Evidence for wall vitrification at the Late Bronze Age settlement of Passo Alto (Vila Verde de Ficalho, Serpa, Portugal)

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ABSTRACT   The Late Bronze Age settlement of Passo Alto includes a defensive complex with partial vitrification of the wall rampart. The mineralogical assemblage identified in the vitrified rock fragments includes neoformed phases and glass as a result of incongruent melting of the original micas of the local substrate (Palaeozoic micaschist). The temperatures achieved were very high, probably exceeding 1100°C. Mineral textures indicate fast cooling of the melt. Burning of a structure made of timber and rock fragments from the local substrate affected a small portion of the rampart adjacent to the probable main entrance, and is considered the most simple and coherent hypothesis to explain all the observed evidence.

RESUMO   O povoado do Bronze Final do Passo Alto possui um complexo defensivo, no qual se pode observar uma vitrificação parcial da muralha. Os minerais identificados nos fragmentos de rocha, que sofreram vitrificação, incluem vidros e fases de neoformação resultado de uma fusão incongruente das micas que fazem parte do substrato pétreo local (um micaxisto do Paleozóico). As temperaturas atingidas terão sido bastante altas, excedendo provavelmente os 1100°C. As texturas minerais indicam, por outro lado, um arrefecimento rápido do material fundido. A queima de uma estrutura feita de madeira e de fragmentos de rocha do substrato local, que constituiria a parte superior da muralha, terá afectado apenas uma pequena porção desta, na área adjacente à provável entrada principal do povoado. Esta hipótese de constituição da muralha e do que lhe terá acontecido pode considerar-se como a explicação mais simples e coerente para a evidência arqueológica observada na área do complexo defensivo do Passo Alto.

1. Introduction

The settlement of Passo Alto is located in southwestern Portugal near Vila Verde de Ficalho (Fig. 1). It extends atop a small hill near the confluence of two rivers (Fig. 2), and is formed by two *loci* 250 m apart (Fig. 3). The archaeological finds, namely pattern-burnished pottery (Fig. 4) collected during several archaeological surveys and excavations carried out at the settlement, indicate that a Late Bronze Age chronology must be assigned to the human occupation of this archaeological site (Parreira and Soares, 1980; Soares, 2003, 2005).

The good natural defenses of the settlement are complemented with a rampart along the easiest northern approach to the settlement (Fig. 3). Outside the rampart, a broad band of chevaux-de-frise provides an additional line of defense around what most probably was the main entrance-way. An archaeological trench excavated near this entrance, perpendicular to and across the enclosure wall, allowed to characterize the rampart (Fig. 5). Its base consists of a line of undressed superposed blocks of schist from the local substrate rock in the outer side (a), and a line of vertical schist slabs in the inner side (b), both limiting an earthen wall of compacted soil with small stones (c). An earthen bank also seems to be placed against the inner side of the wall, i.e. against the vertical slabs.
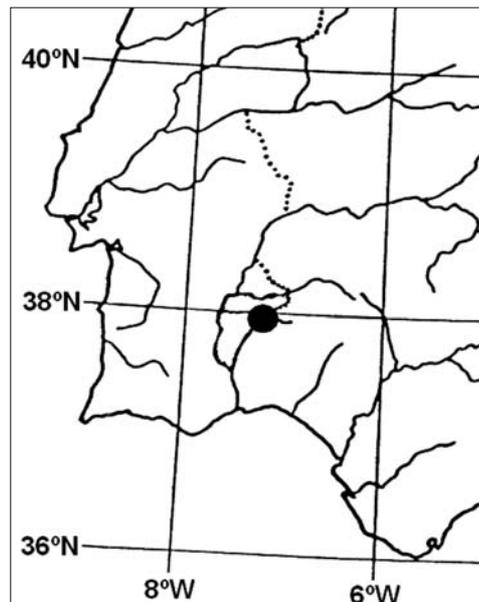

Fig. 1 Location of the settlement of Passo Alto in southwestern Portugal.

