

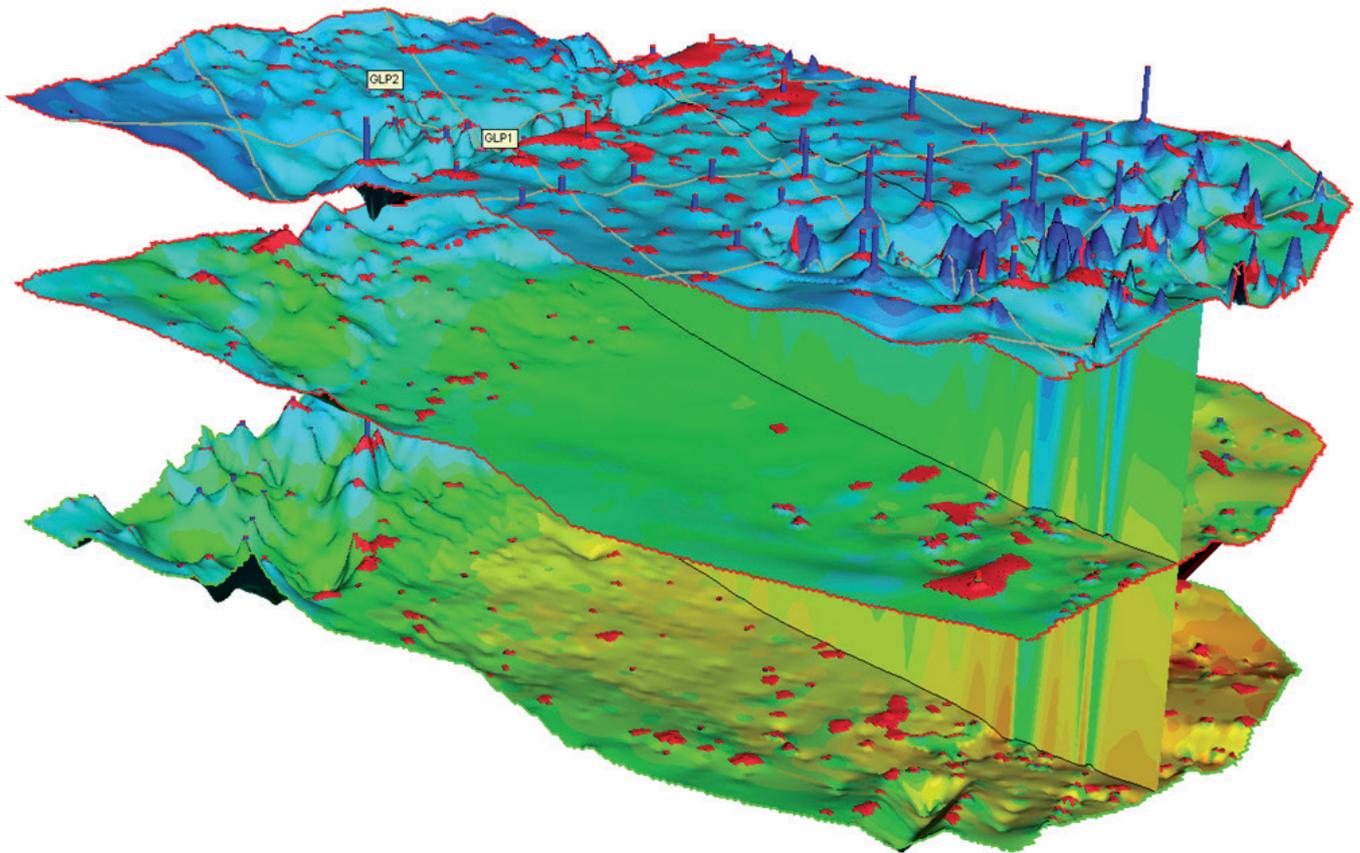
SEMI concept

October 2016

The aim of the SEMI (SEcondary Migration) simulator is to model migration of oil and gas from source rocks to traps in 3D. The outcome provides quantitative estimates of the amounts and phases of hydrocarbons in (undrilled) traps.

