an 1886 miners' uprising, but there is potential for the discovery of additional Roman galleries within this network. Surveys near the mine found geomorphological disturbances

641 RepAB (1995) 65.
642 RepAB (1995) 64. Ciugudean (2012) 224–5: apparently the silver coins were found in the ancient mines. The idea that mining at Bucium predates the Romans is not a new one, and was espoused by Téglàs (1893) 411, who also based his claim on the Thasos coins, as well as the impressively large size of the opencasts.
643 Téglàs (1890) 7; Ciugudean (2010) 263.

on the slopes near Bucium-Poieni village which might be due to gold mining and processing activity, alongside the intensive habitation of the area over the centuries.[644]

The Petru și Pavel mine is currently flooded and access for modern archaeological investigation is limited, but descriptions from Téglàs' and Ciugudean's more recent survey reveal characteristics similar to the underground mines at Roșia Montană.[645] The galleries are trapezoidal in profile, and the average dimensions were 1.40 m wide and 1.60 m high, with tapering width from the entrance (2.20 m) into the mine. Ciugudean was able to access as far as 21 m into the mine before infill and water barred further access. Téglàs reported the dimensions of the galleries as 0.56 m wide at the ceiling and 0.65 m at the base; it is possible that the deeper galleries were narrower than the ones Ciugudean surveyed. The galleries were opened by iron tools, which left tell-tale marks behind on the walls, indicating pre-modern exploitation, and careful excavation of the rock meant that propping was rarely necessary. Lamp niches were also present. Finds include a wooden shovel made of ash, measuring 1.45 m long and 0.45 m wide, that was used for transporting ore.[646]

The most important find, however, is the compartmented water wheel discovered in Petru și Pavel by N. Maghiar. Its present whereabouts are unknown, but the morphology of the hub is identical to other drainage wheels in Dacia.[647] A wooden gutter used to evacuate water from the mine was also found. Although few fragments remain, Téglàs noted at the time the accuracy of the jointing and the precision of Roman engineering.[648] Not much more is known about this wheel, but the current inundated state of Petru și Pavel illustrates

644 CCA 2004 (2005).
645 Téglàs (1890) 10; Ciugudean (2010) 266.
646 Maghiar and Olteanu (1970) 79, 81; cf. photo on p. 80.
647 Maghiar and Olteanu (1970) 72, 76; Oleson (1984) 196–7. See 4.6.1.
648 Téglàs (1890) 10.

precisely why Roman water technology was necessary to work the underground deposits at Vulcoi.

Even though Bucium is better known for its opencast mining, the presence of underground galleries suggests that these two methods of exploitation were deployed as dictated by the geology. In terms of mining technique and technology, the evidence from Petru și Pavel does not seem to deviate significantly from the general characteristics of underground Roman mining at Roșia Montană, which is not particularly surprising given the proximity of the two communes.

Rodu-Frasin

Compared to Vulcoi-Corabia, the mining remains at Rodu-Frasin have not received much archaeological investigation at all, but is likely to yield further evidence of Roman activity (*fig. 38*). Geologically, underground mining can be expected based on the richness of the deposits available, assuming they were identified by the Romans. Deposits strike as veins at Frasin, with slightly more complex geological occurrence at Rodu, where they appear as veins, cross-cutting veins, and stockworks.[649] There is evidence of both surface and underground workings at Rodu-Frasin, with some of them possibly dating to the Roman period.[650] The workings take the form of numerous surface pits, along with mining galleries and corandas. These include, amongst others, the Frasin coranda, Vulturilor coranda, La Vulpea gallery, and Renghea gallery. The traces of past mining can be seen on the northern slopes of Rodu-Frasin, where galleries, dumps, and troughs and canals for collecting water were found. Excavations on the Muncei plateau on the southern side turned up some Roman ceramic fragments, which is highly suggestive. These preliminary

649 Ciugudean (2010) 262.
650 CCA 2004 (2005).

surveys strongly indicate levels of mining activity that could potentially be quite high, particularly if the remains of what appears to be a water-management system reveal evidence of hydraulic mining. There is also the potential to find more underground galleries to supplement Petru și Pavel, the only underground mine in the commune about which we have any detailed knowledge. Further work is very much needed to clarify the chronology and nature of the discoveries at Rodu-Frasin, but does offer the promise of substantiating some of the findings known to date at the other mining points in Bucium.

Bucium: another integrated mining landscape?

Like Roșia Montană, the environs of Bucium are full of potential: studies thus far suggest a veritable mining landscape that still needs to be documented and analysed not simply as an important example of Roman exploitation but as a commune rich in its own trajectory of mining activity. In addition to the Roman finds, there are plentiful modern remains, most of which have received even less scholarly attention. For example, underground galleries from the 18th- to 20th-century at Frasin and Valea Abruzel, and water-powered stamping mills in Valea Negrilesii and Valea Șesii have been recorded but not studied as part of a wider research programme.[651] Verifying these reports is interesting in its own right within the discipline of mining technology, but such an exercise could also broaden what is known about the Roman period. It could, for instance, be a starting point for identifying (or ruling out) any Roman remains, both through exploration of the underground galleries at Rodu-Frasin and surface identification of pre-modern stamping mills or possible gold-washing activity.[652] Numerous entrances to defunct gold-mining galleries from the 19th century dot the western slope of Frasin at the exit of Valea Abruzel

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651 RPER (2017) 15–7; cf. Plans XII.1–2, XIII.1–4, XIV.2 and 5. See also RPER (2013) 6–7.
652 Cf. Wollmann (1996) 142.

near Văleni, as well as the hill's eastern slope near the village of Valea Șesii (*fig. 39*).[653] Locals still refer to these galleries by name, and it would be worth exploring these mines further to identify any possible Roman remains. Cadastral plans from the turn of the 20th century also show that stamping mills lined both banks of Valea Abruzel, downstream from the clusters of mines exploiting the Rodu-Frasin deposits.[654] The prevalence of water-driven mills in the area is recorded as early as the late-18th century in the *Josephinische Landesaufnahme*, indicating the importance of ore processing to the economic life of the mining community and also the need for closer investigation.

A clearer grasp of the modern mining landscape at Bucium would thus allow for better differentiation between the Roman and modern remains. Whilst it would be reasonable to expect similarities to the finds at Roșia Montană, the lack of research at other mining sites in Romania seriously hampers efforts at comparison. Bucium, being a close neighbour to Roșia Montană in terms of distance and geology, is a prime candidate for future studies in this direction. Furthermore, it is important to remember that mining is an activity that destroys earlier traces; what persists in the landscape is a chronological palimpsest, with the modern evidence obscuring the older remains. Although this thesis is most obviously interested in the Roman period, modern mining is an important part of the site's "life", as it were, and Bucium—like Roșia Montană and many of the places in rural Romania where mining has persisted as a relevant economic pursuit until the present-day—is an opportunity to approach the mining archaeology as a complex, holistic landscape with ongoing relevance to the communities that reside there.

653 RPER (2014) 21, nr. 23.
654 RPER (2017) Plan XIV.5.

5.1.3 The Stănija-Zlatna belt

Despite being the seat of Roman mining administration in the Golden Quadrilateral, the mines in the Zlatna region around *Ampelum* have not been studied in any depth. Numerous traces of gold mining have been identified in the hills outside the modern village. The main mines in the Zlatna area include Almașu Mare, Cib, Poiana, Stănija, Techereu, Valea Dosului, and Vălișoara (*fig. 40*). Of these, Almașu Mare and Stănija were the largest and most important.

Almașu Mare was a large mining centre during the Roman period, with exploitation points located in the villages of Poiana and neighbouring Almașu Mic, and also on the surrounding hills of Toți Sfinții, Bojerița, Tuțuman, Runcu, Haneș, Baba, Dealul Negrii, and Piatra Seacă. Most of the mining and a rural settlement are in the hills to the north and north-west of the village. The variety of evidence is sizeable, and includes underground galleries, water conduits, and stamps, as well as possible hydraulic mining occurring at Piatra Seacă.[655] Evidence for additional mining settlements include the traces at Almașu Mic and Haneș Hill. In general, Roman activity at Almașu Mare is characterised by multiple exploitation points, most of which had accompanying settlements of modest size, populated with miners or menial workers (*leguli*).[656]

The mines at Stănija were dependent on Zlatna and the farthest west amongst those of the Crișul Alb. Traces of gold mining can be seen at numerous points in the surrounding hills. Underground galleries are known at Dealul Ungurului, Dealul Măgura, Valea Coacăzelor, and Fericeaua, and finds of bricks, ceramics, mortars, and lamps near the

655 Christescu (1929) 19. See also 6.2.1.
656 Tudor (1968) 189. On aurileguli, see Hirt (2010) 271–2.

village indicate the presence of a related miners' settlement.[657] One of the more significant finds that have reportedly come from the Stănija mines are the remains of a water wheel, but that information is by no means secure.[658] Some fragments of gallery propping have been recovered at Roșia mine, so it is possible that additional wooden remains are yet to be found in the underground galleries at Stănija.

The Roman-period evidence at the other sites around Zlatna also follows the pattern of small settlements associated with the gold-mining activity. Gold—and mercury—was exploited at Cib, where Roman material remains indicate the presence of at least two mining settlements near the village. Traces of a Roman settlement at Poiana was identified at the village's outskirts in association with gold mining; the remains included vestiges of wall, tiles, and ceramic fragments. At Techereu, surface mining occurred in the form of shallow shafts, and was discovered along with housing for the miners. The remains at Valea Dosului (Izvorul Ampoiului) consist of underground tunnels on the slopes of Dumbrava Hill and signs of rural settlement, both of which were probably Roman. Mining at Vălișoara (Porcurea) was related to the activity at Almașu Mare and *Ampelum* to the east, and the western slope of Măgura Hill was intensely worked during the Roman period.[659]

Zlatna itself has few examples of confirmed Roman mining in its vicinity, but is important for its administrative role and strategic location within the Golden Quadrilateral. *Ampelum* was the seat of the *procurator aurariarum*, a post held by freedmen and later equestrians.[660] The Roman settlement and necropolis was located near Pătrângeni, and a

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657 Popa (2002); Tudor (1968) 193; TIR L34.
658 See 4.6.1.
659 Popa (2002); Tudor (1968) 189; Wollmann (1996) 136–8.
660 Hirt (2010) 126–30.

sanctuary of Asclepius may have existed at Pătrângeni-Orlea.[661] A miners' colony with traces of hydraulic infrastructure was also found at Icăești on Mount Breaza.[662] Along with Abrud, *Ampelum* was the other local checkpoint in the heart of the Apuseni, controlling in particular access to Bucium and Roșia Montană. Both *Leg. XIII Gemina* and the *numerus Maurorum Hispanorum* are attested epigraphically, and detachments of soldiers probably dealt with security issues.[663] The relative lack of a stronger army presence is probably explained by the settlement's proximity to the larger legionary base of *Leg. XIII Gemina* at *Apulum* and the auxiliary camp at *Micia*, both of which guarded the approaches to the *aurariae Dacicae* from the east and west respectively. *Ampelum*'s importance in the gold-mining region was such that it attained the rank of *municipium* in AD 200 under Septimius Severus.[664]

5.1.4 The Brad-Săcărâmb belt

The Brad-Săcărâmb district is the farthest south of the three belts in the Golden Quadrilateral, and the largest in terms of geographical extent. The relatively high number of sites populating this sector reflects the complex underlying geology that has given rise to several metallogenically significant volcanic structures. The mines are organised here into three smaller groups: the Crișul Alb mines in the northwest; the mines of Ruda-Brad; and the mines between Brad and Săcărâmb, concentrated around Băița (*fig. 41*).

The mines of the Crișul Alb valley constitute the western-most extent of Roman mining in the Golden Quadrilateral and fall into two distinct groups based on the methods of exploitation, namely underground or alluvial. The largest and most important of the

661 CIL III, 1278–1280.
662 See 6.2.1.
663 CIL III, 1294; 1317; 1318; cf. 1316.
664 CIL III, 1308.

sites was Baia de Criș, where an important rural settlement developed in relation to the gold mining at Baia de Criș. Water conduits were identified, as were building substructures, mining tools, ceramics, and Roman coins.[665] Both underground mining and gold washing took place, with possible exploitation of the alluvial deposits using hydraulic means.[666] Baia de Criș was also the possible seat of a *subprocurator aurariarum*,[667] which hints at both the importance of the gold mines and potential signs of involvement by the state in what might have been alluvial hydraulic mining. The other identified sites in the Crișul Alb with Roman mining remains are Caraciu, Țebea, and Ribița.[668] Of these, Țebea had underground mines on Măgura Hill, with galleries up to 20 m long, whereas the miners at Caraciu probably exploited river alluvia. The evidence at Ribița is unclear, but seems to have had traces of both hard-rock mining and gold washing.[669]

Ruda was the centre of mining in Ruda-Brad, with significant underground mines on the slopes of Ruda Massif and at Barza (*fig. 42*). The most important discoveries are from Ana-Erbstollen mine in Ruda-Barza, where two long galleries (Ruda 12 Apostoli and Zdrahonț-Sf. Ioan), water-wheel remains, and a stepped access gallery ("*Treptele romane*") were found.[670] If early reconstructions of the wheel are reliable, the water-drainage system at Ruda-Barza appears remarkably akin to those from Paru Carpeni at Roșia Montană, suggesting the application of similar techniques at both sites.[671] We do not know the relationship between the mines at Ruda-Brad and Roșia Montană, but the presence of Illyrian miners attested at the associated necropolis of Muncelu supports the hypothesis of

665 Popa (2002); Băeștean (2007) 125; Tudor (1968) 192.
666 See 6.2.1.
667 Wollmann (1996) 134, if one accepts the epigraph's place of origin as attested by Avianus.
668 See 6.2.3.
669 Tudor (1968) 193.
670 Wollmann (1996) 134–5.
671 See 4.6.1.

a skilled migrant workforce working at Ruda-Brad with technical expertise similar to the miners at Roșia Montană. The other villages with traces of Roman activity near Ruda-Brad include Criscior and Bucuresci. At Criscior, surface workings as well as possible gold washing were found in Valea Arsului, and gold may have also been washed at Bucuresci.[672]

The mines of Hondol and Săcărâmb in the south-eastern end of the Brad-Săcărâmb belt comprise the same complex but are poorly reported because of post-Roman mining activity. The Roman remains at Săcărâmb consist of possibly Roman galleries that were opened by fire-setting, whereas at Hondol, Roman underground exploitation was noted at Coranda and Măgura-Toplița.[673]

Another major mining centre was Băița, with smaller dependent mines distributed throughout the eponymous commune (*fig. 43*). The veins of the Băița deposit were accessible from surface, and mining started in the Roman period.[674] Underground mining at Băița concentrated on Măgura Massif, with trapezoidal galleries like those seen at Roșia Montană.[675] The extensive surface remains include hydraulic installations, building remains, tiles, ceramics, and mining tools, indicating the presence of an associated mining settlement. A smaller settlement of miners dependent on Băița was also at Fizeș, which may be the possible origin for one of the known water wheels in Dacia. The other mines are at Trestia, where chained skeletons and Roman lamps were found in galleries;[676] Căinelul de Sus, with underground galleries and a settlement beneath Căinelu de Jos;[677] Crăciunești; Hărțăgani; and the possible Roman activity reported by the RAN at Barbura

672 See 6.2.3.
673 Wollmann (1996) 131.
674 Ianovici and Borcoș (1982) 108–9.
675 See 6.2.1.
676 Tudor (1968) 191–2
677 Wollmann (1996) 132.

and Ormindea. Given the size and centrality of Băița relative to the other sites in the commune, it may have been the main mining centre within its own sub-region.

5.1.5 Discussion

The Golden Quadrilateral was not just a region rich in metal deposits, but one that was remarkably well penetrated by the Romans. Although the evidence is piecemeal, with varying amounts of research on individual sites, the aggregate picture—at least broadly during the Roman period in Dacia—is of an intensely mined district, with evidence of active exploitation and functional mining communities that attained some permanence. The remote mountain locations of most of these sites indicate that settlement patterns in this part of the Apuseni Mountains were very much entwined with metal exploitation. Small, dispersed settlements sprung up around deposits, with a few mining settlements developing into slightly larger mining centres (e.g. Almașu Mare, Baia de Criș, Ruda-Brad, Băița). Even though subsistence farming and transhumance are possible, the lack of a strong villa-based rural economy suggests that the Romans penetrated the Golden Quadrilateral primarily for its mineral resources.

The site of Roșia Montană is an example of how far Roman mining could develop in Dacia, given enough time and opportunity. Roșia Montană is clearly not the only site in the Apuseni with evidence of underground gold mining or of relatively long-lived Roman mining settlements. What we see at Roșia Montană is an elaboration of a phenomenon occurring at multiple mining sites throughout the Golden Quadrilateral, and in that sense, it is not unique. Nonetheless, what *is* exceptional about Roșia Montană is the scale and intensity of mining exhibited, and as such, the value of Roșia Montană as a type-site for underground hard-rock mining in Dacia is without peer. Further research at other sites in the Golden Quadrilateral—especially Bucium—would certainly enrich our understanding of Roman exploitation in the province, but it is probable that Roșia Montană will remain the prime example of Roman hard-rock mining in Dacia, given the richness of its geological deposits and archaeological finds.

5.2 Roman hydraulic mining and gold washing

5.2.1 Roman hydraulic mining

Although hydraulic mining has not received much specialist study in Romania and there are significant problems untangling references to hydraulic mining from gold washing in the secondary literature,[678] there are two examples that can serve as potential type-sites. The first are the remains at Vulcoi-Corabia in Bucium, and the second is Pianu de Sus. These two sites have been briefly touched upon above, but their importance to our understanding of Roman mining in Dacia has perhaps not been sufficiently explored in light of the overwhelming emphasis on the underground workings at Roșia Montană. Vulcoi-Corabia and Pianu de Sus illustrate the application of water's erosive force in two different geological settings, and are the clearest examples of hydraulic mining at a hard-rock and an alluvial mine respectively in Dacia. As such, they can provide a marker against which to identify other possible instances of hydraulic mining in the province.

Type-site I: Bucium

The remains at Vulcoi-Corabia are an example of Roman hydraulic mining techniques applied to a hard-rock deposit, which is most clearly evident at the Ieruga opencast. Identifying characteristics of hydraulic exploitation at Ieruga include a cut at the top, indicating the main trench running vertically down the hillside, and side-conduits

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678 Discussed in 4.7 above.

positioned perpendicular to the vertical trench to channel water to the deposit (*fig. 29*).[679] Traces of these adduction channels are still visible from the air to the east of Ieruga.

