Features and Origin of Red Clays in Castañar Cave: A Touch of Colour

A. Martín-Pérez, R. Martín-García, A.M. Alonso-Zarza, and M.J. Herrero

Abstract In Castañar Cave (Cáceres, Spain), coatings of red clays cover the walls of the chambers, coexisting with diverse speleothems of aragonite, calcite, huntite and dolomite. The mineralogy of the clays is mainly illite, chlorite, kaolinite, smectite, quartz and Fe oxides and hydroxides such as goethite. They can be transported into the cave by infiltration waters or form by in situ alteration of the host rock: layers of dolomite rich in Fe and magnesite interbedded with greywackes and shales. Present-day hydrological conditions in the cave and conditions during the formation of speleothems have determined that the clays have not been transported by any flooding or seepage, but mostly staying in situ, and not included into carbonate crystal forms. Thus, most of the well-preserved speleothems are white and not stained, conforming an interesting chromatic contrast with the red clays that represent an additional attraction in this show cave.

1 Introduction

When speaking about clays in caves, there is an image of wet slippery clayey floors. Clays are common deposits in caves, and they give valuable information to different scientist from geomorphologists to archaeologists. In show caves, when clay covers the speleothems it can spoil the aesthetic appearance of speleothems.

In Castañar Cave, clay deposits are not very abundant, but they appear in most parts of the cave. The clays in the cave have an intense brown-red colour although they usually do not stain the speleothems. The varied calcite, aragonite huntite and dolomite speleothems of Castañar Cave are clean, bright and white, and these characteristics are enhanced by the dark colours of the clays.

A. Martín-Pérez, R. Martín-García, A.M. Alonso-Zarza, M.J. Herrero
Instituto de Geología Económica (CSIC-UCM), Departamento de Petrología y Geoquímica, Facultad de Ciencias Geológicas, C/ Jose Antonio Novais, 2, 28040, Madrid, Spain,
e-mail: andreamartin@geo.ucm.es; rmartingarcia@geo.ucm.es; alonsoza@geo.ucm.es; mjherrer@pdi.ucm.es

In this study, the features of the red clays and their close relationship with the host rock are described to attempt to determine which processes have been involved in their formation.

2 Geological Setting

Castañar Cave is in the town of Castañar de Ibor, in Caceres province, Spain. The study area forms part of the southeastern part of the Iberian Massif, in the Domain of vertical folds (Díez-Balda et al. 1990), the Ibor anticline being the main structure in the area. In the core of this anticline, a mixed carbonate-siliciclastic succession of Neoproterozoic age crops out (Fig. 1a,b). Castañar Cave formed by dissolution and collapse of these materials, following the NW-SE pattern of the main folds and fractures in the area (Alonso-Zarza et al. 2005).

The Neoproterozoics succession that form the host rock consist of shales, greywackes, dolostones and magnesites formed well-defined beds of centimetric to metric thickness (Fig. 1c). In many of the outcrops all these rocks, especially dolostone and magnesites, appear strongly weathered, partially losing their original texture and showing a brown reddish colour and powdery texture. This alteration is also visible inside the cave.

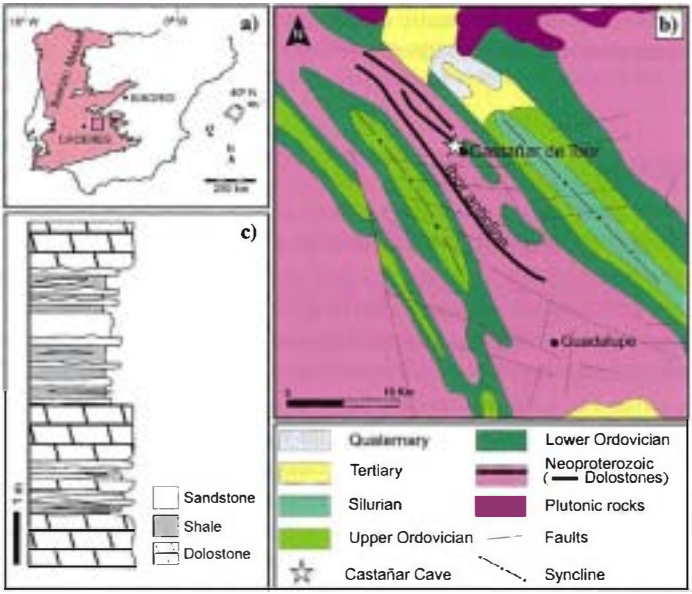

Fig. 1a–c Geological setting of Castañar Cave. **a** Location of the studied area in the Iberian Massif. **b** Simplified geological map of the region. **c** Stratigraphic section of the Neoproterozoic rocks near Castañar de Ibor

