Programme for:

A 3 day Geochemistry and Basin Modelling course

To be held at

IGI's offices, Bideford, Devon EX39 5HE

Tuesday 4th – Thursday 6th May 2010

By:

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Tuesday 4th May: PETROLEUM SOURCE ROCKS

9.00 – 9.45 Introduction to geochemistry (Intro)

Petroleum geochemistry is best understood in terms of 5 geologically-driven processes, viz. source rock deposition, burial and maturation, oil and gas generation, migration and entrapment, and survival to the present day. Together with the volumes generated and trapped, timing and the range of hydrocarbon types, all major areas of risk in exploration and production can be addressed. This module introduces these key concepts so that they can be developed and built upon during subsequent modules.

10.00 – 10.45 Source rock deposition (SR Depo)

Hydrocarbon source rocks are characterised by abundant organic matter of an appropriate type. The type of organic matter normally depends more on the survival rates of various components rather than the intrinsic bioproductivity of the environment. Environments range from delta-top coals accumulating with humic acids under oxic conditions and high sedimentation rates to sub-aqueous accumulations with more modest sedimentation rates compensated by reduced dissolved oxygen levels (‘anoxia’). The mechanisms promoting anoxia are discussed and bacterial respiration, sulphate reduction and fermentation processes contrasted. Deposition in carbonate environments typically produces very rich high quality source rocks in restricted platform depressions. Combining anoxia & sedimentation rate, palaeogeography (plate tectonics) and particle hydrodynamics, source rock predictions can be made on a global scale and through time.

COFFEE BREAK

11.30 -12.30 Source rock characterisation (SRID)

Kerogen quantities (TOC), and classifications based on microscopy (terminology and equivalences) and Rock-Eval pyrolysis are discussed in terms of the techniques and standard interpretation plots. Microscopy is based on visual inspection and defines more than 12 different types of particle which can be broadly grouped as oil-prone liptinites, gas-prone vitrinites and dead carbon or inertinite. In contrast Rock-Eval pyrolysis gives a bulk measure of the average properties of the rock, defining oil-prone Type I (algal), oil-prone Type II (bacterially degraded algal, land plant exinites or mixes), gas-prone Type III (ligno-cellulosic land plant tissues, vitrinite) and dead carbon Type IV (fossil charcoal or inertinite). Confirmatory evidence from pyrolysis-gas chromatography is recommended. Kerogen type can be generalised in terms of mapping organo-facies.

LUNCH

13.30 – 14.15 Introduction to modelling (IntroMod)

Modelling is introduced by comparison of the scope, building times, running times, flexibility of calibration and approximate current costs of 1-D, 2-D and 3-D commercial packages. Burial history plots based on 1-D models are discussed in terms of thermal geohistory and calibration against measured temperature and against measured maturity parameters. Maturation and generation windows may then be displayed on the burial history plot, with limits being placed on the timing of generation. Adding TOC values and kerogen (kinetics), produces a generation plot, showing quantitative generation (mg/gTOC, kg/tonne or bbls/acre.ft) as a function of geological time. The relationships to 2-D and 3-D modelling are briefly covered.

14.15 – 15.45 *Workshop 1 - Entering your simple model*

COFFEE BREAK

16.15 – 17.00 Model input - time & temperature (InMod)

The input of litho-, bio-, and chronostratigraphy to 1-D models is addressed in terms of stratigraphic tops (±datum levels) and thicknesses. The time/age equivalents of various American and European timescales are discussed and the implications of choices addressed. The addition of lithologies to each stratigraphic unit allow the modelling of (de)compaction and hence heat flow modelling. This is followed by a critical discussion of the commonly available compaction options and the implications of choices. The entry of present surface temperatures and the Horner correction of wire line log temperatures may be used to undertake geothermal gradient or heat flow modelling, with the modeller reconciling the differences. Constraints on palaeo-surface temperatures and palaeo-heat flow values are reviewed.

Wednesday 5th May: PRINCIPLES OF MATURITY MODELLING

9.00 – 9.45 Calibrating models with respect to temperature (T-Cal)

As input data are refined, the concept of a cycle of calibration and re-calibration is introduced. This emphasises what is reasonable to change and what is not, in order to obtain a thermal calibration against (corrected) bottom hole temperatures. The benefits of gradients versus heat flow modelling are revisited, and the sometime paradoxical effects of unconformities on heat flow modelling are introduced. The effects of rapid changes in heat flow (crustal stretching, hydrothermal pulses), changes in sedimentation rates and rapid uplift (unconformities) on temperature transients are illustrated. The modelling of igneous intrusions and hydrothermal flow is addressed using delta heat and delta thickness functions. Deep modelling introduces the increasingly recognised effects of radioactive heat within the crust. The effects of temperature on the maturity and generation outputs of the modelling are investigated using various sensitivity analysis approaches.

10.00 – 11.30 *Workshop 2 - Adding lithologies to a model & heat flow*

COFFEE BREAK

12.00 – 12.45 Measured maturity parameters (MeasMat)

Maturity is contrasted with inorganic metamorphism and generation. Vitrinite reflectance measurement procedures are discussed in terms of data quality (microscope standardisation, what to measure, number of particles measured and standard deviation of each reflectance population).Interpretation is then addressed for individual samples (contamination, bitumen, ‘in situ’ and reworked particles), and using depth plots at the single well and multi-well basin-wide scales. Errors are discussed. The effects of unconformities (uplift and erosion), igneous intrusions and hydrothermal flux on reflectance profiles are illustrated. Other maturity parameters such as spore and kerogen colour (SCI1-10 & TAI1-5) and Rock-Eval Tmax are discussed as calibrants for basin modelling.