Although Christescu (after G. Téglàs) did identify hydraulic mining at Bucium, his reliance on Pliny has led to an unclear explanation of the process as the workings at Vulcoi-Corabia were not opened using the *ruina montium* method. The remains at Vulcoi bear some morphological similarities with Pliny's account as described above in section 4.7: a cut or vertical trench in the hillside ("ieugă", or "ieruga" in this case), *corrugi*, and the remains of a reservoir. However, Christescu's description seems to imply that work started from the top, where water would have needed to be channelled and stored on the hilltop above the trench, so that the collected water could be released to work the deposit from above. Although a reservoir is nearby, its location is downhill from the Ieruga opencast, and there are no other known tanks or reservoirs above the working. The reservoir, which was created by damming and deepening a natural hollow, collected rainfall and snowmelt that could be used for ore processing.[680]

Contrary to Christescu's account, exploitation at Ieruga commenced from the base of the opencast and gradually moved uphill as successive levels were worked out. This was achieved by first excavating a hole for water at the bottom to erode out the pit, and then using the channels perpendicular to the main trench to lead water farther up that was released from the top to sweep away the broken rock and ore. The resulting mixture was then "washed" in one of the numerous smaller ponds on Poduri to extract the gold from the waste rock. Wollmann, perhaps not recognising the signs of hard-rock hydraulic mining,

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679 Although not apparent from the bird's-eye view of the satellite image, the exploitation at Ieruga starts at the top of the mountain. RepAB (1995) 65 reports the presence of large trenches with dimensions of 100 x 20 m and depths of 20 m, which could refer to the perpendicular channels along Ieruga, but this is not certain.
680 Wollmann (1996) 142. Wollmann's dimensions for the basin are suspect: he seems to have taken the numbers from Pliny NH XXXIII, 75 and miscited a measurement of 200 x 200 in meters rather than Roman feet.

believed that Ieruga was worked by tools and fire.[681] This misidentification of mining technique might also explain why Ciugudean failed to find evidence for fire-setting at Vulcoi-Corabia in his fieldwork.[682] In general, hydraulic hard-rock mining is almost never described as such in the Romanian secondary literature, which has probably resulted in an under-reporting of any similar sites in Dacia.

An example of how the remains at Ieruga can provide a means of identifying possible hydraulic mining is the case of Gaura Perii, the other opencast at Vulcoi-Corabia, thought to be worked by tools. Like Ieruga, Gaura Perii is similar in shape, being a vertical, v-shaped working, rather than the spreading, open-pit style that existed at Cetate, Roșia Montană (*figs. 30, 31*). The north-eastern side appears to have collapsed or been buried in dumps, but a cleft is still discernible at the top of the working when viewed facing north. The bottom of the working sits in a depression in the landscape (*fig. 32*). Although not visibly aerially, traces of what could be channels for water can be seen near the top and base of the mine. A small ditch, running perpendicular to the main working from the side and partially buried in waste and overgrown is preserved at the bottom of Gaura Perii (*figs. 33, 34*). A second channel is located at the top of the opencast and could have been a water conduit for eroding out ore from the top of the deposit in the later stages of exploitation (*figs. 35, 36*). With the Romans using hydraulic mining at Ieruga, it is entirely possible that they exploited the deposit at Gaura Perii in the same manner.

Type-site II: Pianu

In contrast to Vulcoi-Corabia, the hydraulic mining at Pianu de Sus and Pianu de Jos worked alluvial, rather than hard-rock deposits (*fig. 44*). The two adjacent villages are

681 Wollmann (1996) 141.
682 Ciugudean (2010) 265.

about 25 km southwest of Alba Iulia (*Apulum*) in the north-eastern part of the Sebeș Mountains and situated on the Pianu River, southeast from the Mureș corridor. The area has a long history of gold-mining activity, and antique gold mining near Pianu de Jos was already noted in the 18th-century *Josephinische Landesaufnahme*.[683] The mining remains at Pianu de Sus date to the Roman period based on finds in the area of a gold Roman fibula (1st century or later, probably 2nd–3rd century) and ceramic fragments, amongst others, with epigraphic evidence attesting the presence of *Leg. XIII Gemina*.[684] Buildings, statues, stone reliefs, and traces of a Mithraic temple were also present. Despite the extensive surface remains for what appears to be Roman alluvial gold mining, there are no widely available published works on the subject.[685]

Preliminary surveys in 1999 identified surface mining remains extending over 320 km^2 from Săliștea to the west and Răchita to the east.[686] Workings fell into two main types, consisting of long channels aligned with the slope, and small pits opening onto one another with accompanying waste dumps spread along the lower terraces on the right side of Pianu Valley. At La Margini, the network of canals is particularly complex, stretching 1 km over the slope upstream from the exploitation points where the gold was extracted. Water for sluicing came from tanks and distributed to the exploitation points through a series of channels still visible today. The traces of hydraulic mining at La Margini are identifiable on Google Earth based on the fan-shaped rivulets carved into the landscape as water

683 Gold extraction may have started in the pre-Roman period, under the Dacians; Oltean (2007) 93. See also Wollmann (1996) 149–50, and Popa (2002) for a complete bibliography of 19th-century sources. Contra Davies (1935) 203–4, who views most of the gold-washing along the Mureș and Pianu as post-Roman.
684 RepAB (1995) 146; Horedt (1941–43)163–4; Tudor (1968) 136.
685 In 1999, H. Ciugudean and B. Cauuet surveyed the Pianu valley in preparation for the "Minele de aur antice din Dacia" programme and the Roșia Montană excavations respectively, but the findings were not fully published; see CCA 1999, no. 867 and Cauuet et al. (1999).
686 CCA (1999), no. 867.

travelled downhill and are probably the ancient mines outside of Pianu de Jos noted in the *Josephinische Landesaufnahme* (*figs. 45, 46*).

A clearer example of hydraulically worked alluvial deposits can be seen at Pianu de Sus. The evidence consists of a rectilinear reservoir sited above the modern town and river, with channels and dams built downhill to control the water flow (*figs. 47–49*). The current observable arrangement of features in the landscape, with the water collection reservoir located above the deposit, suggests the use of collected snowmelt and rainfall. Reported remains of a water conduit ("conducte de apă") close to the gold-washing site and modern village could possibly indicate the presence of an aqueduct.[687] However, the meaning of "conducte de apă" is vague and could also easily refer to one of the channels that directed water downhill towards the river. After enough water was collected in the reservoir, the water would then be released, washing out the gold-bearing deposits that could then be further processed. The resulting rush of released water left its mark on the landscape in the form of fan-shaped channels, and its visibility from the air is indicative of the scale of Roman exploitation at Pianu de Sus. This arrangement is reminiscent of Roman methods used at a larger scale elsewhere in the empire, most notably north-western Spain and Dolaucothi. In terms of identifying characteristics, what we can expect to find as indications of alluvial hydraulic mining elsewhere in Dacia would be reservoirs or some means of collecting water on higher ground above the deposits, as well as channels caused by the release of large amounts of water that tend to spread out in a fan. Dykes to control waterflow are also possible, as well as pits and mounds indicating the washing of alluvial gold, but on a larger scale than observed for the river-bank sites.

687 Băeştean (2007) 134; RepAB (1996) 146.

This attempt at a typology is a start based on the limited archaeological study conducted. Roșia Montană arguably functions as a type-site for underground hard-rock mining in Dacia; likewise, both Vulcoi-Corabia at Bucium and Pianu de Sus fulfil the same purpose for Roman hydraulic mining in the province. Given the Romans' extensive application of hydraulic methods in north-western Iberia and at Dolaucothi in Wales, the use of similar techniques during their occupation of Dacia is hardly unexpected. In places where the geology supports application of these techniques, we should be finding more instances of its use. What Bucium and Pianu provide is the basis for identifying and clarifying possible cases of hydraulic mining at other sites. The following discussion examines other known occurrences of gold washing in the secondary literature and attempts to elucidate the differences between the exploitation of gold-bearing alluvial river sands and hydraulic mining proper.

Possible hydraulic mining sites

In addition to the two type-sites of Bucium and Pianu de Sus, five other sites with reported gold washing also have identified hydraulic remains: Almașu Mare, Băița, Icăești (Zlatna), Baia de Criș, and Eibenthal. The forms of evidence include reports of water conduits, canals, and collection basins or reservoirs, but are almost never discussed in terms of possible Roman-style hydraulic mining. The following is an attempt at identifying additional instances of hydraulic exploitation in Dacia, and where possible, differentiate between hard-rock and alluvial exploitation.

Mining at Almașu Mare took place largely in the hills north and north-west of town, where many mining works and settlements from the Roman period have been identified. The mining activity at height suggests that any kind of hydraulic activity that could have taken place would have been at a hard-rock site. The evidence is very piecemeal, but signs of water infrastructure include a water conduit or pipe ("o conductă de apă") at Runcului

Hill, one of the site's principle mining points in the Roman period.[688] According to Téglàs, a fragment from what seemed to be a water pipe was found amidst the mining remnants on the south-western slope of Runcului.[689] The funnel-shaped piece measured 20 cm long, with a circumference of 18 cm and walls 15 mm thick, and had a bright red exterior and black interior. Tudor's brief mention of the pipe in association with the mining settlements at Almașu Mare implies a domestic context—possibly as a water pipe for one of the dwellings.[690] Téglàs, however, did also note that the pipe could have been used for mercury or ore removal instead. In either case, it seems unlikely that the pipe from Runcului is related to hydraulic mining infrastructure.

Although not securely identified in the secondary literature, there may be possible evidence for hard-rock hydraulic mining elsewhere at Almașu Mare similar to the Ieruga opencast at Bucium. According to Christescu, hydraulic exploitation was employed at Piatra Seacă, where conduits led water from the top of the hills for hundreds of meters.[691] Christescu does not elaborate further, but if these works are analogous to Ieruga, one would expect to see notches or incisions on the top of a hill, with a vertical opencast cut into the slope, and the conduits would be the water channels used to work the opencast. Téglàs reported the presence of similar hill-top incisions near Almașu Mare, and it is possible that at least some of these mines could have been worked hydraulically. He identified Roman exploitations at the big expanse at Corava (Coronți?) on Baba Peak and also on the south side at Jeruga Sfincitului Anna, and notches 20 m wide in the mountain at Piatra Seacă, on the border between the villages of Nagy-Almás (Almașu Mare) and

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688 Popa (2002); RepAB (1995) 47–8; Băeștean (2007) 124; TIR L34.
689 Téglàs (1893) 138: "Runcu délnyugoti oldalán régi bányagorczokra akadunk s ezek egyikében egy látszólag vizvezeto cso töredéke merült fel"; cf. Kuun, Torma and Téglàs (1902) 171. It is unclear whether the mining remains were huts, holes, or shafts, but the pipe was found inside one of them.
690 Tudor (1968) 189.
691 Christescu (1929) 19. Christescu's reference to Téglàs (1892) 133 does not exist; see note 101 below.

Dupa Piatra.[692] The inclusion of "jeruga" in the name is intriguing, and could indicate a possible means for identifying additional hydraulic-mining sites in the Apuseni Mountains.

In contrast, Wollmann, who does not appear to have recognised the signs of hard-rock hydraulic mining in Dacia, asserts that the cuts in the hills were surface exploitations, opened by chisel, as Roman galleries appeared in one measuring over 12 m wide.[693] He says the same can be seen at Corneatca, from the Toți Sfinții exploitation; at Coronți on Baba Hill; and at Dealul Negrii, where a group of statues with Jupiter and Juno were found. Wollmann goes on to discuss the underground gallery networks at Dealul Negrii in detail, giving the impression that these are all examples of underground mines or, at the very least, mines opened by tools. Téglàs' account of underground Roman mining at Dealul Negrii accords with Wollman, but there is no clear account of how the surface exploitations were worked. The 12 m-wide incision that Wollmann mentions seems to be the same one Téglàs observed on top of Mount Bozsericza (Bojerița), where the cut was mostly opened by chisel. However, Téglàs also detected traces of fire-setting on the basis of a 1.3 m high arched deflection in the wall, but makes no mention of Roman galleries or hydraulic mining.[694] This is not to say that Téglàs was necessarily incorrect, but there is clearly confusion in the secondary literature whether some of these surface exploitations were opened by hand or by fire, and in both cases, there does not appear to be an understanding of Roman hard-rock hydraulic mining, such as what we see at Vulcoi-Corabia in Bucium. It appears that the aqueducts—or more accurately, water channels—at mining sites have been interpreted by some scholars as providing water for fire-setting, as Davies believes

692 Téglàs (1893) 139.
693 Wollmann (1996) 137.
694 Téglàs (1893) 137.

was the case at Piatra Seacă and Braza (Breada or Breaza).[695] Furthermore, Davies says that the aqueducts at Braza led to a cistern like those at Vulkoj-Korabia (Vulcoi-Corabia). Wollmann did also believe that the Ieruga opencast at Vulcoi was worked in part by fire-setting, in addition to hammer and chisel.[696] It is therefore highly likely that similarly worked hydraulic-mining sites in Dacia have been overlooked. Further fieldwork is needed to ascertain how the mines at Almașu Mare were exploited before further conclusions can be made.

Tudor, for his part, believed the conduits at Almașu Mare were for channelling water to many places to wash the ground gold ore.[697] There is limited evidence for ore processing at Almașu Mare, where an undated stone mill for crushing ore was found at Haneș mine, but thought to be possibly Dacian.[698] But given that the remains of buildings indicate a Roman mining settlement existed at Haneș, the millstone could be Roman. The presence of canals providing water for ore processing is not incongruous with hydraulic mining: a similar situation is evident at Vulcoi-Corabia, where the ore required further crushing and washing after extraction. Both Christescu and Tudor could be right, but additional fieldwork to ascertain Téglàs' reports of "jeruga" and to differentiate between hydraulic-mining and ore-processing infrastructure is needed at Almașu Mare.

Băița was an important Roman mining centre, with extensive mining evidence. Most of the remains were concentrated between Măgura and Cornet hills. Here, 20 buildings, plus water conduits and various mining tools including pestles and grinders,

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695 Davies (1935) 201.
696 Wollmann (1996) 142.
697 Tudor (1968) 190. Both Christescu (1929) and Tudor (1968)'s main text cite the wrong year (1892) and volume (XII) when referencing Téglàs. Wollmann (1996) 137 n. 50, which cites the 1894 volume, is also incorrect, and probably refers to the same 1893 article by Téglàs. The correct reference is given in Tudor (1968) 190 n. 3: G. Téglàs (1893) *Arch. Ért.* XIII, p. 133.
698 Popa (1961) 269.

were found.[699] Silver was exploited at this site. Traces of canals and a rainwater collection basin was probably used for washing non-ferrous ores.[700] There is not enough information to identify whether hydraulic mining took place at Băița; it could be that the water system was used in ore processing only.[701]

At Icăești, on a hillside north-west of Mount Breaza about 4 km away from Zlatna, traces of a triangular basin with channels feeding into the reservoir were found, along with bricks and Roman tiles, attesting the presence of a mining colony.[702] It is unclear what the reservoir was used for, but if Davies is right in associating the remains at Breaza with those at Piatra Seacă (above), there may be possible grounds for considering the reservoir as remains from hydraulic mining, but additional evidence is needed. It could be the case that the water was used for ore processing instead.

At Baia de Criș commune, the identification of water conduits along with building substructures in the secondary literature is somewhat confusing, as some accounts may have conflated the finds from the underground and alluvial sites into one entry.[703] Given the context, it is unclear whether the water conduits ("conducte de apă") were related to industrial or domestic activity. If we understand the water conduits to be pipes, they could have provisioned domestic dwellings, but could also have been pipes for underground mine drainage. If these water conduits were surface channels, they could have been used for ore processing or gold washing, as a water reservoir and gravel piles were also found. The clearest account comes from Wollmann, who reports the presence of a bed of alluvial deposits at Baia de Criș-Țebea, visible near the Brad-Oradea road, measuring around 2.10

699 Popa (2002); Băeștean (2007) 125; CHBR (2006) 133.
700 Wollmann (1995) 131; cf. Téglàs (1883) 144.
701 See 6.2.4.
702 RepAB (1995) 212–3; Băeștean (2007) 131–2; Wollmann (1996) 139.
703 Popa (2002); Băeștean (2007) 125; Tudor (1968) 192.

m high.[704] The deposit has been worked extensively, with most of the excavations probably dating from the 17th to 18th centuries, but basins and water conduits made of earth existed in the 19th century, whence coins from Antoninus Pius and Marcus Aurelius were found. It is very possible, based on Wollmann's description, that some form of alluvial mining using hydraulic methods was taking place near Baia de Criș village.

The last site, Eibenthal, is a copper-exploitation site in the Banat. Canals and water conduits were discovered between the towns of Eibenthal and Tisovița, and it is thought that they relate to the copper-mining activity.[705] Isolated Roman ceramics were also found in the area. It is possible that the Romans were engaging in alluvial mining at Eibenthal, but more fieldwork would be needed to verify this. If it is indeed the case that alluvial mining was taking place, this would render Eibenthal unique—or very suspect—amongst Roman copper-mining sites, as there is no other known example of copper being worked this way in the Roman world.[706]

Overall, there is a lack of concrete evidence for hydraulic mining in Dacia outside of the two type-sites of Bucium and Pianu. It highly likely that this type of mining has been overlooked or incorrectly identified, given the confusion in the archaeological literature. Nevertheless, a few of these sites—especially at Rodu-Frasin in Bucium, Almașu Mare, Băița, and Baia de Criș—could potentially reveal evidence for hydraulic mining with additional research.

704 Wollmann (1996) 133–4.
705 Băeștean (2007) 130; Tudor (1968) 66; Böhm (1880) 180.
706 A.I. Wilson, May 2018, personal communication.

5.2.2 Gold sand exploitation

Based on the criteria enumerated above, these sites are the ones where "gold washing" refers to the exploitation that occurred on or near river banks, namely the extraction of river gold out of alluvia. Of the gold-washing sites in the Golden Quadrilateral, eight are specified in the literature as exploiting gold sands.[707] With the exception of Petroșani, the majority of these sites form a distinct group distributed along the Arieș and its tributaries, in order from upstream to downstream: Lupșa, Baia de Arieș, Sălciua de Jos and Sălciua de Sus, and Vidolm (*fig. 50*). Both Vidra and Surduc can be considered part of the same group as both sites are located on minor tributaries of the Arieș. Alluvial gold in Dacia originates from the erosion of the hard-rock deposits in the Metaliferi Mountains that are carried downstream by rivers, with the Arieș being the richest source.[708] Therefore, it is hardly unusual that the gold-washing sites along the Arieș form a distinct group where exploitation largely consisted of the recovery of gold directly from the river.

The evidence for gold washing at these sites is also in keeping with what was described by Macrea. At Lupșa and Vidra, for example, numerous mounds and pits were discovered on the banks of the Arieș, implying that the activity taking place involved washing alluvia in dug-out pits, with the unwanted gravel left behind in dumps. The Roman date for Lupșa is related to a possible mining settlement in the Hădărău section on Rălii stream, where Roman tiles and ceramics were found in 1979.[709] No details are available for Sălciua de Jos and Sus, but traces of gold washing were found on the banks

707 After Popa (2002), who is the most explicit in identifying the gold-washing sites that worked alluvial sand. Four of these sites are listed as generic gold-washing sites in the RepAB (1995): Sălciua de Jos, Sălciua de Sus, Vidolm, and Vidra.
708 Cf. Christescu (1929) 12, n. 13.
709 Popa (2002); RepAB (1995) 122.

of the Arieș. The date for these activities is based on stray Roman coin finds.[710] Similarly at Vidolm, a Roman date for the gold washing comes from 2nd–3rd century coins, and the possibility of a settlement based on finds of Roman bricks.[711]

The most significant of these sites is Baia de Arieș, which was the most important gold-washing centre in the archaeological literature.[712] Ostensibly its importance is related to the gallery mining and the traces of mining settlements that have also been identified, along with tools, several stamped lamps, and two *denarii* of Commodus and Severus Alexander.[713] This is a cogent reminder that many of the mining sites in the Apuseni are located near local mountain streams, and even in places where underground mining took place, it is likely that some gold washing occurred as well, if alluvial gold was present in high enough concentrations in the river.

