AAPG HEDBERG CONFERENCE
"Deformation History, Fluid Flow Reconstruction and Reservoir Appraisal in Foreland Fold and Thrust Belts"
May 14-18, 2002, Palermo – Mondello (Sicily, Italy)

Diagenetic evolution of Palaeozoic clastic sediments in the Cantabrian Zone, Spain derived from fluid inclusion and clay mineralogy

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Introduction

The Cantabrian Zone (Fig. 1) in NW Spain consists of a succession of Palaeozoic sediments with alternating siliciclastic and carbonate formations. These sediments represent the foreland of the Iberian Variscides and have been complexly folded and thrusted, resulting in several thrust units with diagenetic to very low grade metamorphic overprint (Julivert, 1971; Pérez-Estaún et al., 1988). Major clastic sediments are quartz sandstones of Cambrian to Ordovician and Upper Devonian age. They have been sampled in two thrust units (Somiedo-Correcillas and Sobia-Bodon) of the southern part of the Cantabrian Zone in order to specify the timing of fluid flow in these sediments and to correlate with cementation episodes.

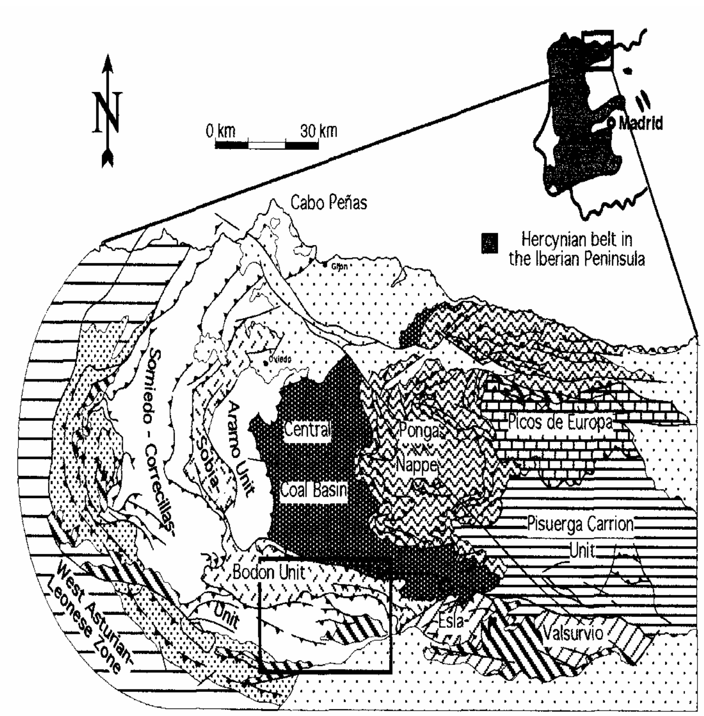

Fig. 1: Geological sketch map of the Cantabrian Zone, showing the main thrusts and the different tectonostratigraphic units. The frame encloses the working area.

AAPG Search and Discovery Article #90011©2002 AAPG Hedberg Conference, May 14-18, 2002, Palermo - Mondello, Sicily, Italy

Results

The samples consist of almost pure sandstones, which exhibit a more or less pronounced quartz cementation by quartz overgrowth. The remaining pore space is partly filled with authigenic clay minerals, mostly illite and subordinate kaolinite. Rare feldspars are completely altered to illite. K-Ar dating of authigenic illites reveals at least two different periods of illite growth. The first episode is in the Upper Carboniferous during the Variscan Orogeny and a second time of illite growth can be traced in the Early Mesozoic.

