THERMAL INTRUSION: A NON-CONVENTIONAL PETROLEUM SYSTEM AND A CHALLENGE FOR BASIN MODELLING

R. Baudino [1]*, M. Pontet [3], H. Coumont [4], F. Schneider[3], F. Rodríguez [2]
,S. Zencich, [2], R. Calegari [2]

1. Repsol-YPF, Talero 360, 8300 Neuquén, Argentina; presently at
Repsol-YPF Brasil, Praia de Botafogo 300, 7 andar, 22250-040 Rio de Janeiro, Brasil.
2. Repsol-YPF, Talero 360, 8300 Neuquén, Argentina
3. Beicip-Franlab, 232 avenue Napoléon Bonaparte, 92502 Rueil-Malmaison, France
4. Beicip-Inc, 1880 S. Dairy Ashford, Suite No 630, Houston, TX 77077, USA

Many hydrocarbon-producing sedimentary basins are affected by magmatic activity resulting in both regional (magmatic chamber, mantle plumes…) and local (sills, dykes, batholits…) thermal anomalies. The effect of regional anomalies is admitted and largely considered in basin modelling studies. However, the real effect of local thermal anomalies related to magmatic intrusions is largely unknown.

The study of the effect of magmatic intrusions onto hydrocarbon generation and expulsion is made difficult by the scale of time at which these events occur.

The aim of this study is to evaluate the ability of a basin model in managing a thermal intrusion. A thermal intrusion (e.g. lava sill or dyke) is characterized by a sharp increase of temperature during a very short time period. The fusion temperature of most of the lava is generally in the range of 800 to 1200°C. We have studied in two dimensions the effect of an igneous intrusion with an initial temperature of 1000°C.

The section at present day is characterized by a simple layered geometry where a 100m thick igneous body is intruding a source rock sequence (Figure 1). The source rock is lying above tuffs and is overlain by sandstones. The sandstones are sealed by argillaceous sediments.

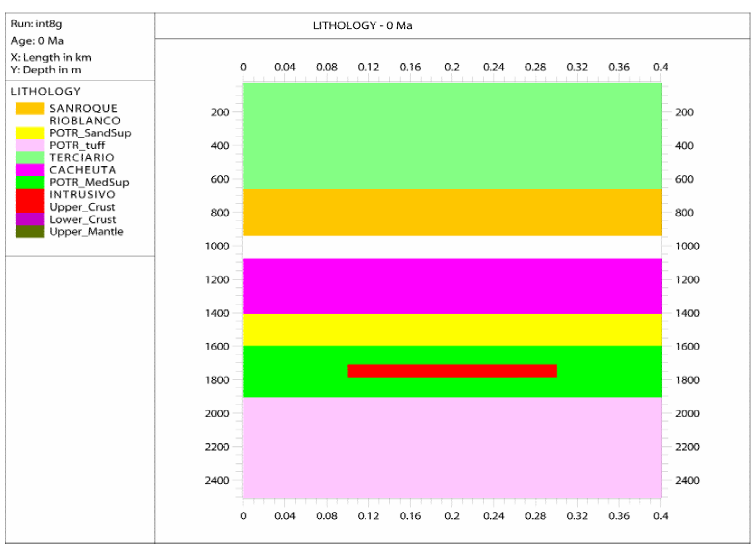

Figure1: Section at present day with the lithology distribution showing the intrusive body (red) inside the source rock (green)

The intrusive body penetrated the source rock at 150 Ma (Figure 2). The intrusion is simulated by a lithology switching. The new lithology is declared as a thermal intrusion with a fusion temperature set to 1000°C.

