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# Characterization of placer gold deposits from central Portugal: preliminary results

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**Abstract.** The streams in the Lower Tagus Basin and along the contact of the Central Iberian and Ossa Morena zones in central Portugal carry significant amounts of gold. In this study, four placer gold deposits have been characterized using geochemical, morphological and heavy mineral data and compared with the styles of gold mineralization in the vicinity. The geochemical similarities of the Tagus palaeo-placer and the Tripeiro and Erges gold placers suggest a primary gold source likely to be similar to the mineralization found at Sarzedas and Pomar. The more heterogenic composition of the Caia gold placer probably reflects the different styles of mineralization found at La Codosera, Los Algarbes and Alburquerque to the east.

**Keywords.** Central Portugal, placer gold, LA-ICP-MS

## 1 Introduction

This study uses minor and trace element data, determined by LA-ICP-MS during a provenance study on the gold of the unique Early Bronze Age Nebra Sky Disk, central Germany. The data is used to characterize four placer gold deposits of potential prehistoric importance in central Portugal together with grain morphology and the associated heavy mineral fraction. The results are discussed further with regard to the styles of gold mineralization found in the vicinity of the placer deposits. Similar studies on the geochemical signature of gold have been carried out since the early works by Watling et al. (1994) on numerous lode and placer gold deposits worldwide, also by studying the microchemical composition of the gold particles (e.g., Chapman et al. 2009). More detailed investigations on further gold samples of these and other, also primary gold deposits, are currently carried out to obtain additional information on the geochemical and microchemical variability of the deposits.

## 2 Geological setting

The study area comprises mainly the Lower Tagus Basin (LTB) which extends from the littoral western part of the Setúbal Peninsula to the region of Castelo Branco at the border to Spain. The Tagus estuary in the Seixal area (Fig. 1a) exhibits auriferous Pliocene sand and gravel deposits of detrital origin, which are located exclusively at the southern Tagus margin and are partially covered by Quaternary alluvial and detrital deposits. Primary gold mineralization is unknown for the greater Tagus estuary.

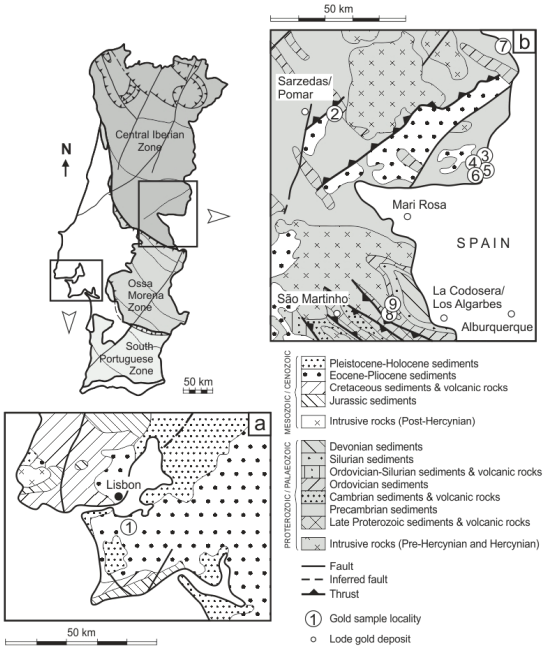


**Figure 1.** Locality maps of the study area, modified after the Carta Geológica de Portugal Scale 1:500.000 (1992). (a) Simplified geological map of the Tagus estuary containing the Tagus palaeo-placer (1). (b) Simplified geological map of the southern CIZ and BCSZ in the Castelo Branco region containing the Tripeiro (2), Erges, Rosmaninhal (3-6), Erges, Vale Feitoso (7), and Caia (8-9) gold placers.

In contrast, mineralization in the Castelo Branco region (Fig. 1b) in the southern Central Iberian Zone (CIZ) and along the left-lateral Badajoz-Cordoba Shear Zone (BCSZ), separating the CIZ in the north from the Ossa Morena Zone (OMZ) in the south, is mainly characterized by post-metamorphic quartz veins that are often associated with late brittle faults of Hercynian to Late Hercynian age (Murphy and Roberts, 1997). The fluids result from devolatilisation and dehydration during prograde metamorphism of a several kilometers thick sequence of Precambrian greywackes and shales (Complejo Esquisto Grauvaquico or CEG) and are of varying aqua-carbonic and meteoric mixture (Murphy and Roberts, 1997). At Sarzedas, Pomar, and Mari Rosa (Fig. 1b), the gold mineralization is hosted in the CEG

