Archaeological research of ancient mining landscapes in Galicia (Spain) using Airborne Laser Scanning data

CONFERENCE PAPER · JULY 2014

DOI: 10.13140/2.1.3122.5608

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Paisagens Mineiras Antigas na Europa Ocidental

Investigação e Valorização Cultural

A reconhecida importância dos valores patrimoniais do vale superior do Rio Terva, em que se destaca o Complexo Mineiro Antigo, classificado como Sítio de Interesse Público, justificou um esforço de convergência de interesses e de ações entre o Município de Boticas e a Universidade do Minho, no sentido de garantir uma valorização sustentada e uma gestão integrada do valioso património identificado, tendo em vista promover a sua difusão alargada, a criação de serviços, o aumento da oferta cultural de Boticas e a internacionalização da história milenar e da identidade do seu território.

Esta publicação corresponde às atas do simpósio internacional **Paisagens Mineiras Antigas na Europa Ocidental. Investigação e Valorização Cultural**, que encerrou o projeto "Conservação, Estudo, Valorização e Divulgação do Complexo Mineiro Antigo do Vale Superior do Rio Terva, Boticas", iniciado em 2006 e financiado por fundos europeus no quadro do EEC PROVERE AQUANATUR-PA/1/2011, do Eixo Prioritário II-Valorização Económica de Recursos Específicos, do ON.2-O Novo Norte.

O Simpósio estruturou-se em dois temas, Investigação e Valorização, através dos quais se pretendeu dar a conhecer o estado da arte, no ocidente europeu, das investigações das paisagens mineiras antigas e dos projetos de valorização das paisagens culturais correlacionadas, abordando-se, para o primeiro tema, questões relacionadas com os objetivos, metodologias, resultados e perspetivas de desenvolvimento futuro das investigações e, para o segundo tema, questões relacionadas com as razões e processos de criação de estruturas de gestão de paisagens culturais, respetiva componente de investigação, modelos de gestão implementados e desafios para o futuro.

ON.2 O NOVO NORTE PROGRAMA OPERACIONAL REGIONAL DO NORTE
QREN QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL PORTUGAL 2007/2013
UNIÃO EUROPEIA Fundo Europeu de Desenvolvimento Regional
BOTICAS CÂMARA MUNICIPAL
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Atas do Simpósio Internacional

Boticas, 25/26/27 julho 2014

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Introduction and objectives

The use of techniques based on 3D point-clouds for modeling and documentation of cultural heritage[1] and the mapping and survey of archaeological landscapes [2] has evolved remarkably and it's becoming of a widespread use. In the case of the mapping and prospection of mining landscapes, areas which are usually densely forested, the identification and documentation of archaeological features, coupled with its size and complexity, is still very problematic when relying on well-known methods such as photointerpretation or fieldwork.

The introduction of airborne laser scanning (ALS) or airborne Light Detection and Ranging (LiDAR) helped to overcome this problem because of its unique capability to penetrate vegetation canopies, allowing the documentation of the underneath topographic surface and thus the identification of archaeological remains[3]. The effectiveness of airborne LiDAR in detecting new archaeological sites and features and in improving the documentation of the already known is well proved, so ALS has completely revolutionized the area of archaeological survey[4]. Given this, we present in this study some preliminary results related to the potential of airborne LiDAR to archaeological research of ancient mining landscapes.

Study areas

We have selected two study areas in Galicia, Spain (Fig. 1), comprising different types of Roman mining: one in a primary context (Carballiño) (Fig. 2-a and c) and the other in a secondary one (Os Milagros do Monte Medo) (Fig. 2-b and d).

The Carballiño area is located in the Galicia-Trás-os-Montes Zone (GTMZ zone)[5]. The GTMZ belongs to the internal zone of the Hercynian belt and is composed of a relative autochthonous and parautochthonous units overthrusted by allochthonous complexes. This area is located in the Schistose Domain, which is composed by a monotonous sequence of schists crosscutted by the so called G2 granites (Carballiño massif) that are syn-D3 two micas granites and leucogranites[6]. Gold mineralizations are spatially associated with G3 granites (Boborás and Irixo massifs)[7]. G3 granites are biotite-dominant two mica granites[8] (Fig. 3-a). Locally called Gobras de Madarmás, it was exploited in quartz veins (with strike N10ºW that agree with the open pit main orientation), where arsenopyrite, scorodite and gold can be found in veins[9].

