# ESTUDOS ARQUEOLÓGICOS DE OEIRAS

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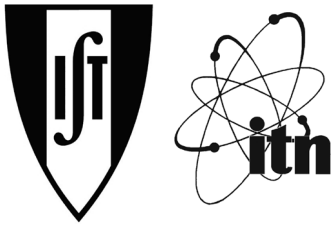
## Actas do IX Congresso Ibérico de Arqueometria

**(Lisboa, 2011)**





SAPaC

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# APRESENTAÇÃO

A Nona Edição do Congresso Ibérico de Arqueometria (CIA IX) decorreu em Lisboa de 26 a 28 de Outubro de 2011 nas instalações da Fundação Calouste Gulbenkian. A proposta e compromisso da organização deste evento foi feita pelo Grupo de Geoquímica Aplicada & Luminescência no Património Cultural (GeoLuC) (IST/ITN), dois anos antes na Assembleia Geral da Sociedad de Arqueometría Aplicada al Patrimonio Cultural (SAPaC), e foi aceite por unanimidade.

Com esta decisão, a SAPaC consolida uma linha de actuação, cujo objectivo é difundir e fomentar a colaboração entre os grupos de investigação arqueométrica que trabalham na Península Ibérica. Este objectivo viu-se reforçado e reflectido na composição dos novos órgãos sociais dirigentes da SAPaC, eleita durante a celebração do IX Congresso em Lisboa, que incorpora deste então investigadores portugueses e espanhóis, sendo presidida pela Doutora M. Isabel Dias (IST/ITN, Portugal).

As Actas que aqui se apresentam são uma prova tangível da via integradora desta IX edição do Congresso, verificando-se existir equilíbrio numérico entre os trabalhos apresentados por grupos de investigação portugueses e espanhóis, evidenciando-se mesmo um incremento de projectos em que participam conjuntamente investigadores dos dois países, mostrando o grande interesse que desperta a Arqueometria, em si mesma de natureza interdisciplinar, e os objectivos comuns partilhados pela comunidade científica ibérica.

Definitivamente, este Congresso constituiu um ponto de encontro dos investigadores da disciplina, tendo contribuído para a troca de experiências e o aprofundar de conhecimentos nas diversas metodologias e técnicas aplicadas à caracterização do nosso património histórico e cultural.

A publicação dos trabalhos do CIA IX nos *Estudos Arqueológicos de Oeiras* (EAO), órgão científico do Centro de Estudos Arqueológicos do Concelho de Oeiras/Câmara Municipal de Oeiras, constituiu uma oportunidade única e vantajosa para ambas as partes, já que esta inédita parceria entre uma entidade vocacionada para a investigação e uma Câmara Municipal permitiu uma sinergia de interesses quanto aos custos da publicação deste número e a sua adequada distribuição nacional e internacional. A escolha de uma revista periódica constituiu sem dúvida, a melhor opção, para a garantia de uma divulgação adequada. E a revista sobre a qual recaiu a escolha, prontamente homologada pelo Senhor Presidente da Câmara Municipal de Oeiras, Dr. Isaltino Morais, responde sem dúvida àquele requisito: além de constituir uma referência no panorama editorial nacional em matéria de publicações arqueológicas, com 18 números publicados desde 1991, mantém permuta com cerca de 200 revistas periódicas especializadas, todas de

Arqueologia e Património Arqueológico, especialmente de Espanha, França, Itália, Alemanha, Polónia, Reino Unido, Mónaco e Marrocos, para além de Portugal, incluindo as publicações mais importantes produzidas naqueles países.

Esperamos, deste modo, com a publicação deste volume, ir ao encontro dos interesses de todos os participantes do CIA IX, de todos os que contribuíram com os seus trabalhos para a excelente qualidade deste volume, dos interesses dos associados da SAPaC, dos munícipes de Oeiras, e da comunidade científica nacional e internacional no domínio da arqueometria e da arqueologia.