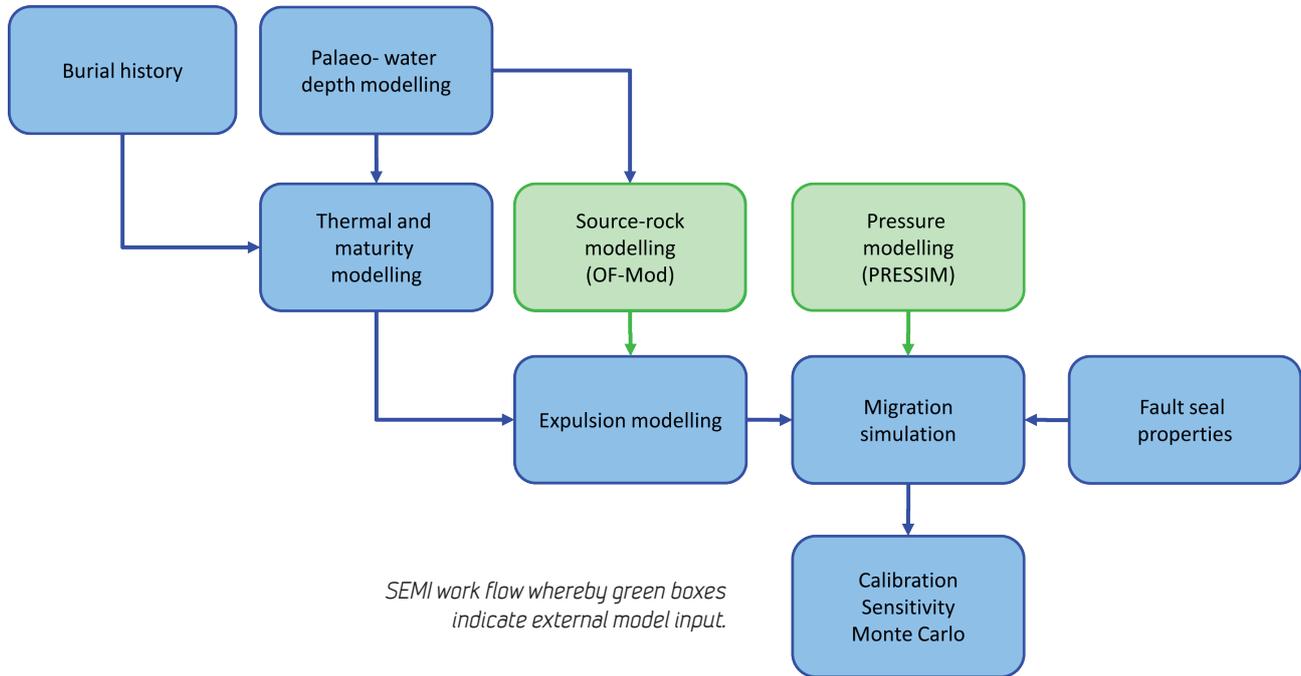
A quick-look analysis can be performed with SEMI Light, which provides results within one hour, employing a minimum of input data. A full SEMI model typically requires at least a few days for calibration, and sensitivity and risk analyses.

A scripting language is implemented to provide a flexible model build environment and to perform advanced and complex simulation runs (e.g. Monte Carlo sensitivity analyses).



The intention of SEMI is that all available data and concepts can be used in the building of the geological model and the representation of the hydrocarbon system. New information (e.g. new wells) can be incorporated easily

into existing models, allowing for efficient re-usage of older set-ups. It is also easy to import results from other basin modelling tools and thus take advantage of existing mapping and modelling work.



Input

Required input data needed for model building include seismic interpretation results such as depth maps and fault polygons as well as thermal history. If available, input including but not limited to, structurally restored horizons (3DMove), carrier and source rock properties, kinetic models for kerogen transformation, and overpressure histories can be used.

Multiple import formats are supported (e.g. Irap, ZMap, CPS-3 and xyz format).

Geological model construction

Geological model building facilities in SEMI include a module for palaeo-water depth reconstruction using interpreted seismic horizons. Palaeo-bathymetry is used to constrain the structural basin evolution in conjunction with burial histories determined by vertical decompaction of a series of (present-day) depth maps.

The PRESSIM module simulates overpressure evolution in pressure compartments bounded by low-permeability faults. Overpressure build up is caused by shale compaction and sandstone diagenesis, while a fault transmissibility model dissipates the overpressures laterally between compartments.

Source

Source rock property distributions (e.g. modelled using SINTEF's organic facies modelling tool OF-Mod) are used in the generation and expulsion modelling.

Transformation of kerogen to oil and/or gas is determined using kinetic schemes and is based upon geothermal histories. Grid-based vitrinite reflectance computations are also implemented. Other first order kinetic models can be added by the user. Multi-component kinetic maturation models can also be utilised.

Expulsion from the source rock is calculated based on the properties mapped or modelled for the source rocks, and on the mineralogical properties of the rock itself. The (multi-component) expulsion model is saturation or adsorption dependent, and includes cracking of oil that remains in the source rock.

Migration

SEMI secondary hydrocarbon migration is the engine in the system. Flow is simulated in multiple layers, with up to 2 million grid cells per layer. Migration and associated losses of oil and gas are modelled along the top of a (decompacted) carrier bed. The carrier bed topography may change during burial, causing creation and/or destruction of traps during the modelling. In multi-component mode, 10 hydrocarbon components can be migrated simultaneously.