and mainly associated with arsenopyrite and minor pyrite (As-Au, Sarzedas and Pomar) or stibnite (Sb-Au, Mari Rosa). Late stage remobilization at Sarzedas and Pomar resulted in the deposition of gold and Cu-Pb-Zn sulphides. At La Codosera, Devonian slates and sandstones form the main lithological host of the auriferous quartz-pyrite-(arsenopyrite) veins (Murphy and Roberts 1997) while several kilometres to the west at Los Algarbes, Devonian quartzites contain Sb-Au mineralization. Stratabound mineralization occurs at Alburquerque, where gold is disseminated and found parallel to the bedding of Ordovician-Silurian black shales or in gossanous veinlets within quartzites (Murphy and Roberts 1997). At São Martinho within the BCSZ, post-metamorphic gold mineralization is also mainly disseminated and runs parallel to the foliation of Late Proterozoic schists, with arsenopyrite, pyrite, and chalcopyrite as main mineral phases (Oliveira et al. 2007). Late stage remobilization during granitic magmatism resulted in the deposition of gold with pyrrhotite, pyrite, chalcopyrite and loellingite.

## 3 Samples and analytical techniques

The recent placer gold samples derive mainly from a rare earth reconnaissance survey on Portuguese stream sediments, which included sampling, determination and quantification of heavy minerals (Inverno et al. 2007) with grain sizes below 3 mm. From the rivers with a prehistoric potential for recoverable gold placers, ten representative particles per deposit were selected to characterize the morphology and chemical composition. The Tagus palaeo-placer (Salgueiro et al. 2000) and Tripeiro gold placer were sampled separately. For the study of the grain morphology, a light microscope and scanning electron microscope were used. Concentrations of major, minor, and trace elements were determined by LA-ICP-MS at the Curt-Engelhorn-Zentrum Archäometrie (CEZA), Mannheim, Germany. Full details on the operating conditions for the ICP-MS and laser ablation systems are given in Schlosser et al. (2009). Due the low thickness of most of the gold samples and based on the initial aim of the analyses to obtain the average composition of the natural gold for comparison with artefact gold, line ablation with a spot diameter of 50 µm and energy of 45% was performed over a length of 300 to 600 µm on all samples. A pre-ablation time of 20 to 40 s using a spot diameter of 75 µm and energy of 30% was applied to eliminate surface contaminations and to diminish the influence of supergene rims on the results.

## 4 Grain morphology

The grain morphology has been investigated using the criteria by Townley et al. (2003) with the obtained results summarized in Table 1. The gold from the Tagus palaeo-placer and Tripeiro placer shows a very regular to regular morphology with strong signs of folding or hammering. In contrast, placer gold from the river Erges shows a regular to very irregular morphology suggesting a shorter distance to its primary sources compared with the Tagus palaeo-placer and Tripeiro placer. The largest variation in morphological characteristics, also in grain size, is observed for placer gold from the river Caia with the number of populations, present at both sample localities, to be investigated.

**Table 1.** Morphological characteristics of the studied placer gold deposits using the criteria by Townley et al. (2003). Tri. = triangular, rect. = rectangular, elong. = elongated, reg. = regular, irreg. = irregular.

| Deposit | Shape | Outline | Surface | Assoc. mineral | Sub-ordinate |
|---|---|---|---|---|---|
| Tagus | oval-round; rect. (10%) | very reg.; reg. (10%) | very reg. (folded); reg. (hammered) (10%) | - | - |
| Tripei-ro | rect.-oval | very reg.-reg. | very reg. (hammered) | qtz | folding |
| Erges, Rosm. | tri.-rect. | reg.-very irreg. | reg.-irreg. | qtz | folding, welding |
| Erges, Vale Feitoso | rect. | reg.; irreg. (20%) | reg.; irreg. (20%) | -; qtz (20%) | ham-mering |
| Caia | elong.-rect. | very reg.-irreg. | very reg.-irreg. | qtz | - |

## 5 Chemical composition

From the 25 elements measured by LA-ICP-MS, the concentrations of Co, Ru, Os, Ir, Pt, Tl, and Bi were below the detection limit of 5 ppm. Cr, Mn, Zn, Pd, and Pb were only determined occasionally and, therefore, not considered further for chemical characterization. The remaining elements and their general significance for the chemical composition of the placer gold deposits are summarized in Table 2. The variation of the minor and trace elements is illustrated in Figure 3.