Fig. 2 View of the settlement of Passo Alto from the northern access road. The arrow indicates the probable main entrance where the chevaux-de-frise and vitrified rocks are found.
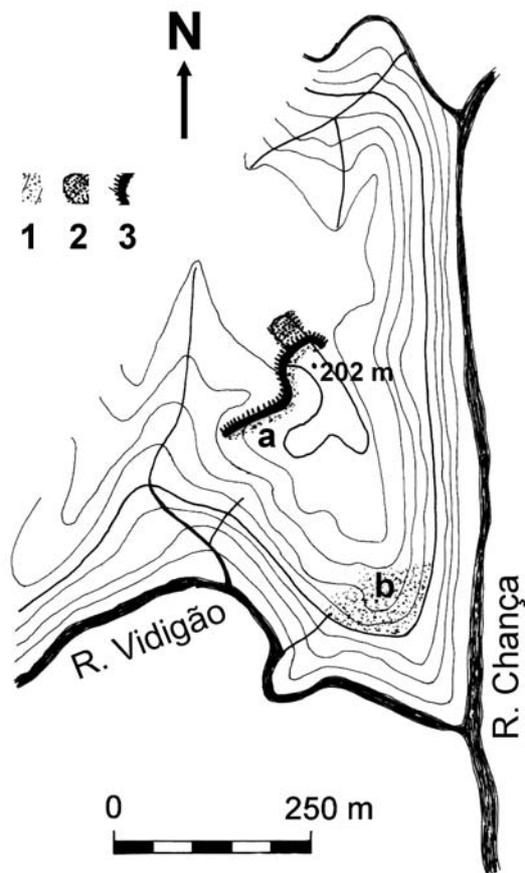
Fig. 3 Survey of the settlement of Passo Alto: 1 - area with scattered pottery sherds; 2 - chevaux-de-frise; 3 - wall rampart. Distance between contour lines: 10 m. See text for further explanations.
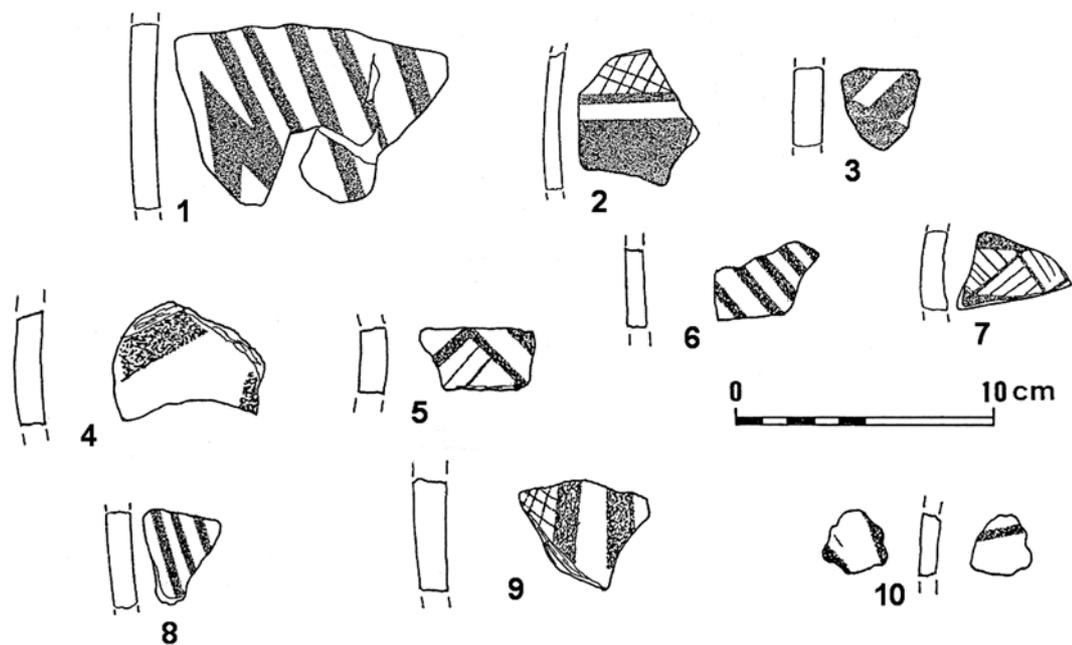

Fig. 4 Late Bronze Age pattern-burnished pottery shards from the settlement of Passo Alto.

Fig. 5 Internal structure of the enclosure wall at the settlement of Passo Alto: a - line of undressed superposed blocks of schist (outer face); b - vertical schist slabs (inner face); c - compacted soil with small stones (base and inner part of the wall).