The site of Petroșani, in contrast, lies outside of the Metaliferi Mountains and on the river Jiu, south of the Orăștie region. The Austro-Hungarian literature mentions gold-washing installations, along with traces of mines.[714] A bust of Ares was found near one of the installations.[715] A notable aspect of this site are the hoards, some of which were quite large. One contained 2,500 silver coins from Trajan, Hadrian, Antoninus (?), Marcus Aurelius, Gordian III, and Philip the Arab, as well as some Republican coins.[716] Many coins from the 4th century BC have also been found.[717] The dates from these coins suggest

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710 Sălciua de Jos: Sestertius (?) of Trajan, bronze coin of Severus Alexander, worn coin from the 1st–3rd c. AD (?). Sălciua de Sus: Dupondius of Marcus Aurelius, denarius of Septimius Severus, sestertius of Severus Alexander. Find location unknown for all coins; Popa (2002), RepAB (1995).
711 Popa (2002); RepAB (1995) 205; TIR L34; Tudor (1968) 202. Téglàs, who reported these traces, also acquired an iron tool from the area.
712 Wollmann (1995) 146–7.
713 Popa (2002); RepAB (1995) 51. Cf. Davies (1935) 203: Baia de Arieș was certainly a mining centre by 1325, and likely for river gold.
714 Popa (2002).
715 Maghiar and Olteanu (1970) 60; Boroneanț (2000) 125; CHBR (2006) 139.
716 Popa (2002).
717 Davies (1935) 204.

a period of activity extending longer than the Roman finds from the sites along the Arieș. The dating of gold washing activity is extremely difficult, but it could be the case that the placers at Jiu were being worked later than some of the sites in the Golden Quadrilateral.

5.2.3 Gold washing – further clarification

There now remains a category of generic gold-washing sites, for which the method of exploitation is not specified in the literature. These other gold-washing sites (i.e. river gold exploitation) can broadly be identified based on whether they fall along river valleys. If so, they are more likely to be engaging in gold washing, rather than hydraulic mining. Amongst the sources listed by Macrea with evidence for Roman gold washing, it is possible to group the remaining sites by the Arieș, Crișul Alb, and Jiu rivers and the Banat.

Firstly, given that there is already a cluster of established gold-sand washing sites on the Arieș, it is probable that the other sites located on tributaries of the same river belong to this category. Near the head of the Arieșul Mare, this would include Scărișoara, Albac, Neagra (Poiana Vadului), and Avram Iancu. Bistra and Câmpeni are also probable candidates. At Câmpeni, mounds, ditches, and pits related to gold washing were found on the banks of the Arieș.[718] Another two sites are farther downstream, located on the Iara, which also feeds into the Arieș: Făgetu Ierii and Băișoara.

The sites on the Crișul Alb are slightly more difficult to differentiate, as some sources conflate the information for the alluvial and underground mines. The river itself flows east-west, cutting through Brad and the heart of the Brad-Săcărâmb district. There are references to auriferous sand and widespread gold washing along the entire valley at

718 RepAB (1995) 82.

Ribița, but the exploitation at Bucureșci is uncertain at best.[719] The main site is Baia de Criș, where hydraulic mining could have been employed.

Next, the sites on the Jiu can probably be grouped with Petroșani. These include Iscroni and Uricani. The activity here is likely to have been sand washing, given the proximity to Petroșani and longer history of pre-Roman exploitation in this area. Davies also claims that an aqueduct brought water up to the upper terraces to wash away overburden—indicating Roman hydraulic mining of the alluvial deposits—but there are no other references to this aqueduct or the specific location along the Jiu in the archaeological literature.[720]

The final group consist of the mines in the Banat. Both Christescu and Davies were unsure whether the Olt and Banatean rivers were exploited by the Romans, even though they are known to contain gold.[721] These are Turnu Rueni, Bolvașnița, and Borlova. The latter two are noted as having installations for gold washing, but it is unclear what these installations are.[722] It is not possible to say with any certainty what exactly is meant by "gold washing" at these locations, only that the activity took place.

Some Roman gold-washing installations are also thought to exist within the commune of Vințu de Jos, but no further information is available.[723] Given its proximity, the gold washing is probably related to the alluvial exploitation at neighbouring Pianu de Jos and Pianu de Sus. There is, however, evidence for both pre- and post-Roman activity, so any presumed gold exploitation may not necessarily be Roman.

719 Popa (2002); Wollmann (1996) 134; Christescu (1929) 13.
720 Davies (1935) 204.
721 Christescu (1929) 13; Davies (1935) 204, n. 6.
722 CHBR (2006) 134.
723 RepAB (1995) 209, no. 18.

One cannot be certain, but it appears that most of the reported gold-washing sites in Dacia are more likely to be the river-side exploitation of alluvia. Where landscape alterations such as channels and basins exist, it seems likely that "gold washing" could refer to the use of hydraulic mining techniques instead.

5.2.4 Ore processing and gold washing

Of the gold-washing sites, five sites also have evidence for ore-processing activity: Bucium, Băița, Băișoara, Avram Iancu, and Scărișoara. Ore processing is a necessary procedure in separating ore from gangue prior to smelting or further refinement. Signs of such activity is not in itself particularly unusual at a hard-rock mining site, but is usually not needed for alluvial deposits. Distinguishing which sites in Dacia were washing gold as part of primary ore extraction as opposed to a step in ore processing is problematic, and we need to clarify the use of "gold washing" in the scholarly literature when applied to ore processing.

A second difficulty is dating. As with much of the surface mining remains, ore-processing activity is difficult to date in the absence of associated Roman finds. Evidence include pestles, mortars, and grinders that would indicate crushing by hand, to larger scale installations such as ore stamps and mills. Even then, the use of technologies such as mortars and pestles for ore grinding persisted well beyond the Roman period; even wooden water-driven ore stamps in Romania changed little since the time of Agricola until they fell out of use in the early to mid-20th century.[724] Although ore stamps have been reported at two of these sites—Avram Iancu and Scărișoara—the lack of additional detail makes it

724 E.g. Roman's photographs of mining life and technology in the Apuseni Mountains in the early 20th century; Roman, Sîntimbrean and Wollmann (1982). Cf. the medieval ore-crushing machine in Agricola's De Re Metallica, Book 8.

difficult to establish a secure Roman provenance. Additionally, all the evidence for Roman water wheels come from underground contexts in Dacia where the wheels were used for mine drainage. If water was used to power ore-stamping machines, the morphology of such wheels or devices are currently unknown.

Hand-operated devices such as pestles and mortars or hand grinders were by far the most common means for breaking down ore. Such finds were present at Bucium, and at Băița and Băișoara. At Bucium, mortars and grinding stones found near the two opencasts and the miners' housing on the south-eastern slope of Vulcoi-Corabia indicate that ore processing by hand took place near the mines as well as at designated areas farther away. The grinding tools were used to break down mined rock after extraction—whether dug out by hand or from the hydraulically worked opencasts—before washing with water to separate out the gold from the gangue through gravity. The basins, channels, and waste dumps on Poduri slope downhill from the Ieruga and Gaura Perii opencasts are the remnants of this type of ore-processing activity. The numerous mortars found at the end of Pârâului Iadului, near the reservoir on the road south to *Ampelum*, and at Valea Ruzii to the south-west suggest that these two areas in particular may have been designated for ore processing.[725] "Gold washing" at Bucium almost certainly describes the processing of ore rather than extraction, as the gold was mined through hand tools and hydraulic means.

It is likely that the "washing" at Băița, in the Brad-Săcărâmb belt, was similar to Bucium and refers to the processing of already extracted ore. The mines of Băița were hard-rock sites, with underground gallery systems at several massifs where silver and gold were exploited. Although the *TIR* reports "traces of gold washing" at Băița, it does not specify one of the known gold mines in the area (e.g. Trestia, Câinelul de Sus, Hărțăgani),

725 Wollmann (1996) 142.

and what evidence we do have seems to indicate the washing of non-ferrous ore using a system similar to that at Vulcoi-Corabia.[726] Ore processing and washing occurred at Măgura Băiței on the basis that mortars ("piulițe") and stones for grinding rocks were found there.[727] The pestles and grinders amongst the mining tools at a group of 20 buildings suggest that manual processing took place near the miners' dwellings between Corneț and Sfredel hills, and the canals and basins between the Corneț and Magura hills were used to collect rainwater for washing ore. In the absence of additional evidence demonstrating that hydraulic mining occurred at Măgura Massif or elsewhere at one of the gold mines at Băița, ore processing appears to be the most likely activity and application of the water infrastructure identified to date.

At Băișoara, the situation is complicated by the probable exploitation of both underground and river deposits. A mill for crushing ore ("piua") was probably for processing, but references to gold washing could refer to either beneficiation or river-side exploitation as Băișoara belongs to the group of sites exploiting golden sand along the Arieș valley. It is worth noting that mills ("pive") for crushing ore were also found at Bucium, in the mining settlement at the foot of Vulcoi-Corabia.[728] The modern translation for "pive" is "fulling mills", which could imply mechanisation in the form of water mills used to drive hammer or stamping mechanisms. However, there are few details given in the literature about the exact nature of these mills, either at Băișoara or Bucium.

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726 TIR L34 s.v. Băița Dac. Sup. It is possible that the gold washing in question refers to the gold washing also reported at Hărțăgani by TIR.
727 Tudor (1968) 191. CHBR (2006) 133 translates "piulițe" as "screw nuts", which implies machinery of some sort, but it is more likely that "piulițe" is being used in the traditional sense and refers to mortars, which are also known in Romanian as "mojare" and "pive" (sg. "piuă").
728 Popa (2002) s.v. Bucium, section B; RepAB (1995) 65.

Evidence for Roman ore stamps is extremely rare, but may have been present at Avram Iancu and Scărișoara, two sites possibly exploiting gold sand.[729] It is unclear whether the stamps are ancient. If these purported stamps were in fact Roman, it could possibly hint at the scale of production that stamps were needed, since breaking down ore was a bottleneck in the process. Mechanisation in ore processing was common in the Iberian Peninsula and also employed at Dolaucothi in Roman Britain—two provinces where the Romans gained experience of mining before Dacia—so the technology was certainly available.[730] Further work identifying Roman-period stamps is needed before any conclusions can be drawn, but could provide insight into the economic importance of mines with mechanised ore processing.

5.3 The non-precious metal mines

In addition to its gold deposits, Romania also possesses significant non-precious metal supplies. Although gold mining has been the focus here so far, gold was only one of several metals exploited by the Romans and its relative importance to the sum of mining activity in Dacia has not been fully appreciated due to the lack of contextualised analysis studying both the precious and non-precious metal mines in concert. The following section reviews the evidence for the non-precious metal Roman mines in Dacia to establish how it related to or differed from gold mining within the province.

Both iron and copper are available in economically viable quantities, particularly in the southwestern parts of the country: iron in the Poiana Ruscă Mountains, Hunedoara, in

729 Popa (2002); RepAB (1995) 51, 166.
730 See Wilson (2002) on mechanization in mining, especially p. 21 ff.

southwestern Transylvania, and copper in the Banat (*figs. 51, 52*).[731] However, compared to the state of research on the precious-metal mines in Dacia, the iron and copper mines have received far less attention, despite the quotidian nature of these two metals in Roman life. Of the collated mining sites with non-precious metal resources, only one site (Teliucul Inferior) has been researched and two verified (Teliuc, Bocșa), out of 22 reported, for which the type of metal exploited is known (*Table 7*).[732] All three are iron-working sites; none of the known copper sites have been confirmed. The Romans also exploited polymetallic deposits and a small cluster of polymetallic mines are located in Caraș-Severin county. Beyond the compilation of sites by M. Simion and V. Boroneanț respectively, no further fieldwork or synthesis of the material has been done in recent years, and what can be said about non-precious metal mining in Roman Dacia is based on extremely sparse and outdated information. The best analysis of the extant evidence is still V. Wollmann's, whose brief chapter offers a concise summary of the Austro-Hungarian mining literature on iron, but information on copper mining is still lacking.[733] Compounding the lack of research is the continued exploitation of the non-precious metal ores in the post-Roman period to the modern day, which has destroyed much of the earlier evidence in the Banat.[734]

731 The Banat is a historical region spread across south-western Romania, north-eastern Serbia, and south-eastern Hungary. Within Romania, the region comprises the counties of Arad, Timiș, Caraș-Severin, and Mehedinți, with the last three being most relevant to Roman mining activity in Dacia. NB: TIR has misidentified the location of Moravița, which should be modern Ocna de Fier, an eponymous commune in Caraș-Severin.

732 Data based on gazetteer of mines in Dacia (see Appendix). Not included in this table are entries for which the metal type(s) exploited is uncertain.

733 Wollmann (1996) Ch. 7.

734 Tudor (1968) 61.

5.3.1 Iron

Surprisingly little has been written about iron exploitation in Roman Dacia, even though a province as heavily militarised as Dacia presumably would have needed to supply the army as well as provide implements for rural and industrial work. Extractive industries such as mining and quarrying would also have required metal tools: if the scale of gold mining—especially hard-rock mining—seen thus far in the province is any indication, the procurement of sufficient equipment for mining would have added to the demand for iron beyond basic needs. Iron, in particular, was essential as bronze and copper tools were unsuitable for mining, being both more expensive and less durable than iron.[735] Iron exploitation was therefore especially vital in fuelling everyday life in Dacia.

There are some differences between the exploitation of gold and iron, but most requirements remain the same. Geologically, iron is more abundant in the landscape than gold, but not in a pure form, and can be extracted from rocks in which iron oxides exist in sufficient concentrations. Of these, magnetite, hematite, and limonite are the most iron-rich, and were exploited by the Romans in Dacia. The heart of iron exploitation in the Roman period centred around Hunedoara, in the Poiana Ruscă Mountains. This cluster of mines consists of activity at Teliucu Inferior, Ghelari, Ploțca, and Hunedoara itself. Evidence for iron processing at the polymetallic mines in the Banat also suggests the exploitation of iron, such as at Ciclova Romană and Ocna de Fier. Less certain is the presumed activity around the Iron Gates near *Drobeta*-Turnu Severin, despite the numerous Roman settlements in the area.[736] Iron resources are also known elsewhere, however—most notably in the Șureanu (Orăștie) Mountains where there is some evidence of pre-Roman exploitation, in

735 Davies (1935) 35.
736 Wollmann (1996) 232–4.

the form of ores from Batrana found near the kilns at *Sarmizegetusa Regia*. Additional sources can be found at Dealul Negru, Steaua Mare, between Valea Mlacii and Valea Provatului, in the hills north-west and south-west of the river Strei, Rudele, Federi, between Sipca stream and Bosorod valley, and at Dosul Vartoapelor-Sub Cununi.[737]

In addition to ore deposits, iron mining required ready access to a plentiful timber supply. Most Roman iron mining occurred on the surface in the form of opencasts, but more crucially, wood was needed to make charcoal for smelting to produce useable iron. The mountains of Romania, however, are densely wooded, albeit diminished in areas with a history of mining; dense forest cover would presumably also have been the case during the Roman period. Sites located in the Dacian heartland of the Orăștie had access to the necessary timber for ore smelting, as did the areas around Hunedoara and in the Poiana Ruscă Mountains where Roman iron mining was concentrated.

Modern mining, unfortunately, has destroyed much of the earlier, Roman mines in Hunedoara. Reports from the 19th century indicate that shafts were worked in the Hunedoara area at Ploțca commune, Dumbrava Hill, and at the Sf. Ștefan and Grezenstein mines, with Roman miners displaying a preference for the softer rocks.[738] Underground exploitation took place in galleries opened with hand tools at Teliucu Inferior and Ghelari, with the exploited magnetite at Teliucu being of particularly good quality. One of the largest Roman workings found measured 11 m long, 7 m high, and 2 m wide. At Ghelari, Roman tools, coins, and skeletons of humans and possibly horses were found in one of the chamber-shaped workings, as well as a stamped lamp (FESTI). Elsewhere in Hunedoara, mining also occurred at Ruda and Alun.

737 Oltean (2007) 39; cf. pp. 104–5 on pre-Roman evidence for ore reduction and slag at Dacian sites.
738 Wollmann (1996) 233.

In the absence of known mines, iron exploitation can also be identified by smelting remains. Unlike gold, iron ores required an extra stage to separate out the base metal before use, as most mined deposits occurred as oxides that needed to be reduced. Ore preparation first involved beneficiation and washing to remove as much gangue as possible, and then roasting to drive off excess water. Smelting then occurred in a carbon-rich, high-temperature environment, achieved using charcoal fuel. The result was a spongy, unworked "bloom" of iron metal and waste slag. Archaeological remains include waste-rock dumps and stamps from beneficiation, hearths for ore roasting, furnaces for smelting, and slag. These types of supplementary evidence is sometimes used to confirm possible Roman iron mining in Dacia, such as the slag dumps at Berzovia and the ore kilns at Fizeș and Șosdea,[739] but no one has undertaken work similar to that of D. Mladenović on the slag remains in Moesia Superior to identify the extent of Roman mining.[740] These types of remains are also difficult to date, and—as for gold mining—establishing a more precise chronology for Roman iron mining in Dacia is problematic. This is further compounded by the reworking of ancient slag heaps by the Austro-Hungarians. Nonetheless, a more careful examination of the ore-processing remains is a possible area for future investigation.

One key question is why the Romans chose not to re-work the iron deposits exploited by the Dacians.[741] There are resources available in the Șureanu Mountains where the Dacian citadels were located, but the Romans do not appear to have resumed the mining at these sites, having opted instead to relocate and concentrate their attentions on the deposits in the Poiana Ruscă Mountains (*fig. 53*). Whilst the location of the mines

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739 Wollmann (1996) 235. Fizeș is a gold-mining site and listed as such in CHBR (2006); this is a different site with the same name in Caraș-Severin located south of Berzovia.
740 Mladenović (2009) 71–4. Although Moesia was most famous for its silver and gold, some sites such as the late antique centre of Zajecak-Kremici smelted ores rich in iron, gold, and copper.
741 Oltean (2007) 182.

necessarily corresponds to the location of the ores, the relationship between iron exploitation in Dacia seems closely tied to the shift to Roman settlement patterns. Unlike the gold mines of the Golden Quadrilateral, the iron mines and quarries in Dacia were located near centres of demand. This difference in location is arguably tied to the needs of the army and urban centres, as iron—unlike gold—was used to create everyday objects. One parallel trend can perhaps be seen in the location of quarries: those that specialised in marble were located where the stone was found, but quarries exploiting more common stones like limestone and sandstone were sited near major centres of demands (i.e. major and minor towns).[742] Iron is relatively common in the landscape and cheap; therefore sources that were readily accessible and connected by a transport network would be the preferred choice for the settlements and forts that needed the metal.