LUNCH

14.00-15.30 *Workshop 3 - Maturity calibration options*

COFFEE BREAK

16.00 – 16.45 Calibrating against measured maturity (MCal)

Calibrating against measured maturity parameters such as vitrinite reflectance, Rock-Eval Tmax and spore colour is at the heart of good modelling. standard cross-correlations between these parameters are critiqued, with the conclusion that they need to be checked with local data prior to their use for calibration. The modeller needs to gain a 'feel' for the model, with intuition as to how a change in input will affect the output. At the basic level, changes in heat flow and hence temperature gradients (given thermal conductivities) are seen to rotate maturity-depth trends, this being contrasted with the effects of variable amounts of uplift and erosion which translate the maturity-depth trends. The possibility of calibrating against molecular and isotopic parameters is introduced. In addition to geothermal controls, the effects of stratigraphy and tectonic inversion on the maturity and generation outputs of the modelling are investigated using various sensitivity analysis approaches.

Thursday 6th May: CALIBRATING YOUR MODEL

9.00 – 9.45 Maturity modelling history and kinetics (ModHist)

History of modelling concepts is investigated by following the sequence depth ? temperature ? Effective Heating Time ? TTI ? single value kinetics ? distributed value kinetics ? n-component kerogen kinetic networks. The intellectual progression from Lopatin-TTI modelling to the use of the Arrhenius equation (activation energies and frequency factors) is followed and the central position of the Transformation Ratio is emphasised. The importance of calibration procedures is elaborated upon, with advice on establishing local calibrations of kinetically-derived Transformation Ratios against measured Rock-Eval and extract depth trends. The basis for the Lawrence Livermore (LLNL) and Easy-Ro methods for the kinetic calculation of vitrinite reflectance is reviewed.

10.00 – 10.45 Generation of oil and gas (Gen)

Generation, as opposed to maturation, is measured in terms of kerogen conversion (Transformation Ratio) and should be used to define the oil and gas windows. screening Rock-Eval or solvent extract data, the process can be monitored using the properties of the residual kerogen or from measurements of the masses (volumes) of generated oil or gas. The scaling problem of moving from a gram of source rock (Rock-Eval) to basin-scale volumes is identified. Generation is a kinetically controlled process, being a function of the effects of both temperature and time on the breakage of the kerogen's chemical bonds. It can be modelled (Basin Modelling) using simple reactions or networks of competing or sequential reactions. A quantitative understanding of generation (in addition to maturation and expulsion) is essential for successful prospect evaluation.

COFFEE BREAK

11.15 – 13.00 *Workshop 4 – Kerogens and generation*

LUNCH

14.00 – 14.45 Expulsion of hydrocarbons (Expel)

Expulsion is the first step in moving generally monophasic hydrocarbon (oil & gas) from the organic kerogen matrix and through fine grained source lithologies (claystone, coal, micrite) via silty laminae or fractures within the source rock interval to the secondary migration conduit. Though we can define the efficiency of the expulsion process relatively accurately, there is no clear consensus concerning the mechanism(s) involved. Currently fashionable front runners include permeable silty interbeds; transient micro-fractures; capillary movement through a kerogen wick within the source rock; diffusion down a concentration gradient away from kerogen particles; pressure driven flux of monophasic 'oil' via stylolites (carbonates). Expulsion efficiencies are calculated from pyrolysis or extract yields and commonly lie in the 30-70% range, increasing to 100% with extreme maturity (graphitic schists).

15.00 – 15.45 Migration of oil and gas (Migr)

Migration is the process by which expelled oil or gas moves from the source rock to the reservoir, from reservoir to reservoir (remigration), or from reservoir to the surface (dismigration or leakage). Once oil has left the source rock (expulsion) three progressively less important processes are involved in the movement of hydrocarbons: buoyancy due to density contrasts in the formation fluids; movement limited by capillary pressures; movement along pressure potential gradients. The mechanisms of, and scales at which, these processes work are currently the subject of debate. Current models envisage migration as occurring in focused conduits, either through an oil-wet network within porous beds or through faults. A description of 'braided rivers of oil' may be applied. Mainly propelled by buoyancy, migration can be a relatively efficient process, though models are only semi-qualitative.

COFFEE BREAK

Final review of principles of maturity modelling & geochemistry

16.15 -17.00 Calculation of charge to trap – a worked example (Charge)

The reduction of exploration risk is discussed in terms of quantifying petroleum systems.Calculation of oil and gas charge in terms of source rock yields, volumes and timing are based on the efficiencies of generation, expulsion, migration, entrapment and leakage.Workflow for Quantitative Prospect Evaluation is described in the context of regional geology, defining source rock, and calculating initial yield; establishing measured maturity-depth trends, calibrating models and predicting generation; defining source rock kitchens; estimating migration efficiencies; calculating prospect charge; and predicting in-place volumes and properties.The final step is to compare the predictions with the bulk molecular and isotopic properties of the oils and gases discovered.

Discussion & Conclusions