LiDAR Datasets Applied to Roman Gold Mining Studies in NW Iberia. Response to Paper: Roman Gold Mining at “Las Miédolas” (NW Spain): Lidar and Photo Interpretation in the Analysis of “Peines”

Javier Fernández-Lozano1 · Gabriel Gutiérrez-Alonso2 · Rosa M. Carrasco3 · Javier Pedraza4

Received: 30 March 2021 / Accepted: 18 February 2022 / Published online: 2 March 2022
© The Author(s) 2022

Abstract
Early LiDAR datasets in Spain are available since 2014 (5-m resolution), when the first works were carried out by our team (Fernández-Lozano and Gutiérrez-Alonso Mapping 167:22–29, 2014; Fernández-Lozano et al. J Archaeol Sci 2014:356–373, 2015). The implementation of LiDAR to 1-m resolution was subsequently used and compared by Fernández-Lozano and Gutiérrez-Alonso (J Archaeol Sci 5:509–520, 2016) in combination with UAV-derived (Unmanned Aerial Vehicles) photogrammetry. These works showed different Roman gold mining scenarios that were modeled providing outstanding results even with the poorest resolution LiDAR datasets. Moreover, the implementation of visual enhancement tools, widely used in different fields of archeology, geomorphology, and geology, such as Sky-View, Multi-hillside, Slope, LRM, Openness, and Principal Components have improved notably the interpretation of results in both mining and archeological works. This paper discusses the potential and insights provided by our methodological approach and shows that the results of its application to the study area of Las Miédolas can provide better results than those obtained by Matías and Llamas (Geoheritage 13(2):1–22, 2021).

Keywords LiDAR · Roman gold mining · Visual enhancement methods · UAV · Hydraulic network · Geomorphological features

Introduction

We welcome and acknowledge the work by Matías and Llamas (2021) for providing new data and interpretations on the “Las Miédolas” roman gold mining complex. Nevertheless, we disagree with several misleading statements in the text concerning our pioneering work using the LiDAR technology in nearby areas (Fernández-Lozano and Gutiérrez-Alonso 2014, 2016; Fernández-Lozano et al. 2015) without providing adequate discussion. For instance, in their paper, Matías and Llamas (2021; pag. 5) wrote “Other authors made similar studies with scarce results in the Roman mining located in the Iberian Northwest (Fernández-Lozano and Gutiérrez-Alonso 2014; Fernández-Lozano and Gutiérrez-Alonso 2016).”

Nevertheless, the use of LiDAR technology in characterizing and documenting Roman gold works in NW Iberia was first done by Fernández-Lozano and Gutiérrez-Alonso (2014) and Fernández-Lozano et al. (2015), who were able to discover and describe new sectors of Roman gold mining in the Eria river area, where part of the hydraulic and mining infrastructure was unknown. This work improved the mapping of some sectors carried out to date with traditional aerial orthoimages. Subsequent works carried out by Matías and Llamas (2018, 2019, 2021) were all based on the methodological approach shown in the pioneering work developed by Fernández-Lozano and Gutiérrez-Alonso (2014) and Fernández-Lozano et al. (2015). On the other hand, the implementation of unmanned aerial vehicles (UAVs) and
visual enhancement methods (VEM) shown in Fernández-Lozano and Gutiérrez-Alonso (2016) has demonstrated the potential of this methodology, lately used by different researchers in other archeological and geomorphological papers (e.g., Sonnemann et al. 2016; Poirier et al. 2020; Carrasco et al. 2020).

The Roman exploitation of secondary placer gold deposits of reduced thickness and extensive surface was based on converging furrows also known as “peines.” This method was a standardized practice between the first and third centuries A.D. as shown by the several examples recorded in Northwest Iberia (not only in the Province of León, as stated by Matías and Llamas 2021); Galicia and Portugal (Chá do Castro, Los Milagros de Monte Medo, As Covas, Avintes, etc., Sánchez-Palencia 1983); Salamanca (Ruiz del Árbol Moro and Sánchez-Palencia 1999; Ruiz del Árbol Moro et al. 2014); Zamora (Rio Negro, Andrés-Bercianos et al. 2021a); and León (Destriana, Las Murias-Tallares, Castro de Cepeda, Vallico La Escoba, Torneros de Jamuz, respectively, studied by Domergue (1973); Sáenz and Vélez (1974); González-Gutiérrez (1999); Fernández-Lozano and Gutiérrez-Alonso 2016; Fernández-Lozano et al. 2019). Some of them, like El Cabaco (https://el-cabaco.com/cavenes/), in the Province of Salamanca, represent an outstanding example of this exploitation method, having their own Interpretation Centre of the Roman Gold Mining Industry, which contributes to the promotion of geotourism.

