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From carbonate–sulphate interbeds to carbonate breccias: The role of tectonic deformation and diagenetic processes (Cameros Basin, Lower Cretaceous, N Spain)

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ABSTRACT

Interpreting the origin of carbonate breccias requires a detailed analysis because they may be the result of a wide variety of processes that produce similar features. This is the case of the Lower Cretaceous carbonate breccias of the Cameros Basin (previously interpreted as slump or collapse breccias), whose origin is interpreted after performing a detailed sedimentary, petrographic and tectonic study.

The studied carbonate breccias consist of angular carbonate mudstone fragments floating in a matrix of calcite and quartz crystals. The breccias are interbedded with, and laterally associated to, alternating layers of carbonate mudstone and calcite and quartz pseudomorphs after gypsum, which show strong similirities to the breccia fragments and matrix, respectively, suggesting that the brecciated beds were originally composed of identical alternating carbonate mudstone and gypsum layers as the unbrecciated layers. The breccias are associated with frequently polyharmonic deformation structures, which are similarly oriented as the regional tectonic structures, indicating that they are related with the alpine contractional deformation of this area of the Cameros Basin. All these features suggest that the carbonate breccias were formed by tectonic deformation of alternating layers of carbonate mudstone and calcium sulphate, which have very different rheological behaviours. As a result, during tectonic deformation, sulphate flowed and carbonate layers were broken and displaced, producing a breccia of carbonate fragments within a sulphate groundmass. Afterwards, the sulphate groundmass was replaced by quartz and calcite, and the breccia acquired its final composition.

1. Introduction

Carbonate breccias are sedimentary rocks made up of gravel-sized, angular, limestone or dolostone fragments embedded in a groundmass consisting of fine-grained matrix and/or cements (Flügel, 2010, and references therein). Carbonate breccias may be formed by a wide variety of syn- and post-depositional processes (e.g. Norton, 1917; Blount and Moore, 1969; Richter and Füchtbauer, 1981; Flügel, 2010), such as deposition of eroded material, pedogenesis, slumps, faulting, or collapse caused by solution of evaporites or carbonates. For this reason, an appropriate interpretation of the process that caused the carbonate breccias may be an essential clue to understand either the sedimentary environment or the diagenetic or tectonic processes. However, classifying these rocks is often challenging because different processes may produce similar features, and thus, lead to completely different interpretations about the sedimentary environment or the post-depositional processes (e.g. Norton, 1917; Blount and Moore, 1969; Hoffman et al., 2009; Flügel, 2010, and references therein; Vlahovic et al., 2012).

The carbonate breccias of the Lower Cretaceous Oncala Group from the Cameros Basin (northern Spain) show several features that could lead to interpret them as the result of slumps (Salomon, 1982; Gómez-Fernández, 1992; Gómez-Fernández and Meléndez, 1994a; Meléndez and Gómez-Fernández, 2000), and some other characteristics suggest that they could be related with evaporite-solution collapse (Gómez-Fernández, 1992; Gómez-Fernández and Meléndez, 1994a; Meléndez and Gómez-Fernández, 2000; Mas et al., 2002). However, the integrated analysis of field and petrographic data suggests a new brecciation mechanism related with tectonic, frequently polyharmonic, deformation of two interbedded lithologies (carbonates and sulphates) with different rheological behaviours. Although tectonically-driven evaporite-flow processes have been described in the literature from décollement horizons of thrust faults (Helman and Schreiber, 1985;

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Lugli, 2001; Schreiber and Helman, 2005; Warren, 2006), to our knowledge, the formation of tectonic sulphate-flow carbonate breccias unrelated to thrusts has not been studied. This is the case of the carbonate breccias of the Oncala Group, which were developed in an area deformed by large-scale folds. The studied deposits provide an excellent example to understand this brecciation mechanism, because all the different stages of deformation, from undisturbed strata to slightly deformed and chaotic beds, can be observed. Moreover, it is possible to compare the calcitised sulphate–carbonate deposits present in most of the Oncala Group with uncalcitised gypsum–carbonate deposits preserved in a small area of the basin, which allows us to verify the proposed tectonic sulphate-flow brecciation model. The aim of the present study is to interpret the brecciation mechanism that caused the carbonate breccias of the Oncala Group by combining all the sedimentary, petrographic and tectonic criteria available. Furthermore, this article provides criteria to recognise similar breccias in other ancient successions, which may be useful for avoiding confusion with synsedimentary slump breccias caused by gravity instability, or with diagenetic collapse breccias formed after dissolution of sulphates by meteoric waters undersaturated in $CaSO_4$. The recognition of tectonic sulphate-flow breccias may also be useful to identify intense structural deformation in, otherwise, apparently undeformed successions.

2. Geological setting

The studied carbonate breccias are part of the sedimentary infill of the Cameros Basin, northern Spain (Fig. 1A), which is the northwesternmost basin of the Mesozoic Iberian Rift System (Mas et al. 1993; Guimerà et al., 1995). The Cameros Basin was formed during Late Jurassic to Early Cretaceous intraplate rifting in Iberia as a consequence of the opening of the North Atlantic Ocean (Álvaro et al., 1979; Vegas and Banda, 1982; Salas et al., 2001). This basin recorded high subsidence and accumulation rates, with more than 6000 m of vertical thickness of sediments from the Tithonian to the early Albian (Mas et al., 2011; Omodeo-Salè et al., 2014). The infill of the Cameros Basin corresponds to a large cycle or supersequence divided into eight depositional sequences (Fig. 1B), which consist of continental and coastal deposits (Mas et al., 1993, 2011; Quijada et al., 2013b, in press; Suarez-Gonzalez et al., 2013, 2014, in press). The Cameros Basin was affected by two hydrothermal metamorphic events during the mid-Cretaceous and the Eocene, which reached temperatures up to 350–410 °C and 300 °C, respectively (e.g. Alonso-Azcárate et al., 1995, 1999; Mata et al., 2001; Mantilla-Figueroa et al., 2002; González-Acebrón et al., 2011). The Cameros Basin was uplifted from the Paleogene to the middle Miocene due to the Alpine Orogeny (Casas-Sainz and Simón-Gómez, 1992; Mas et al., 1993; Guimerà et al., 1995).

