PETROLEUM SYSTEM APPRAISAL IN A COMPRESSIVE AREA

EXAMPLE FROM VENEZUELAN FOOTHILLS

F. J. S. Schneider

Beicip-Franlab, 232 avenue Napoléon Bonaparte – BP213 – 92502 Rueil-Malmaison Cedex, France

Introduction

The area selected for this study is a north-south transect (Fig. 1a) within the Eastern Venezuelan Basin. The focus of this study was to understand the geological history of the two major reservoir units (Upper Cretaceous and Oligocene Formations) of the El Furrial structure. In a first step, mineralogical and geochemical data from the two formations were collected. Some data were also collected for the surrounding seal, the Carapita black shales (Roure et al., 1994). In a second step, basin modeling techniques have been used in order to achieve an understanding about the temperature, pressure and fluid evolution in the considered reservoirs.

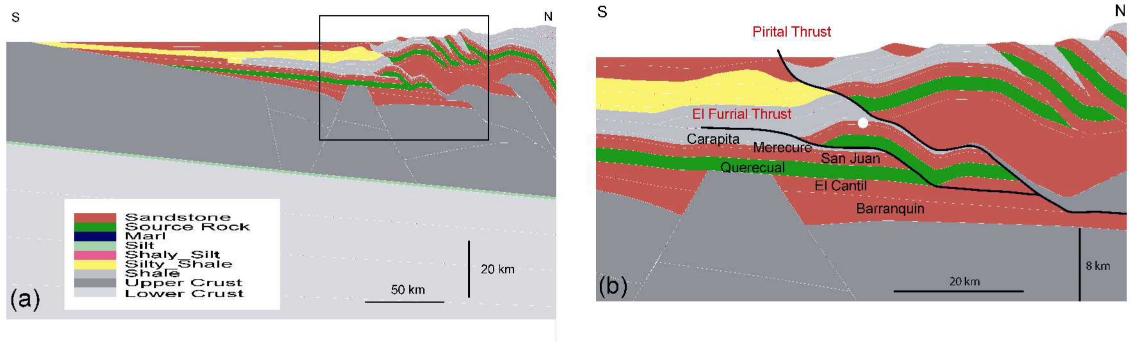

Figure 1: (a) Geometry and lithology distribution of the section at present day. (b) Zoom of the section showing the area of main interest. The white dot indicates the El Furrial structure.

Data

The sandstones of the San Juan Formation (Fig. 1b) are moderately to well sorted with a fine to medium grain size (from 0.125 to 0.5 mm). Monocrystalline quartz grains comprise the major detrital constituent with abundance ranging from 60% to 70%. Feldspars are the second most important detrital grains ranging from 4% to 14% in abundance. Quartz overgrowths around detrital quartz grains are well developed in the coarse-grained samples.

Locally, two generations of quartz overgrowths can be observed. The onset of silicification occurs at temperatures ranging from 100 to 125°C (Schneider et al., 2005).

The thick sandstones of the Merecure (Fig. 1b) Formation were deposited during the Lower Oligocene transgression. Calcite veins can be observed in the black shale layers of the Miocene Carapita Formation. They may have been formed by hydrofracturing and they are filled by calcite cement. The fluid inclusions study associated with a reconstructed thermal history allowed to conclude that this fracturing period is dated from 22 to 16 Ma.

Basin modelling

The geometry evolution scenario is characterized by five major episodes in the geodynamic evolution. (1) The first episode represents the formation of a prerift megasequence in Paleozoic time. The corresponding sediments are included in the brittle upper crust of the *Ceres* section. (2) The second episode corresponds to a rifting period during Jurassic and earliest Cretaceous times. Only the upper part of the synrift sediments is considered and the corresponding sediments are partly included in the brittle upper crust in the *Ceres* section. (3) The third episode corresponds to a period of passive margin development during the Cretaceous to Paleogene. In the *Ceres* section, this episode begins with the deposition of the Barranquin Formation and ends at -22.5 Ma. (4) From –22.5 to -15 Ma., the fourth episode captures the deposition of the synflexural Naricual-Carapita Formation, and is characterized by a phase of tilting with deposition of a thicker isopach in the northern part of the section. (5) The fifth phase occurs from -15 Ma onward when the thrusts developed.