Blocks of schist covering the earthen wall and making part of the tumble (Fig. 5) suggest that the upper part of the rampart wall was made of these blocks in an undressed and superposed way. Rock fragments with evidence of partial melting as well as welding of clasts are abundant in a restricted area of the rampart zone near the possible main entrance. The first preliminary interpretation of these rock fragments assigned them to metallurgical processes (Soares, 1988, 2003). However, more detailed analyses identified a lack of ore minerals or smelting slag at the site, and a large volume of rocks affected by partial melting, both characteristics hard to reconcile with typical small-scale Bronze Age metal smelting. Hence, an alternative interpretation had to be considered, and this was partial vitrification of the enclosure wall near the probable main entrance. This new interpretation implies that, at least at the entrance, the defensive wall consisted of an upper part made of rock fragments within a timber framework, in a way similar to other Bronze and Iron Age vitrified hillforts known from northern and central Europe (Youngblood et al., 1978; Nisbet, 1982; Fredriksson et al., 1983; Kresten et al., 1993). The objective of this article is to document the evidence which has led us to infer burning of a timber structure and partial vitrification of the rampart as the most probable interpretation of the partially-melted rock fragments, and to discuss the results in the light of the latest evidence for protohistoric vitrification of fortresses in the region (Díaz-Martínez, 2004a, 2004b; Díaz-Martínez and Soares, 2004).

2. Evidence for wall vitrification

A detailed study of the partially melted and welded fragments was undertaken in order to explain the apparent incongruence of metallurgical processes resulting in such a large volume of these fragments. The study consisted of field description and hand-specimen study of the clasts (areal distribution, shape and size, surface features, etc.), petrological and mineralogical analyses under optical polarizing microscope, identification of mineral phases with whole-rock powder X-ray diffraction (XRD), analysis of secondary and backscattered electron (BSE) images under electron microscope, and chemical analysis with electron microprobe.
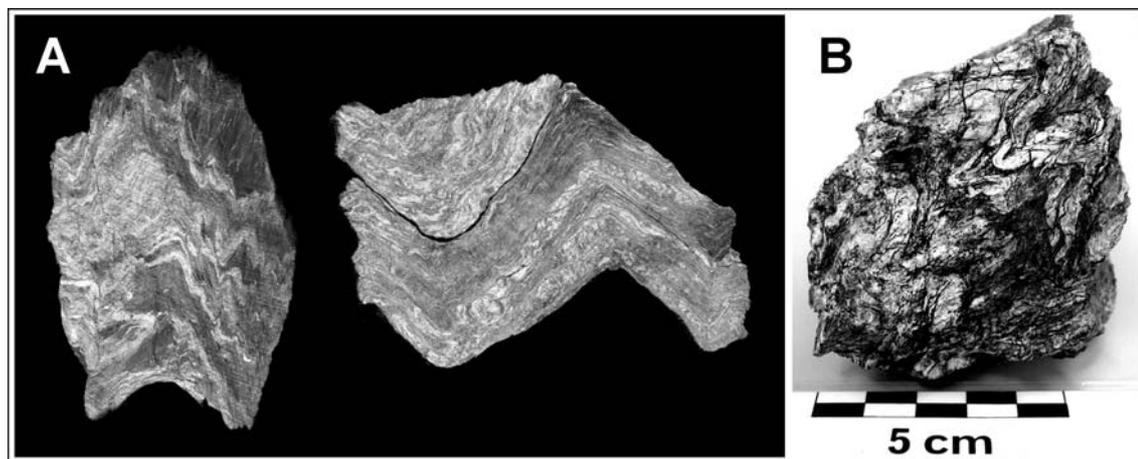

Fig. 6 Comparison of the local substrate rock at the settlement of Passo Alto (A), characterized by folded alternating bands of quartz (lighter) and micas (darker), and the vitrified rock (B), where the folding is preserved, but the micas have been melted and transformed into dark glass with neoformed minerals. The 5-cm scale is valid for all samples.

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2.1. Field and hand-specimen description

The local substrate rock consists of fine- to medium-grained micaschists of Palaeozoic age, with abundant millimeter-scale quartz lenses (Fig. 6A). Microfolding, chevron-folding and kink-bands are conspicuous features, indicating that the rock unit was subject to several tectonic deformational phases during the Late Palaeozoic. Relics of these features are preserved in the partially-vitrified rock fragments, where light-colored bands of quartz are interbedded with darker bands of vesicular vitreous material (Fig. 6B).