Besides their impressive geometrical appearance, the interest of the convergent furrows exploitation method is supported by the comprehensive information that emerges from their complex infrastructure of water channels and drainage systems (evacuation channels). This type of exploitation is easily recognized from aerial imagery since their extension and magnitude are large enough to preserve the mining infrastructure remains. In the area of Las Miédolas, several systems of exploitation, comprising convergent furrows and trenches, trench-channels, and large trenches and simple trenches are combined to exploit the larger extension using the minimum hydraulic resources (Fig. 1). Therefore, their analysis using technologies such as LiDAR or UAVs can improve the results of the documentation works in these areas, unlike other mining sectors with minor works and more densely vegetated, developed also over the Raña deposits of the western Duero Basin (Fernández-Lozano et al. 2019; Andrés-Bercianos et al. 2021b).

In the light of the above, in order to correct the statement made by Matías and Llamas (2021; pg. 5) and to support our methodological approach, we present here an example of its potential as an application to the area studied by Matías and Llamas (2021), which can improve their results on deciphering the hydraulic and mining complex at Las Miédolas site. It is also interesting to note that using LiDAR in areas with reduced vegetation cover, or minor anthropic modifications, such as Las Miédolas, where the infrastructure can be directly observed from aerial images, provides little difference in the interpretation from previous works (see previous cartography presented by Sánchez-Palencia 1983).

The emergence of LiDAR and UAV technologies

The use of light detection and ranging (also known as LiDAR) in archeological and prospection works has grown lately. The high accuracy and resolution of LiDAR point
clouds datasets boosted the ability to investigate large areas in remote regions with dense vegetation cover. In Spain, the Instituto Geográfico Nacional (IGN; www.ign.es) provides first cover point clouds with density 0.5–4 points/m² and altimetric precision of 20 cm. The dataset provided by the IGN has multiple returns (4 per pulse), which are always used to obtain a more detailed and accurate interpolation of the ground surface. As explained by Fernández-Lozano and Gutiérrez-Alonso (2014), the DTM, depending on the LiDAR coverage, can be interpolated to different high resolutions, from 1 to 5 m. However, as these authors suggest in their subsequent paper in 2015, depending on the characteristics of the elements and landforms (i.e., channels, water tanks, and anthropic landscape modifications), 3 or 5 m LiDAR resolution may improve the prospection results (Fernández-Lozano and Gutiérrez-Alonso 2015). It is important to pinpoint that early public IGN datasets available and published in Fernández-Lozano et al. (2015) were 5-m resolution.

Unmanned aerial vehicles or UAVs also show promising results for the exploration of ancient mining sites. First implemented in the Roman gold mining of NW Iberia by Fernández-Lozano and Gutiérrez-Alonso (2016), the photogrammetric-based products (i.e., mdt, orthomosaics, and 3D texture maps) have contributed to improving the mapping of mining infrastructure and to the public diffusion and conservation of Roman remains (Fernández-Lozano et al. 2018; Fernández-Lozano and Sanz-Ablanedo 2021). The UAV pioneering work was systematically overlooked by the authors of the paper Matías and Llamas (2021) (and previous works, see García-Ramos 2017; Matías and Llamas 2018), the former carried out a similar study in the area without crediting. It is important to remark that UAVs are not geographic information systems as it is suggested from a poor precise title with no relation with the content of the technical document published by García-Ramos (2017), but it is an airborne geomatic technology that uses different sensors (i.e., LiDAR, RGB, multi-hyperspectral sensors) for exploration and mapping.