Pela Comissão organizadora do CIA IX, Presidência da SAPaC
e comissão editorial deste volume dos Estudos Arqueológicos de Oeiras,

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19, Oeiras, Câmara Municipal, 2012, p. 223-230

# INTERPRETATION OF CLAY MINERAL ASSOCIATIONS OF QUATERNARY SEDIMENTS AT ALTO RIBATEJO (CENTRAL PORTUGAL)

Hugo Gomes[1], Pedro P. Cunha[2], Pierluigi Rosina[1] & Luiz Oosterbeek[1]

**Abstract**

Research has been carried out in Alto Ribatejo (central Portugal, western Iberia) with the purpose of contextualizing Late Pleistocene and Early Holocene archaeological remains within the coeval landscape. Several regional Quaternary deposits were analysed in terms of their sand fraction mineralogy (microscopic observation) and clay mineralogy (X-ray diffraction of orientated aggregates).
The sedimentary record ascribed to the ~30-12 ka interval (Last Glacial and Tardi-glacial periods) is represented by colluviums and aeolian sands with predominance of illite. Illite is progressively replaced by vermiculite and some kaolinite or smectite in the upper stratigraphic levels of the Holocene deposits. The obtained data indicates cold and dry conditions during the Last Glacial/Tardi-glacial and a temperate climate in the Holocene.

*Keywords*: Alto Ribatejo, Quaternary, Clay mineralogy, XRD.

**Resumo**

A investigação realizada no Alto Ribatejo (Portugal Central, no Oeste da Península Ibérica), tem como objectivo a contextualização de vestígios arqueológicos do Pleistocénico final e início do Holocénico. Vários depósitos quaternários foram analisados em termos da mineralogia da fracção arenosa (observação microscópica) e mineralogia de argilas (difracção de raios X de agregados orientados). O registo sedimentar atribuído ao intervalo ~ 30-12 ka (períodos Último Glacial e Tardi-glacial) é representado por coluviões e depósitos de areias eólicas com predomínio de ilite, a qual é progressivamente substituída por vermiculite e alguma caulinite ou esmectite, nos níveis estratigráficos superiores dos depósitos Holocénicos. Os dados obtidos indicam condições de frio e seca durante a última era Glacial / Tardiglacial, e um clima temperado no Holocénico.

*Palavras-chave*: Alto Ribatejo, Quaternário, Mineralogia de Argilas, DRX

## 1 – INTRODUCTION

One of the main avenues of the Transition Landscapes project (FCT funded, ref. PTDC/HAH/71361/2006) was the study of potential postglacial environmental constraints on human behavioural processes in the dawn of agro-pastoralism in the Alto Ribatejo (central Portugal, western Iberia). In order to assess the long-term mechanisms, but also short-lived processes and human activities, a special attention has been paid to contexts from the Late Pleistocene to Early Holocene. Taking into account the existence of climatic oscillations within this time frame it was hypothesised that a sedimentological perspective on selected open-air archaeological sites could allow the reconstruction of regional diachronic landscape variations.

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Clay mineral is a hydrated aluminium silicate basically composed of aluminium oxide, silica and water. It is the result of a slow decomposition and fragmentation process of rocks into grains of various sizes. This complicated process varies depending on the type of rocks (*e.g.*, crystalline, eruptive), atmospheric agentes and erosion involved (CLARK, 1992).

A distinction exists between primary and secondary clays, the latter being finer and more plastic; they may also contain impurities due to a mixing with organic matter. Secondary or sedimentary clays are those that were transported further from the bedrock by water or wind. In the case of water, during the selective transportation clay particles of different sizes are sorted making the first deposits heavier; the others will deposit during the process according to their weight and the lighter particles are deposited where the water stops. Several studies were published relating different clay minerals with different palaeoclimatic conditions.

Clay mineral identification also allows the acquisition of information related to post-depositional evolution of sedimentary units (*e.g.*, CHAMLEY, 1989; ROCHA, 1993).

This study analyses clay mineral associations presented in sedimentary samples collected from different archaeological contexts, dating from the last 30,000 years, in an attempt to correlate climatic variations and cultural phases.

This study focuses on i) the recognition of depositional contexts and anthropic influence in regional Quaternary deposits, and ii) the establishment of possible correlations between archaeological levels and climatic variations. Sedimentological characterization and archaeological data were integrated, in order to build a chronostratigraphic framework linked to the cultural sequence.