The Oncala Group, which contains the studied carbonate breccias, corresponds to the third depositional sequence of the basin (Mas et al., 1993, 2002; Gómez-Fernández and Meléndez, 1994b) and was deposited in the eastern sector of the Cameros Basin (Fig. 1A) during the Berriasian (Salomon, 1982; Schudack and Schudack, 2009). The Oncala Group contains both siliciclastic and carbonate-evaporitic deposits, which are laterally related (Fig. 1). Western to central areas of the Oncala Group consist of siliciclastic deposits interpreted as formed in fluvial systems in westernmost areas (Gómez-Fernández and Meléndez, 1994a, 1994b; Meléndez and Gómez-Fernández, 2000; Quijada et al., 2013b) and broad tidal flats in central areas (Quijada et al., 2013b, in press). The tidal siliciclastic deposits change gradually eastwards to carbonate-evaporitic deposits, which are interpreted as formed in coastal, shallow, carbonate–sulphate water bodies and their mudflats (Quijada et al., 2013a, 2013b). The carbonate-evaporitic deposits consist mainly of alternating laminae of carbonate mudstone

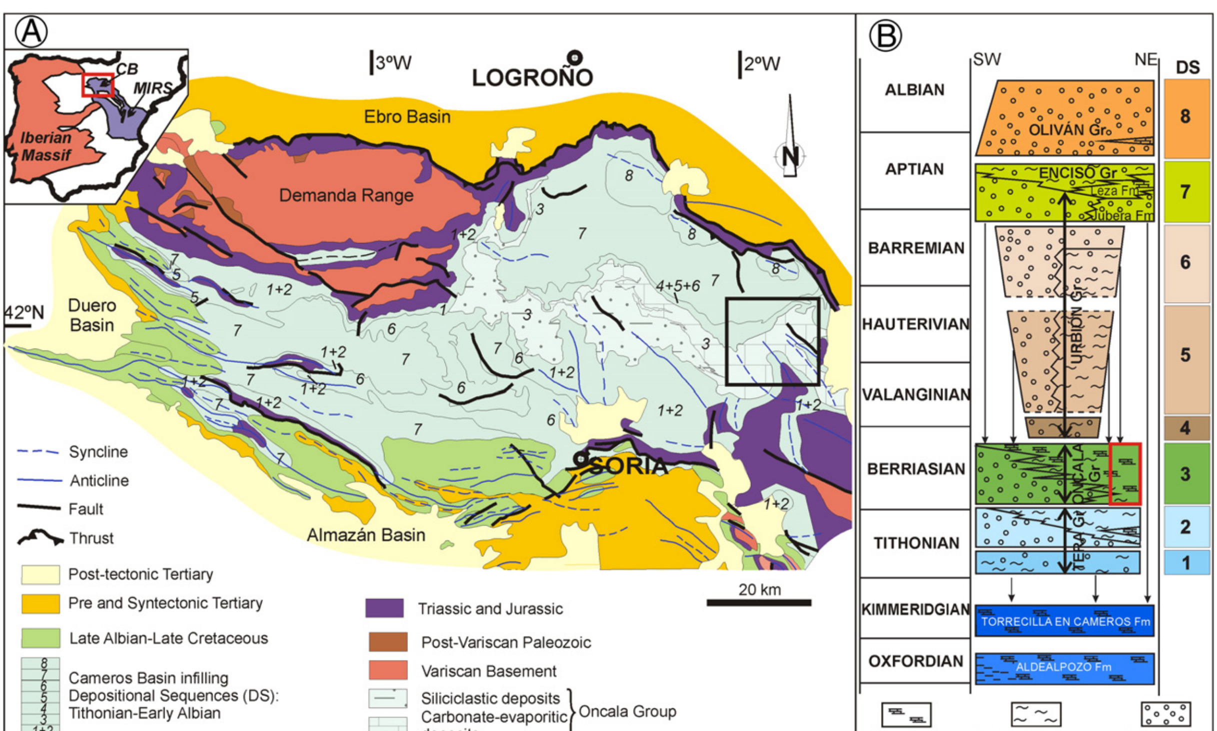

Fig. 1. (A) Geological map of the Cameros Basin and location within the Iberian Peninsula. Note that the Oncala Group (Depositional Sequence 3) contains laterally related siliciclastic and carbonate-evaporitic deposits. The black rectangle marks the mapped area in Fig. 2. Modified from Mas et al. (2002). "CB" = Cameros Basin, "MIRS" = Mesozoic Iberian Rift System. (B) Stratigraphic framework and depositional sequences (DS) filling the eastern Cameros Basin. The focus of this study, the eastern deposits of the Oncala Group, is highlighted with a red rectangle. Modified from Mas et al. (2004). "Gr" = Group, "Fm" = Formation.