The Palaeozoic micaschist unit presents heterogeneities such as variable percentages of quartz, variable degrees of tectonic deformation, and variable mica composition, all of them probably influenced by heterogeneities in the sedimentary protolith. Similarly, the degree of partial melting in the vitrified rock fragments varies from clast to clast, as well as within single fragments, in which differential melting broadly defines bands. The micaschist unit is traversed by small (centimeter to decimeter scale) quartz vein dikes which, in the vitrified rock fragments, seem to be mostly unaffected by the high heat.
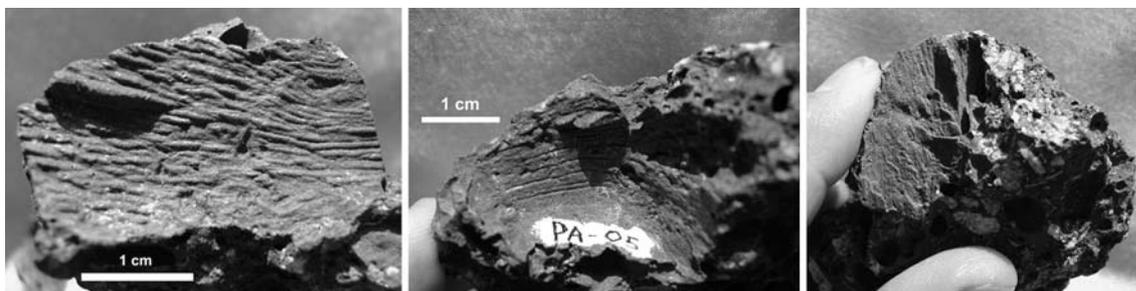

Fig. 7 Molds of charcoal on the surface of vitrified rock sample (PA-5) from the settlement of Passo Alto.

A characteristic feature of some fragments of vitrified rock is the presence on their surface of charcoal molds (Fig. 7). The pieces of partly-burnt wood were usually small (average between 2 and 4 cm; largest mold found is 7 cm), and the molten material adapted to the cracks, knots, pores, and other surface features of the charcoal. Apart from the need for flowage of the partially-melted rock in order to adapt to the surface of the charcoal, in some cases there is also evidence for later viscous flowage and deformation of the mold after it was made, indicating that the heat persisted at least during the complete combustion of the charcoal.

2.2. Optical petrology and mineralogy

Under the optical polarizing microscope, the local substrate micaschist consists of micro-folded millimeter- and submillimeter-size alternating bands and lenses of quartz and micas, mostly muscovite, biotite and chlorite. Also present are small feldspar grains, and very minor amounts of heavy minerals such as rutile, zircon, and iron oxides. The vitrified fragments consist of similar sized and shaped bands and lenses. However, there is some glass and vesicles within the quartz layers, and what is more conspicuous, the mica layers are completely absent and substituted by vesicular glass with very small (< 30 µm) crystals apparently consisting of opaque minerals and octahedron of spinel-group mineral phases difficult to identify.
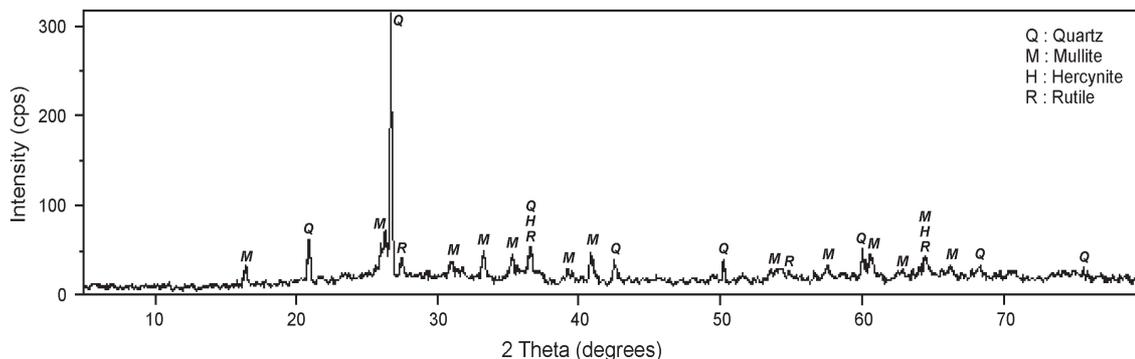
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Fig. 8 X-ray diffraction pattern of vitrified rock from the settlement of Passo Alto, with interpretation of the main intensity peaks. The small size and volume of the neoformed mineral phases complicates their interpretation: mullite may also include sillimanite, and hercynite may also include other mineral phases of the spinel group.