## 2 – REGIONAL SETTINGS

The ~2,500 km$^2$ study area is located in the Alto Ribatejo, corresponding to the central-northern sector of the Lower Tejo Basin. The main Tejo tributaries, such as the Ponte da Pedra, Nabão, Zêzere and Ocreza rivers, show north-south drainages in this area. The three main geological units of the Alto Ribatejo (Fig. 1) have the following characteristics: 1) the Hesperian Massif, a Variscan basement comprising metamorphic (*e.g.* phylites, metagreywakes and quartzites) and magmatic rocks (dominated by granites) of Pre-Cambrian and Palaeozoic age; 2) the Estremenho Massif, which comprises Mesozoic limestones with some marls and sandstones; 3) the Lower Tejo Cenozoic basin comprising sands with minor silts and gravels. More specifically, Pleistocene deposits comprise karstic cave fillings (in limestone areas), fluvial terraces, colluvium and aeolian sands. The Holocene is mainly recorded in the valley floor infill and consists of sands and silts (ROSINA, 2004; ROSINA *et al.*, 2005, 2009; VIS *et al.*, 2010a, b).

## 3 – MATERIALS AND METHODS

The following open-air archaeological sites were selected: Ribeira da Ponte da Pedra, Amoreira, Santa Margarida da Coutada, Lajinha dolmen, Alvega historic alluvium. All of them are within the study area (Fig. 1) and were previously correlated with different archaeological cultural phases, spawning from the Upper Palaeolithic to modern times (*e.g.* ROSINA, 2004; CRUZ & OOSTERBEEK, 2005).

The information presented here is derived from stratigraphic, archaeological and chronological data collected under a standard geoarchaeological fieldwork approach. The sites were studied from a geomorphological and geological perspective; field description of sedimentary sections and stratigraphic