Access to a transport network was key. The cluster of mines around Hunedoara are clearly connected to the main east-west road running along the Mureș valley and close to the north-south artery towards *Ulpia Traiana Sarmizegetusa*. The Dacian citadels and their iron sources, in contrast, are all located in remote sites in the Șureanu Mountains. Dacian exploitation was very localised, matching their settlement pattern of isolated hillforts. Whilst this type of exploitation might have suited smaller populations where production was a local affair, the effort required to access and transport ore from the Șureanu Mountains elsewhere on a provincial level would be extremely high. Aggregating production around a centralised hub, rather than pursuing small-scale, scattered exploitation, helps explain why the Romans bypassed the more remote sources of iron for the deposits in Hunedoara to supply the main towns of *Ulpia Traiana* and *Apulum*.

742 Oltean (2007) 216: Note that Oltean's conclusions are based on an analysis of the base-metal mines and quarries of Dacia, but not the gold mines of the Golden Quadrilateral, which she sees as a specialist case.

One could then expect to see increased oversight by the central authorities to ensure a sufficient iron supply for the major towns and forts, as was indeed the case during the Roman period when *conductores ferrariarum* were installed at Teliucul Inferior to administrate the iron mining in the Poiana Ruscă Mountains.[743] A legionary guard post also existed at Hunedoara near the Roman settlement, thus providing local military support. Alongside the larger scale mining, small-scale exploitation of local deposits by the Romans for daily use—such as at *villae rusticae* like Cinciș and Mănerău—helped fulfil the needs of the provincial population.[744]

5.3.2 Copper and tin

In addition to iron, copper and tin were the two other main non-precious metals mined in Dacia. Local uses included the production of tools and weapons, as well as high-status or ornamental objects. Unfortunately, copper and tin are also by far the least studied of all the mineral resources exploited by the Romans in Dacia and little is known about the mines. Wollmann only touches upon copper in passing with respect to the mines of the Banat.[745] The only other work to address the subject in any depth is Davies, whose summary—although brief and unverified—is the most thorough attempt at synthesis.[746] Boroneanț offers slightly more information for individual copper mines in his compilation of sites, but much of the focus is on post-Roman activity. Tin is not addressed in any detail at all in the secondary literature. This particular area of Roman mining in Dacia is a subtopic that needs considerably more fieldwork before further conclusions can be drawn.

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743 IDR III/3, 37.
744 Oltean (2007) 184; Tudor (1968) 111.
745 Wollmann (1996) 150–2.
746 Davies (1935) 206–7.

Copper

Modern copper reserves can be found at Roșia Poieni (Abrud-Alba), Moldova Nouă (Caraș-Severin), Bălan (Harghita), and Baia de Aramă (Mehedinți). Of these, the mines at Roșia Poieni and Moldova Nouă are still active, whilst Bălan is closed and Baia de Aramă is undergoing rehabilitation.[747] Roșia Poieni is the most important for modern exploitation, but as a porphyry copper deposit is of little interest with respect to Roman mining. The other three main sources—Moldova Nouă, Bălan, and Baia de Aramă—have common copper ores such as chalcopyrite, with varying levels of reported Roman activity, as modern mining has destroyed most of the ancient remains.

Significant porphyry copper deposits occur within Dacia, but the Romans do not appear to have worked these resources, even though gold can also be present. The main examples include the opencasts at Roșia Poieni, Bucium-Tarnița, and Rovina, near Brad.[748] It could be the case that the massive modern workings have obliterated traces of ancient exploitation, but the barrier is likely due to technology and sub-economic ore concentrations. The working of low-grade porphyry copper was not common until the advent of steam mechanisation owing to the high volumes and low ore concentrations involved. Even Roșia Poieni—the largest copper deposit in the Apuseni Mountains with an estimated 1,000 million tonnes of ore—contains only 0.36% Cu.[749] This percentage is already at the lower end of feasibility for modern recovery, and arguably negligible for Roman miners without the technology to shift sufficient amounts of rock to justify

747 Stumbea (2013) 7645; Bostan (2013) 283.
748 NB: Boroneanț (2000) 117 lists Bucium as a gold and copper exploitation site, which is slightly misleading as the evidence is mainly the Roman gold mining at Vulcoi–Corabia and Sf. Petru și Pavel. Whilst there is indeed modern mining activity at Bucium–Tarnița, Roman mining of the copper porphyry has not been identified.
749 Milu et al. (2002). For a sense of scale, the authors note that Roșia Poieni contained enough ore to be active for at least the next 50 years at the time of publication.

exploitation of the ore. The barren upper structure of the Roșia Poieni deposit would have also precluded ancient prospection. Furthermore, Roman activity has also not been found at Rovina farther south, where the Cu-Au mineralisation does outcrop in the Baroc Valley for approximately 300 m.[750] This seems to suggest that the Romans could not identify or were not interested in these deposits. Despite its economic significance to modern mining in Romania, porphyry copper was probably of little interest to the Romans in the Apuseni, given the presence of richer, more readily identifiable and accessible forms of gold in the region and the availability of copper elsewhere in the province.

Roman copper mining is thus largely clustered in the south-western part of Dacia in the Banat (*fig. 51*). Moldova Nouă, although important for modern copper mining, is discussed later in the section on polymetallic mines given the mixed nature of the deposit. As the following discussion illustrates, the piecemeal nature of the evidence makes it extremely difficult to identify any clear centre or pattern of organisation of Roman copper mining in the province.

Besides the polymetallic mines, the other Banatean mines of Tisovița, Eibenthal, and Ciclova Montană offer some of the more substantial evidence of Roman exploitation identified to date. The mines of Tisovița and Eibenthal are in Dubova commune, west of Orșova, sited on eponymous streams near the river Danube, and were subsequently re-worked in the 18th and 19th centuries by the Bohemians.[751] D. Tudor locates the extraction points in the valley between the two villages, where discoveries of isolated ceramic finds, canals, and water conduits offer indirect evidence for Roman mining.[752] No modern

750 Carpathian Gold Inc. (2012) 7–10.
751 Luca (2010) 98; Boroneanț (2000) 129–30; Macrea (1969) 304. For Eibenthal, the reference to Maghiar and Olteanu (1970) by Boroneanț (2000) could not be found.
752 Tudor (1968) 66; cf. Băeștean (2007) 130. Davies (1935) 207 notes mines of "uncertain date" at Tiszovicza. Although listed as two separate sites, it is possible that the Tisovița and Eibenthal mines refer to

fieldwork has been carried out since the early pre-20th century observations of undated ancient remains. The presence of what appears to be water management systems is intriguing, however, and suggests that the Romans may have also applied hydraulic techniques to the exploitation of copper in the region. Whether the methods were used for prospection or beneficiation of extracted ore is uncertain. The workings at Eibenthal and Tisovița could well be Early Modern or Austro-Hungarian. But if they are indeed Roman, the mines would be a unique example as there are no known parallels of hydraulic techniques applied to copper deposits elsewhere in the Roman world.[753]

Of all the known Roman mines in Caraș-Severin, Ciclova Montană is reported as a copper-exploitation site.[754] The ore at Ciclova consisted of chalcopyrite, with occasional gold, silver, and lead.[755] Little is known about pre-modern mining: although Boroneanț lists the site as a medieval and modern mine, with systematic exploitation beginning in the 18th century under the Habsburgs, the copper deposits were allegedly known as early as the Bronze Age or the Roman period. There are no sources that offer more specific details, however.[756] Given the proximity of Ciclova Montană to Ciclova Romană 4 km away—where the Romans extracted iron—and the polymetallic nature of all the other Roman mines in Caraș-Severin, it probably makes more sense to conflate the two sites and consider any Roman activity as the exploitation of a larger mixed deposit.

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exploitations in the same general area: Böhm (1880) 180 reports that the mines are half an hour's walk away from Eibenthal village, in Tissoviczer (Tisovița) Valley. NB: There is also a modern copper mine named Eibenthal at Dubova village, approximately 12 km upstream and NNE of Tisovița. This is the listed site location for Eibenthal—and not the modern town of the same name—in the RAN.

753 A.I. Wilson, May 2018, personal communication.

754 Boroneanț (2000) 120 lists the site as "Ciclova", presumably to differentiate the copper mine from the iron mine at Ciclova Romană.

755 Davies (1935) 207, n. 9.

756 Maghiar and Olteanu (1970) 192 notes that pre-existing ancient mines were re-worked in the feudal period in the "Berg Aemiter" mining district, where Ciclova is located. No further references are provided.

Copper exploitation also occurred at Turnu Roșu in Sibiu county, farther to the east than the main cluster of Banatean mines. In terms of location, Turnu Roșu is something of an outlier due to its easterly location, but its proximity to a fort guarding a key north-south corridor across the Southern Carpathians might suggest the possibility of an association between the two. Exploitation of the chalcopyrite deposits started in antiquity, and Roman activity is inferred from the finds of isolated coins, a hoard with pieces from Hadrian to Philip the Arab, and a lamp.[757] The exact location of the mines is uncertain: there are adits for ore extraction on the shores of the Olt in front of Cozia Monastery and also reports of mines stretching to Boița, near Câineni, where two Roman coins and a lamp were found in a gallery opened by iron tools.[758] The situation at Turnu Roșu is not entirely clear, but this may be an isolated incidence of local exploitation or perhaps mining associated with the site's defensive location. Turnu Roșu is near *Caput Stenarum* (Boița) at the defile of the river Olt, through which the major north-south road from Dacia to Moesia Inferior crossed the Southern Carpathians (*fig. 54*). A detachment from *Leg. Gem. XIII* was stationed at the strategically important *castrum*, where excavations also revealed traces of civilian housing as well as a probable *statio portorii*.[759] A piece of slag and two small bronze objects were also found in the camp, but this is not enough information to draw any conclusions about the relationship between the *castrum* and the purported mining at Turnu Roșu. *Caput Stenarum* was a key outpost in the sparsely populated eastern part of Dacia and additional

757 TIR L35. The marked location for Turnu Roșu in the Barrington Atlas corresponds with modern Câineni, south of Boița, rather than the modern town of Turnu Roșu. Davies (1935) 207 mentions the argentiferous copper of Rothenturm with respect to the provenance of pre-Roman and Roman bronze objects in Romania, but does not explicitly assert the exploitation of its deposits in the Roman period.
758 Wollmann (1996) 150; Marțian (1909) 325; Neigebaur (1851) 120. The deposits here also exhibit a mixed nature: the metamorphic rocks contained "nobler metals" along with the copper gravels (Wollmann (1996) 150, n. 111), and Schwanz von Sprengfels (1783) 197 reports that the rock was "silver-bearing"; cf. Davies (1935) 206.
759 Lupu (2002); Tudor (1968) 372–3.

research about the copper mine would help illuminate any possible relationship between the two.

Finally, four other sites with possible Roman mining are absent from the *CHBR* and Boroneanț catalogues, with no explanation for their omission. These sites are Bălan, Baia de Aramă, Vețel, and Ljubostine. This selection is in no way exhaustive, but an assessment of their archaeological potential illustrates the clear need to ascertain pre-18th century remains and identify sites where no further fieldwork is possible.[760]

Two modern copper-mining sites, Bălan and Baia de Aramă, appear in the secondary literature, but Roman mining is not confirmed by fieldwork or other sources and could be spurious. Modern mining of the Cu-rich pyrite and chalcopyrite deposits at Bălan (Harghita) started in the 18th century until exploitation ceased around 2006.[761] Christescu noted in the early 20th century that the Romans mined copper there, with no further detail.[762] Subsequent scholars after Christescu have not verified claims of Roman exploitation, citing only mines of uncertain date.[763] Although it is certainly possible that the traces of ancient activity are now lost, Harghita and the Eastern Carpathians in general are not known for Roman mining. In fact, no Roman mining sites have been identified in the Eastern Carpathians so far, and Bălan constitutes an anomaly if significant Roman mining did take place. This is one site where further clarification would also contribute to our understanding of the economic situation in the eastern half of Dacia, a comparatively understudied region overall.

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760 Wollmann (1996) 153 rightly notes the difficulty of cataloguing mining sites in Dacia, having omitted references he could not verify or were not mentioned by other bibliographic sources. Cf. Rusu (1977) 210, Table 9 for a list of Medieval copper sites that could offer additional opportunities for identifying Roman activity.
761 Stumbea (2013) 7644–5.
762 Christescu (1929) 30.
763 Davies (1935) 207. Christescu, Davies, and Wollmann all cite Marțian (1909) 326, who simply notes traces of old copper mines, along with masonry remains.

The name Baia de Aramă ("Copper Mine") offers some indication of the importance of copper exploitation to the town, but the prospect of Roman mining activity has not been substantiated. Such a possibility was first suggested by Davies, who considered Baia de Aramă one of Dacia's most important copper-districts along with the mines of the Banat.[764] However, his assertion is based on unconfirmed reports from C.S. Nicolaescu-Plopșor—the excavator of Bumbești, the main settlement in the area—and Davies is rightly cautious in accepting the results from provenance studies that identify Baia de Aramă as a copper source for Roman bronzes in Transylvania, especially since the mines in Banat and at Turnu Roșu also bear similar trace silver impurities.[765] Nonetheless, there are limited signs that Davies could be right. Mining was well-established by 1718, with accounts of old copper mines already in the area, as well as possible salt and iron mining.[766] There is, unfortunately, no indication of date. Roman mining at Baia de Aramă is not attested in the other modern bibliographic sources, and if it did occur, could have been an isolated instance similar to the possible exploitation of iron at Cârșu, some 11 km to the south.[767] The relatively remote location of Baia de Aramă would support this, as there are almost no other examples of Roman mining in the area. The closest known Roman copper mines are at Eibenthal, some 60 km away from Baia de Aramă and nearly twice the distance from Bumbești. The isolation of the Roman settlements of the Southern Carpathians and the Târgu Jiu Depression from the Danubian sites and their strongly rural character indicate a separate *territorium* administrated by the *castrum* of Bumbești.[768]

764 Davies (1935) 207.
765 The most recent study using isotopic analysis on Romanian bronzes is Mason et al. (2016), tracing Bronze Age artefacts from the Central Balkans more generally, which includes the Banat and the Apuseni within the study area.
766 Wenzel (1880) 242–3.
767 See Cîrșu: TIR L34; Barrington Atlas 21.
768 Tudor (1968) 362.

Assuming that the Romans could identify the Baia de Aramă copper deposits, the nearby military encampment at Bumbești would have provided demand for the metal—as suggested by the presence of numerous bronze and iron implements found within the fort and its environs, most notably everyday tools such as sickles, axes, chisels, and adzes.[769] It would make sense for the Romans to have exploited local sources of copper if available, and further work at Baia de Aramă could help verify this hypothesis.

The site of Vețel holds much promise for additional research, and its absence from the *CHBR* and Boroneanț catalogues is surprising. Located north-west of Deva on the river Mureş, Vețel's location between two key Roman mining areas placed it at a convenient crossroads for the processing and transport of ore, in addition to the exploitation of metal. The modern town is about 15 km away from the Roman iron-mining centre at Hunedoara and borders the southern extent of the Golden Quadrilateral, 15 km away to the north-east, towards the mines at Băița. The wider commune also possesses its own polymetallic and copper sulphide resources in the surrounding mountains, especially to the south-east at Muncelu Mic and Muncelu Mare. Large reserves of lead, zinc, and copper, some gold and silver, as well as rare elements have resulted in modern mining that continued until the end of the 20th century.[770] Austro-Hungarian geologists recorded these deposits in the middle of the 19th century, but exploitation in the surrounding area is believed to be much older, with silver ore reputedly found in a prehistoric settlement at Muncel.[771]

769 Tudor (1968) 363.
770 Glumac (1991) 89; Primaria Vețel (2013). The Muncelu Mic opencast mine represents one of the largest remaining iron ore reserves in Romania, and also contains economically viable quantities of gold and silver. There are concerns that mining could resume, as European Goldfields Deva SRL (owned by Eldorado Gold) holds an exploration license as of 2013; Pencea, Brădățan and Simion (2013) 26.
771 Davies (1935) 206.

Despite the wide range of minerals available, the Romans seem to have only exploited copper at Vețel.[772] There has been no modern archaeological investigation targeting the mining remains, and the reported Roman date by early 20th-century Romanian scholars is presumably based on the settlement remains and wide range of finds associated with the nearby *castrum* of *Micia*, 2 km north-east of Vețel on the banks of the river Mureș.[773] In addition to copper, the Romans may have also exploited salt. The presence of salt deposits and mineral springs in the area, together with epigraphic attestation for a *conductor salinarum* at *Micia* (*IDR* III/3, 119), suggests their probable exploitation.[774] Despite the lack of explicit evidence, there is no reason to dismiss out of hand the likelihood that the Romans made full use of the variety of mineral resources available around *Micia*. Although Vețel is nominally categorised here as a copper-mining site, what the discussion thus far has revealed is the polymetallic nature of several of these sites. It illustrates how categorising the non-ferrous metal mines and discussing them as such is, to some extent, an artificial exercise that discounts the reality of geological and economic complexity.

In light of this, the relationship between the mining in Vețel commune and the military camp at *Micia* also bears further investigation, as this is one site for which a close connection between the two exists and a significant body of information for the *castrum* is already available. *Micia* was an important Roman auxiliary fort and its significance within the province is well attested: excavation has revealed extensive physical remains and numerous epigraphic and sculptural monuments, as well as a flourishing civilian

772 Wollmann (1996) 149; Christescu (1929) 30; Marțian (1909) 349.
773 Micia: Neigebaur (1851) 52–65; cf. Luca (2008) 35, 114, 185–7. The area around the fort is currently under arable cultivation; Hanson and Oltean (2003). Vețel and its mine also appears to have been active in the post-Roman period (c. 4th–6th century AD); see RAN Site 91991.02 and 91991.04.
774 Oltean (2007) 39; Luca (2008) 14.

population.[775] Buildings in addition to the military fortification included large baths, an amphitheatre, two temples, and commercial and craft production facilities, along with two cemeteries on the outskirts. Its riverine location also facilitated trade, making *Micia* an important customs outpost as well as a port, with a shipping association (*nautae*) present. Furthermore, the fort secured Dacia's main east-west corridor along the Mureș valley towards Apulum and the interior, controlling access to the gold mines of the Golden Quadrilateral. The site had a long life and was not abandoned until the 4th or 5th century AD. The presence of the army, its *vicus*, and a thriving economic life at *Micia* would thus have presented considerable demand for common goods. The exploitation of a full range of local resources—amongst which base metals (and salt) would have been a part—is a logical outcome. Although only copper mining has been reported so far, the presence of other metals suggests that there may be room for further investigation into their use. Vețel, with its proximity to both a major military garrison and two economically vital mining regions, is well worth additional study.