Fluid inclusions (FI) in quartz reveal several fluids, which affected the sediment during the burial history (Fig. 2). The earliest generation of fluid inclusions is developed along the boundary of detrital quartz grains and quartz overgrowth and within the overgrowth. These FI contain NaCl-solutions as deduced from the eutectic melting temperature (Te) of –21°C with moderate salinities, which correlate positively with the homogenisation temperatures (Th) of 100 to 150°C. A second type of aqueous FI occurs as trails, which crosscut several detrital grains and overgrowth, and in quartz veins. This fluid has a very low salinity and shows a large spread of Th between 70 and 180°C. This spread is probably not because of huge variations of the fluid temperature but the result of secondary alterations of the fluid inclusions leading to some leaking of the fluid. The majority of the Th cluster between 90 and 110°C, which should represent more precisely the original temperature. The third type of aqueous FI has Te < -50°C pointing to Ca-Na-Cl dominated solutions. The salinity is increased compared to the first two generations but shows a high variability. These inclusions with Th between 90 and 130°C are found predominantly in quartz veins, where they alternate with zones of FI with low salinity.

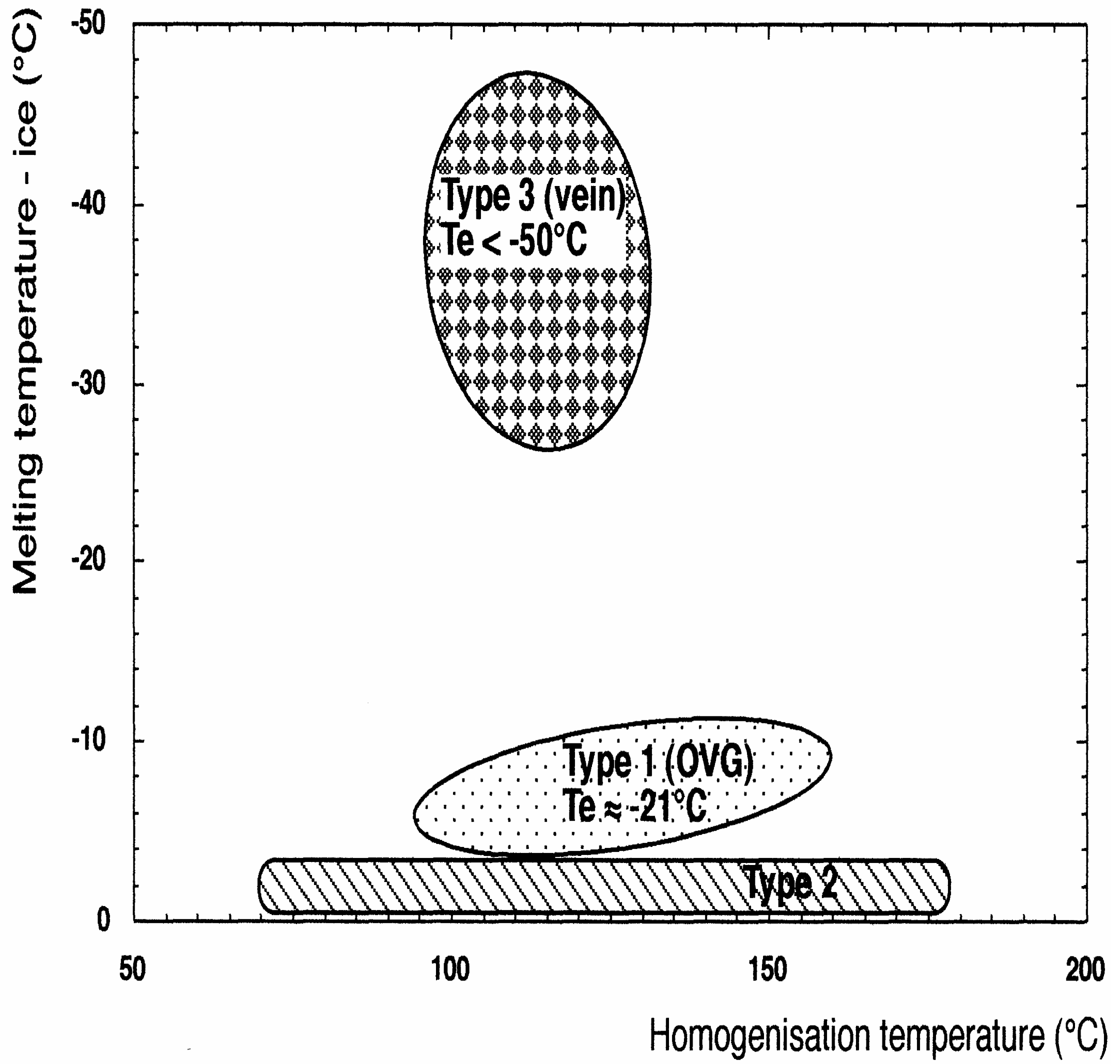

Fig. 2: Homogenisation vs. melting temperature for the different types of fluid inclusions in quartz. Type 1 are from quartz overgrowth (ovg), type 2 are secondary FI in detrital and authigenic quartz as well as from quartz veins. Type 3 are high salinity inclusions in quartz veins. Te indicate the eutectic melting temperature for the different fluids.

Discussion

During the burial of the sediment cementation starts with the formation of quartz overgrowth on detrital quartz grains. Dissolution of detrital grains is the source for the quartz of the overgrowth precipitated from buried porewater, which increases in salinity during increasing burial, as reflected by the positive correlation of Tm and Th.

In the Upper Carboniferous the sediments are subjected to thrusting and uplift. At this time microcracks develop in the consolidated sediments, which affect detrital grains and overgrowth. By sealing these microcracks secondary fluid inclusions of very low salinity are trapped, which are characteristic for Variscan mineralizations (Behr et al., 1987; Schroyen & Muchez, 2000). The percolating fluids also cause the dissolution of feldspar and lead to the first period of authigenic illite growth replacing feldspar on one side and filling part of the remaining pore space.

