Mineralogical and geochemical characterisation of clayey-iron palaeosols from the South Iberian Palaeomargin: palaeoclimatic inferences

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INTRODUCTION

The Betic External Zones within the Betic Cordillera (S and SE of Spain) comprise Mesozoic to Lower Neogene sedimentary rocks from the South Iberian Palaeomargin (Western Tethys). The Betic External Zones are divided into Prebetic and Subbetic, being the Prebetic formed by shallow marine facies with continental episodes and the Subbetic dominated by pelagic facies (García-Hernández et al., 1980). The Middle-Upper Jurassic materials studied in this work are found in External Prebetic outcrops, where the Callovian/Oxfordian boundary is located between the Lower–Middle Jurassic Chorro Formation (Foucault, 1971) and the Middle–Upper Oxfordian Lorente/Yátova formations (Gómez & Goy, 1979). In the External Prebetic, clayey-iron crusts containing iron-coated grains have been observed, indicating palaeosols development (Reolid and Abad, 2019).

This work focuses on the mineralogical and geochemical study of the clayey-iron crusts and the iron-coated grains, emphasizing clay minerals analyses. The genesis of clay minerals take place predominantly in those areas where chemical weathering and edaphic processes occur. These processes are strongly controlled by climatic factors and thus, the study of clay minerals in palaeosols gives key information for palaeoenvironmental reconstructions (e.g., Laita et al., 2022). Here we present the results of the study of clayey-iron crusts from the Prebetic (SE Spain) in order to evaluate the palaeoclimatic and palaeoenvironmental conditions under which they were generated during the Middle-Upper Jurassic transition and to compare them with similar materials from the Iberian Range (NE Spain).

DESCRIPTION OF THE SAMPLES AND METHODS

Eight clayey-iron crusts from the External Prebetic sections have been analysed. Those from Sierra de Cazorla (Central External Prebetic) and Altos de Chinchilla (Eastern External Prebetic) were previously studied by Reolid et al. (2008) and Reolid and Abad (2019). This work also reports new outcrops from Sierra de Las Villas (Central External Prebetic). The crusts are from millimetric to centimetric (2-10 cm). Over the crusts, there is a 10-40 cm thick ferruginous oolithic limestone in the Sierra de Cazorla and Altos de Chinchilla, whereas in the Sierra de Las Villas, a ferruginous-carbonated breccia containing iron-coated grains is found over the crust. In the Iberian Range, equivalent ferruginous oolithic limestones are recorded, the Arroyofrío Formation, which precedes the Oxfordian Yátova Formation.

The clayey-iron crusts and the iron-coated grains were studied by X-ray diffraction to determine the mineralogical composition of the whole rock and the clay fraction (< 2 µm) at the University of Jaén (Spain). Polished thin sections of the crusts and the different lithofacies (ferruginous-carbonated breccia and ferruginous oolithic limestone) from the External Prebetic and the Iberian Range were also studied by optical and field emission scanning electron microscopy (FESEM) at the University of Jaén to determine their texture. Geochemical analyses of the major and minor elements of the crusts and the iron-coated grains were carried out by X-ray fluorescence and inductively coupled plasma mass spectrometry at the University of Granada. Palaeoclimatic and palaeoweathering proxies and indexes were calculated from the geochemical analyses: Ba/Sr, Sr/Cu, Ga/Rb and Rb/Sr ratios, Chemical Index of Alteration (CIA) and Chemical Index of Weathering (CIW).

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RESULTS AND DISCUSSION

The clayey-iron crusts are mainly composed of clay minerals (kaolinite, illitic phases and illite/smectite mixed layers) and hematite and goethite (Reolid et al., 2008; Reolid and Abad, 2019; Laita et al., 2024). FESEM analyses revealed kaolinite forming subhedral to euhedral nanometric plates and book-type aggregates indicating that it is authigenic and crystallised as a result of chemical weathering processes during soil development. Conversely, the illitic phases present subhedral morphologies with higher sizes than kaolinite crystals (5-10 µm) and showing their sheets separated, which indicates that they are probably detrital phases (Laita et al., 2024).

Two types of iron-coated grains, according to Reolid et al. (2008) classification, are identified in the studied materials: type A and type B pisoids. Type A pisoids are found in the clayey-iron crusts. They have a nucleus of an indeterminate ferruginous lump or a broken grain, surrounded by a cortex formed of concentric layers. Both the nucleus and the cortex are composed of kaolinite, hematite, and goethite, indicating in situ formation during soil development. Erosion of the crusts during middle Oxfordian transgression reworked some type A pisoids, incorporating them into the ferruginous oolithic limestone and the ferruginous-carbonated breccia. Type B pisoids are just found in the ferruginous oolithic limestone. Their nucleus is composed of an iron ooid, bioclast, foraminifera, or quartz grains. The cortex is thicker and more irregular than that of type A pisoids. This more complex structure suggests that type B pisoids were formed in a marine context. Both type A and type B pisoids were also found in the ferruginous oolithic limestone from the Iberian Range (Laita et al., 2024).

The mineralogical composition, along with the presence of iron-coated grains, allowed the clayey-iron crusts to be classified as plitinthic palaeosols (Reolid and Abad, 2019), which are characteristic of tropical environments. The High CIA (91-96) and CIW values (88-96) observed in the crusts indicate intense chemical weathering under warm and humid conditions, particularly in the Sierra de Las Villas, where the Ba/Sr and Rb/Sr ratios are higher. The Sr/Cu ratios < 5 and the Ga/Rb > 0.25 of the crusts further corroborate warm and humid climatic conditions (Laita et al., 2024).

All these data suggest then a tropical climate during the Middle–Upper Jurassic transition in the Central and Eastern External Prebetic (South-Iberian Palaeomargin). The presence of type A and type B in the ferruginous oolithic limestone from the Iberian Range (NE Iberia) suggest that the same climatic, warm and humid, conditions took place in the East Iberian Palaeomargin (Laita et al., 2024).

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