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Diagenesis controlled by tectonic burial in a foreland basin turbidite formation. The case example of the Grès d'Annot, French-italian external Alps

P. Labaume (1), J.P. Sizun (2), D. Charpentier (2), A. Travé (3), F. Chirouze (1), M. Buatier (2), A. Chauvet (1), F. Walgenwitz (4), M. Jolivet (1), P. Monié (1), and N. Arnaud (1)

(1) Laboratoire Géosciences Montpellier, Université Montpellier 2, INSU-CNRS, Montpellier, France (pierre.labaume@gm.univ-montp2.fr), (2) Laboratoire Chrono-Environnement, Université de Franche-Comté, INSU-CNRS, Besançon, France, (3) Departament de Petrologia, Geoquimica i Prospecció Geològica, Universitat de Barcelona, Barcelona, Spain, (4) CSTJF, TOTAL, Pau, France

Diagenesis of a foreland basin-fill is likely to be strongly influenced by compressional tectonic activity, in particular when recently deposited sediments are buried under thrust units. We have investigated this process and its effects on reservoir properties in the Grès d'Annot Fm. This upper Eocene-lower Oligocene arkosic turbidite succession of the French-italian external Alps was partly buried below allochthonous units during the Oligocene and exhumed by thrusting during the late Miocene (Labaume et al., 2008*). We have combined petrological, geochemical, petrophysical and thermochronological methods for studying samples from a transverse section of the basin, from the external domain (Annot area) in the SW to the front of the Internal Alps (Penninic front) in the NE. In its internal part, the section follows the lateral border of the Embrunais-Ubaye (E-U) nappes, derived from the Internal Alps.

Vitrinite reflectance measurements, as well as the reset level of apatite fission tracks show that the maximal temperatures (Tmax) reached by the Grès d'Annot during burial ranged from less than 60°C in the external domain up to around 250°C below the Penninic front. Tmax of 70-80°C coincide with the along-strike projection of the E-U nappes front, strongly suggesting that the higher Tmax in the more internal domains were primarily related to burial under the allochthonous units. Assuming an average geothermal gradient of 25°C/km allows reconstructing the thrust units tapering, with burial depths from less than 2.5 km in the SW to about 10 km in the NE.

In the external domain, shallow burial of the Grès d'Annot is registered by the relatively weak, mainly mechanical compaction of sandstones. SEM observations show that intragranular microfracturing sealed by authigenic quartz was involved in compaction mechanisms. The main cement is calcite, mainly present close to the lithological boundaries with the pelitic intervals, suggesting that dissolution of carbonate in the pelites was the main source of sandstone cementation. Due to this heterogenous distribution, porosity and permeability are relatively high in the calcite-poor homolithic facies (thick to massive sandstone beds with porosities up to 10-20% and permeabilities of a few mD to tens of mD), whereas they are strongly reduced in the calcite-rich heterolithic facies (alternance of decimetric sandstone and pelite layers). The isotopic composition of calcite ($\delta^{18}O$ of -6 to -10‰ PDB and $\delta^{13}C$ of -1 to -3‰ PDB) is consistent with precipitation from a mixed marine-continental water at relatively low temperature (<60°C). Clay minerals are characterised by the abundance of detritic illite and IS illite-smectite, as well as newly-formed kaolinite, attesting to a low level of transformation in this low temperature context.

More to the NE, pressure solution of quartz and other silicates became a major compaction mechanism due to Tmax>80°C. However, intergranular quartz cement is very scarce, never exceeding a few percent and often undetectable. Drainage of dissolved silica with compaction fluids may be an explanation of the low quartz cement level, but importance of intragranular deformation by microfracturing may also have contributed to reduce porosity and hence available volume for cementation. These compaction mechanisms resulted in a strong reduction of porosity (in general <2%) and permeability (around 0.1mD) in all lithologies, with quasi-desappearance of macroporosity. The remaining porosity is mainly represented by microporous domains associated with clay minerals. Transformation of phyllosilicates also registered the Tmax increase toward the NE, with desappearance of kaolinite and smectite and increasing illitisation, up to the formation of small white micas associated with increasing alteration

of feldspars when approaching the Penninic front. Distribution of calcite cement with respect to lithofacies remains basically unchanged compared to the external domain. However, the progressive decrease of δ^{18}O down to -18‰ PDB below the Penninic front attests to calcite recristallisation under increasing temperatures, in waters increasingly involved in interactions with silicate minerals. By contrast, the δ^{13}C remained unchanged, indicating the absence of carbon derived from other source than the original water.

In summary, all diagenetic markers in the Grès d'Annot are coherent with a north-eastwards Tmax increase related to increasing burial below the front of the thrust units. Three main processes were responsible for degradation of reservoir properties, i.e. (i) calcite cementation close to interfaces with pelites which began before burial under the nappes, (ii) pressure solution of silicates triggered by temperature increase below the nappes which mainly affected the lithologies not previously cemented by calcite, and (iii) strong intragranular microfracturing favoured both by the arkosic nature of the sandstone and the compressional tectonic context. The isotopic composition of calcite cements attests to a hydrologic system closed to the intrusion of external waters and where diagenesis was dominated by in-situ water-rock interactions controlled by the temperature increase.

(*Terra Nova, 2008, vol. 20, pp. 95-101)