Recent work by Fernández-Lozano and Sanz-Ablanedo (2021) represents a step forward in the study of the Roman gold mining by implementing high-resolution UAV photogrammetry and multispectral analysis, which constitutes a promising method for exploration in extremely vegetated areas or where other technologies, such as LiDAR, do not offer enough resolution. This is the case of the Montealegre sector, near the El Bierzo Basin, where 1 m LiDAR data and PNOA orthoimages (Plan Nacional de Ortofotografía Aérea, IGN, www.ign.es) do not allow the accurate identification of the hydraulic network in certain sectors (Fernández-Lozano and Sanz-Ablanedo 2021). However, in those sectors, the implementation of UAV photogrammetric and multispectral flights efficiently highlights the location of the channels.

Thus, UAV-derived data allow the accurate location and morphometric analysis of these structures providing new insights into the magnitude of the Roman works in northwest Iberia. Even though complex areas with poor LiDAR data coverage are difficult to explore, generally, this technology provides outstanding results in regions with dense point clouds dataset (a high-resolution LiDAR coverage depends also on the type of vegetation and its density. For instance, pine trees provide better surface coverage than oak trees and dense scrub). Therefore, excellent areas for interpretation of Roman gold mining remains based on LiDAR data are, for instance, the Teleno Mountains (Fernández-Lozano et al. 2020), Las Miéndolas Mine (Matías and Llamas 2021), or Las Murias-Los Tallares (Castrocontrigo; Fernández-Lozano and Gutiérrez-Alonso 2014; Fernández-Lozano et al. 2015), where a low vegetation cover enhances a better reconstruction of the terrain.

**Visual enhancement tools for Roman gold mining documentation**

Visual enhancement tools (VET) are widely used in archeological, geomorphological, and mining works due to their potential for improving the identification, description, and interpretation of different anthropic and natural landforms (Challis et al. 2011; Kokalj et al. 2011; Štular et al. 2012; Doneus 2013; Carrasco et al. 2020). These methods have been successfully implemented in the study of Roman gold mining remains by Fernández-Lozano and Gutiérrez-Alonso (2016) and Fernández-Lozano et al. (2018, 2019, 2020). These works have shown that VET is a powerful tool to explore complex settings where the anthropic signature hides most of the remains as a result of farming and other forestry exploitation activity. The different proposed methods have also contributed to improving the initial digital 5-m elevation models available from 2014 (Fernández-Lozano and Gutiérrez-Alonso 2015).

The low vegetation cover affecting Las Miéndolas allows the rapid interpretation from aerial imagery, especially from the so-called Vuelo Americano (American Flight; from 1956–57). However, in areas with dense vegetation cover, the identification of mining infrastructure becomes complicated. In this case, the use of LiDAR and the processing techniques can efficiently improve the prospection results. Different techniques can be implemented at Las Miéndolas mining sector following the methodology by Fernández-Lozano and Gutiérrez-Alonso (2014, 2016), which provide insightful information and details of the hydraulic system and mining infrastructure (Fig. 2). Besides the clear anthropic features observed from aerial imagery, the implementation of Sky-View Factor, SLRM, Slope, and Openness algorithms can provide useful details about the drainage.
to decipher their processing methods, provides important errors due to the used shading algorithms. A good example of this problem is shown in Fig. 23 (location of water tank D-16), which is, in fact, located at the bottom of a mining trench. Basically, these authors have only used the LiDAR-derived DEM as a cosmetic image to locate the Roman workings and not as prospecting and documenting tool.

Moreover, the work published by Fernández-Lozano and Gutiérrez-Alonso (2015, 2016), focused on different interpolation resolutions and datasets, has shown the importance of using different gridding resolutions and VET techniques depending on the type of feature that needs to be investigated and the landscape transformation (i.e., presence of a water tank, channel, mining feature, anthropic activity). In fact, the studied sector of Valdepinillos (Castrocontrigo, Eria Valley; Fernández-Lozano and Gutiérrez-Alonso 2015) was subsequently re-published in the catalogue of Roman Gold Mining Inventory of Junta de Castilla y León (Page 49 in Matías 2017) without citation.

What do the Romans exploit at Las Miédolas?