The Os Milagros do Monte Medo area is a secondary deposit in opposition to the primary deposits of Carballiño. The geology is very simple and the Romans exploited the horizontal layers of quartz conglomerates, deposited over barren clay-sand formations, all from the Quaternary period[10] (Fig. 3-b).

LiDAR data processing

The PNOA (*Plan Nacional de Ortofotografía Aérea*), the Spanish National Plan for Aerial Orthophotography (http://www.ign.es/PNOA/), promoted by the Spanish National Geographic Institute (IGN), has made public available an almost complete LiDAR and orthophotographic coverage of Spain. In our study areas, the aerial images for orthophoto production were acquired in June 2011, while the LiDAR data were acquired in September 2011 using an IGI LM 5600 sensor, operated at a laser wavelength of 1064 nm from a flight altitude of 1000 to 1800 m (above sea level). The beam divergence was 0.5 mrad, the pulsing frequency 70 kHz, the scan frequency 50 Hz, and the scan angle ±10. Up to four returns per pulse were registered, with an average measuring density of about 0.5 points per square meter. To generate the Digital Terrain Models (DTM), the Adaptive Morphological Filter (AMF)[11] was used for filtering terrain points. A kriging interpolation method with a 1 m cell size was used to generate the DTM.

To enhance the contrast of archaeological features, we have applied the Morphological Residuals Model (MRM)[12], that uses a mesh decimation algorithm that allow us to discriminate between positive and negative microtopographies at a local scale, representing real changes in elevation rather than calculations based on steepness and slope direction or light exposure.

Results

As we can see from the chosen examples, Romans were able to mine primary and secondary gold deposits. In case of the primary ones, they tend to be limited in space, since they usually exploited structural (linear) enrichments. That is not the case for secondary deposits, since they need to wash a huge amount of rock remains, that Las Médulas is an extreme example, in order to extract the low gold content.

In the Carballiño area, one can clearly appreciate the contrast between the original and the modified landscape, both by the mining activities and the construction of a hillfort[13]. The morphology of the mining operations indicates that the excavation was applied directly onto a vein or veins system sharply defined. The southern extension of the open-pit should be understood as a need to drain the mining works.

In the case of the Os Milagros do Monte Medo exploitation, it occupies an area of approximately 6 km2, dug on alluvial Plio-Quaternary or earlier belonging to an ancient river channel, now defunct. Despite the vegetation that nowadays covers the mined area, is possible to reconstruct the mining structures from historical aerial photos, before afforestation has been made[14] (Fig. 5-b). One can notice several levels of operation (up to 3), conducted on the remnant river terraces, using different methods like "trench-channels" (Fig. 4-1) and "stream-cuts" (Fig. 4-2), which in some cases tend to overlap, and "convergent furrows" (Fig. 4-3). When compared to the previous photo interpretation (Fig. 5c), the MRM image shows a greater level of detail of the mining structures (Fig. 5d).

Final remarks

The MRM images have allowed an immediate general display of the surface mining operations without the need of a detailed processing of aerial photos, a task that can be very demanding when dealing with complex structures, as in this case. Thus, the initial work of photo-interpretation is speeded, although one cannot completely ignore a more detailed and integrated study of the landscape and, of course, ground-truthing the archaeological evidences.

Note:This work has been supported by the Archaeolandscapes Europe project (www.archaeolandscapes.eu). The first author acknowledges the Portuguese Science Foundation (FCT) for the SFRH/BD/65143/2009 grant.