2.3. X-ray diffraction analyses

The analysis and interpretation of whole-rock powder XRD patterns of the vitrified rock (Fig. 8) proved the abundance of quartz, as well as the presence of other minor mineral phases difficult to determine with confidence due to the superposition and low intensity of the peaks. Amongst these latter are minerals of the spinel group (spinel structure minerals), mostly coinciding with the main spacings of hercynite. Aluminum silicate is also present, most probably as mullite, but sillimanite is not discarded. The main spacings of rutile are also present. Overall, these results confirm and agree with the mineralogical composition identified for the vitrified rock samples with the optical microscope, and are corroborated with the electron microscope.
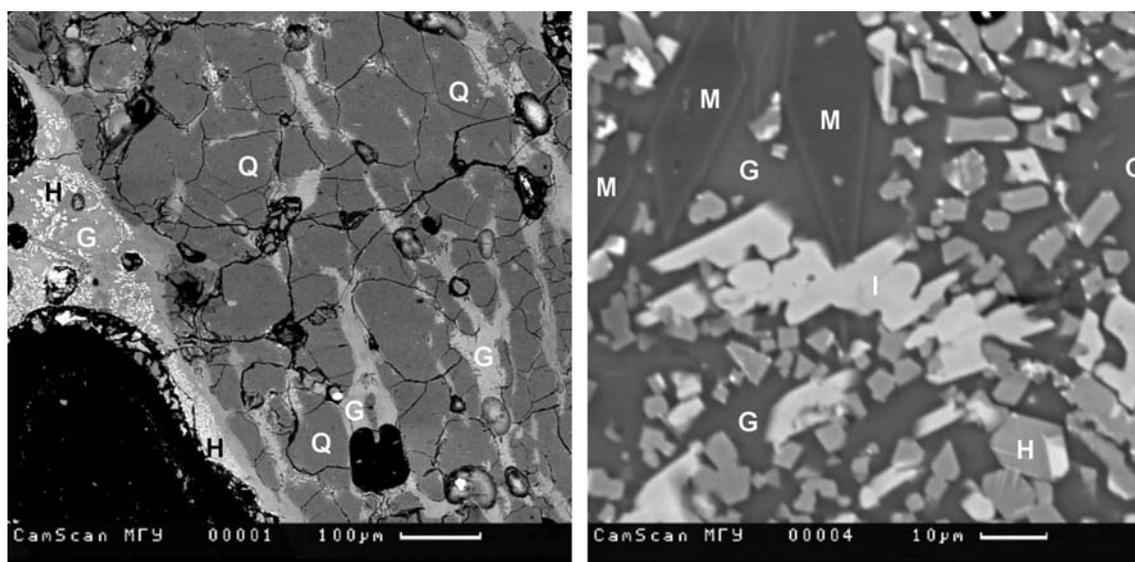