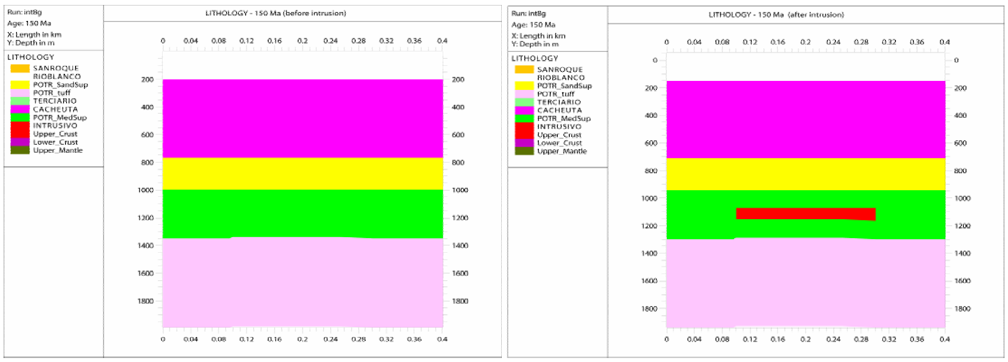

Figure2: Section at 150 Ma just before the intrusion and the same section 100 years later at the end of the injection.

At the end of the intrusion, after 100 years, the temperature profile shows a transient shape with a maximum temperature around 650°C. 750 years after the beginning of the intrusion, the transient shape still exists but the maximum temperature is now around 220°C. The system is completely relaxed after 1 Ma and the temperature of the intrusion is around 60°C, which is the regional temperature at this depth (Figure 3).

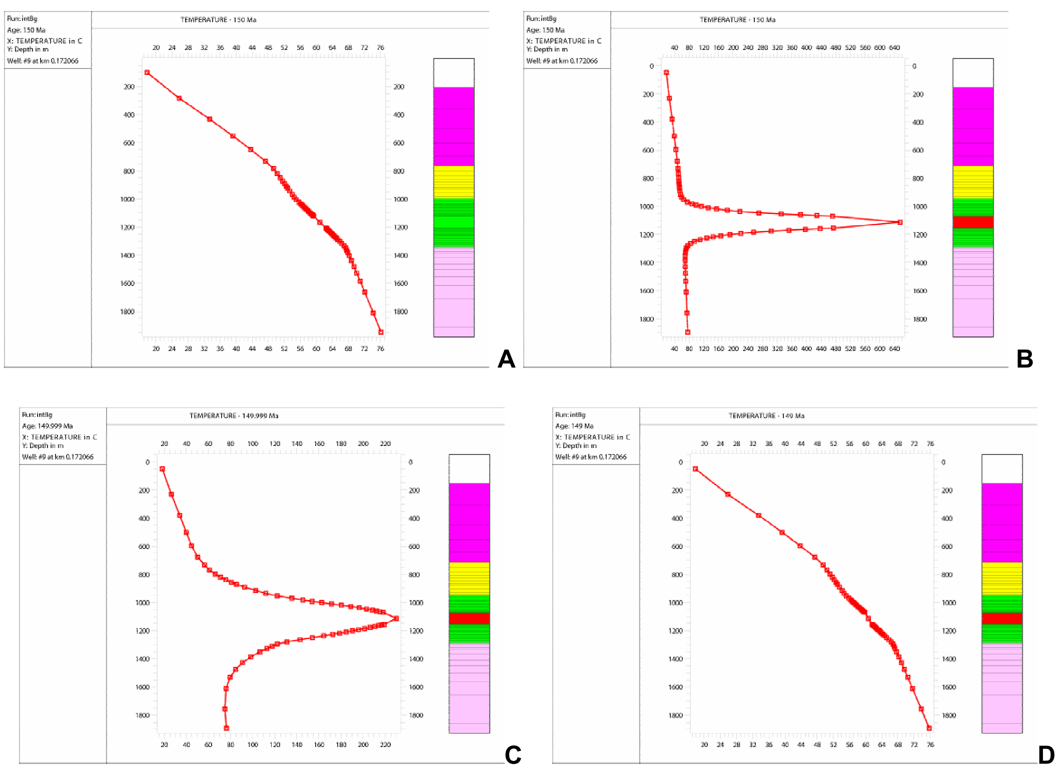

Figure 3: Thermal evolution in one vertical showing the transient thermal effect that vanished after one Ma. (A) at 150 Ma, (B) after 100 years, (C) after 750 years, (D) after 1 Ma.