3 Methods

The mineralogical composition of the red clays and the host rock was determined by X-ray diffraction using a Philips PW-1710 XRD system between 2 to 65° 2θ. For clay mineralogy, fractions > 20 μm were analyzed using oriented air dried slides that were ethylene glycol solvated and heated at 550°C. Host rock textures were studied under conventional optical petrography in double polished thin sections. Scanning electron microscopy observations were performed on gold-coated samples using a JEOL 6400 electron microscope working at 20 kV and with a resolution of 35 Å.

4 Mineralogy and Petrography of the Host Rock

The siliciclastic rocks in the Castañar area are composed of quartz, K-feldspar, plagioclase, clay minerals and, in some cases, authigenic pyrite (Fig. 2). The sandstones are classified as greywackes because they contain up to 40% of clayey matrix (epimatrix and pseudomatrix) mainly consisting of illite, chlorite, smectite and kaolinite. There is also a noticeable amount of dolomite cements replacing part of the matrix.

Carbonate beds (Fig. 3a) are dolostones, magnesites or mixtures of both. In the dolostones Fe-dolomite crystals form non-planar mosaics. Some quartz cements are also present. Magnesite appears as euhedral crystals with shapes varying from prismatic to hexagonal. Minor amounts of siderite have also been found. Dissolution of dolostones and magnesites leads to formation of soft and very porous material (Fig. 3b) mainly composed of goethite (Fig. 3c). Goethite probably formed by oxidation and hydration of Fe present in the carbonates and is seen under SEM as small star-shape aggregates of fibres of about 5 μm in size (Fig. 3d).

5 Red Clays in Castañar Cave

Red clays in Castañar Cave appear forming coatings from 2 mm to 3–4 cm thick over the ceiling and walls of most of the chambers. In some parts of the cave, they also cover the breakdowns and the floor. These coatings have formed on the host rock and it is possible to recognise a gradual transition between the texture of the host rock and the clays (Fig. 3e). Only in very few cases the clays have been washed off by dripping water and deposited over speleothems. No lamination or other depositional features that could suggest deposition by water floods have been found. The clays in the coatings are moist and show porous structure under the SEM. They can be rather homogeneous or have a lumpy texture, forming globular aggregates of 1–2 mm diameter and smooth surface. In some cases the clays act as the substrate for the nucleation of delicate aragonite frostwork, providing a beautiful chromatic contrast (Fig. 3f).