Fig. 9 Backscattered-electron images of the vitrified rock from the settlement of Passo Alto, showing (A) the boundary between alternating bands of relic quartz and vesicular glass, and (B) a detail of neoformed minerals within the glass: G - silicate glass; H - hercynite; I - ilmenite; M - mullite; Q - quartz.
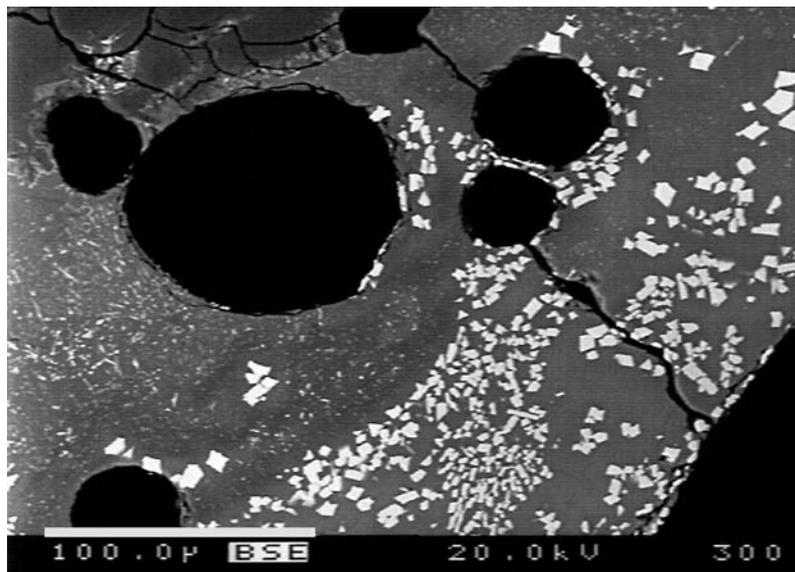
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Fig. 10 Backscattered-electron image of vitrified rock from the settlement of Passo Alto, showing glass with rounded vesicles, cracked and partially resorbed quartz (upper left), hercynite (lighter-colored neoformed rhomboid-trapezoid crystals), and alumosilicates (smaller and darker neoformed fibrous crystals towards the left).

2.4. Electron microscopy and microprobe analyses

Secondary electron images of polished and carbon-coated thin sections clearly showed the bands previously identified in the micaschist, broadly due to interbedded quartz and micas, as well as the bands previously identified in the vitrified rock, broadly due to quartz and vesicular glass (Figs. 9 and 10). Backscattered electron (BSE) images and electron microprobe analyses of the same thin sections allowed to identify both the variable composition of the different phyllosilicates in the micaschist, and the strong compositional heterogeneities within the glass of the vitrified rock.
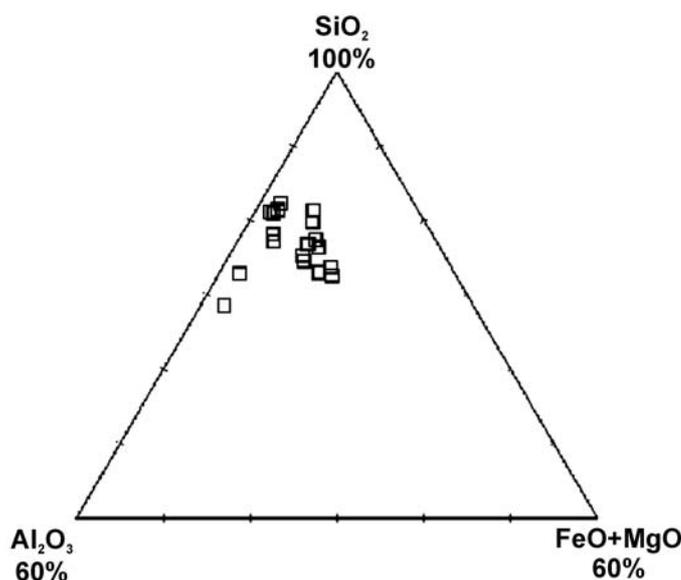

Fig. 11 Ternary diagram of the chemical composition of pumice from the settlement of Passo Alto. Data correspond to several raster analyses with electron microprobe, and confirm the abundance of quartz, together with minor aluminum silicates and mafic mineral phases.

BSE images and microprobe analysis also allowed to identify the small crystals present within the glass of the partially-melted rocks (Figs. 9 and 10). The most frequent ones are mullite and hercynite, with frequent variability in the composition leading to other similar phases such as ferrous mullite or magnesian hercynite. Also present are magnetite, ilmenite, and droplets of native iron. Zoning of the spinel group mineral phases is frequent, generally with iron increasing and magnesium decreasing towards the rims leading to the following type trend within a single crystal: spinel – magnesian hercynite – hercynite – magnetite, the latter frequently just at the edges. Native iron droplets are locally frequent, and usually include some phosphorous content (up to 3%). Raster (2x2 mm^2) analyses of the pumice with the electron microprobe show slight local variations in the composition (Fig. 11), probably due to the local differential abundance of each of the different micas (muscovite, biotite and chlorite) in the original micaschist source rock.