Most of the maturity is acquired after 750 years and, the impact of the intrusion is seen up to a distance of 120 m (Figure 4).

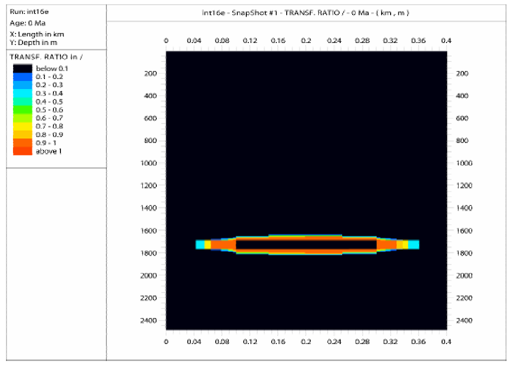

Figure 4: Transformation ratio at present day.

During the transformation of the kerogen into hydrocarbons, the excess of fluid is converted in overpressure. The overpressure evolution for one cell immediately below the intrusion (Figure 5) shows a sharp increase related to the intrusive event.

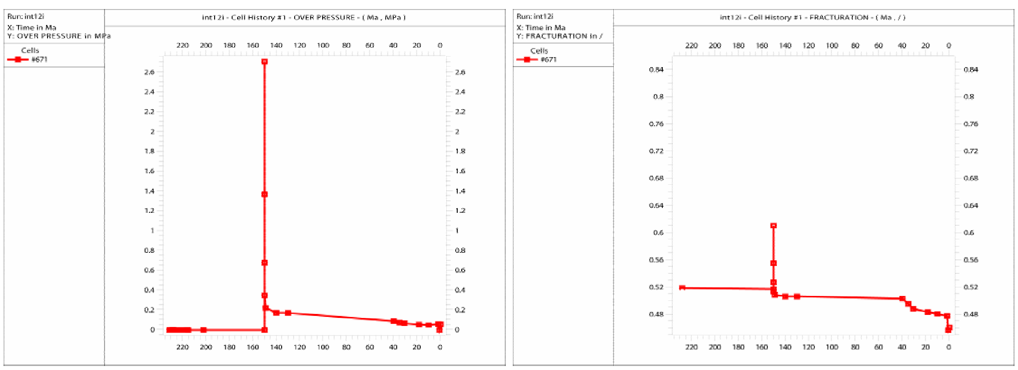

Figure 5: Overpressure and Fracturing Index evolution for one cell situated immediately below the intrusion.

For non-compositional simulations, maturation, expulsion and migration can be well simulated provided that the time step management is set in order to “follow” the physical process (Figure 6).

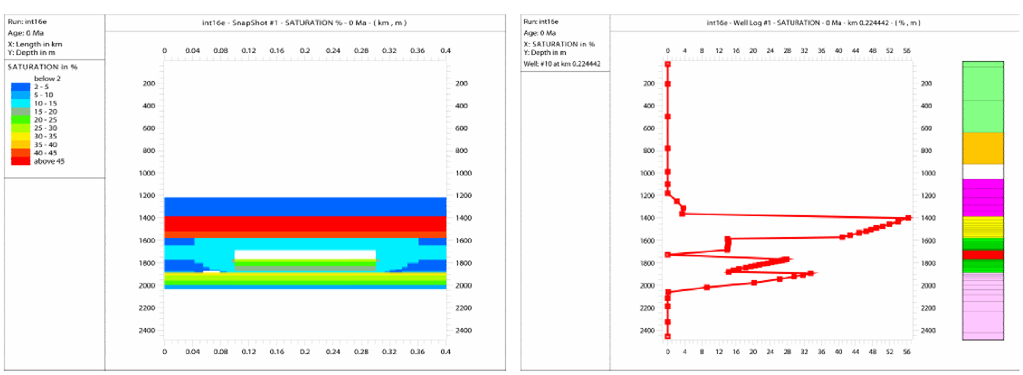

Figure 6: Hydrocarbon saturation distribution for one of the most favourable case.