Las Miédolas gold mine forms part of the eastward side of a large-scale alluvial fan developed from the mountainous region of the Cantabrian Mountains situated further to the NNW of the area (also known as Quintanilla del Monte alluvial fan; Moro-Martínez 2020). These sediments comprise boulder-like red conglomerates that represent the Plio-Quaternary Raña deposits (Fig. 1, R1) and do not correspond with the underlying Miocene conglomerates as stated in the Matías and Llamas (2021) paper. They represent the final stages of basin growth before the fluvial incision of the Orbigo and Omañas Rivers started. These deposits have been sampled by Moro-Martínez (2020), indicating gold grades over 120 mg/m³. Given that gold grades in such placer-like deposits may greatly vary across their length, more representative results are achieved if the whole sedimentary body is sampled and not only a few punctual locations (see Moro-Martínez 2020). The Miocene orange conglomerates underlie the Raña deposits (Fig. 1, M2, M3, M5). In addition, the formation of gold placers associated with the debris slopes (Fig. 1, D4) has been exploited in some sectors of the lower third of the mine. These materials can be considered secondary deposits recycled from the Raña and Miocene conglomerates and, in turn, both represent a paleoplacer deposit at Las Miédolas.

Some interesting remarks of the geological and geomorphological analysis are that the exploitation method selected for each sector of the mine depends on the main characteristics of the sedimentary materials. Thus, convergent furrows (i.e., “peines”) were developed in Raña deposits
(Fig. 1, R1), which are characterized by reduced thickness (0.5–10 m in the Quintanilla del Monte alluvial fan, Moro-Martínez 2020) and large extension, while trench-channel structures and large trenches were used to exploit thicker Miocene deposits (Fig. 1, M2, M3, and M5). In addition, minor trenches or grooves were carried out in the debris slope materials of reduced thickness and extension (Fig. 1, Quaternary debris, D4).

It is also noticeable that Fig. 30 in Matías and Llamas (2021) corresponds to a structured natural deposit, not anthropogenic since the remains of the mining activity produce two types of anthropic material: coarse tailing deposits (muriás boulders) and unstructured fine-grained sediments (≈ mud flows) at the end of the evacuation channels. To understand such an interpretation, it is instructive to review the characteristics of the Roman debris accumulated from the Chao de Maseiros sector at Las Médulas gold mine (Sánchez-Palencia 2000). Therefore, the deposits shown in Fig. 30 are associated with debris slope materials (D4 in Fig. 1). These deposits, therefore, are unlikely to be related to different phases of exploitation as suggested by Matías and Llamas (2021). Recent works by Fernández-Lozano and Gutiérrez-Alonso (2016) are challenged. These geomatic technologies have provided in the last few years outstanding results in different fields of application worldwide. The Roman gold mining research is no exception. It has benefited from these methods providing researchers with insightful datasets to accomplish new and profitable results. As it has been shown, these technologies and the methodological approach we have shown in the Roman gold mine of Las Miédolas provide promising insights into the hydraulic and mining infrastructure. Besides, we highlight the importance of an accurate interpretation of the geomorphological features preserved on the landscape. Poor interpretations will lead to wrong conclusions as we demonstrate for the gold placer deposits exploited by the Romans in this sector. All in all, the future of the Roman gold mining studies lies in a correct interpretation of datasets derived from geomatic technologies (i.e., LiDAR and UAVs), remote sensing methods, the geological, and geomorphological analysis supporting fieldwork. Therefore, multidisciplinary studies will be necessary to gain new insights into the recognition and interpretation of Roman gold mining activity in NW Iberia.

Funding Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature.

Declarations Not applicable.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

Conclusions

Matías and Llamas (2021) misleading statements about previous studies based on LiDAR, UAVs, and visual enhancement methods by Fernández-Lozano and Gutiérrez-Alonso (2014), Fernández-Lozano and Gutiérrez-Alonso (2015), and Fernández-Lozano and Gutiérrez-Alonso (2016) are challenged. These geomatic technologies have provided in the last few years outstanding results in different fields of application worldwide. The Roman gold mining research is no exception. It has benefited from these methods providing researchers with insightful datasets to accomplish new and profitable results. As it has been shown, these technologies and the methodological approach we have shown in the Roman gold mine of Las Miédolas provide promising insights into the hydraulic and mining infrastructure. Besides, we highlight the importance of an accurate interpretation of the geomorphological features preserved on the landscape. Poor interpretations will lead to wrong conclusions as we demonstrate for the gold placer deposits exploited by the Romans in this sector. All in all, the future of the Roman gold mining studies lies in a correct interpretation of datasets derived from geomatic technologies (i.e., LiDAR and UAVs), remote sensing methods, the geological, and geomorphological analysis supporting fieldwork. Therefore, multidisciplinary studies will be necessary to gain new insights into the recognition and interpretation of Roman gold mining activity in NW Iberia.

