Physical models of chemical compaction, overpressure development and hydraulic fracturing in various tectonic contexts

A. Zanella, P.R. Cobbold, A. Lemrabott
Géosciences-Rennes (UMR6118), Université de Rennes 1 et CNRS, Campus de Beaulieu, 35042 Rennes Cedex, France

Chemical compaction, overpressure development and hydraulic fracturing are common in source rocks for petroleum, yet there is no consensus as to the underlying physical processes. We have investigated them by physical modelling. In our experiments, mixtures of coloured silica powder and beeswax microspheres (50% by volume) formed two basal layers of source material, whereas the overburden was of pure silica powder. By submerging the materials in water, we avoided the high surface tensions, which arise within pores containing both air and liquids. Also we were able to measure pore fluid pressure in a model well. We built and deformed the models within a rectangular box, which rested on an electric flatbed heater. During heating, the basal temperature of the model surpassed the melting point of beeswax (62°C), reaching a maximum of 90°C. A piston at one end of the model was capable of horizontal displacement. Thus the experimental variables were (1) rate of heating, (2) amount and sense of piston displacement, and (3) piston velocity. When the piston was static, rapid melting led to compaction of the source layer and to development of high overpressure (lithostatic or above). The liquid wax migrated through pore space and into open hydraulic fractures. Most of these fractures were horizontal and in apparently random positions. In experiments, for which the piston moved outward, causing horizontal extension of the model, some of the intrusive bodies were dykes, especially near the piston, whereas others were sills. For the highest piston velocity, the basal temperature dropped, some 20 minutes after the beginning of deformation. In experiments, for which the piston moved inward, causing compression of the model, overpressure reached higher values. Sills and faulted laccoliths formed near the piston, the laccoliths resembling saddle reefs. In these experiments, sills appeared mostly between the two source layers.