The computed temperatures were compared to the observed temperature data until a reasonable fit was reached. A good fit was obtained for a thermal heat flow of 40 mW.m^{-2} and a basement radiogenic source term equal to 1.7 □W.m^{-3}

With realistic permeability values for the different formations are applied, the simulation reproduces the observed hydrostatic water pressure in the southern part of the section and overpressure in the El Furrial structure.

The simulated fracturation ratio of the Carapita seal suggests that these shales might have fractured between 21 and 15 Ma. This period of fracturation is related to the increase of the fluid pressure as a consequence of the tilting period where low permeable sediments are deposited with a quite high sedimentation rate.

A calibration of the chemical compaction model (Schneider *et al.*, 1996) within *Ceres* has been performed with data from the Upper Cretaceous San Juan Formation. The results show that a good fit between the modeled and observed porosity system is reached with activation energy of 17.5 kJ/mole and a macroscopical viscosity of 29.2 GPa.Ma.

The fluid flow history has been analysed for the Oligocene age Merecure Formation. For the Oligocene sandstones of the El Furrial structure, the fluid flow history is a direct consequence of the deformation and lithology distribution.

The simulated filling history of the El Furrial structure (Fig. 2) shows that the initial hydrocarbons generated by the Querecual source rock first reach the sandstones of the San Juan Formation. This occurred around 17 Ma ago. At around 12 Ma, the hydrocarbons reached the Oligocene sandstones. The increase of the hydrocarbons saturation in the Oligocene sandstone is correlated with the creation of the El Furrial structure some 7 to 5 Ma ago.

Furthermore, the simulations showed that the filling history of the El Furrial structure is contemporaneous with its fault bend fold deformation. As a consequence, what is now its southern flank was filled by hydrocarbons when it was at the top of the anticline structure.

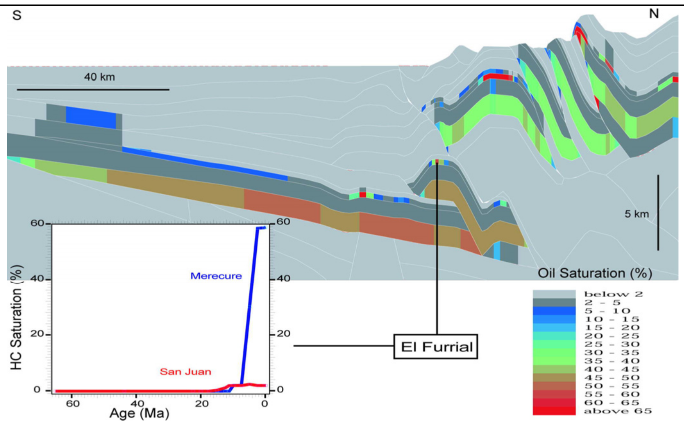

Figure 2: Computed HC saturations at present day and filling history of the El Furrial structure.

Conclusions

An important contribution of this work is the construction of a coherent scenario for the geological evolution of the El Furrial structure. Porosity evolution of the Oligocene and Upper Cretaceous sandstones can be well simulated with a chemical compaction model.

Quartz overgrowths display oxygen isotope values ($\delta^{18}O$) that suggest the main phase of quartz cement precipitated from marine waters, whereas the second generation of quartz overgrowth probably formed from evolved basinal fluids. This is consistent with the results from Ceres modeling, which demonstrates that formation (marine) waters were circulating in the system without restraint until tectonic accretion occurred. Then, due to the deformation, deeper and shallower sedimentary units were in tectonic contact, which probably resulted in the opening of the geochemical system. In other words, fluids with different temperatures and compositions (evolved basinal fluids) entered the system, resulting in additional but minor silicification.

The simulated hydrofracturing of the Carapita seal prior to the hydrocarbons filling of the structure is consistent with the previous works. At last, it seems that the hydrocarbon filling of the El Furrial structure was contemporaneous with its fault bend fold deformation.

References

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