Funding Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature.

Declarations Not applicable.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

Andrés-Bercianos R, Alonso-Gavilán G, Fernández-Lozano J (2021a) Caracterización geológica e identificación de nuevas labores de minería aurífera antigua en los sectores de cabecera de los depósitos tipo raña en el valle del río Negro (Zamora). In: Sánchez de la Parra S, Díaz-Navarro S, Fernández-Lozano J, Jiménez-Gadea J (eds) The Archaeology of ‘Underdog Sites’ in the Douro Valley. From Prehistory to the Modern Age. Archaeopress, Oxford, pp 345–358

Andrés-Bercianos R, Fernández-Lozano J, Alonso-Gavilán G (2021b) Documentación de explotaciones mineras romanas y caracterización geológica de los placeres auríferos del piedemonte de Justel (Zamora). In: Sánchez de la Parra S, Díaz-Navarro S, Fernández-Lozano J, Jiménez-Gadea J (eds) The Archaeology of ‘Underdog Sites’ in the Douro Valley. From Prehistory to the Modern Age. Archaeopress, Oxford, pp 329–344

Bennett R, Welham K, Hill RA, Ford A (2012) A comparison of visualization techniques for models created from airborne laser scanned data. Archaeological Prospection 19(1):41–48

Carrasco RM, Soteres RL, Pedraza J, Fernández-Lozano J, Turu V, López-Sáez JA, Karampaglidis K, Granja-Bruña JL, Muñoz-Martín A (2020) Glacial geomorphology of the High Gredos Massif: Gredos and Pinar valleys (Iberian Central System, Spain). J Maps 16(2):790–804. https://doi.org/10.1080/17445647.2020.1833768

Challis K, Forlin P, Kincey M (2011) A generic toolkit for the visualization of archaeological features on airborne LiDAR elevation data. Archaeoel Prospect 18(4):279–289

Domergue C (1973) La mise en valeur des gisements d’alluvions romaines en el noroeste peninsular. Mapping 167:22–29
Fernández-Lozano J, Gutiérrez-Alonso G (2016) Improving archaeological prospection using localised UAVs assisted photogrammetry: an example from the Roman Gold District of the Eria River Valley (NW Spain). J Archaeol Sci 5:509–520. https://doi.org/10.1016/j.jasrep.2016.01.007

Fernández-Lozano J, Sanz-Abianedo E (2021) Unraveling the morphological constraints on Roman gold mining hydraulic infrastructure in NW Spain. A UAV-derived photogrammetric and multispectral approach. Remote Sensing 13(2):291–1–24. https://doi.org/10.3390/rs13020291

Fernández-Lozano J, Gutiérrez-Alonso G, Fernández-Morán M (2015) Using airborne LiDAR sensing technology and aerial orthomages to unravel Roman water supply systems and gold works in NW Spain (Eria valley, León). J Archaeol Sci 2014:356–373. https://doi.org/10.1016/j.jas.2014.11.003

Fernández-Lozano J, Gutiérrez-Diez A, Gutiérrez-Alonso G, Carrasco RM, Pedraza J, García-Talegón J, Remondo J, Bonachea J, Morellón M (2018) New perspectives for UAV-based modelling the Roman gold mining infrastructure in NW Spain. Minerals 8(11):518. https://doi.org/10.3390/min8110518

Fernández-Lozano J, Palao-Vicente JJ, Blanco-Sánchez JA, Gutiérrez-Alonso G, Remondo J, Bonachea J, Morellón M, González-Diez A (2019) Gold-bearing Pliao-Quaternary deposits: insights from airborne LiDAR technology into the landscape evolution during the early Roman mining works in north-west Spain. J Archaeol Sci Rep 24:843–855. https://doi.org/10.1016/j.jasrep.2019.03.001

Fernández-Lozano J, Carrasco RM, Pedraza J, Bernardo-Sánchez A (2020) The anthropic landscape imprint around one of the largest Roman hydraulic gold mines in Europe: Sierra del Teleno (NW Spain). Geomorphology 357(107094):1–13. https://doi.org/10.1016/j.geomorph.2020.107094