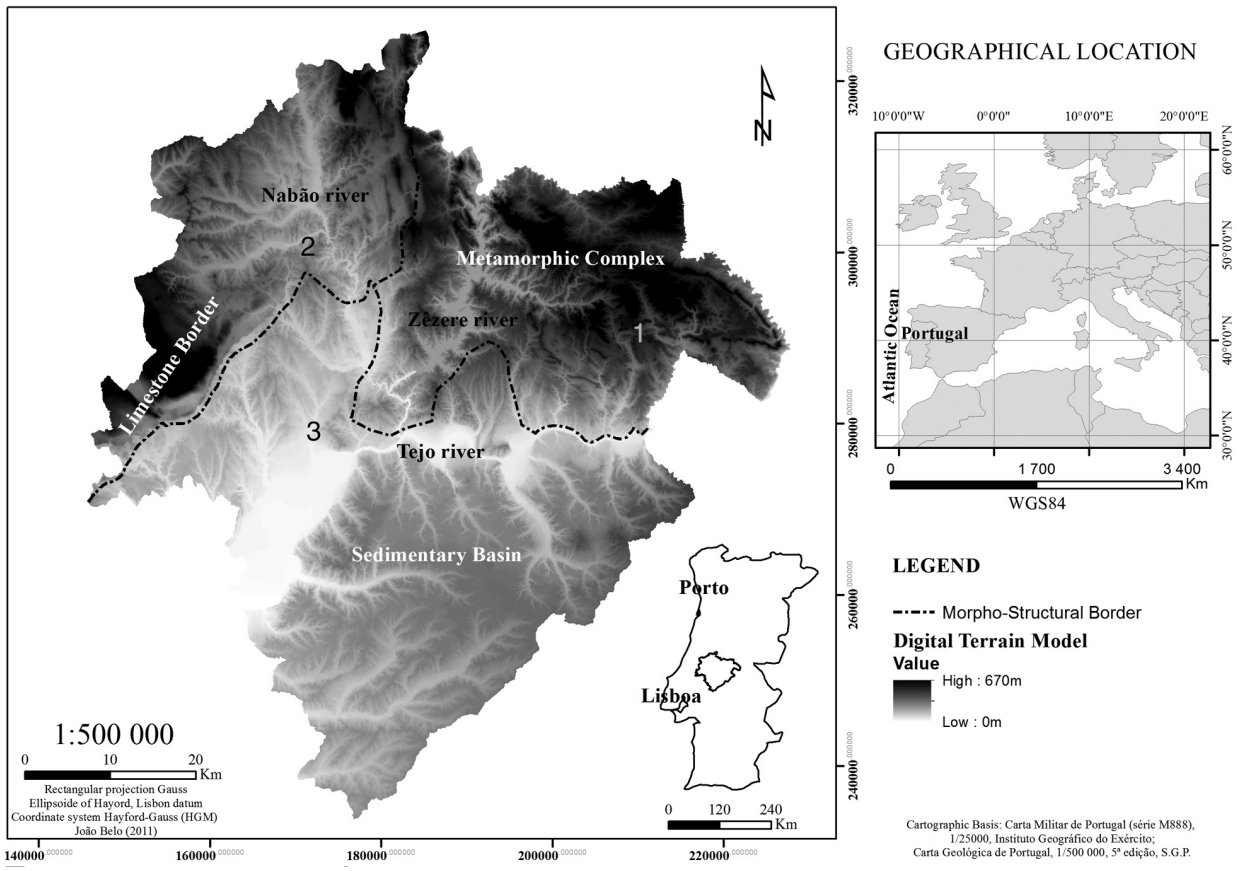


**Fig. 1 –** Digital Elevation Model (DEM) of the Alto Ribatejo region and geographic location of the studied sites.

correlation of the deposits and archaeological occupations were achieved. Sampling for laboratory analysis (*e.g.* absolute dating, sedimentology) was implemented (*e.g.*, BUTZER, 1982, 2008; TEXIER, 2000). A descriptive form was used to address the lithostratigraphic, sedimentary, pedogenic and anthropogenic characteristics of the deposits (cf. GRIMALDI *et al.*, 1999; ANGELUCCI, 2003; ROSINA *et al.*, 2005).

Sedimentological laboratory work included particle size analysis of unconsolidated sands, silts or clays, with application of sieving and laser methods (COURTY *et al.* 1989; BLOTT & PYE, 2001; DINIS, 2008). Mineralogical identification of the sand fraction was achieved by microscopic observation and of the < 2µm (clay mineralogy) by X-ray diffraction of orientated aggregates (THOREZ, 1975; CUNHA, 1992). These analyses were made in order to better recognise natural deposition origin and anthropic influence or perturbation. They are also useful techniques to correlate archaeological levels and climatic variations.

## 4 – RESULTS AND DISCUSSION

– Ribeira da Atalaia: the clay mineral association at the base of the colluviums is identical to the one presented by the T4 deposits (Table 1). Kaolinite peaks are large in the diffractograms indicating that the mineral is not well crystallized. The increase of kaolinite in the top layers of the sequence is probably the result of chemical weathering under good drainage, helped by warmer and humid climatic conditions.