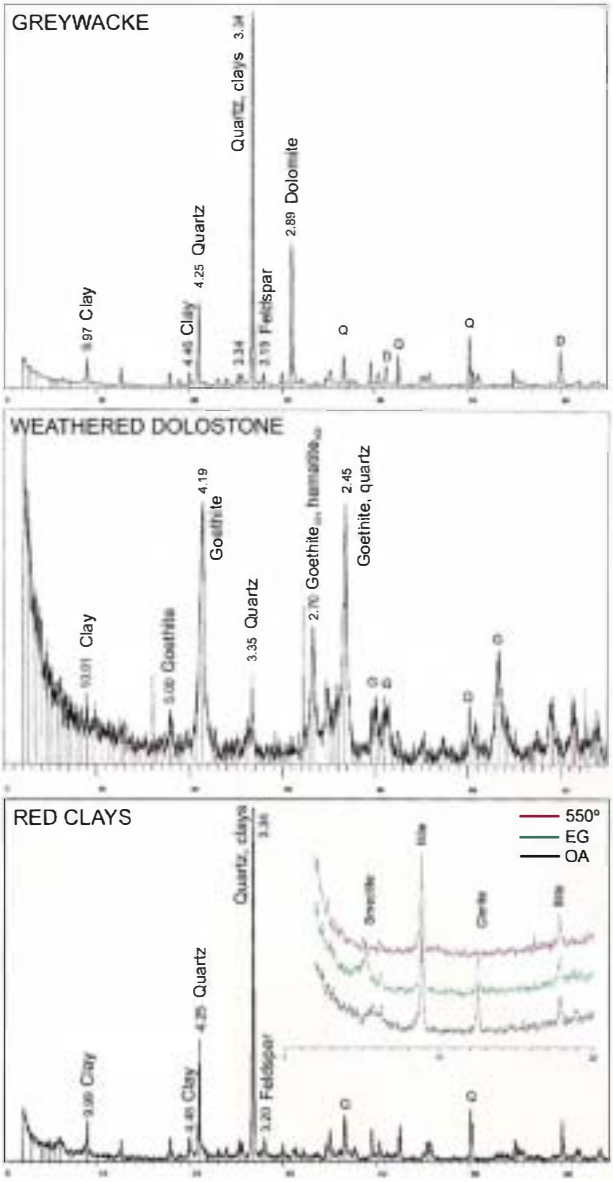

Fig. 2 XRD patterns showing mineralogy of the greywackes, weathered dolostone and clays

The clays are mainly formed by quartz, clay minerals and goethite having smaller amounts of feldspars, dolomite, magnesite and hematite. Clay minerals are illite, chlorite, kaolinite and smectite. Goethite appears in variable amounts, and it is the main mineral responsible for the red-brown colour of the clays (Fig. 2).