One final site worth mentioning is that of Ljubostine, where copper exploitation appears to have been noteworthy. According to one 19th-century account, traces of significant amounts of mining were present, as well as the remains of slag, ores, and walls.[776] The site also apparently had aqueducts that channelled water for washing ore.[777] Unfortunately, the location of Ljubostine is unknown. Davies, who reports the site as being on the Danube, was unable to locate it, but believes that it is probably Lubositiu, west of Orșova and near the Mrakonija (Mraconia) valley.[778] Wollmann mentions Ljubostina in former Yugoslavia, but only in passing, which may locate the site near Trstenik in

775 IDR III/3, s.v. Micia.
776 Böhm (1880) 180.
777 Davies (1935) 207.
778 Davies (1935) 207, n. 5. Unfortunately, Lubositiu could not be located.

Serbia.[779] Of the two, Davies' suggestion is perhaps preferable, on the basis that Mraconia has known chalcopyrite deposits and is about 4 km away from Eibenthal mine near Dubova, where canals and conduits for ore washing have also been reported.[780] In either case, there is no indication that this site—if it exists—was Roman.

One would be hard-pressed to identify a centre for copper mining in Dacia based on the available evidence. Whereas the exploitation of iron shows signs of centralised control, the known instances of copper mining in the province are scattered, and it is difficult to discern a broader organisation of copper-mining activity. Geology obviously constrains site distribution, but extraction for local use probably accounted for at least some of the mines, particularly at relatively remote sites and places where metal for everyday use was in high demand. Moreover, Roman exploitation of copper in Dacia also needs to be viewed with respect to the polymetallic deposits of Caraș-Severin, where copper was one of several metals mined alongside gold and silver. The mines in that part of the Banat do exhibit some clustering largely because of the location of the deposits in the Semenic Mountains. But whether the Banat constituted a centre for non-precious metal mining in Dacia is debatable and remains to be seen.

Tin

Tin is even rarer in Dacia than copper. Few sources are known, and the quantity is small. The metal has been found in the Banat, in the Semenic Mountains (Piatra Semenicu) between Reșița and Caransebeș. Recent work has also identified cassiterite ores near Radna and Hondol in the Apuseni, and tin-bearing deposits at Grădiştea de Munte, either

779 Wollmann (1996) 150.
780 On the geology of Mraconia, see Anason et al. (2011).

of which were possibly exploited in the Late Bronze Age.[781] According to Davies, however, ancient exploitation is unknown.[782] Why this is so has yet to be addressed, but the question bears consideration given that the Romans seem to have exploited all the other types of minerals that they could readily identify. Possible answers include the lack of research into tin mining in Dacia; the destruction of ancient remains; Roman failure to recognise the presence of tin deposits; or negligible levels of exploitation, for whatever reason.

After gold and silver, tin is the proverbial "third precious metal" due to its scarcity and provinciality as it only occurs in a few specific places in the world. Its orogenesis is related to a group of granites whose occurrences in Europe are largely limited to Bohemia (Erzgebirge), Brittany, Iberia, and Britain.[783] Of these, the tin belts of north-west Spain and Portugal, and Devon and Cornwall were most important to the Romans.

It is unlikely that a lack of technological ability constituted a barrier to exploitation, with the range of mining expertise evident elsewhere in Dacia and in the provinces of Iberia and Roman Britain. Ancient authors such as Diodorus, for example, recount how the natives of Cornwall (*Belerium*) mined tin out of earthy seams, then smelted the ores for onward transport.[784] The Romans also certainly possessed the technology to apply hydraulic methods to mine alluvial tin deposits, which could require high-volume processing to wash out the desired ore.

A more likely reason is that the Romans were unable to identify the tin sources in Dacia, either because the quantity was too small or the ores inconspicuous. The most

781 Mason et al. (2016) 110.
782 Davies (1935) 206. There are no known tin mines in the catalogue of Dacian mines in the appendix.
783 Valera and Valera (2003) 10. Evidence for pre-modern tin exploitation in Europe: Davies (1935) 83–5, 91–3 (Gaul); 103–5 (NW Spain); 140–8 (Cornwall).
784 Diod. Sic. V.22.

common tin ore is cassiterite (SnO_2), which contains high concentrations of tin and tends to occur as alluvial or secondary deposits. Another ore, stannite (Cu_2FeSnS_4), a copper-iron-tin sulphide, is also exploitable, but its occurrence is rarer and smelting is more complicated. It is possible that Roman miners had difficulties distinguishing some of the darker-coloured ores. At Rio Tinto, for instance, the Romans worked the more obvious brightly coloured tin oxides to exhaustion but not the black sulphide ores, suggesting that they were unaware of the value of the darker ore as a source of tin.[785] However, tin in Dacia tends to occur in mixed deposits, and it could be the case that the Romans were extracting mixed copper ores that produced a natural bronze when smelted, rather than specifically seeking out tin. A more fruitful approach would be to consider tin mining as part of polymetallic metal exploitation.

The absence of Roman tin mining in Dacia cannot be fully explained and it may well be that Roman exploitation was negligible. In a province rich in mineral resources, tin mining may not have been economically viable given its limited occurrence in Dacia, and the Romans probably directed their energy towards the higher-value exploitation of gold instead. The presence of an empire-wide network of metal supply also meant that demand for tin could be fulfilled by the richer tin mines of Cornwall and north-western Spain and Portugal instead. On a local level, another possible tin source closer to Dacia could be worth further exploration to answer the question of regional supply and demand. Cassiterites are also known in the Balkans—such as the placer deposits near Mount Cer, in western Serbia—but little work has been conducted on their exploitation, and certainly not for the Roman period. If the demand for tin in Dacia did exceed the resources available

785 Dayton (1971) 56. Note, however, that Dayton may have confused the two types of copper ore, but his point regarding the overlooked darker ore is still valid.

locally, it would make sense for ores to be preferentially sourced from regional rather than distant deposits, unless there were reasons precluding their exploitation. The lack of information on tin mining in the Balkans prevents a full analysis. But research using isotopic analysis to identify the provenance of prehistoric bronzes from the central Balkans has already established a distinct Sn-isotope signature for the deposits of the Banat and Transylvania from that of western Serbia.[786] Applying this technique to Roman-period bronzes could help shed light on a severely understudied sub-area of Roman mining in the province of Dacia and on tin mining in general.

5.3.3 Polymetallic exploitation

The discussion thus far has largely been organised around the exploitation of specific metals. However, base metals frequently occur in mixed geological deposits, and disambiguating the type of minerals extracted is difficult. The Romans were not unfamiliar with mixed deposits, having encountered them elsewhere in the empire: Iberia had pyrite-copper and Cyprus copper-zinc deposits, for example. The polymetallic workings of Dacia are treated here as predominantly non-precious metal mines, but this categorisation is, to some extent, artificial. The exploitation of both base and precious metals in the same area certainly occurred in Dacia, illustrating both economic reality and the complexity of trying to categorise past mining activity. For the purposes of this section, however, the focus will be on the mines of Caraș-Severin in particular, as these mines are all located in the same geographical region and, despite their diversity, arguably constitute a group of workings distinct from those of the Golden Quadrilateral and Hunedoara.

786 Mason et al. (2016).

Of the 15 mines known in Caraș-Severin county, six are reported polymetallic sites, all of which are in the piedmont of the Banat Mountains. These are Sasca Romană, Moldova Nouă, Vărad, Dognecea, Surducu Mare (*Centum Putea*), and Bocșa (*Table 7; fig. 51*).[787] Geologically, the Semenic Mountains are part of the wider Banatitic Magmatic and Metallogenetic Belt (BMMB), a 1,500 km-long belt that stretches across parts of Romania, Serbia, and Bulgaria, and hosts a variety of Cu, Au, Mo, Zn, Pb and Fe deposits, as well as Europe's only world-class porphyry-copper deposits.[788] The most economically important districts are the porphyry Cu-(Au)-(Mo) and associated epithermal sulphides with active Cu-Au mines, one of which is at Moldova Nouă. The base metals occur in the more abundant Fe, Cu, and Zn-Pb skarns and were mostly mined in the past. All six of the Caraș-Severin mines are reported as exploiting a variety of base metals (Cu, Fe, Pb), as well as gold and silver.

On cursory examination, it appears the Romans exploited a whole range of metals where geologically possible. But the nature of the evidence for most of the mines in the Banat is indirect, and Roman mining is attributed based on associated surface finds. The earliest secure date for mining activity is 1718, when mining was systematically organised under the Habsburgs at Bocșa, Dognecea, Oravița, and Moldova Nouă.[789] Another significant problem is the lack of clarity in the secondary literature between mines that are located on mixed geological deposits and sites where the Romans actually did exploit more than one of the metals available. In other words, it is not always entirely clear whether a mine is "polymetallic" with respect to its geology or its mining activity, and sometimes the two may be conflated.

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787 As reported in CHBR (2006) Appendix D.
788 Ciobanu, Cook and Stein (2002). The Banatului Mountains
789 Hillinger, Olaru and Turnock (2001).

The exploitation of gold in the Banat is also complicated in this respect, as gold-mining activity could refer to gold washing or the exploitation of alluvial river gold or the gold occurring within mixed deposits. The problems associated with use of the term “gold washing” in the literature have already been discussed above at length, being most relevant here to the sites of Borlova and Bolvașnița, with possible gold-washing activity. But to briefly illustrate some of the difficulties with the available evidence, the site of Nera—where mining activity is uncertain and attributed to the Dacian and medieval periods—is reported as a gold mine with the probable exploitation of other metals, with no further details with respect to dating or mining methods.[790] It is entirely possible that gold was won by washing, as free alluvial gold is present in Nera River.[791] But it is unclear that the exploitation of other metals took place. Another example are the two adjacent villages of Sasca Montană and Sasca Romană. The *CHBR* asserts the extraction of gold as well as silver, copper, lead, and iron, whereas the *TIR* notes only the exploitation of iron, silver, copper, and lead.[792] Both are entirely plausible, as the Nera River also flows past these two towns and gold would have been available, but there is no way to ascertain the situation without additional fieldwork. This is only a start at highlighting the problems, but future work needs to differentiate between the exploitation of mixed deposits and the exploitation of a range of available metals.

The mines of the Banat appear to have achieved a modest level of development, insofar that traces of settlement and funerary remains have been identified at some of the

790 Boroneanț (2000) 122 has identified the site as Slatina-Nera. It is unclear why he has attributed a Dacian date to Nera, but not a Roman one. TIR L34 notes that there were traces of mining and a Roman road; no metal type specified.
791 Croitoru (2009).
792 CHBR (2006) 140; TIR L34 s.v. Sasca Montană. Cf. Tudor (1968) 62: Sasca Montană and its annex, Ciclova Romană to the north, exploited gold, both mined and from gold sands, as well as smaller quantities of copper, silver, iron, and lead. Copper was certainly viable, as the rich deposits were still being extracted in the 19th century; Maghiar and Olteanu (1970) 229; Wollmann (1996) 152.

sites, even though their numbers are outstripped by those found in the Apuseni Mountains. Where the mining evidence is clear enough, the Romans applied a range of techniques to work the polymetallic deposits in the Banat, as suited to the geology. Furthermore, there appear to be suggestive traces linking some of these mines to military supervision, far more closely than observed with the gold mines of the Apuseni. However, the development of the mines in relation to the presence of the army cannot be sketched out with greater certainty.

The site of Moldova Nouă is probably the most important polymetallic mine in Caraș-Severin, as evidenced by the relatively extensive surface finds. The area consists of the adjacent villages of Moldova Nouă and Moldova Veche;[793] a necropolis at Sălişte, on the road towards Macești;[794] as well as the *castrum* of Pojejena about 10 km to the north-west, on the Danube (*fig. 55*). Exploitation of the ores took place since at least the Roman period through to the modern, with copper being particularly important: the deposits at Moldova Nouă constituted Romania's principle source of copper until 1989.[795]

Roman mining at Moldova Nouă was like Sasca Montană to the north, with many small workings exploiting the same metals of gold, copper, silver, iron, and lead. Speculation by early scholars have placed the fortress of *Centum Putea* at Moldova Nouă on the basis of the numerous mines in the area.[796] The name of *Centum Putea*—"One Hundred Wells"—is suggestive, but the fort's location has since been identified at Surducu Mare through archaeological excavation. Nonetheless, the importance of mining at Moldova Nouă is indicated by reports of "tens and hundreds" of wells spread across

793 CHBR (2006) and Boroneanț (2000) list only Moldova Nouă as a gold, silver, copper, lead, and iron-mining site, and have probably conflated the two villages into a single site.
794 Luca (2010) 169–70.
795 Bozu (2010).
796 Wollmann (1996) 151. Francesco Griselini was the first to propose Moldova Nouă as a possible candidate for Centum Putea in the 18th century.

Başedin Hill from Mount Bosniac, whose presence could not be attributed wholly to Ottoman activity and was thought to be Roman by the 18th-century Austrian cartographers. Further exploration in the 19th century identified Roman activity at Cânepiște, under the peak of Mount Baron Drachenfels, in Valea Bătrâna near the modern mine of Ogaşul Băieşului, 3 km north of Moldova Nouă.[797] Roman mining has also been found at Ogașul Grec and Valea Apele Albe.

The deposits at Ogașul Băieșului were mined in shafts. Rescue excavations in 1986–1987 identified more than 20 vertical wells on the north-west slope of Boșneag (Bosniac) River, up to 600 m in elevation, most of them blocked with trees. The shafts were rectangular in section, nearly square, measuring approximately 2 m by 1.6–1.8 m. The walls were precisely worked with hammer and chisel, and nearly vertical.[798] Geza von Bene, who entered the mines in 1896, reported a network of Roman galleries underneath, as well as working chambers and wooden platforms for access to the lower galleries, and lamp niches. He also detected possible signs of fire-setting. The extent to which flooding was a hindrance is unknown: water was noted, but there was no accumulation in the upper levels.[799] Further south at Ogașul Grec (Griechental), the Romans exploited the silver veins in underground galleries, where a lamp was found. However, the mines were abandoned before they were fully exploited. Evidence for Roman activity is also seen on the western slope of Floricica Hill in Valea Apele Alb, where a trapezoidal gallery opened with hammer and chisel exploited copper. A 10 m-long side gallery tracked a complex ore

797 Luca (2010) 170; Cântar et al. (2015) 208–9.
798 CCA 1983–1992.
799 Bozu (2010) 204–6.

body underground, with the swings in sudden directions and an abrupt termination suggesting a prospection gallery. Several lamp niches were also identified.[800]

A Roman *vicus* also existed at Ogașul Băieșului, with groups of miners' housing implied by finds of ceramics and coins, dating the settlement to the 2nd to 3rd centuries AD.[801] The small-scale nature of the mining and the compactness of the site limited the development of *vici*, resulting in small settlements for the miners' homes, leading Tudor to believe that the community at Moldova Nouă was temporary.[802] Tudor's observation regarding Moldova Nouă's seasonal character is certainly plausible, as most mining camps tend to be impermanent in nature, but the transience of the miners at Moldova Nouă is difficult to gauge. The location of the mines near the Danube, plus the longer history of settlement in the area before the Romans, make it extremely difficult to single out mining as the main reason for high turnover. Furthermore, the necropolis at Moldova Veche-Săliște in addition to finds of epigraphic monuments and hoards—probably related to the mining activity—suggest that a portion of the inhabitants was more established or wealthier than Tudor believed, and that the community was not wholly transient.[803]

Although no longer thought to be *Centum Putea*, the military was present at Moldova Nouă and its environs. The *castrum* of Pojejena was located 10 km from Moldova Nouă and about 20 km from the Roman mines, securing access to the Locvei Mountains.[804] A rectangular stone fortification containing Roman buildings was uncovered at the border with Sasca Montană to the north.[805] Most importantly, a building measuring

800 Bozu (2010) 206–7; CCA 1983–1992.
801 RAN Site Code 51065.02.
802 Tudor (1968) 62.
803 Wollmann (1996) 150. A 4th-century hoard of 740 coins was found north-west of the Suvarov mines, approximately 1.5 km upstream of Tisa-Potoc valley; RAN Code 51065.10.
804 Bozu (2010) 203.
805 Luca (2010) 170.

19 by 9.70 m, with eight rooms, a paved inner courtyard with stamps of *Leg. VII Claudia*, and a three-room annexe was identified at Ogașul Băieșului.[806] The main rooms consisted of two living rooms (one with a hypocaust), two small internal areas with baths, and four rooms functioning as a workshop for processing and re-casting silver and copper. Remnants of slag and molten iron suggest that the annexe housed workshops for processing raw iron. Traces of iron mines and ore-reduction ovens may have been located approximately 50 m to the north and north-west, on the banks of the Ogașului. Although the mines have not been fully explored, the associated surface remains indicate that mining at Moldova Nouă was active, related in some manner to the military, and that the workforce possessed technical skills like those seen in the miners of the Golden Quadrilateral.

The mine of Vărad near Coronini, about 5 km away from Moldova Nouă, was possibly an annexe of the latter and also provides evidence for an established Roman mining settlement. The same types of ores were exploited here as at Moldova Nouă. Boroneanț surveyed the old mines in the 1970's and found cuprite ore on the surface, along with remains of furnaces, habitation, and ceramics. A Roman cemetery was also reported in the vicinity, and mining objects were found there in 1848.[807] It is likely that the remains reported by Boroneanț are the same ore-processing workshop and necropolis excavated by O. Bozu in the 1980's. The exact relationship between Vărad and the mining activity at Moldova Nouă is unclear, but given the nearness and size of Moldova Nouă, it is probable that the two were related in some way or possibly under the same mining administration, perhaps from the *castrum* at Pojejena.

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806 Bozu (2010) 202–3; CCA 1983–1992.
807 Luca (2010) 80; Boroneanț (2000) 123; CHBR (2006) 142; Maghiar and Olteanu (1970) 60, n. 19. Modern mining around Moldova Nouă and at Vărad have probably destroyed all traces of ancient activity; cf. Cântar et al. (2015).

The iron reserves were most important in Dognecea commune and Mount Moravița near Ocna de Fier village, but the other metals were exploited as well, with extraction occurring in adits and—even more so than in the Apuseni mines—as open shafts or surface stopes. These workings are concentrated in the Ioan, Tâlva, Danieli and Ocna de Fier Mountains (*fig. 56*).[808] In addition to the examples of Sasca Montană and Sasca Romană above, Dognecea had a mix of underground and surface exploitation, with traces of gold, silver, iron, and copper extraction shafts as well as gold washing.[809] It is not entirely clear, however, what is meant by gold washing, but the situation of Dognecea in a river valley would have allowed the use of water to separate out ore by gravity. Traces of gold washeries that processed the gold from veins were reportedly identified in Valea Sălașilor or Valea Secașului in the late 19th century.[810] Cupellation of gold using lead also took place.[811] Unfortunately, the location of the miners' settlement in Dognecea is uncertain. The degree to which the army was involved in directly supervising mining activity is unclear, but there are signs that detachments from *Leg. IIII Flavia Felix* were present in some capacity in the wider Dognecea region. Like the small-scale mining exploitations scattered throughout the mountainous terrain, military deployment stations in the Banat were also diminutive in size, consisting of small detachments of soldiers.[812]

The fort of *Centum Putea* has now been identified at Surducu Mare*,* where traces of vertical copper and silver shaft mines have been found, as well as the reported

808 Wollmann (1996) 152.
809 TIR L34 s.v. Dognecea.
810 Wollmann (1996) 152. Téglàs (1899) 223 noted the "characteristic gravel pebbles" along the main valley from Dognecea to Vaskő (Ocna de Fier).
811 CHBR (2006) 136.
812 Tudor (1968) 62–3.

exploitation of gold and lead.[813] The remains of a camp (160 by 130 m) and stamped bricks and roof tiles indicate that a vexillation of *IIII Flavia Felix* was stationed at *Centum Putea*. There was also a necropolis, as well as the remains of the *Lederata-Tibiscum* road.[814] The civilian settlement merged with the fort's *canabae* and was probably mostly populated by miners. The exact location of Surducu Mare's mines has not been specified in either the *CHBR* or by Boroneanț, but it is likely that the mines in question refer to those in the wider region around Dognecea.