**Table 1 –** Sedimentary and clay results with the descriptions of depositional context and ages.

| Site | Sample code | Deposits | Granulometry | Mineralogy of <2 µm fraction | Periods |
|---|---|---|---|---|---|
| Outeiro Pedro | OP2 A | Alluvium | very fine sand | S.I.K | Actual Floodplain |
| Outeiro Pedro | OP2 B | Alluvium | coarse sand | S.I.K | |
| Outeiro Pedro | OP2 C | Alluvium | fine sand | S.I.K | |
| Outeiro Pedro | OP2 D | Alluvium | very fine sand | S.K.I | |
| Outeiro Pedro | OP2 H | Alluvium | coarse sand | S.K.I | |
| Outeiro Pedro | OP 5 A | Eluvium | fine sand | V.I.K | |
| Outeiro Pedro | OP 5 B | Eluvium | coarse silt | I.K.V | |
| Alvega | ALV10 | Alluvium | coarse silt | I.V.S | |
| Alvega | ALV7 | Alluvium | very coarse silt | V.I.K | Little Ice Age (LIA) |
| Alvega | ALV4 | Alluvium | very fine sand | I.V.K | |
| Alvega | ALV2 | Alluvium | very fine sand | I.K.V | |
| Santa Margarida Coutada | SMAC-B | Colluvium /Anthrophic | very fine sand | V.I.K | Subboreal |
| Lajinha dolmen | LAG-A | Eluvium | very fine sand | V.I.K | Atlantic |
| Lajinha dolmen | LAG-B | Eluvium | very coarse silt | V.I.K.GT | |
| Lajinha dolmen | LAG-C | Eluvium | very coarse silt | V.I.K | |
| Amoreira Settlement | AMR-C | Alluvium | very fine sand | V.I.K | |
| Santa Margarida Coutada | SMAC-C | Aeolian | very fine sand | I.K.V | Late Glacial (Dryas?); |
| Atalaia | RPP 3 | Colluvium 01 | coarse sand | K.I.S.GT | |
| Atalaia | ATL-H | Colluvium C1a | coarse sand | K.I.V | |
| Atalaia | RPP 2 | Colluvium | coarse sand | V.I.K | MIS2 |
| Atalaia | ATL-G | Colluvium C1b | coarse sand | V.I.K.GT | 25 ka (Dias *et al*., 2009) |
| Atalaia | ATL-E | Colluvium C1b | coarse sand | V.I.K | |
| Atalaia | ATL-D | Colluvium C1b | coarse sand | V.I.K | |
| Atalaia | ATL-C | Colluvium C1b | coarse sand | V.I.K. GT | |
| Atalaia | ATL-A | hearth C2 | very coarse sand | I.V.K | |
| Atalaia | ATL-B | hearth C2 | coarse sand | I.V.K | |
| Atalaia | ATL-F | Colluvium C2 | very coarse sand | I.K.V | |
| Atalaia | RPP 1 | Terrace 5/ Colluvium | coarse sand | V.K.I | MIS 5 |
| Atalaia | RPP0802 | Terrace 5 | very fine sand | S.I.P | |
| Atalaia | RPP0803 | Terrace 5 | coarse silt | I.K.V | |
| Atalaia | RPP0804 | Terrace 5 | coarse silt | I.K.S | |
| Atalaia | RPP0805 | Terrace 5 | coarse sand | I.K.V | |
| Atalaia | RPP0806 | Terrace 5 | coarse sand | I.K.V | |
| Atalaia | RPP 10 | Terrace T4 | very fine sand | I.K.S.GT | MIS 7 or 9 |
| Atalaia | RPP 8 | Terrace T4 | coarse sand | I.K.S.GT | |
| Fut. Field | FBF 3 | Terrace T4 | very coarse silt | K.I.V | |
| Fut. Field | FBF 2 | Terrace T4 | very fine silt | I.K.V | |
| Fut. Field | FBF 1 | Terrace T4 | very coarse sand | K.I.V | |

Legend: I - Illite; V - Vermiculite; K - Kaolinite; S - Smectite; Gt - Goethite; P - Palygorskite

