

### 3 Modeling Methods

The approach used here is to input variables as if they are known into the petroleum systems modeling software (Temis2D™ by Beicip-Franlab, France), and compute thermal history to assess maturation of source rocks. Changing one variable at a time allows us to gauge its effect on the outcome of the model. This results in many ‘answers’, but also allows us to identify variables and unknowns that have the greatest impact on estimates. Temis2D™ also predicts patterns of fluid and hydrocarbon flow. One can then evaluate different structures in the basin and how they might have affected migration and trapping of hydrocarbon.

Computation of the temperature distribution as a result of heat transfer through the sedimentary basin requires the definition of a thermal basement. The thermal basement describes the lithosphere lying below the sediments. The lower crust and the upper mantle act as a thermal buffer between the lower limit of the upper mantle and the lower limit of the sedimentary section. It can also be the location of radiogenic heat production.

Heat transfer computation implies that adequate thermal conditions along the upper and lower boundaries are defined. The upper condition is set by a history of surface temperature. The lower condition is imposed at the lower limit of the sedimentary succession and is defined by a given mantle temperature and a set of properties defining the lower crust and the upper mantle, which act as a thermal buffer. In addition to this mantle derived heat, Radiogenic Heat Production in combination with radioactivity depth decay account for radiogenic heat flow and therefore production of heat within the lithosphere. This heat is generated by disintegration of radioactive elements such as uranium or potassium.

Plate thickness as defined in the Temis2D™ software is divided into upper crust, lower crust and upper mantle layers, according to the continental lithospheric stretching model of McKenzie (1978). During simulation of a rift event, the crustal layers are thinned according to the pure shear lithospheric stretching model of McKenzie (1978), while the upper mantle thickness is increased, so the total thickness of the plate remains constant. The temperature of the bottom boundary of the plate is defined to be an isotherm. The thinning coefficient or  $\beta$ -factor defines the magnitude of crustal (upper and lower crust together) thinning; this simulates uplift of the Moho.

During the numerical simulation a grid, based on a geological cross-section, is used to define a set of cells, which represents the sedimentary section of the basin through time. The upper and lower limits of each cell correspond to isochron markers. The lateral limits of the cells are vertical. Each row of cells, therefore, describes a stratigraphic formation or layer that has been deposited during the time interval defined by the ages of the top and bottom isochron. Cells are assigned physical properties (permeability, grain density, TOC etc.) needed by the algorithm to simulate the process of sediment deposition, compaction, fluid flow, hydrocarbon generation and migration. Faults are treated as

having 10-times the vertical and 2-times the horizontal permeability of the assigned lithology over the whole time of their existence.

Backstripping attempts to correct the stratigraphic record for the effects of loading in the past prior to forward modeling of sedimentation, compaction, thermal regime, maturation, hydrocarbon generation and migration, (e.g. McKenzie, 1978; Steckler & Watts, 1978; Sclater & Christie, 1980).

Simulation calculates temperature and heat flow distribution, vitrinite reflectance ( $\%R_o$ ),  $T_{max}$ , transformation ratio, hydrocarbon saturation, and migration pathways through time.