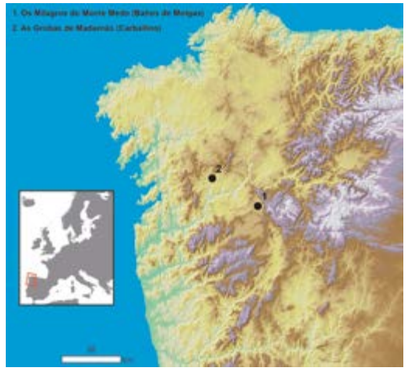

Figure 1 - Location of the study areas

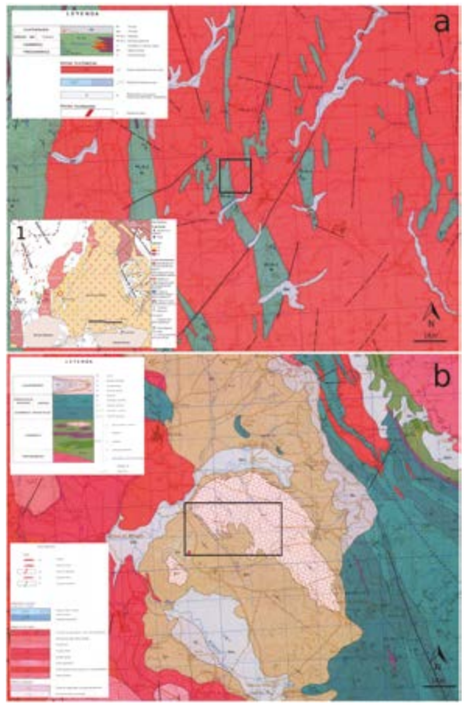

Figure 3 - Geological maps at 1:50.000 scale: *Carballiño* region (a), *Os Milagros do Monte Medo* (b) and Au and Sn-W mineralizations and relationships with different granites in the surroundings of the Carballiño study area (1) (Gloaguen 2006)

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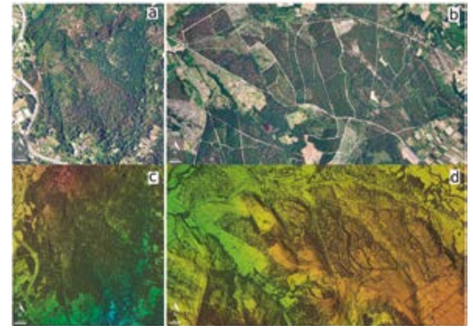

Figure 2 - *Carballiño*: Orthophoto (a) and Digital Surface Model (DSM) (c); *Os Milagros do Monte Medo*: Orthophoto (b) and DSM (d)

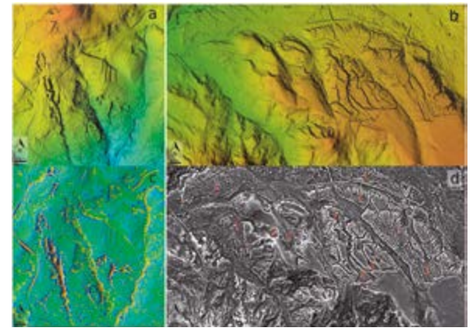

Figure 4 - DTM and MRM of *Carballiño* (a and c) and *Os Milagros do Monte Medo* (b and d) respectively

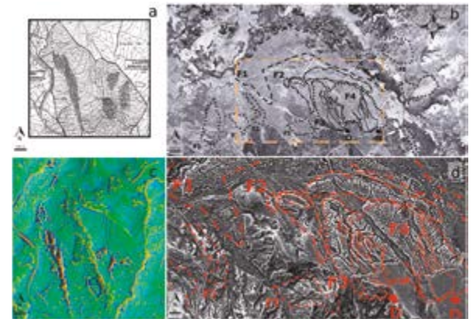

Figure 5 - MRM results from *Carballiño* (c) and *Os Milagros do Monte Medo* (d) compared to previous archaeological interpretations: open-pits and hillfort from *Carballiño* over a topographic map (a) (AMADO-ROLÁN 2005) and exploitation phases of *Os Milagros do Monte Medo* traced over the 1956 USAF aerial photographs (b) (SÁNCHEZ-PALENCIA et al., 2009)

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