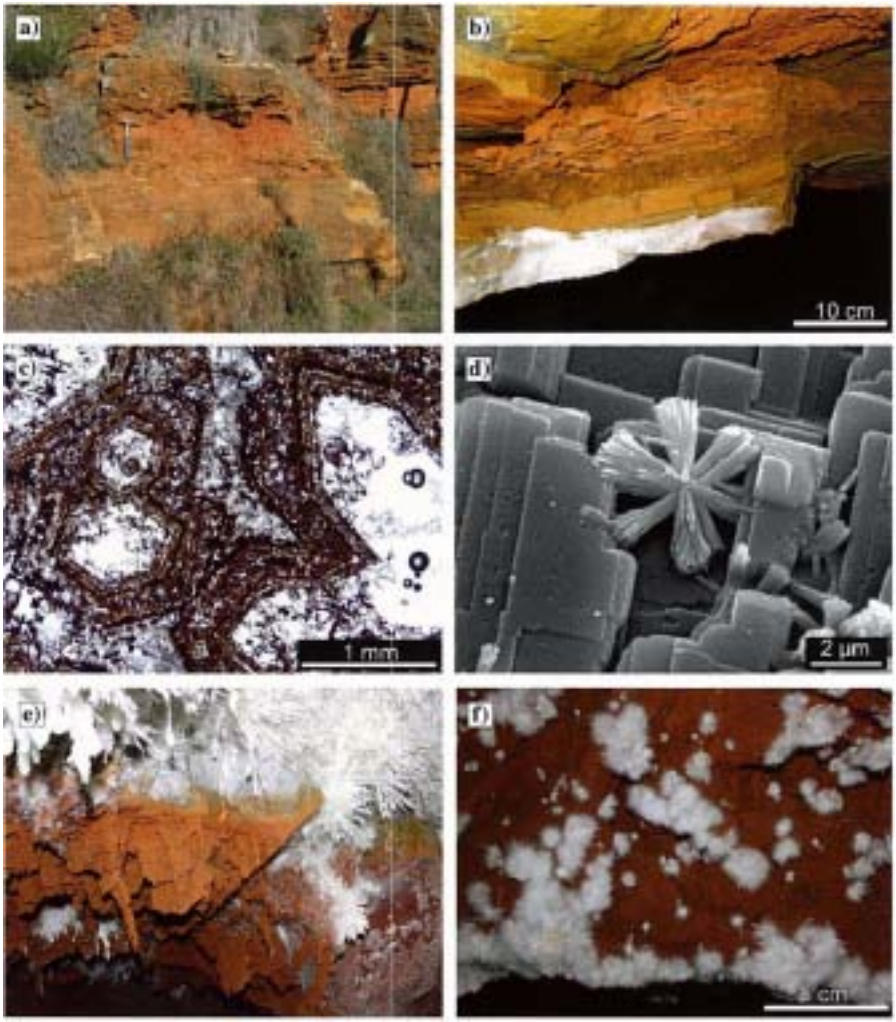

Fig. 3 **a** Weathered dolostones and greywackes in an outcrop near the cave; **b** The thin bedded host rocks are being altered also inside the cave; **c** Photomicrograph of the euhedral crystals of magnesite largely transformed into goethite. Plane polarized light; **d** SEM image of the fibres of goethite growing over dolomite crystals; **e** Gradual transition between the host rock and the red clays in the cave; **f** Aragonite frostwork nucleating over the red clays

6 Discussion and Conclusions

There are two possible origins for the clay deposits in caves (Ford and Williams 2007): allochthonous, as fluvial flows or infiltration from soils overhead, or autochthonous, coming from the weathering of the walls. In Castañar Cave there is no evidence of major streams transporting clastic sediments, and host rock-clay re-

lationships point towards a predominant autochthonous origin. Further evidence of this formation mechanism is the similar mineralogy of the host rock and the clay deposits. Clay minerals, quartz and feldspars can come directly from disgregation of shales and greywackes and from the dissolution of dolomite cements. Clays can also represent weathering remains produced by hydrolysis of silicates (Velde 1992). Iron oxides and hydroxides in caves are generally considered to form by oxidation of iron sulphides, such as pyrite (Onac 2005, Palmer 2007). In Castañar Cave, pyrite is not very common, so it is considered that goethite and hematite formed by oxidation of Fe present in dolomite, magnesite and siderite.

Such in situ transformation of the host rock into red clays is produced by water-rock interaction. In present days, water in the cave comes mainly from the surface by percolation. There are no streams and only small pools. However, climatic and hydrological conditions may have changed during time, as shown by the diversity of morphologies and mineralogies of the speleothems, and the diagenetic processes that affect them (Martín-García et al. 2009).

As can be seen, the varied lithologies of the host rock, and the distribution and composition of cave waters through time are responsible for the remarkable features of the red clays. These special features, such as the colour and distribution, cause the clays to be an attractive element to the tourists that visit Castañar Cave.

Acknowledgements This research has been supported by: FEOGA-ORIENTACION-FEDER funds and projects CGL-2008-05584-C02-02 from the MCINN and UCM-910404 and it is a contribution to IGCP 513: Global Study of Karst Aquifers and Water Resources from UNESCO. A. M-P was supported by an I3P-CSIC grant and R. M-G by a JAE Predoc-CSIC grant. Adrijan Košir is thanked for interesting discussions in the field and comments on drafts of this paper. Helpful suggestions from an anonymous reviewer contributed to improve the quality of the manuscript.

References

Alonso-Zarza AM, Gil Peña I, Martínez Flores E, Muñoz Barco P (2005) La cueva de Castañar. In: Muñoz Barco P and Martínez Flores E (eds) Patrimonio Geológico de Extremadura: geodiversidad y lugares de interés geológico. Junta de Extremadura, Mérida.

Díez-Balda MA, Vegas R, González-Lodeiro F (1990) Central-Iberian Zone. Autochthonous Sequences: Structure. In: Dallmeyer RD and Martínez-García E (eds) Pre-Mesozoic Geology of Iberia. Springer-Verlag, Berlin.

Ford DC, Williams PW (2007) Karst Hydrogeology and Geomorphology. Wiley, Chichester, England.

Martín-García R, Alonso-Zarza AM, Martín-Pérez A (2009) Loss of primary texture and geochemical signatures in speleothems due to diagenesis: Evidences from Castañar Cave, Spain. Sediment Geol 221:141–149.

Onac BP (2005) Minerals. In: Culver DC, White WB (eds) Encyclopedia of Caves. Elsevier Academic Press, London.

Palmer AN (2007) Cave Geology. Cave Books, Ohio.

Velde B (1992) Introduction to clay minerals. Chapman & Hall, London.