Modern mining has unfortunately destroyed the remains at Moldova Nouă and in the areas around Dognecea and Ocna de Fier. But if the early reports of vertical open-air workings at these sites and *Centum Putea* can be believed, this method of shaft mining may be comparable to the type of exploitation employed elsewhere in the Roman Empire, such as at *Vipasca*, Portugal, which were also polymetallic mines dominated by copper-silver production. The arrangement of self-contained vertical workings at *Vipasca* allowed for management of the mines as concessions, leased out to private individuals by the state.[815] The lack of extant remains in the Banat precludes further fieldwork for comparison, but it is possible that the Romans applied this method of exploitation to similar polymetallic sites in south-western Dacia, having successfully managed the mines of Iberia in this manner previously.

Roman mining is verified at Bocșa Montană, where finds in the shafts link the mine workings to the Roman period. In addition to iron ores, gold veins to the south-east

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813 CHBR (2006) 140; Boroneanț (2000) 123; Christescu (1929) 30; Téglàs (1899) 223. The introduction of gold as one of the exploited metals in the CHBR and Boroneanț stems from Macrea (1969) 304, who lists Surducu Mare as one of three localities in the Banat—along with Dognecea and Sasca Montană—where gold was exploited along with the silver, copper, and sometimes lead. There is a lack of clarity in the secondary literature, as the mines of Centum Putea, Dognecea, and Ocna de Fier are sometimes treated as one general area; cf. Téglàs (1899), Wollmann (1996) 152–3.
814 TIR L34 s.v. Centum Putea; Tudor (1968) 48.
815 Cauuet (2004); Domergue (2008) 102.

of Bocșa were also worked in antiquity.[816] The main Roman discoveries, however, come from Cracul cu Aur to the south, west of Ocna de Fier (*fig. 56*). Shafts identified at the massif contained a rich cache of Roman objects including lamps, iron bars, spades, hammers, and chocks. A hoard of *denarii* from Vespasian to Decius (AD 70 to 251) was also found in the same mine.[817] Despite the mine's name, the main metals exploited at Cracul cu Aur were silver or possibly tin. Remains of buildings and traces of a Roman road offer evidence for a settlement, and brick stamps from *Leg. IIII Flavia Felix* provide signs of the Roman army at Bocșa. Detachments of *IIII Flavia Felix* at the forts of *Centum Putea* and *Berzobis*, both within 20 km of Bocșa, help explain the military presence. However, it is insufficient to argue in favour of forced labour at the site (slaves and *damnati ad metalla*), as Tudor has hypothesised, especially without further evidence from the miners' civilian settlement.[818]

The other Roman fort in the area is *Berzobis* (Berzovia) on the left bank of the river Bârzava, north of *Centum Putea* on the *Lederata-Tibiscum* road. Preservation of the fort's remains are poor due to modern impingement, but fragmentary tiles with stamps of *Flavia Felix IV* were found.[819] An earth mound found at Berzobis presumably stemmed from gold washing, but no further details are available.[820]

There are limitations to organising the mines by the nature of their deposits, and examining just the polymetallic mines results in the omission of over half the known sites in Caraș-Severin. Nonetheless, the nine other mining locales known in addition to the six polymetallic mines seem to support the general picture of the Romans exploiting any

816 Wollmann (1996) 152–3.
817 TIR L34 s.v. Bocșa.
818 Tudor (1968) 62.
819 RAN Code 51519.01; CCA 2000; CCA 2002.
820 TIR L34 s.v. Berzobis.

metals they were able to locate and work, as well as a certain level of association with the military. The sites in question are Ciclova Romană, Ciclova Montană, Maidan, Marga, Slatina-Timiș, Borlova, Bolvasnița, Turnu Ruieni, and Tincova. Firstly, as already argued above in the section on copper mines, Ciclova Romană (Fe) and Ciclova Montană (Cu) could be included here as examples of polymetallic mines, given their proximity to each other and to other polymetallic sites such as Sasca Montană to the south.

Then there are possible polymetallic sites where gold was the main metal, with the uncertain exploitation of other metals. These are Maidan, Marga, and Slatina-Timiș.[821] Both the *CHBR* and Boroneanț note that the exploitation of other metals is "probable" at these mines, but do not provide evidence supporting this assertion. One wonders if such a claim is based on the mixed exploitation observed at the other polymetallic mines. Not much information is available in the secondary literature about the mining that occurred at these three places, but it is perhaps noteworthy that two of these sites have some affiliation with the provincial road network and the military. Mining at Maidan is not entirely secure, but the exploitation of the copper veins is associated with Roman coins and building remains.[822] Marga—where traces of gold extraction were identified—was the *mansio* (MP XV) on the road to *Sarmizegetusa Ulpia Traiana* towards the interior of the province to the east. The fort of *Pons Augusti* was also nearby at Voislova, about 5 km to the west of Marga. Likewise, Slatina-Timiș was a *mansio*, but on the *Dierna-Tibiscum* road running north-south (MP XIV from *Tibiscum*).

In addition, three gold washing sites are known in Caraș-Severin, of which two—Borlova and Bolvașnița—have already been mentioned above, plus the site of Turnu

821 CHBR (2006) 138, 140; Boroneanț (2000) 121–2, 123; Macrea (1969) 303; TIR L34 s.v. individual entries on Maidan, Marga, and Slatina-Timiș.
822 TIR L34: "probable" Roman mining; cf. Wollmann (1996) 152. NB: Maidan in Caraș-Severin is the now re-named Bradișoru de Jos (1924) and not the modern town of Maidan in Suceava.

Ruieni, where the remains of a Roman road were also identified.[823] These three sites—along with Vârciorova in neighbouring Mehedinți county, where possible traces of Roman mining were reported—are just off the *Dierna-Tibiscum* road (*fig. 50*). The small concentration of mining sites close to a major highway is suggestive: all four are within the 25 km stretch of road between *Tibiscum* and Slatina-Timiș, which may possibly indicate military oversight of some sort, or the development of settlements at mining sites close to frequented roads. There are also limited signs of later activity at Borlova and Bolvașnița, which may possibly suggest that mining continued in this area after the *floruit* of the gold mines in Dacia's interior. Roman coins from the 3rd century were found at Bolvașnița, and a large hoard with hundreds of pieces, the latest of which date to Constantius II, indicate that exploitation at Borlova continued until the 4th century.[824]

Finally, there is the iron mining at Tincova.[825] Geologically speaking, Tincova's location in the eastern range of the Poiana Ruscă Mountains places it closer to the cluster of iron mines in Hunedoara county further east, even though the mine is within the modern county of Caraș-Severin (*fig. 53*). However, there is perhaps a wider case to be made that Tincova—like Marga, Slatina-Timiș, and the gold-mining sites along the same road—developed in relation to the network of roads and military installations in the immediate area. Tincova is located north of *Tibiscum* off the main north-south artery and south of the iron mine at Criciova. As such, it would have been better placed to supply the fort at *Tibiscum*, being closer than the Hunedoaran mines. Located at the intersection of two main public highways—the *Dierna-Tibiscum* road and the road east to *Sarmizegetusa*—*Tibiscum* (Jupa) was probably the immediate hub for the area's economic life, even if there

823 TIR L34 s.v. Turnu Rueni.
824 Borlova: Tudor (1968) 62; cf. TIR L34: 3rd–4th c. AD hoard. CHBR (2006) 134 incorrectly cites the coin as one from Constantius III.
825 Boroneanț (2000) 123; Macrea (1969) 305; TIR L34 s.v. Tincova.

is no direct evidence for its involvement in mining activity. This is one group of sites where, despite exploiting different metals, could possibly be considered a small cluster oriented around *Tibiscum* and its road network.

The importance of the Banat as a mining area within Dacia is not as clear-cut as the other two mining regions of the Golden Quadrilateral and Hunedoara. Differentiating between the exploitation of different metals is difficult, and it is likely that Romans mined whatever they could identify that was of value to them. The base metals—especially copper—were of particular significance, as the mining around Moldova Nouă and Dognecea seems to suggest. Although not as important as the deposits in the Apuseni, gold seems to have been exploited where available in Caraș-Severin, both in the form of underground and alluvial deposits. There is not enough information to specify when gold exploitation occurred—whether soon after conquest, simultaneously with base-metal mining, or later in the 3rd century—but the diverse nature of the evidence, coupled with the range of base of metals at several of the mines, suggest an enterprising response to the availability of local mineral resources.

There is also reason to believe that mining in the Banat shows a closer relationship to the army than seen elsewhere in Dacia. Some sites, such as Surducu Mare, reveal that miners and soldiers shared the same settlement, as at *Centum Putea*, whilst others may have developed in relation to access to the road network and demand generated by a local fort. Arguments for military supervision of gold-mining sites in the Golden Quadrilateral tend to assume imperial ownership of the mines or a desire on the part of the Romans to protect a valuable resource. With the non-precious metal mines, however, the commonplace nature of the metals extracted seems to support the extraction of iron and copper for everyday needs, which a military fort would have required to a greater degree than the small-scale exploitation of rural inhabitants. The corresponding evidence from the copper mines is not very clear, but there are some examples such as at Turnu Roșu and Vețel where the exploitation of copper ores may be related to the demand created by nearby military camps. Additionally, the association with the army may have also benefited the mines of the Banat in the later years of Roman rule as the number of foreign invasions increased, as there is some evidence for activity in the 3rd century (e.g. Bocșa Montană) and mining seems to have persisted longer here than elsewhere in Dacia.

5.4 Conclusion

Although the location of mining sites is dictated by the occurrence of metal deposits by default, the differences between the precious- and base-metal sites in Dacia reveal that the Roman quest for mineral resources exerted a definite impact on settlement patterns in the province. The sites are clearly integrated into the wider provincial infrastructure, with access to transport networks and urban centres (*fig. 57*). The exploitation of base metals appears more closely tied to the location of centres of demand (e.g. towns, military fortifications) and to meeting the local needs of rural inhabitants (*fig. 58*). The clear clustering of centrally controlled iron mines around *Micia* and roughly midway between the two principal towns of *Sarmizegetusa Ulpia Traiana* and *Apulum* on the main transport corridors provides an ideally located hub to serve the wider requirements of the province. In contrast, the lack of a villa-based economy and rural settlements except for mining villages in the Golden Quadrilateral suggests that the Romans were primarily there for the mineral wealth, despite the remoteness of location (*fig. 59*). In fact, the need to connect these dispersed mining sites to the central highways helps explain the presence of roads running through the Apuseni Mountains, linking these mines to the seat of mining administration at *Ampelum*, flanked by the fortifications at *Potaissa* and *Micia*.

The richness of the archaeology yet to be studied in full at mining sites beyond Roșia Montană indicates an active mining economy in Dacia. The Romans employed a full range of exploitation methods from underground to surface mining, as well as gold washing and the use of techniques like hydraulic mining and fire-setting (*fig. 60*). Identifying hydraulic mining in Dacia is especially problematic and overlooked in the literature, but such remains do exist and offer potential for future study. Of particular note for the underground mines are the trapezoidal galleries and the water-lifting wheels, which provide evidence for the presence of skilled mining labour from Illyria and investment in the workability of the underground mines (*figs. 61 and 62*).

In terms of scale, the majority of the known mining sites are small or considered small scale, due in part to our relative lack of knowledge and problems of archaeological recovery. Of the approximately 90 sites identified in this thesis, the largest site remains Roșia Montană, which proves that Roman mining could and did occur on a large scale in Dacia. But further research into other sites such as Bucium and Pianu de Sus highlights how large-scale mining also took place elsewhere in Dacia, employing Roman methods of hydraulic mining not clearly elucidated in the Romanian literature and probably underreported. Other sites with potential importance include Ruda-Brad, Baia de Criș, Baița, and Moldova Nouă, and future research could help in identifying local mining centres and work towards building a site hierarchy. Mining activity in Dacia was by no means trivial: even though we do not know enough to truly gauge the size of individual sites, the total number of mines known, the density of exploitation in the richest ore regions, and the startling distribution of a pronounced spine of mines down the western half of Dacia suggest significant activity on an aggregate—if not necessarily a local—level.

The polymetallic mines of the Banat region also reveal higher levels of Roman activity than acknowledged in the secondary literature, having been bypassed in favour of the gold mines of the Golden Quadrilateral. Although one can persuasively argue for a "heartland" of Roman precious-metal mining in the Apuseni Mountains, gold and silver were also present in the mines of the southwest, and their relative importance and relationship to the mines of the Golden Quadrilateral bear further consideration. These sites remain particularly understudied; future work could help highlight their possible importance to Dacian mining in the later periods of Roman rule and as a source for copper and silver.

Rather strikingly, there is a curious silence in the secondary literature regarding Roman silver mining in Dacia. Despite known sources of silver, Romanian scholars do not address silver-mining activity—or the lack thereof. The main reason is probably the scholarly preoccupation with the gold mines, but silver was arguably just as important—if not more so—to the Romans when considered in light of their currency and the need to coin *denarii*. Although gold was the predominant metal mined in the Apuseni region, some of the deposits there are extremely high in silver, and silver was also present in the polymetallic mines of the Banat. The Romans did know how to extract silver from gold and lead, and application of its use is indirectly suggested by the find of a lead litharge roll from Roșia Montană.[826] Also noteworthy in this respect are a specific group of Illyrians that immigrated to Roșia Montană: although scholars tend to treat the Illyrians *en masse* as gold miners, the *Pirustae* came from the south-eastern silver-mining region of their home province and not from the central gold-producing region.[827] It seems to be the case that silver mining *was* occurring in Dacia, albeit somewhat invisibly alongside the exploitation of gold and other metals and as a metallurgical step in the process. If this is indeed so,

826 Baron *et al*. (2011).
827 Glicksman (2018) 278.

tracking silver mines (and mining) in Dacia could prove a difficult task. However, the tremendous inroads by K. Butcher and M. Ponting in provenancing Roman silver coins using trace-element analysis provide a possible means for identifying sources of Roman Dacian silver and could help address this lacuna in the literature in the future.[828]

Finally, military supervision of the mines in Dacia is best described as strategic. At important gold-mining sites like Roșia Montană where we would expect to see closer supervision, the evidence for the Roman army is surprisingly limited. The situation of the army seems to be at key control points in the province along key routes such as at Abrud and *Micia*, where the military was sited to take advantage of the limited points of access into the Apuseni and Poiana Ruscă Mountains, respectively. Sites like Zlatna that hosted the Roman mining administration and Pianu de Sus, where large-scale hydraulic alluvial mining occurred, also had a stronger military presence. This suggests that either additional evidence for military involvement at sites like Roșia Montană and Bucium remains to be found, or—for whatever reason—there was no need for close oversight or that the strategic distribution of military outposts in the wider province was sufficient. Overall, Roman mining in Dacia was adapted to local circumstances and appears to have been controlled strategically by the state.

828 Butcher and Ponting (2014). This volume stops after the currency reforms of Domitian, with subsequent works to follow.

6

Mining Administration and Labour Organisation

Roman mining administration was not uniform across the empire and varied amongst the provinces depending on local circumstances, the need for centralised direct control, and even the type of metal that was being exploited.[829] The mineral deposits of Dacia clearly constituted an important economic resource for the Romans, given the extent and variety of mining activity evidenced in the province, and it stands to reason that Rome would have benefited from a system of management that encouraged local mining activity with minimal input from the central government. This chapter examines how the central authorities managed the Dacian mines, looking at aspects including the administrative apparatus, organisation of concessions, composition of the workforce, as well as the role of the Roman army. It also contextualises the relatively high levels of mining activity in Dacia Superior within the wider province to see how areas with markedly low levels of economic activity compare to the mining heartlands in Transylvania. Although rarely highlighted in the secondary literature, coverage of certain parts of Dacia remains unequal, with emphasis placed on the urbanised regions of Dacia Superior, and little mention of the sparsely colonised fringes of the province. The low levels of Roman penetration cannot be entirely explained, but it may be related in part to the lack of mineral resources in the outer regions.

829 See Hirt (2010) for full treatment.

6.1 Mining administration and personnel

The administration of gold mines could take various forms, some involving more coercion than others, particularly in areas with local resistance to Roman rule. Despite the violent nature of Dacia's incorporation into the Empire, the evidence available at the mining sites does not seem to indicate the need for high levels of coerced labour by the central authorities.

The exact territorial extent of the gold mines of Dacia is not clear, and apart from a general consensus that the head of mining administration was based at *Ampelum* (Zlatna) on the basis of the epigraphic evidence, there is no proof of an official delimited or unified mining territory.[830] It is likely that the mines were only "unified" on an administrative level. The evidence for direct links to the mining administration at individual sites is also extremely scanty, with the most compelling evidence coming from Roșia Montană.

The main body of evidence are the epigraphic inscription from *Ampelum*, which reveal the presence of a procuratorial system, initially run by imperial freedmen who were later replaced by members of the equestrian order after the Marcomannic Wars. The known procurators are eight in total: Ulpius Hermias, Romanus, M]aximus, L. Macrius Macer, Aelius Sostratus, A. Senecius [-] Contianus, (M. Iulius Apollinaris (?)), and Papirius Rufus. A sub-procurator, Avianus, under Septimius Severus, is also known.[831] This change of status of procurators in Dacia is unique,[832] and the replacement of imperial freedmen by equestrians and their subordination to the procurators may reveal the increased geographical spread of the gold-mining area under management and the

830 Contra Noeske (1977), who argued for an extensive Dacian gold district lying between Baia de Criş, the Mureș in the east, and the boundaries of Micia and Apulum in the south. There is no evidence to date confirming Noeske's hypothesis; Hirt (2010) 74–5.
831 Hirt (2010) 126–30, cf. Table 1.
832 Hirt (2010) 146, 149.

increased administrative load. There is also ample evidence from *Ampelum* for imperial freedmen and subalterns working in the mining administration.