2. Discussion of results

The aforementioned small crystals, preliminarily identified with the optical microscope and XRD, and confirmed with the electron microscope and microprobe, are interpreted as neoformed mineral phases resulting from incongruent melting of micas and fast cooling of the melt, giving place to the observed quenched minerals within the glassy matrix. The presence of these neo-formed minerals is related with the Fe and Al content of the silicate melt, and of the overall vitrified rock (Fig. 11), and can be explained as a result of incongruent melting of the micas present in the micaschist. The mineralogical assemblage of the vitrified rocks implies that the temperatures achieved during partial melting may have exceeded 1100°C, with both fast heating and fast cooling at ambient surface pressure, in accordance with similar data from other European vitrified hillforts (Kresten et al., 1993). According to the related literature (Youngblood et al., 1978; Nisbet, 1982; Fredriksson et al., 1983; Kresten et al., 1993), vitrification is a relatively common process when structures of wood and stone are destroyed by fire, or burnt under control as a constructive technique.

Charcoal molds on the surface of the vitrified rock indicate that partial melting inside the wall was reached before complete combustion of the wood. Apart from providing evidence for the direct contact between the timber structure and the rocks forming the defense wall, it also provides another explanation for the local heterogeneities in the composition of the glass. It is probable that the local high concentrations (at microscale) of P and K in the glass may be a result of the resorption of ash from wood combustion. Furthermore, these two elements also contribute to lower the melting point of the silicates and *solidus* temperature of the rock, at least near the surface of the vitrified clasts, thus leading to the formation of less viscous melt and glass, and facilitating the observed welding of clasts.

Vitrification of fortified settlements in Portugal was first identified at Monte Novo, near Évora (Burgess et al., 1999, and references therein), and there are also descriptions of vitrification at a dolmen of Neolithic Age near Viseu (Abrunhosa et al., 1995). The presence of pumiceous and scoriaceous rocks is frequent at many archaeological sites. Most of them are clearly related with metallurgy, such as the ones described from the Iron Age settlement of Castelo Velho de Safara (Soares et al., 1985), not far from the settlement of Passo Alto. In other cases, there are features such as the lack or scarcity of ore, the large volume of rock affected by partial melting, the longitudinal distribution of these rocks around an archaeological site, and/or the frequent presence of charcoal molds, which are difficult to reconcile with metallurgical processes. In these cases,

vitrification of a wall made of timber and stone seems to be a more proper hypothesis. In Spain there is a well-studied example of an Iron Age fortress with evidence for burning of the wall (Palol, 1964). It consisted of a multiple timber palisade with adobe and timber logs between 20 and 30 cm in diameter, but vitrification was not documented. Also in Spain, the pumiceous rock present at a site previously considered as a volcano was reinterpreted as a result of vitrification of a fortress (Díaz-Martínez, 2004a, 2004b). Other vitrified defensive enclosures of Bronze/Iron Age settlements recently identified in the southwestern region of the Iberian Peninsula are briefly described by Díaz-Martínez and Soares (2004), and are subject of a publication in preparation. In some cases, new technologies are allowing the reinterpretation of the pumiceous and scoriaceous facies within their archaeological context. Whereas the basic concepts of hillfort vitrification are not new, we believe that they have not been sufficiently considered by researchers. Thus, we foresee new discoveries and reinterpretations as more detailed studies are undertaken. These should be based on detailed petrology and geochemistry using electron microscopy and microprobe, thermoluminescence, etc. Recent trends towards non-destructive techniques such as Raman microprobe have also been applied to vitrified forts (Smith and Vernioles, 1997).

3. Conclusion

The Late Bronze Age settlement of Passo Alto includes a defensive complex with partial vitrification of the wall rampart. The mineralogical assemblage identified in the vitrified rock fragments includes neoformed phases and glass as a result of incongruent melting of the original micas of the local substrate (Palaeozoic micaschist). The temperatures achieved were very high, probably exceeding 1100°C. Mineral textures indicate fast cooling of the melt. Burning of a structure made of timber and rock fragments from the local substrate affected a small portion of the rampart adjacent to the probable main entrance, and is considered the most simple and coherent hypothesis to explain all the observed evidence.

Partial melting of rocks and/or sediment is frequent at archaeological sites. Many of these remains are connected with metallurgical operations, but some of them may have resulted from vitrification of defensive walls, and require reassessment including detailed petrology and geochemistry. The Late Bronze Age settlement of Passo Alto is a good example of the reinterpretation of vitrified material thanks to collaboration within a multidisciplinary team.

Acknowledgements

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