For compositional simulations (3 classes), a rapid evolution of the composition of the fluid generated according to the distance from the intrusion is observed (Figures 7-8).

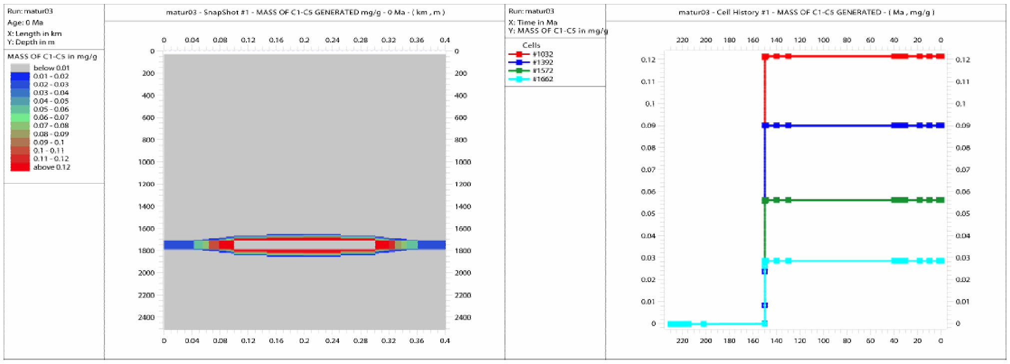

Figure 7: C1-C5 generated at present and as function of time for selected cells.

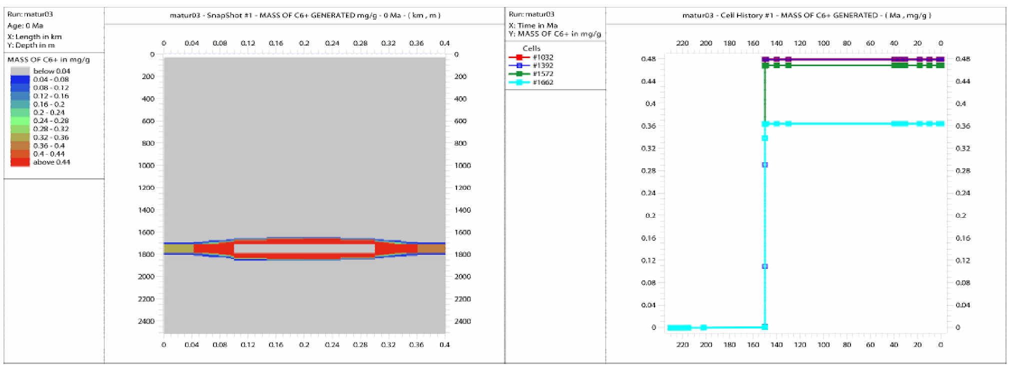

Figure 8: C6+ generated at present day and as a function of time for selected cells.

This preliminary study shows that basin model can account for thermal intrusion. The main condition is that the time step management of the simulations should be set in order to follow the physical processes. As the relaxation time of the thermal effect is in the order of 1000 years, the time step should be lower during this specific period. In this study time steps of 10 years have been used during this short period. The rest of the simulation has been run with classical time steps around 10000 years.

Pyrolysis techniques demonstrate that it is possible to generate hydrocarbons at high temperatures in a short time frame. Furthermore, the kinetic parameters determined by lab experiments are more representative of what occurs during thermal intrusion than of what occurs during classical burial history.

Maturity indicators measurements from wells and surface samples show high maturity levels reached by source rocks in contact with intrusive bodies. Our tests demonstrate that this high maturity level is observed up to 100 meters from an intrusion a 100 m thick. The affected thickness depends on intrusion initial composition and volume (that control the heat flow produced) and the intruded rocks heat conduction.

Several hundred meters of cumulative thickness of intrusives are described in wells and the surface of each one can be of several tens of square kilometres. Considering these dimensions, the potential volume of hydrocarbon generated could be significant. Further tests on real cases are planned in order to perform a complete mass balance.