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Diagenesis in Foreland Fold and Thrust Belts : synthesis of an overregional study

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Exploration in Foreland Fold and Thrust Belts is a very challenging task in present-day petroleum exploration. It necessitates a good understanding of pre-, syn- and post-tectonic processes which can be inferred from seismics and forward kinematic modelling. Also with regard to the processes that might affect the reservoir units, a lot of new insights in the fracturing, cementation and porosity development history has been gained which help to reconstruct the entire fluid flow history. This can be achieved by classical petrographical and geochemical studies as well as by modeling. In this contribution a synthesis is given of a number of particular results of a petrological study in carbonate systems in different Foreland Fold and Thrust settings (i.e. the Cretaceous-Eocene Ionian zone of Albania, the Eocene Potwar Plateau and Salt Range of Pakistan, the Cretaceous Cordoba Platform – Veracruz Basin in Mexico, the Devonian – Carboniferous Canadian Cordillera and time equivalent systems in the Variscan frontal zone in Belgium).

Of particular interest in reconstructing the paragenetic history is the development of two types of stylolites, so-called BPS which are bed parallel planes and thus compactional in origin, and TS or tectonic stylolites which often are perpendicular planes to the sedimentary layering. The BPS stylolites develop at burial depth >600-800m in function of the nature of the carbonates. The TS relate to parallel shortening during tectonic compression. According to a number of authors, TS stylolitic planes develop immediately prior to thrust emplacement. Of importance here is that layer parallel shortening may cause some reservoir anisotropy.

Generally, preservation of matrix porosity or late stage development of secondary matrix porosity is often closely related to the sedimentary framework. Here early diagenetic cementation and especially dolomitisation is often framework stabelizing, counteracting burial compaction. Exhaustive cementation is often related to preferential fluid flow pathways as well as the availability of nucleation sites.

In all systems the fracturing history can be split up into a pre-BPS, a post-BPS but pre-TS, and a post-TS history. Often different periods with hydraulic fracturing and development of crack and seal fractures can be recognised, at the onset and during the first episodes of tectonic contraction.

They reflect the generation of overpressures in the system during tectonic deformation. Its effect on porosity preservation during tectonic pressure dissolution is, however, not yet fully studied. Of importance, however, is that this hydraulic fracturing may also cause fracturing of the sealing rocks, causing release of hydrocarbons present in the system.

Based on stable isotope data, as well as on a limited number of Sr-isotope data and fluid inclusion analysis, in general the pre-TS fracturing history (including thus the hydraulic veins) is mainly rock buffered. In several cases also some karst related meteoric water fluxes were recognised if the deformation period follows deposition of the carbonates (e.g. Cretaceous carbonates with Laramian/Alpine deformation). Karst dissolution and reservoir development can especially be important in fore bulge settings during deformation. The position of the latter can be predicted by modeling. The post-TS fractures often reflect intra- as well as extra-formational, i.e. closed and open diagenetic fluid circulations, respectively. Since the latter are often not in chemical equilibrium with the host rock they can generate secondary porosity. If siliciclastics occur adjacent to the carbonate reservoirs as basin fill, saddle dolomite and sometimes barite vein infills are recorded in the post-TS fracture fills as well as ferroan calcites, while if evaporites occur in the reservoir units or in the subsurface (which often act as décollement horizon) then some of the fractures or matrix cements contain fluorite cements. Thermal sulphate reduction may also cause late stage pyrite and calcite formation. Since the Fe in the diagenetic system is blocked by the precipitation of pyrite, often fractures infilled at this stage are bright yellow luminescent. This also accounts for these settings where mineralisations occur in the FFTB-systems. However, in general it is assumed that fluid circulation is limited. This is rather in conflict with the pervasive development of mesodolomite which is time equivalent with the main compressional phase. We therefore invoke layer parallel shortening as mechanism for mesodolomite recrystallisation and replacement. Nonetheless, focalised expulsion of hot fluids may cause dissolution of carbonates and cause a kind of hydrothermal karstification event (often occurring along former emergence surfaces), explained by cooling of formation waters. Another system reflecting focalised fluid flow gives rise to zebra dolomites. The latter develop by hot (hydrothermal) dolomitised fluids in overpressured settings, along satellites next to overthrust faults or next to specific transitions in paleo-environmental setting (e.g. basin – platform margins) at burial depth of several kilometers. Porosity enhancement is however limited (order of 5 %), Here a link with MVT-mineralisations is often present. Based on the same chemical principles as cooling of formation waters, the overthrusting of entire tectonic units also may have caused a large scale cooling down, which in carbonate reservoirs could result in secondary porosity development. However, this hypothesis still has to be tested by modeling. Also at the moment of hydrocarbon migration occurs, some secondary porosity enhancement can be expected to develop, due to the expulsion of aggressive fluida.

Of major importance is however that most of these fracture systems as well as the stylolites may become reactivated during folding and faulting (e.g. development of “extrados” fractures). In this respect the TS and vertical fractures are of major importance since they will guarantee a vertical connectivity.

In conclusion it seems feasible to predict from these studies the different episodes of fluid release. It therefore should be possible to model this diagenetic history by linking it to the deformational history.