Secondary migration column heights, velocities, average hydrocarbon saturation and loss distribution are computed for migration pathways. Saturation dependent relative permeabilities are determined from simulated oil and/or gas flow-rates.

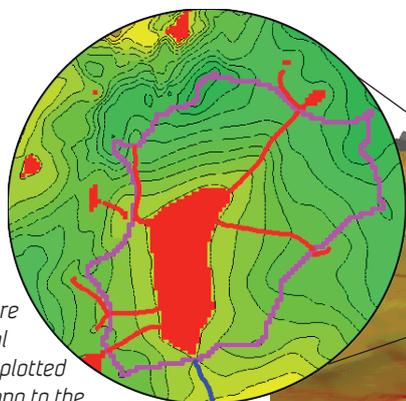
Flow path determination is based on a steepest ascent method ("ray-tracing technique"), and includes the blocking effects of fault seals and carrier bed pinch-outs.

Hydrocarbons can leak vertically to a shallower layer if no seal is present, or along faults (this includes migration from a younger to an older layer).

Overpressure distributions within the carrier bed can be simulated on-the-fly or imported from external sources (e.g. PRESSIM).

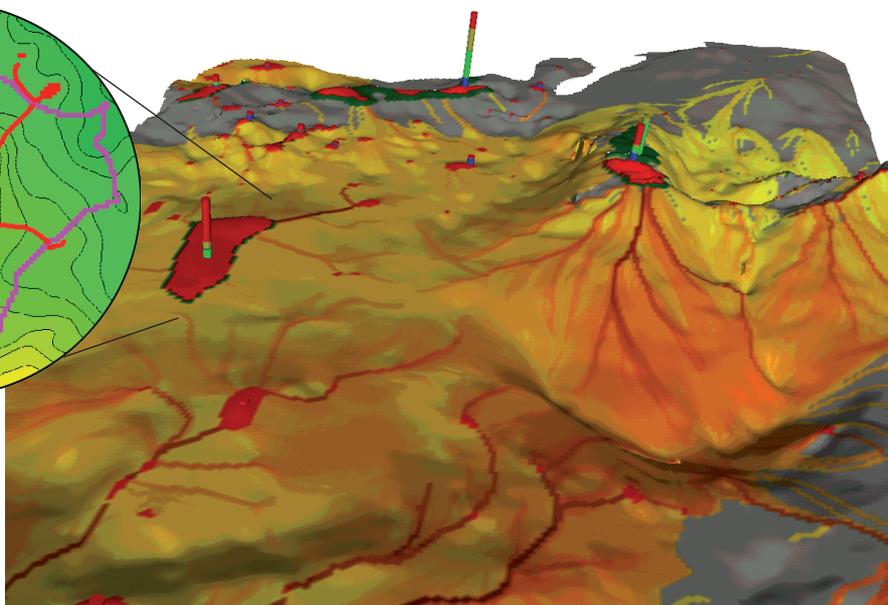
Several built-in functions are available for analysing the migration, both to determine where the hydrocarbons are coming from, and to investigate how sensitive the trapping of hydrocarbons is to alternative spill points in the traps. The sensitivity of migration patterns and spill paths can be analysed from flow path and drainage area information during migration.

Information from regional simulation runs can be used for more detailed simulations in a smaller area.



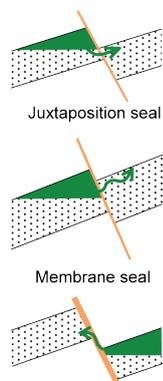
Example of a gas trap with its associated drainage area (pink). Spill paths into the trap are shown in red, the potential spill path from the trap is plotted in blue. Contour lines belong to the structural depth map.

Gas flow rate map with green to red colours indicating low to high flow rates, respectively. Oil and gas entrapment are displayed in dark green and red colours. Colour coded columns show the phase composition of the traps.



Faults

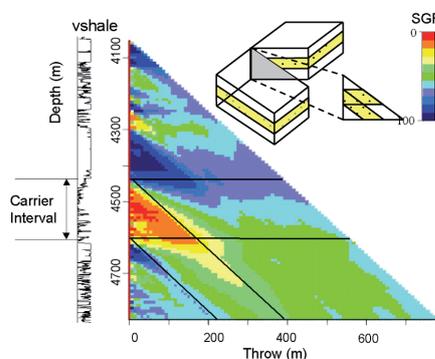
Faults are an important factor in determining flow paths and traps, and SEMI includes the definition of different fault types and properties. Sealing options include juxtaposition, membrane and along-fault sealing, as well as a shale gauge ratio (SGR) approach for defining sealing properties. Regional shale gauge ratios are calculated based on well log information and the corresponding fault seal potentials are given as the equivalent hydrocarbon column heights for a specified hydrocarbon density. Fault seal properties and the fraction of vertical leakage along faults can be changed through time (e.g. as a result of tectonic activity).