The bulk of the epigraphic evidence at *Ampelum* seems to date after the Marcomannic Wars, with a possible peak at the start of the 3rd century.[833] This epigraphic activity may reflect a corresponding rise in levels of administrative activity around the end of the 2nd and start of the 3rd century, which could be indicative of an increase in mining or a need to re-organise the mining region after the recent troubles. Although the reason for the increase is ultimately unclear, it does indicate that *Ampelum* continued to be an important administrative centre after the Marcomannic Wars, which would suggest that mining in the Golden Quadrilateral remained active despite any possible disruption in the 160s.

There is evidence for a centralised mining bureaucracy in Dacia that operated from *Ampelum*, but on a local site level mining activity was not tightly controlled by the central authorities but sub-contracted to lessees. Such an arrangement arguably allowed for greater freedom on the part of concession owners with respect to how mines were run, allowing for flexibility in employment and the organisation of concessions, while still providing the state with the profits of leasing out mining concessions.

6.1.1 Organisation of concessions

The lack of legal documentation on the organisation and management of mining concessions in Dacia leaves us reliant on the archaeology. Only Roșia Montană has been studied in enough depth for any kind of analysis involving the spatial organisation of the mines. The main work is by Cauuet, who compares the mines of Roșia Montană to those at *Vipasca* (Aljustrel) based on the roughly contemporaneous 2nd and 3rd century dates of

833 Hirt (2010) 149–50, 152.

the two mining areas, and the survival of the *Vipasca* bronze tablets.[834] The second bronze tablet, in particular, offers valuable insight into Roman mining legislation governing private concessions in the copper and gold mines, even though the applicability of the legal measures outside of *Vipasca* is debatable.

Based on excavation results, Cauuet has extrapolated from the underground surveys at both *Vipasca* and Roșia Montană to model the spatial organisation of the mines into groups. The main differences in spatial organisation at these two sites are largely dictated by the underlying geology. The mines at *Vipasca*—which exploited polymetallic deposits—are marked by an oxidised "cap" of iron with copper, silver, and gold variously distributed in the upper zones.[835] Vertical shafts were sunk downwards from the surface and tended to be narrow and deep. The geology at Roșia Montană, in contrast, displays far more complexity with the richest deposits occurring where zones intersect. This diversity of stockwerks, breccias, and veins is also reflected in the various exploitation methods, oftentimes resulting in complicated networks of chambers, galleries, etc. Whereas the workings at *Vipasca* tend to be vertical, neat, and systematic, the layout at Roșia Montană spreads horizontally, following the precious metal veins across two to three levels. These groupings, Cauuet proposes, reflect the organisation of work into concessions at the two sites.

In terms of the economic benefits, Cauuet points out that the division into numerous smaller concessions allowed the state to prevent a monopoly whilst also maximising revenue to the fisc.[836] Both her observations are sensible, and it can be added that the multiplicity of concessions also allowed for greater flexibility in managing some

834 Cauuet (2004).
835 Cauuet (2004) 37.
836 Cauuet (2004) 58.

of the risks involved in mining, even though the Romans would not have viewed it in such terms. The failure or closure of one exploitation point, for instance, would be buffered by the continued operation of the remainder.

These points on economic benefits, however, can be made independently of being able to identify the exact spatial organisation of the concessions. Cauuet's article is an invaluable contribution, but it is simply the start to modelling and understanding concessions at Roșia Montană. The work in the 2004 article has not been updated or expanded on since. It is also worth noting that the proposed model for Roșia Montană appears to be based on the areas of Cârnic 1, 2, 3, 4, 5, and 8 that had been surveyed by 2002. To begin with, the evidence from Cârnic is particularly complicated because of subsequent re-working in later periods, especially at exploitation sites close to the surface. Furthermore, similar analysis of the reconstruction of underground workings has not been done for the other massifs, as only Cârnic has been studied to this level of detail. It is not entirely clear to what extent this model can be extrapolated to the other mining zones at Roșia Montană—let alone to other comparable hard-rock sites in Dacia—where archaeological study is sorely lacking. When compared to the vertically oriented mines at *Vipasca*, Cauuet's reconstruction of horizontally grouped concessions at Roșia Montană is certainly compelling, but neglects to highlight that the model is specific to Cârnic rather than applicable site-wide.

Even taking into consideration the limitations of Cauuet's model as a hypothetical rather than actual reconstruction, additional questions about central organisation still need to be addressed. The vertical arrangement at *Vipasca* is more readily recognisable as separate operations, as each unit is distinct, with individual access to the surface. The workings at *Vipasca* appear strictly demarcated, with concession owners limited to their allocated space.[837] The model for Cârnic is different: whilst clustered around extraction points that could be worked by separate teams as individual concessions, the mining units are still embedded in a wider network of tunnels and accessways, some of which pass through other units before accessing the surface. Who was responsible for the creation, use, or maintenance for what appears to be communal areas? What happened in the case of disputes? Concessions located deeper within the massif would presumably be at a disadvantage if such a situation were to occur, and a rival team blocked access to the deposits. We also do not know how miners from one concession knew not to tunnel through to another one accidentally, in the event that two groups were working the same deposit. Given what appears to be shared galleries connecting the proposed concessions, it would be logical if some kind of central authority had oversight of the proceedings. The role of the state needs to be given greater consideration in the analysis of how the spatial layout of mining concessions were related to one another.

In addition, further consideration of the relationship between the actual size of the concessions and the labour force is still necessary. At its most basic, the size of the underground works offers a rough indication of the number of people needed to work a deposit or who could be accommodated in a given space. Admittedly this figure is difficult to pinpoint as a precise chronology is not available for when specific galleries or chambers were in use. The smaller galleries flanking the main chambers in Cârnic 1, for example, could only have comfortably accommodated two workers at the ore face: these trapezoidal exploration galleries ranged between 1.20 to 1.40 m wide and 1.50 to 2 m high, with

837 Cauuet (2004) 39.

openings averaging between 1.53 and 2.80 m^2.[838] It would be difficult to fit more than two miners actively swinging pick axes in such a tight space, and more likely that only one person worked the face at a time.

In contrast, the larger works such as C5 in Cârnic 1 or the three sets of pillared chambers in Cârnic 3 are capacious enough to have accommodated more people. But here, too, trying to estimate the number of workers is problematic. These chambers obviously would have increased in size over time, but the rate of extraction is unknown. Furthermore, their current dimensions belie their original limited capacity: the mining technique to create the pillared chambers involved driving several tunnels in a radiating spoke formation before breaking through the adjacent walls, leaving behind supports for the larger space.[839] Even if the tunnels were excavated concurrently—which we are unable to identify—each individual gallery would still be limited to approximately two miners at the work face.

These estimates based on the size of each working would also not account for the even larger number of labourers needed to empty the fill and excavated ore so that those at the mine face could work without interruptions. Although shifting gangue is a menial job, the rate at which a working gallery could be kept clear was of utmost importance as it hampered the effectiveness of the miner at the workface. This would be especially problematic for mines at deeper levels needing access via long stairwells and circulation galleries to reach the surface. Even positing a model that involves stationing a line of workers to pass along filled waste buckets, an exploitation point located several kilometres within a massif would require a large number of people for waste management alone.

838 Average gallery dimensions for Cârnic 1 as reported in CHBR (2006) 89. For a more specific example of such galleries, see Cauuet (2009a) 137–8 on G1 in Cârnic 1 Middle, which developed off of C5 in Cârnic 1 Superior.
839 See p. 134.

Multiply this across several concessions in a site like Cârnic and one begins to get a sense of the considerable number of people needed to keep a mine in operation.

This analysis of the spatial organisation at Cârnic is preliminary, but offers an example of how future work in this direction can help in estimating the number of miners needed to work different concessions or the underground mines, and to get a better sense of the labour needs for a large mining site like Roșia Montană.

6.2 The mining workforce

Along with the limitations imposed by local geology and technological capability, labour capacity was the third major factor affecting mining output. Mining as an industry has always required significant amounts of labour. Not only was manpower needed in the first instance at the mine face, additional workers were required for haulage of ore and waste, as well as auxiliary activities like processing and smelting extracted ore. In the absence of mechanisation, humans also provided the main source of motive power in the Roman world, especially in underground mines where cramped conditions prevented the use of draught animals. In addition to recruitment, local and provincial administrators were also needed to help organise mining operations. Successful management of the human resources involved was unquestionably a crucial aspect of Roman mining.

6.2.1 Demographics of the labour workforce

The focus here is on the mine workers at established, larger-scale mines, with the most detailed evidence coming from Roşia Montană. It is also necessary to note that small-scale mining—namely, gold panning or the casual exploitation of surface ore—is difficult to detect even under the best circumstances, and that activities like panning could be undertaken by anyone with a trained eye. It is therefore difficult to say with any certainty who, precisely, participated in small-scale mining activities. In general, the main evidence for the types of labour involved in the Dacian mines consists of a handful of possible instances of forced or unfree labour; free workers employed on a contractual basis; and immigrant workers hailing predominantly from Illyria.

Slave and convict labour

The use of slaves or convict labour in the mines remains a contentious issue, depending on whether one sees forced labour as the default starting point for the mining workforce. The use of forced labour in Dacia is certainly a possibility, but archaeological evidence for the presence of slaves within the mining sites themselves is limited. We know of slave sale contracts from the Roșia Montană wax tablets, but the high costs of sale ranging from between 205 to 600 *denarii* indicate that the slaves in question were probably meant for household use.[840] Otherwise, one would have to assume that there were reasons to justify such a high cost for deploying these slaves in a mining context: one would assume that either the returns were sufficiently high, or that the slaves possessed some specialist skill.

The closest hint of what could be slaves employed at the work face comes from Trestia (Hun. *Tresztya*), Băița in Hunedoara county. A 19th-century report by G. Téglàs mentions chained skeletons, which he believed were slaves, in collapsed old galleries at Trestia mine.[841] His perspective seems based on the assumption that metal mining in Dacia was under imperial monopoly, and slaves were condemned *ad metalla* as per Diodorus' account on Egyptian mining. Maghiar and Olteanu also reference several skeletons at Trestia but offer no citations; presumably these are the same remains from Téglàs' report. Named "The Bath of Bones" due to the grisly finds, the mine yielded a few skeletons

840 TabCerD VI–VIII.
841 Téglàs (1883) 145. CHBR (2006) 141 cites Téglàs, but is more cautious in asserting the possible slave status of the miners.

found with iron chains intact.[842] The size of the exploitation was reportedly small scale.[843] Whether or not these remains indicate the presence of slaves working underground in the galleries is debatable. While it is certainly a sensible assumption, restraints only suggest the use of forced labour and not definitively that of slaves. Manacles and fetters could also serve as a means of punishment. If the *Vipasca dicta* are anything to go by, those who transgressed the rules safeguarding mine security were subject to swift and severe punishment, and it is possible that the chains were used for law enforcement.[844] However, given the reported "several" skeletons found at Trestia, along with the presence of iron chains, the likelihood of the individuals having been slaves (or convicts condemned to hard labour) is very much possible. No further detail is available from Trestia, and the only other possible example is from Băişoara, where a human skeleton with shackles (?) was found.[845] The site, unfortunately, has not been archaeologically researched and Téglàs' report remains unverified.

In the absence of additional evidence, it is not possible to argue definitively for a slave labour force in the Dacian mines—or at least one that was significant enough in numbers to be archaeologically visible. What can be said is that some form of forced labour, possibly in the form of convicts, did exist, although it is difficult to track directly in the archaeological record. Menial tasks such as powering water-drainage wheels, hauling gangue, or crushing ore for processing needed cheap and plentiful labour, and it would not be surprising if at least some of these tasks employed unfree labourers, leaving the more skilled work to paid miners.

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842 Maghiar and Olteanu (1970) 55.
843 Boroneanţ (2000) 129.
844 Holleran (2016).
845 There is another confused and contradictory report of a bearded skeleton found along with a cache of wax tablets in Sf. Iosif mine at Lety Massif, Roşia Montană, but without evidence of restraints. IDR I, p. 173; CHBR (2006) 166. Băişoara: RepCJ (1992).

Forced servitude in mines was a notorious punishment in the Roman period, and a well-documented example can be found in the mines of the Wadi Faynan in Jordan. There, a series of observational towers were strategically sited to not only guard the mines from outside attack, but to survey the interior and prevent possible revolt amongst the convicts and Christians condemned to working in the mines.[846] Most notably, the Roman state was able to site their towers in the most effective locations and make use of the local topography to create a landscape of surveillance that resulted in the use of minimal military force in controlling the population. Another possible scenario could be the Romans pressing the natives into service after the Dacian wars, similar to the *corvée* service extracted from conquered locals in western Spain. However, the indigenous Dacians are largely invisible in the Roman mines, and there is insufficient evidence to ascertain their status as either free or unfree miners. Furthermore, this scenario would also assume that sufficient numbers survived the wars and continued to live, work, and reproduce in captivity well into the 2nd century to provide a workforce for the mines.

Although we lack extensive written or archaeological evidence for similar groups of convicts in Dacia, there is a case, perhaps, for a similar system of strategic population control as that seen in the Wadi Faynan, especially in the remote mountains of the Apuseni. The low numbers of military personnel at the mining sites themselves, coupled with the calculated location of fortifications at Abrud within the Golden Quadrilateral and at *Potaissa*, *Micia*, and *Apulum* on the main roads north, south, and east respectively, lend credence to the argument. The lack of evidence for forced labour does not necessarily mean unfree people were not present in the mining workforce of Dacia's mines, only that we might not be able to identify them.

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846 Friedman (2010).

Free wage labour

The presence of free labour, on the other hand, is attested in Dacia on the basis of three labour contracts from Roșia Montană (TabCerD X to XII). The contents of these contracts for leasing out one's services in a gold mine indicate roughly similar levels of pay (90?, 70, and 105 *denarii* respectively), as well as stipulating against unforeseen circumstances such as flooding or the closure of the mine. The length of service varied between five months to a year, suggesting that there was some flexibility involved depending on the needs of the mine owner. In TabCerD XI, Memmius Asclepius also appears to be leasing out the services of his children,[847] which could indicate that children constituted part of the workforce.

The legal status of the mine worker was reasonably high. Memmius was able to engage the services of Flavius Secundinus as a scribe, request a written copy of the agreement (*scripsi rogatus*), and enter into a legal contract with the mine employer of his own volition. It is also perhaps striking that Memmius signed the document himself despite his illiteracy, and that his handwriting was not noticeably worse than the others'.[848] Although it was unlikely that the document would have offered the labourer much protection in a court of law should a dispute arise,[849] the juristic importance lies in the right of the mine worker to ask for a written statement. This strongly suggests that Memmius was not a slave, which is further confirmed by the penalty clauses in the worker's favour.[850] The labour contracts are the key sources demonstrating the presence of freemen working at the Roșia Montană mines. This is important because working conditions were

847 This depends on whether one accepts the reading of the text as *liberisque* or *cibariisque*. If the latter, one would assume that Memmius was being paid both in cash and in kind.
848 Berger (1948) 232.
849 Du Plessis (2012); Brunt (1989) 90–1.
850 Berger (1948) 232–3.

such that there was enough incentive for freemen to hire themselves out for work that was frequently hard, dangerous, and physically exhausting. The use of contract labour also benefited local concession owners who could hire mine workers as needed, depending on the number of people needed to exploit a concession. The flexibility of this approach, in a sense, helped defray the economic risks associated with mining and recruiting workers when needed.

6.2.2 Immigrant labour

With most mines located in remote places, the mining workforce was, to some extent, brought in from the outside. Set against the backdrop of the Roman Empire, the heavy dependency on migrant labour in mining necessarily raises questions of geographical mobility and the role of the state in ensuring enough workers. In Dacia, the most visible members of the mining workforce were, by far, the Illyrians, who arguably constituted the most important group of those working the Dacian mines.[851]

We have ample evidence for peregrine Illyrian miners, who are attested above ground by epigraphic and funerary remains at Roșia Montană, and also by their burial practices. Onomastic evidence can be seen in the wax tablets, where names such as Bato, Beucus, Dasius, and Verzo are common. Out of 187 unique individuals known in the *Alburnus Maior* area from the inscriptions and wax tablets, 102 are Illyrian, constituting over half of the reported population (*Table 6b*). Of these, 49 individuals immigrated from Dalmatia, which is supported at Roșia Montană by incineration burials of the Mala Kopašnica-Sase (MKS) type. The names of *vici* also reflect their Illyrian roots, and indicate the presence of entire groups of miners like the *Pirustae*, *Baridustae*, and *Sardeates*.

851 Mihailescu-Bîrliba (2011) 13–9.

Evidence for Illyrian miners is also seen underground by the use of trapezoidal mine galleries: a feature occurring not just at Roșia Montană, but also at nearby Vulcoi-Corabia; at Almașu Mare, Ruda-Brad, and Băița elsewhere in the Golden Quadrilateral; and also at Valea Apele Alb in Moldova Nouă (*fig. 61*). With respect to the mines of the Golden Quadrilateral, the presence of Illyrians at Bucium and Ruda-Brad is corroborated by funerary evidence from the burials at Vulcoi-Corabia and Muncelu respectively. What is interesting is that all these named sites could—with further research—be potentially important mining hubs within their local area.[852] To what extent the expertise of the Illyrian miners contributed to the development and significance of these other mining sites is a question that remains to be answered, but one would suspect that their skill as experienced miners would have helped in the speedy establishment of Roman mining in the years after Dacia's conquest.

The reason for the strong Illyrian presence in Dacia is almost certainly the economic impetus of the province's precious metal resources. The common consensus in the Romanian literature is a Trajanic arrival date of the Illyrians specifically to exploit the gold deposits.[853] But explanations as to how and why the Illyrians migrated to Dacia tend not to proceed much beyond the generic lure of the gold mines or a mass resettlement movement after Trajan's conquest: the former attributable to common sense; the latter to Eutropius' account of colonists pouring into Dacia *ex toto orbe Romano*.[854] Some scholars, such as I. Oltean, believe that *Alburnus Maior* was subject to a state-controlled colonisation where mining communities were imported from Dalmatia and settled in ethnic

[852] Cf. 5.4 above.
853 E.g. Wollmann (1996) 158–85; Ardevan (1998) 84, 293–4; Ciobanu (1999).
854 Eutropius 8.6.2.

groups under their own leaders.[855] The concentration of individuals from specific communities (e.g. *Pirustae*, *Sardeates*) at Roșia Montană does seem to suggest that people moved as entire groups rather than singly from Dalmatia. A state-driven resettlement is certainly possible, but not the only scenario available.

The most compelling explanation so far is that put forth by Claire Holleran. Although her study focuses on the Iberian gold mines, the analysis also touches upon the Dacian labour contracts and argues that labour in the Roman world was a commodity that could be sold like any other, and that miners were mobile and free to sell their labour as they saw fit.[856] This model is attractive because it explains why skilled miners might have chosen to immigrate from their homeland to sites like Roșia Montană in a new province, of their own volition. The longevity of a mine is notoriously fickle and highly dependent on the ore body; once a deposit runs out, mining communities often have no choice but to move on. The search for new deposits and better employment opportunities in the wake of Dalmatia's failing gold mines at the beginning of the 2nd century may have prompted the large-scale migration of Dalmatian miners to Dacia after Trajan's conquest of the province where their expertise was needed.[857] The latest dateable evidence for Roman gold mining in Bosnia is AD 112 and the earliest date for a Dalmatian in Dacia is AD 131 from the wax tablets at Roșia Montană (TabCerD XVIII), which would support the gradual petering out of gold-mining activity in Dalmatia as miners immigrated to the new province. This mass movement of people could have been solely triggered by economic conditions back home or been encouraged by the state through some financial or social incentive, but migration in this scenario is not forced. This is not to say that the state was not involved in some

855 Oltean (20090 94.
856 See Holleran (2016) 103 on Dacia specifically.
857 Glicksman (2018) 277–8)

form, but there is room for an argument where groups of professional miners with high horizontal mobility were free to move to new mining sites in search of work as old deposits were exhausted.

