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Dual porosity reservoirs in the Ionian zone of the Albanian FFTB

Swennen, R.[1], Van Geet, M.[1], Durmishi, C.[2] and Roure, F.[3]

1. Fysico-chemische Geologie, K.U.Leuven, Celestijnenlaan 200C, B-3001 Heverlee, Belgium; e-mail: Maarten.Vangeet@geo.kuleuven.ac.be, Rudy.Swennen@geo.kuleuven.ac.be,
2. Laboratory of Sedimentology, University of Tirana, Tirana, Albania
3. Institut Français du Pétrole, avenue de Bois-Préau, F-92852 Rueil-Malmaison Cedex, France; e-mail: Francois.Roure@ifp.fr

Hydrocarbon exploration in fold and thrust belts, like in the outer Albanides in Albania, is often a high-risk operation. Here seismic interpretation and structural-thermal modeling of large regional transects is one of the prerequisites to reconstruct the deformational history through time and to model the maturation history correctly. Within these settings it is also important to get a control on type of fluids that circulated through the system in space and time. In this study, data on an outcropping reservoir analogue of Upper Cretaceous to Eocene age will be presented. The latter is equivalent to many of the turbiditic reservoirs drilled in the Ionian Zone of Albania and the adjacent Adriatic Sea. The following important diagenetic stages can be recognised:
- an eogenetic stage whereby dissolution of unstable sedimentary components, which became deposited in basinal settings, contributed to the development of isopacheous and syntaxial low-Mg calcite cements in coarser grained bottom parts of the turbidites. Upon ideal nucleation sites like crinoid ossicles and rudist fragments, these cements pervasively developed with a nearly total porosity loss as consequence. This is especially the case in the lower part of the turbidites where bioclastic grainstones, consisting of debris material of rudists, occur. Upon reworked micrite constituents, which are more common in overlying pack- and wackestones, cement development is less apparent. Thus within lithology intervals where the latter constituents are mixed with bioclasts, the cement development around the bioclasts stabilized the framework, preserving the primary porosity. These isopacheous and syntaxial cements possess a uniform dull orange luminescence, which is similar to the luminescence of the host rock. The fact that they can make up 30% of the bulk volume and their stable isotopic signature ($\delta^{18}O$ and $\delta^{13}C$ varying respectively around -0.5‰ VPDB and +2‰ VPDB), which is within the field of time-equivalent marine carbonates, testifies of their marine phreatic origin;
- a pre-orogenic, compactional mesogenetic stage during flexural loading of the foreland. Porosity decrease due to physical and chemical compaction especially affected fine-grained turbidite intervals. It is during this pre-folding stage that bed parallel stylolites developed. Commonly subvertical veins, cut by the latter form in relation with formation of normal faults developed in an extensional stress regime;
- a footwall syn-orogenic deformational stage with development of layer parallel shortening (LPS) features such as stylolites. These stylolites are perpendicular to bedding. The indentations of the stylolites are parallel to the major compressional directions. The complex vein textures (calcite infill with brecciated host rock fragments, crack and seal features, …) are interpreted to relate to the expulsion of overpressured fluids in the footwall or just within the deformation front

zone. Development of crystal twin planes is a typical feature of all these cements. These cements all possess a dull orange luminescence similar to their adjacent host rock. A rock buffered, i.e. closed diagenetic system is reflected in the stable isotopic signal of these veins ($\delta^{18}O$ of –3.86 to –0.85 ‰ VPDB and $\delta^{13}C$ of -0.14 to +2.98‰ VPDB). Some of the LPS-stylolites reopened during deformation and became subsequently calcite cemented. Based on the same luminescence as the host rock and their isotope composition ($\delta^{18}O$ of –1.81 to –1.14 ‰ VPDB and $\delta^{13}C$ of +1.52 to +2.56‰ VPDB) the cementation is interpreted as rock buffered;

- a syn-orogenic deformational stage with development of folds and major faults and fractures. Some of the calcite veins still reflect a closed diagenetic system ($\delta^{18}O$ of –0.96 to +0.2 ‰ VPDB and $\delta^{13}C$ of +0.79 to +1.37‰ VPDB) while others reflect large scale fluid circulation. Basement derived fluid circulations or fluids which interacted with Triassic evaporites, which form the decollement horizons in the study area, are reflected in calcite veins which typically possess positive $\delta^{18}O$-values ($\delta^{18}O$ around +3.0‰ VPDB and $\delta^{13}C$ around +1.5‰ VPDB). Other veins with depleted $\delta^{18}O$- and enriched $\delta^{13}C$-signatures ($\delta^{18}O$ around –7.1‰ VPDB and $\delta^{13}C$ around +9.3‰ VPDB) relate to the fluid circulation in relation to the maturation of hydrocarbons. Acidic fluids generated during this diagenetic stage are made responsible for the secondary porosity development along the stylolites.
- a late syn-orogenic extensional stage in uplifted areas, with the formation of open joint networks. The latter are of major importance for oil production;
- a post-orogenic telogenetic stage, which has been dated as pre-Burdigalian based on the emergence contact studied at the anticlinal crest. At this stage a karst cavity network with larger cavities and conduits developed which subsequently became infilled by sediment. Since the latter sediments have not been lithified they thus yield a rather high porosity and permeability.

These different diagenetic stages fit well with modelled numerical experiments of thrust propagation systems. With regard to reservoir performance it is clear that storage is mainly within the turbidite matrix pores. The vertical connection of this layer-cake reservoir, however, is guaranteed by the existence of a vertical late syn-orogenic joint network and by the presence of vertical LPS-stylolites along which secondary porosity developed.