Fernández-Lozano J, Carrasco RM, Pedraza J (2021) A multiapproach for solving geoarchaeological problems: inferences from Roman Gold mining in the Eria Valley (León). Geogaceta 69:1–4

Fernández-Lozano J, Gutiérrez-Alonso G (2015) Uso de LiDAR y aeronaves no tripuladas para la cartografía y registro de zonas de interés geomorfológico: un ejemplo de la minería aurífera romana en el valle del Eria (León, España). Actas de las V Jornadas de Investigación Geográficos en la prospección de mineralizaciones de oro en la Sierra del Teleno (León, España). Universidad Politécnica de Madrid, Madrid, 693 pp

García-Ramos E (2017) Aplicaciones del LiDAR y Sistemas de Información Geográficos en la prospección de mineralizaciones de oro en la Sierra del Teleno (León, España). Universidad Politécnica de Madrid, Madrid, Proyecto Fin de Grado, p 62

González-Gutiérrez RB (1999) Las explotaciones auríferas romanas del río de las Huelgas y su influencia en la transformación del paisaje (el ejemplo de Veguellina de Cepeda, León). Cuadernos De Investigación Geográfica / Geogr Res Lett 25:111–124

Kokalj Ž, Zakšek K, Oštir K (2011) Application of sky-view factor for the visualisation of historic landscape features in lidar-derived relief models. Antiquity 85(327)

Matías R, Llamas B (2018) Use of LIDAR and photointerpretation to map the water supply at the Las Murias-Los Tallares Roman gold mine (Castrocontrigo, León, Spain). Archaeol Prospect 25(1):59–69

Matías R, Llamas B (2021) Roman gold mining at “Las Miédolas” (NW Spain): Lidar and photo interpretation in the analysis of “Peines” system. Geoheritage 13(2):1–22

Matías R (2017) Actualización del inventario de minas de oro romanas en los Montes de León (Bierzo Oriental, Cabrera y Maragatería. Fase II. Memoria Final. Fundación Gómez Pardo. Junta de Castilla y León, León, 172 pp

Matías R, Llamas B (2019) Analysis using LiDAR and photointerpretation of Las Murias-Los Tallares (Castrocontrigo, León-Spain): One of the biggest Romangold mines to use the “Peines” system. Geoheritage 11(2):381–397

Moro-Martínez A (2020) Caracterización geológica y minera del abanico aluvial de Quintanilla del Monte. Trabajo de Fin de Grado (BSc, unpublished). Universidad de León, León, p 44

Poirier N, Baleux F, Calastrenc C (2020) The mapping of forested archaeological sites using UAV LiDAR. A feedback from a south-west France experiment in settlement & landscape archaeology. Archéologies Numériques 4(2)

Ruiz del Árbol M, Sánchez-Palencia J, Sastre-Prats I, Orejas del Valle A (2014) Water networks of Roman gold mines of Northwestern Iberian Peninsula. Water History 6(1):95–113

Ruiz del Árbol M, Sánchez-Palencia FI (1999) La minería aurífera romana en el Nordeste de Lusitania: Las Cavenes de El Cabaço (Salamanca). Arch Esp Arqueol 72(179–180):119–139. https://doi.org/10.3989/aespa.1999.v72.299

Sáenz C, Vélez J (1974) Contribución al estudio de la minería primitiva del oro en el Noroeste de España. Ediciones Atlas, Madrid

Sánchez-Palencia J (1983) Las Míedolas. In: La explotación del oro de asturias y gallecias en la antiguedad. Tesis Doctoral, Universidad Complutense de Madrid, Madrid, 693 pp

Sánchez-Palencia J (2000) Las Médulas (León). Un paisaje cultural en la Asturias Augustana. Diputación de León, Instituto Leonés de Cultura, León, 351 pp

Sonnenmann TF, Ulloa Hung J, Hofman CL (2016) Mapping indigenous settlement topography in the Caribbean using drones. Remote Sensing 8(10):791

Štular B, Kokalj Ž, Oštir K, Nuninger L (2012) Visualization of lidar-derived relief models for detection of archaeological features. J Archaeol Sci 39(11):3354–3360