6.3 The role of the Roman army

The role of the Roman army in mining could take several forms, some more direct than others. These include the provision of technical expertise, surveillance and security, and administrative liaisons. The army was also a consumer, as fortifications acted as local centres of demand, particularly with respect to the non-precious metals needed for tools and weapons. Despite the prominent levels of militarisation in Dacia, the role of the Roman army in mining was probably largely indirect, allowing for administrative oversight of mining in the province rather than a direct management of individual mines.

The evidence for the army's involvement in mining in Dacia is lacunose and surprisingly sparse despite the size and significance of the gold mines of the Golden Quadrilateral. Only a few epigraphic inscriptions of military personnel are known from Roșia Montană and *Ampelum*, and evidence for structures related to the army at Roșia Montană have been difficult to identify to date.

Direct army involvement in the form of providing engineering expertise is a possibility, but there is no strong evidence to indicate that this was the case in Dacia, except perhaps at Roșia Montană and sites where alluvial gold mining may have occurred. Although brick stamps bearing the mark of *Leg. XIII Gemina* have been found at Carpeni at Roșia Montană, there is no particular reason to link the army to the construction of water-lifting devices. It is, however, possible that they provided instructions on how to do so.[858] The miners of Roșia Montană were an extremely skilled group, and the high levels of carpentry evident in the preserved woodworks indicate that the presence of specialist carpenters at the site who were capable of constructing the water wheels, perhaps under the instruction of an army engineer. The construction of larger structures like aqueducts for hydraulic mining could have required the army's engineering expertise—such as at Dolaucothi in Wales—but again, there is no clear evidence linking the army to any of the hydraulic mining sites in Dacia. This is true of the open-cast hard-rock mines at Vulcoi-Corabia at Bucium, where there is no evidence for a military presence, or at Pianu de Sus, where the hushing of the alluvial deposits occurred on a large scale. The absence of signs, however, does not necessarily mean that the army or the central authorities were completely absent. Both the mines at Bucium and at Pianu de Sus are located close to Roman administrative centres, and it could be the case that local military instalments were unnecessary, especially if the required assistance could be achieved by temporarily dispatching personnel to the site. Bucium is about 12 km away from Abrud, the nearest securely identified Roman fort, and Pianu de Sus about 24 km from *Apulum*. Although we have yet to discover evidence for aqueduct constructions requiring army engineering at either Bucium or Pianu de Sus, there is evidence of a military presence at Pianu de Sus, where *Leg. XIII Gemina* is attested. More information is needed, but it is tempting to associate the alluvial mining at Pianu de Sus with military supervision, possibly due to the scale of the works involved.

Based on the available evidence, it is far more likely that army involvement took the form of surveillance and security, and acting as administrative liaisons for the central provincial authorities. Measures needed to be taken to prevent theft and to ensure the safe

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858 See 4.6.2.

transport of ores. Being on the *limes*, Dacia was a highly militarised province and it is difficult to disentangle the province's security needs against external invaders from the internal needs of controlling the transport and urban networks and providing security for safe passage. Nonetheless, the establishment of a militarised road network provided for the surveillance and the security needs of the mining regions as well. The strategic location of forts such as Abrud, in the heart of the Metaliferi Mountains, and *Micia*, to the entrance of the Golden Quadrilateral, allowed the Romans to control key access points. Abrud, for example, is the closest military outpost to both Roșia Montană and Bucium, and lies on the road south from these two sites to *Ampelum* (*fig. 25*). Access to Roșia Montană from the north would involve passing along the Arieș valley and its gold-washing sites, with the fort of *Potaissa* securing the eastern end of the road. Access to the southern half of the Golden Quadrilateral was controlled by *Micia* and *Germisara* on the province's main east-west artery, as well as *Apulum* in the east.

Individual soldiers also fulfilled administrative roles and could serve as liaison officers linking the financial and mining administration of the province.[859] The evidence for a military contingent at *Ampelum* is not plentiful, but it could be explained by the proximity of the legionary headquarters of *XIII Gemina* at *Apulum* and the auxiliary camp at *Micia*. Inscriptions from *Ampelum* attest the presence of *beneficiarii consulares/procuratoris*, as well as two *librarii* from the *Leg. XIII Gemina*. These officers were most likely present to serve as a liaison between the financial procurator based in *Apulum* and the mining procurators in *Ampelum*. Overall, the role of the Roman army in mining was more likely to have been an administrative one on a local level, rather than a direct one involving force or actual participation in mining activity.

859 Hirt (2010) 199.

6.4 Other regions in Dacia

The discussion of mining in Roman Dacia has, understandably, centred on Transylvania and the Banat where the metal deposits are most concentrated. Mining activity is limited *de facto* in geographical scope by the location of the ores, but the high levels of activity seen in Dacia Superior and the Banat contrast sharply with the absence of evidence from the far northern, eastern, and southern regions of the province. This lack may well represent a gap in research in these parts of Romania, but also highlight the different trends in economic and settlement activity in regions where mining was an important part of the local economy.

In addition to the gold resources of the Apuseni Mountains, another important district is known in north-western Romania in Maramureș County. The Baia Mare ore district contains abundant low-sulphidation epithermal gold and polymetallic ore fields with deposits of Au-Ag, Pb-Zn, and Cu. Two of the gold deposits—Cavnic and Baia Sprie—were classified as world class, with the Main Vein in Baia Sprie mine being the longest ore vein in Europe at 8 km long.[860] The earliest secure evidence of mining activity dates from the medieval period, starting around the 13th century onwards, but mining in Maramureș is presumed to be much older on the basis of numerous Bronze Age discoveries in the area, especially at Baile Borșa.[861] There are no indications of Roman mining, however, despite the richness of the deposits and the geological similarities to the type of ore found in the Roșia Montană district in the Golden Quadrilateral. The medieval galleries opened by hand tools are mostly rectangular but are less uniformly shaped and

860 Kovacs and Fülöp (2009); Plotinskaya et al. (2009).
861 Maghiar and Olteanu (1970) 111–4; Istvan and Minghiraș (2004); Kacsó et al. (2010b), (2011), (2016). Baile Borșa: Kacsó et al. (2010a) 506–7.

narrower than Roman galleries, and do not display the quadrilateral profile seen at the underground mines in the Apuseni.

One simple explanation for the lack of Roman activity is the location. Despite the seeming attraction of Baia Mare's metal resources, the boundaries of modern Romania are not the same as Roman Dacia. The Baia Mare deposits lie outside the northern borders of Roman Dacia, and the Romans in all likelihood did not find the gold or see the need to establish mining camps in unconquered territory. The richness of the deposits still present at Roșia Montană—arguably the heart of Roman gold mining in Dacia—suggests that there was enough gold within the province's border to keep the Romans occupied or at least little impetus to risk mining outside the *limes* in unsecured land.

The concentration of Roman efforts within the key mining regions of Dacia Superior may help explain the lower levels of economic and urban activity in the eastern and southern parts of Dacia. The Eastern Carpathians form a natural boundary to the eastern extent of the province. Although the area has some copper-rich pyrite resources and there has been modern mining, this sector of the Carpathians is not abundant in metal ores. There is also no secure evidence for Roman mining to date. In general, eastern Dacia is lacking in the economic resources—particularly mineral resources—of the western Transylvanian plateau. If Dacia was an underpopulated province prior to the arrival of the Romans,[862] it could be that the population levels in the east reflects the lower population density pre-conquest, compared to areas with dense Roman-style urbanisation in the west. The area is not completely devoid, however, as there is evidence for rural settlements, most likely indigenous Dacians, located along the tributaries of the Olt. The preservation of the Dacian name "Cumidava" for the fort at Râsnov is suggestive. The predominance of

862 Mihailescu-Bîrliba (2010).

military fortifications securing the road networks and their related settlements suggests that security—rather than the pursuit of economic resources—may have played a larger role in the organisation of eastern Dacia.

Like the eastern part of Dacia, Dacia Inferior is underpopulated in comparison to Dacia Superior and marked by an almost complete absence of mining activity. The department mainly consists of the Southern Carpathians and the lowlands north of the Danube. Most of the economically important ores in the Southern Carpathians are in the Banat Mountains—if they are considered part of the Carpathian range—and this sector would have held limited interest to the Romans with respect to metal resources. Reported instances of mining are confined to locations in the Carpathians: these include Turnu Roșu, Cârșu, and Baia de Aramă, where the limited evidence for mining could indicate the possibility of local exploitation of non-precious metals, as noted in the previous chapter. Although quarrying is also known, most of the sites are near *Drobeta*, the largest town in the area, apart from Albești near the *Limes Trans Alutanus*, which provided limestone for the construction of the *castrum* at Jidava.[863] On the whole, the extractive industries did not feature strongly in this part of Dacia at all. Little is known about the local economy otherwise, although *villae rusticae* were likely numerous in the lowlands. Instead, the region is characterised by limited urban development and what was probably a largely indigenous urban and rural population. Only the towns of *Drobeta* and *Romula* achieved the ranks of *municipium* and *colonia* by the Severan period, whilst the rest remained *vici*. Place names such as *Drobeta*, *Sucidava*, *Acidava*, *Rusidava*, and *Buridava* suggest the persistence of the autochthonous population in these parts. The military maintained a strong presence in Dacia Inferior, with fortifications along the major access routes of the

863 TIR Dac. Inf.

Southern Carpathians connecting Dacia Superior to the north with Moesia Superior to the south, via the defiles of the Jiu and Olt rivers. Many of the settlements are located close to the fortifications and the road network, with the largest settlements sited in the lower lying areas or on the Danube (*Drobeta*, *Romula*, *Sucidava*).

The similarities between southern and eastern Dacia in terms of the lack of mineral resources, lower levels of urbanisation, and highly fortified accessways may be coincidental and a more systematic analysis is necessary, but there does appear to be a preoccupation with military and security concerns in these two regions of Dacia rather than an economic focus, in the absence of available metal resources. This contrasts with the density of urban and economic development seen in western Dacia, where both precious and non-precious metal were in plentiful supply and played a key role in the local economy. Although Dacia is considered a marginal province within the context of the Roman Empire, the pockets of economic disparity within Dacia itself reveal the importance of mining to the provincial economy.

7

Conclusion

This thesis set out to re-assess the existing secondary literature in light of the modern archaeological work conducted at the key site of Roșia Montana in the past 20 years and to synthesise the current state of research on the Dacian mines. The driving question has been understanding how the Romans managed the metal resources they found in Dacia, and what impact Roman mining left on the fabric of the province.

Such an endeavour has not been without its problems. Much of what we know relies on Austro-Hungarian archival literature and reported information, with little fieldwork verifying earlier accounts of Roman mining. Identifying the location of mining sites and clarifying reports of gold-washing activity in the Romanian literature have proved particularly problematic. More archaeological fieldwork is certainly needed to clarify the inconsistencies in the secondary literature, but attempts at establishing type-sites for hard-rock and hydraulic mining in Dacia illustrate the potential for further identification of overlooked workings of a similar kind.

The site of Roșia Montană was most likely the biggest of the gold-mining sites in Dacia and remains our best source of archaeological evidence. As a type-site for underground Roman mining, it is without peer and provides crucial supplementary information for other sites where the Roman remains have since been destroyed. However, sites like Bucium and Ruda-Brad, amongst others, indicate that Roșia Montană was not unique, and characteristics such as dispersed settlement patterns, a skilled mining labour force, and knowledge of techniques like trapezoidal galleries and water-drainage systems were also the case at some of the other sites in the Golden Quadrilateral.

Technology was not a limitation to Roman mining in Dacia. If anything, Dacia is an illustration of how the Romans brought to bear all the technology and techniques refined during the previous century of mining in north-western Spain and, to a lesser extent, in Roman Britain. In Spain and Wales, the Romans conquered a hostile landscape and refined techniques for alluvial and hard-rock hydraulic mining that—along with knowledge of underground exploitation, water-lifting technology, and fire-setting—allowed them to undertake mining on a larger scale than before. In particular, the speed at which mining commenced in Roman Britain soon after conquest indicates their readiness and proficiency with organising and implementing the entire process in a new province. Although not as visually striking as the massive works at Las Médulas in Spain, what is truly spectacular about Roman mining in Dacia is the sheer variety of mining methods attested in one province. These range from the impressive underground remains of Roșia Montană to the opencasts at Bucium, as well as the large-scale hydraulic exploitation in the Pianu valley and the aggregate mass of smaller gold-washing sites dotted throughout the river basins of the Apuseni Mountains. The same techniques were also used to mine base metals, and in regions like the Banat where the Romans encountered complex mixed deposits, exploitation of both precious and non-precious metals frequently occurred within the same site. There are lacunae in our knowledge, to be sure, especially with respect to the non-precious metal mines and our understanding of the chronology of exploitation, but the only other province that exceeded the scale and variety of mining activity seen in Dacia is western Iberia, where mining took place over a longer period of time. Nonetheless, the array of techniques available to the Romans and their facility in organisation allowed them to exploit almost all the major mineral deposits of Dacia and to establish a mining economy.

Mining was, without a doubt, a vital part of the economic life of Dacia. It may be impossible to know whether the Romans conquered the region for the express purpose of gaining control over Dacia's metal reserves, but one can say with a fair amount of certainty that the Romans were able to exploit their provincial acquisition with resourcefulness, skill, and a certain degree of thoroughness whilst it was in their possession and soon after conquest. The advent of Roman rule brought with it mining on a scale larger than practised previously and the exploitation of a wider range of deposits using new techniques. Along with rural production, mining arguably formed the backbone of Dacia's economy, influencing both the migration of labour and patterns of settlement. Entire groups of skilled Illyrian miners settled in Dacia at sites like Roșia Montană, Bucium, and Ruda-Brad, migrating from neighbouring Dalmatia and illustrating the economic lure of the Dacian mines. Although we may never determine whether the mass movement of people was state-led or voluntary, the specific population of the Golden Quadrilateral with expert miners and possibly engineers indicates a purposeful penetration of the region. In addition, the presence of additional mining sub-regions in Hunedoara for iron and in the Banat for complex mixed deposits indicate the thoroughness with which the Romans were able to identify and exploit Dacia's metal resources, and not just the gold. Although it remains difficult to estimate the scale of Roman silver mining, there is no reason not to believe that the Romans were also extracting the metal where available, whether as ore or via cupellation.

The Roman state organised mining in Dacia, but did not seem to require high levels of military supervision in their routine operation. Strong central control of the mines did not necessarily result in a large military presence on individual sites. Supervision was instead achieved by monitoring access and administrated via *beneficiarii* and procurators, requiring a relatively low number of soldiers. The lack of a heavy army presence at key mining sites like Roșia Montană and Bucium suggests that government oversight of the mines was operated strategically by the control of key access points to the mining regions. This was possible due to the remote and widely dispersed location of the mines in the Apuseni Mountains, rendering a local detachment of soldiers at each individual site both unfeasible and unnecessary. In regions like the Banat, mining sites are more closely associated with military fortifications and frequently found in closer proximity than in the Golden Quadrilateral. The closest signs of physical control by the state can be seen in the presence of the army at the iron mines of Hunedoara, which the state secured to ensure sufficient metal for the everyday needs of the major towns and fortifications in a frontier province. The Romans did bring their knowledge to bear on mining in Dacia by employing various techniques gleaned from experience elsewhere in the Empire and organising mining concessions, with varied levels of involvement on the part of the central authorities depending on the nature of the site. The system of leasing out concessions is widely attested elsewhere in the Roman Empire and its application in Dacia allowed the state to exercise control over mining activity at sites like Roșia Montană and extract profits without having to directly operate the mines itself. Instead, the Roman state facilitated the process by providing the provincial infrastructure, administrative personnel, protection, and opportunities for mining to flourish. This allowed for the influx of experienced army personnel and engineers, entrepreneurial mine owners and merchants, and skilled miners and menial labourers into Dacia's mining regions, with specific sites worked according to the individual circumstances. Mining in Dacia did not adhere to a pre-set formula but varied depending on situation and time period, and employed a whole range of techniques, people, and means of organisation, all overseen by the Roman state.

There is still considerable scope for further work on the mines of Roman Dacia, and it is my sincere hope that this thesis provides a springboard for future research. Not only is archaeological fieldwork urgently needed at some of the sites under threat of modern destruction, substantial gaps still remain in our knowledge for most of the mines discussed. For Roman mines that still exist, we need more detailed recording in order to assist attempts at quantification. In addition to mapping the mining works, this would include documenting data such as the size and quantity of slag heaps and associated ore-processing debris, and a greater attention to the different surface remains. Only by careful recording can archaeologists start to quantify the volume of ore removed for opencasts and work toward a meaningful discussion of scale of exploitation. Studies of surface evidence also need to expand beyond the work done at Roșia Montană and Bucium. Settlements, cemeteries, and processing areas all constitute an integral part of a mining site. Only by paying closer consideration to various related sub-sites alongside the mineral exploitation can we start to understand individual sites as a whole, and move towards constructing mining landscapes in Dacia suitable for comparison with mining landscapes in other Roman provinces. Finally, another avenue for future work are provenance studies comparing ores and metals to Roman coinage using trace-element analysis, especially with platinum and palladium. The tests already done on the Dacian Koson coins and *Sarmizegetusa* bracelets is an example of how this type of analysis has helped identify alluvial gold as the most likely metal sources for the pre-Roman material in Dacia. Similar projects on the Roman material using museum holdings of gold coins could be a fruitful way of tracing the gold sources used for Roman imperial and provincial coinage.[864] Such

864 E.g. Project AUREUS (http://www.iramat-ceb.cnrs-orleans.fr/spip/spip.php?article136&lang=fr) and “Gold Coinage in the Roman World” (https://www.ashmolean.org/gold-coinage-roman-world).

tests would need to be complemented by analysis of the originating ore, but would provide a means of identifying and tracing the importance of Dacian gold to the Romans vis-à-vis their eventual use in coinage.

Under the Roman Empire, Dacia changed: from a collection of isolated hillforts practising small-scale, local exploitation, it transformed into a mining province with a diverse and vibrant mining economy. These changes left their imprint on the landscape and provincial infrastructure of Roman Dacia by marking the western half of the territory with a distinct cluster of mines near all the major mineral resources whilst leaving the eastern half strikingly empty. The obvious focus on the metal resources reveals the impact that being part of the Roman Empire had on the organisation of the province, leaving one with the profound impression that Dacia was fundamentally an imperial mining landscape.