Deformation of the Upper Cretaceous carbonates from the Eaux-Chaudes massif (France): constraints from cathodoluminescence analysis

Norbert Caldera (1*), Albert Griera (1), Marc Guardia (1), Juan Diego Martín-Martín (2)

(1) Departament de Geologia. Universitat Autònoma de Barcelona, Bellaterra, 08193, Barcelona (España)
(2) Departament de Mineralogia, Petrologia i Geologia Aplicada, Universitat de Barcelona, Barcelona, 08028 (España)
* corresponding author: norbert.caldera@uab.cat

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INTRODUCTION

The Upper Cretaceous limestone of the Eaux-Chaudes massif, located on the north-western edge of the Pyrenean Axial Zone, has experienced complex deformation events during the Alpine orogeny. It was ductily deformed under low-grade metamorphic conditions, in the greenschist facies (Caldera et al., 2021). Complex dolomitization and matrix recrystallization processes are widespread developed along the massif, in both large- and small-scale. The aim of this work is to determine the paragenetic relationship between dolomitization and matrix recrystallization, and its timing with respect to ductile deformation.

METHODOLOGY

32 samples of deformed and non-deformed limestones have been analysed by optical and cathodoluminescence petrography (CL). The latter is a useful tool commonly applied to identify dolomitization and recrystallization processes, as well as diagenetic relationship in carbonates (e.g., Fairchild, 1983; Purser et al., 1994; Choquette & Hiatt, 2008). Electron micro probe analyser (EMPA) has been used to obtain the chemical composition of dolomite phases from five selected dolomitized samples.

RESULTS

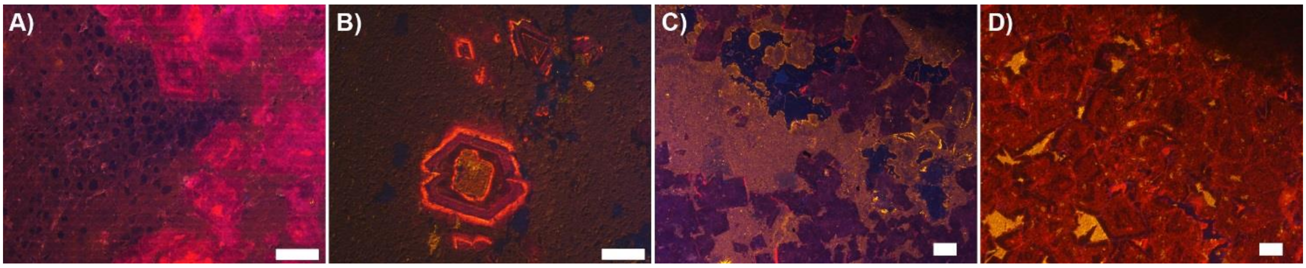

Fig 1*. Representative photomicrographs of the Eaux-Chaudes dolomitized limestones view under CL. A) Polymodal planar-s dolomite in bright magenta and recrystallized calcite matrix with non-luminescent cores, ductily deformed. B) Polymodal planar-p dolomite with complex zonation: cortical overgrowths on the homogeneous cores with a series of fine-scale zones. Dark yellow recrystallized calcite matrix. C) Polymodal planar-e dolomite in dull purple with yellow calcite matrix. Porosity within the matrix is partially cemented by yellow and non-luminescent calcite. D) Polymodal planar-s dolomite with red cores and dark rims. Yellow calcite void-filling. Scale bar are 100 µm long in all cases. Average of dolomite EMPA analyses: MgO (19.3%), SrO (0.0003%), FeO (0.5%), MnO (0.03%), CaO (32%), Na2O (0.001%), C (46.9%), total (99.2%).*

Luminescence response of dolomite crystals of the study samples show an assorted variety of orange-red to purple colours (Fig. 1). Dolomite growth is characterized by both homogeneous (C) and heterogeneous (A, B, D) development, likewise complex overgrowths are also identified (B). Partial dolomitization process is dominant with respect to total dolomitization, which was just observed in two samples. In strongly deformed samples, dolomite is affected by incipient calcite replacements and dolomite aggregates feature small-scale folds following the foliation

trend. Dolomite as porphyroclasts is developed in the most deformed limestones and attest a non-coaxial deformation due to its asymmetry.
The CL response of calcite phases are also very variable from non-luminescent to bright yellow. Generally, calcite matrix is characterized by a homogeneous appearance. Nonetheless, overgrowths are developed in some large recrystallized calcite crystals (C) or even in the matrix, surrounding non-luminescent calcite cores (A). EMPA results (Fig.1) evidence the presence of Mn in the crystal lattice structure, which is the most important luminescence activator in carbonates (e.g. Schulman et al., 1947; Gies, 1975; Mason & Mariano, 1990 and references therein).
Polymodal planar-s, -e and -p dolomite textures have been identified according to combined Gregg & Sibley (1984) and Sibley & Gregg (1987) dolomite textural classification (Fig. 1). Porosity is filled by two phases of calcite cement, the first with yellow CL colour and the latter with non-luminescent CL response.

DISCUSSION

It is well-known that differences in CL colour and intensity represent variations of carbonate Fe and Mn concentrations, motivated by changing redox conditions during its emplacement (i.e. Choquette & Hiatt, 2008). Complex zonations growth in dolomite and calcite crystals suggest abrupt changes in the chemistry composition of the pore fluids (i.e. mixture of meteoric, basinal or marine waters) (Choquette & Hiatt, 2008 and references therein). In addition, some dolomite crystals show multiphase growth history with multiple nucleation events (Fig. 1, B). Porosity is filled by two phases of different calcite aggregates. Dedolomitization processes occur probably due to calcite matrix dynamic recrystallization, which is conditioned by ductile deformation during the Alpine orogeny. Dolomites that are not affected by recrystallization processes may have an origin posterior to ductile deformation.

CONCLUSIONS

The diagenetic evolution of the Eaux-Chaudes Upper Cretaceous limestone resulted on its partial to complete dolomitization represented by polymodal planar-s, -e and -p dolomite textures. The matrix is formed by calcite phase and the remaining porosity is partially filled with calcite cement. Cathodoluminescence analyses show different colours and intensities in dolomite and calcite crystals evidencing the change of fluid composition during its circulation and redox conditions during its crystallization. Multiphase dolomite overgrowths have been identified in samples which are strongly ductily deformed by the Alpine orogeny. This event invoked the development of matrix recrystallization and new dolomitization processes. Some dolomites have emplaced prior to deformation evidenced by its folded features according to the Alpine deformation patterns. Overgrowth is also developed in calcite matrix, affected by dynamic recrystallization and sometimes dissolving dolomite edges.

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