**Table 2.** Trace elements of the studied placer gold, discriminated by their median concentrations. References for heavy minerals: [1] = Inverno et al. (2007), [2] = Salgueiro et al. (2000). and = andalusite, c = cassiterite, cy = cyanite, hem = hematite, il = ilmenite, lx = leucoxene, r = rutile, sil = sillimanite, st = staurolith, tu = tourmaline, zr = zircon.

| Deposit | Trace elements (median >25 ppm) | Trace elements (median 25-5 ppm) | Main heavy minerals (>5%) |
|---|---|---|---|
| Tagus | Fe, Cu, Ni | Se, Ti | il, st, tu, and, sil, cy, zr, r [2] |
| Tripeiro | Cu, Fe | Ni, Se | not determined |
| Erges, Rosm. | Cu, Fe | Ni, Te, Se, As, Cd | hem, lx, zr, tu [1] |
| Erges, Vale Feitoso | Fe, Cu, Ni | Te, Se | - |
| Caia | Fe, Sb, Cu, Ni | Sn, Te, Se | c, il, lx, r [1] |

Ni and Se show the smallest variations in concentration with the concentrations being similar for all placer gold deposits. The Tagus palaeo-placer and Tripeiro gold placer are characterized by low Ag and Te concentrations, with the Tripeiro gold placer being, in total, most depleted in trace elements (Fig. 3a). The relatively high Ti and Fe concentrations in the Tagus palaeo-placer may result from secondary mineral formation or inclusion during the long weathering process. However, the main geochemical associations of the Tagus palaeo-placer and the Tripeiro and Erges gold

placers, namely the median Ag, as well as (Fe), Cu, Ni, and Se concentrations, can be considered similar given the natural variability in composition within one gold deposit, as well as the influence of supergene formation and modification of the primary gold and its chemical composition during weathering and transport. In contrast, the Caia gold placer also contains significant amounts of Sb or Sn, with the corresponding gold samples deriving from different localities located two km apart from each other (No. 8 and 9 in Fig. 1). However, at both localities, the heavy mineral fraction contains more than 25% cassiterite (Table 2). The heterogenic composition of the Caia gold placer is also displayed in the large variation in Ag concentrations, ranging from 0 to 15 wt.% at the locality 8 and from 5 to 32 wt.% at the locality 9.

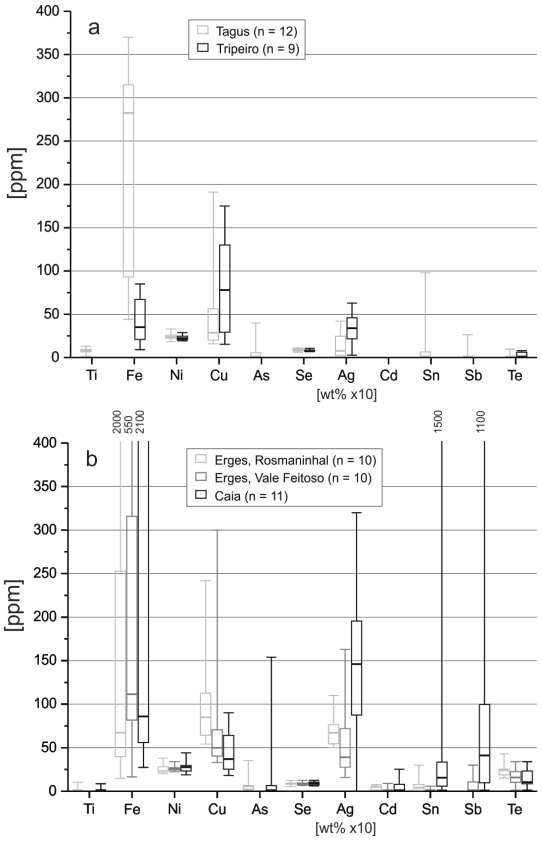


**Figure 3.** Variation of minor and trace elements in gold from (a) the Tagus palaeo-placer and Tripeiro placer, as well as (b) the Erges and Caia placers. Concentrations are in ppm, except for Ag and Au. n = number of data sets acquired.

## 6 Discussion

The geochemical similarities of the minor and trace elements in the Tagus palaeo-placer and the Tripeiro and Erges gold placers suggest a similar style of gold mineralization for the primary gold sources, although differences in the Ag and Te concentrations between the Erges gold placers and the Tagus palaeo-placer and Tripeiro gold placer have been detected. However, since the very regular to regular morphology of the Tagus palaeo-placer and Tripeiro gold placer suggests a much longer fluvial transport compared with the Erges gold placers, a stronger depletion of elements such as Ag is possible. In addition, different mineralization events, investigated for the Sarzedas and Pomar primary gold deposits in the vicinity of the Tripeiro and Erges gold placers, promote the formation of gold with different initial chemical compositions. As the rivers Tagus, Tripeiro and Erges cross the same lithology found at Sarzedas and Pomar (CEG), similar post-metamorphic (As-Au) to late stage mineralization is likely to be found, with the Tagus palaeo-placer being located farthest away from known primary gold deposits. The heterogenic composition of the Caia gold placer may reflect the heterogenic mineralization of As-Au and Sb-Au found to the east, including the primary gold deposits of La Codosera, Los Algarbes and Alburquerque. The high Sn concentrations in the Caia gold placer may result from the influence of the Sn-W mineralization in the aureole of the adjacent Alburquerque Late Hercynian granitic batholith, which will have to be investigated by obtaining more data, also on the primary gold deposits.

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