Mesozoic extension leads to reactivation of the Variscan thrusts and induces pathways for fluids to circulate, not only in veins but also to penetrate to some extent into the sediments and to precipitate the younger generation of authigenic illites. The distribution of K-Ar ages indicates that illite growth occurs in the Mesozoic in significant amounts only in the vicinity of major thrusts possibly because the porosity in the sediment was already highly reduced by the first episode of illite growth and fluids were prevented from penetrating deeper. Characteristic fluids for post Variscan mineralizations are highly saline Ca-Na-Cl brines (Behr et al., 1987), which are preserved in the Cantabrian Zone in fluid inclusions in quartz veins occurring in the sediments. These fluids are suspected to originate from deeper crustal levels from where they ascend due to mechanisms such as seismic pumping (Sibson et al., 1975) and to spread out in the vein system. The Ca-Na-Cl brine are mainly restricted to the vein system where they mix to some degree with low salinity fluids as indicated by the large spread of final melting temperatures. Despite of the mixture of the high salinity fluid with some low salinity fluid a zonation in the quartz veins can be detected with the major part of the quartz veins containing only inclusions with low salinity fluids. The part of the quartz veins, which is marked by the low salinity fluid, has also authigenic illites grown in some cavities. The low salinity fluid, probably of meteoric origin is the prevailing fluid in post Variscan times leading to the second generation of authigenic illite and is for some short episodes displaced in the vein system by a high salinity fluid from deeper crustal levels.

Conclusions

The clastic sediments of the southern Cantabrian Zone were exposed to various fluids with different origin in dependence on the changing tectonic setting. Authigenic minerals formed at several times. Quartz is precipitated from fluids of very low to very high salinity but quartz overgrowth in the sediment is mainly restricted to the burial period where moderate saline pore fluids occur. Younger quartz of Variscan and post Variscan age is prevailing in veins precipitated from very low and very high salinity fluids. Authigenic illites were grown also during the build up of the Variscan Orogen and in post Variscan times but are always attributed to low salinity fluids.

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