Along fault flow (vertical)

Left hand side: Different styles of fault sealing/leakage.

Right hand side: Example of a shale gauge ratio diagram used to define fault sealing properties.



Traps

SEMI models the changes of hydrocarbon composition inside traps. These changes include cracking of oil into gas (cracking of component groups when using multi-component system), and biodegradation.

Traps themselves can change when the carrier bed configuration changes, so SEMI models spill and associated losses of oil and gas from traps through time. Trap capacities change as a function of increased burial, due to decreasing carrier bed porosity and thickness and/or as a result of structural reorientation (basin inversion, regional tilt, uplift etc.).

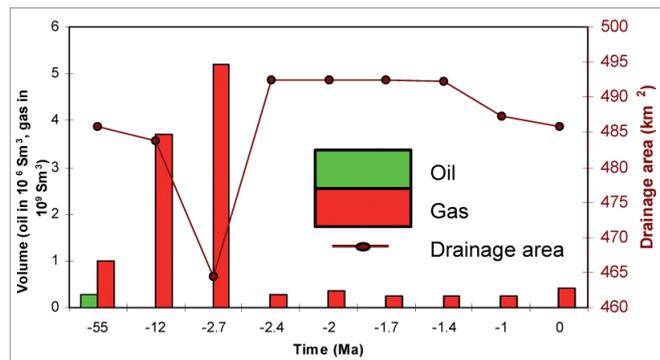
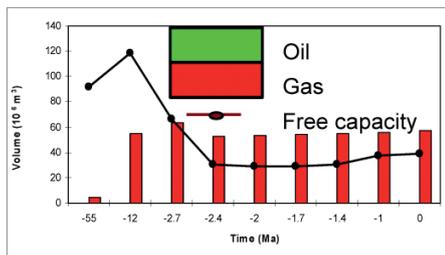
Output

The majority of modelled parameters are stored as grid files that may be plotted in 2D or 3D, and can be exported as grid or images files (e.g. Irap, Zmap, Postscript or TIFF).

Spill and leakage take place in response to changes in entry pressure, faulting or excessive overpressure. Cap rock sealing and leakage processes are modelled either as capillary leakage based on hydrocarbon column heights (simplified model), or as hydraulic leakage resulting from excessive overpressures. The hydrocarbon column heights are included in the pressure calculations, causing gas traps to leak more easily than oil-filled traps.

Many trap properties are recorded during simulation, including trap geometries, hydrocarbon volumes, gas and oil densities, GOR, CGR, and hydraulic capacity of a trap, expressed as the maximum hydrocarbon column height the individual traps can maintain.

Tabular data for each trap can be extracted for each time step modelled. The tables contain up to 50 parameters for each trap.

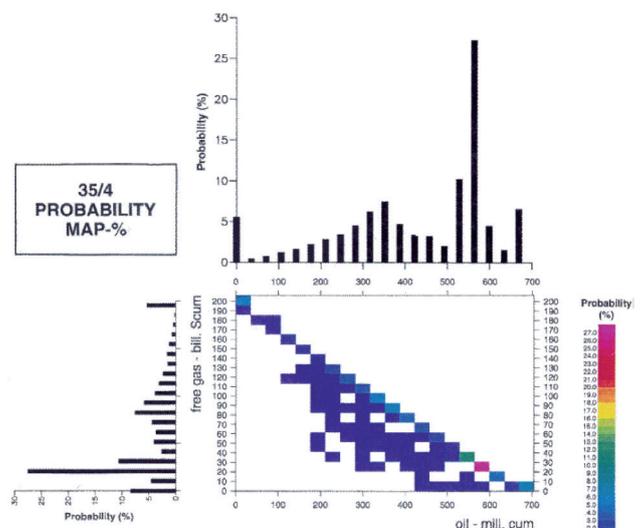


The left graph shows a history plot of entrapped hydrocarbon volumes for a particular trap. The right hand plot shows the volumes of hydrocarbons that move into a trap from the corresponding drainage area over time.

Monte Carlo simulation

SEMI can run Monte Carlo simulations to assess uncertainties in modelling. Most user variables in SEMI can be described by probability distributions. When running SEMI in the Monte Carlo mode, new values of each variable will be sampled from corresponding distributions. Sensitivity analyses can be performed e.g. by systematically varying single input variables.

Probability cross plot of oil and gas entrapments within a particular trap derived from SEMI Monte Carlo simulation runs.



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