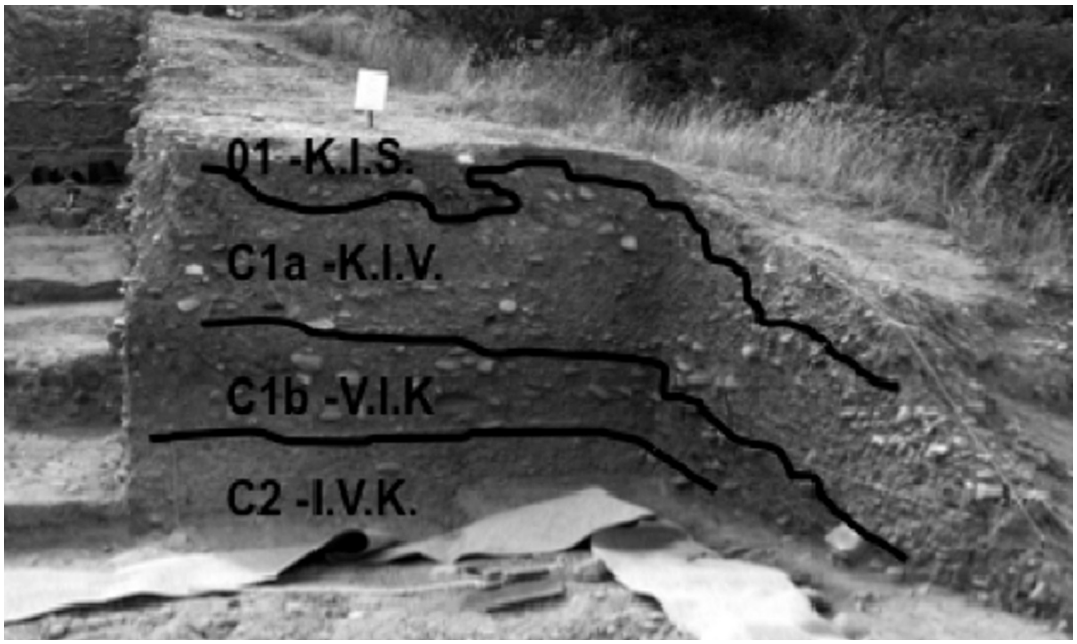


**Fig. 2 –** Ribeira da Atalaia site with indication of the identified colluvium layers. I: ilite, V: vermiculite; K: kaolinite; S: smectite.

Since the base of the colluvial unit is dated ~25 ka, the vertical evolution on the relative abundance of the clay mineral should record the transition from the cold and dry climate of the Late Pleistocene to the temperate and humid environmental conditions of the Holocene. The identification of the clay minerals confirmed the macroscopic interpretation of three existing layers (Fig. 2). An association of illite, vermiculite and kaolinite was identified, but illite dominates at the base and kaolinite towards the top. The composition and texture of the colluvium indicates its sourcing by erosion of the terrace T4 deposits (IKS).

– Santa Margarida da Coutada: sediment analysis indicate that the layer C (Table 1; sample SMAC-C) consists of a silty very fine sand and illite is the main clay mineral (associated with kaolinite and vermiculite); illite generally indicates the degradation of micas under dry conditions. Temperate dry climate with enough water in the soil promote the genesis of vermiculite by chemical weathering. The sand associated with the archaeological level (SMAC-B) is very similar to the layer bellow, with the same grain-size statistical parameters, changing only in the clay mineral composition (vermiculite is predominant); it seems to be aeolian sand reworked by anthropic activities. Data integration leads to the interpretation that, probably during the Tardi-glacial to Preboreal periods a deposition of aeolian sands under cold and dry conditions occurred. Human occupation at ~30 ka was made under a probable temperate dry climate, with enough water in the soil to promote the genesis of vermiculite by chemical weathering.

– Amoreira: the sediment at the top of the fluvial terrace consists of silty very fine sand (Table 1), vermiculite being the most abundant clay mineral (associated to illite and kaolinite). The colluvium matrix (fraction <15 mm) consists of medium sand, associated with silt and pebbles (respectively, 18% and 17% of total weight).

– Lajinha dolmen: clay mineral identification showed almost identical percentages of vermiculite (the dominant mineral), illite and kaolinite in all samples. The sediment characteristic of the mound can be explained by the anthropic reworking and accumulation on the monument of a silty soil generated in the area by physical

weathering of the metamorphic substratum. Vermiculite indicates later chemical weathering, probably during the Atlantic and Subboreal periods.

– Alvega: comprises a ~8 m thick alluvial sedimentary succession, with several beds, finning upwards. The alluvium has a gravelly base (30 cm thick); no pebbles were found in other levels. Some layers have minor quantities of organic material. The clay mineral associations present ilite-kaolinite-vermiculite at the base of the sequence and an improvement of vermiculite, until the top of the sequence that presents illite (again dominant), kaolinite and smectite. This mineralogical variation could be explained by changes in climatic or drainage conditions.

## 5 – CONCLUSION

The sedimentary record ascribed to the ~30-12 ka interval (Last Glacial and Tardi-glacial periods) is represented by colluviums and aeolian sands, contain Upper Palaeolithic or Epipalaeolithic industries associated to open-air sites, and have illite as the predominant clay mineral (association IVK), suggesting probable cold and dry conditions. In the Holocene deposits, illite is progressively replaced by vermiculite and some kaolinite or smectite in the upper stratigraphic levels, which could be related with temperature and humidity changes in temperate climate.

The clay mineral association is controlled by provenance but also by weathering process. Sediment ascribed to the Last Glacial and Tardi-glacial periods (cold and dry environmental conditions) have typically associations dominated by illite, but in the ones dated as Holocene, illite is progressively replaced towards the top by vermiculite and some kaolinite (generated in temperate climate). Several lithic industries were found associated with these deposits.

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