OPTIMIZATION/INVERSION — A TECHNIQUE TO EFFICIENTLY AND EFFECTIVELY CALIBRATE PETROLEUM SYSTEM MODELS

J.E. Leonard[1] (*); S.M. Stoufer[1]; M.W. Titus[1]; C. Hermanrud[2]

[1] Platte River Associates, Inc; 2790 Valmont Road; Boulder, CO 80304; USA; (*) j.leonard@platte.com
[2] Statoil; Research Centre; Arketikt Ebbelsvei 19; Trondheim 7550; Norway

Optimization/inversion is an advanced technique widely used in science and engineering to efficiently and effectively calibrate a model to measured data. Traditional petroleum system model calibration techniques such as trial-and-error and linear search methods can prove time consuming and subjective, especially when used for complicated models. With the large numbers of wells and associated measured data available today, computerized optimization has the potential to become a valuable tool for petroleum system model calibration.

An adaptive simulated annealing (ASA) inversion algorithm is used to determine the input parameter values that produce a model most closely matching the measured data. This process allows simultaneous, automated calibration of a large number of models to measured bottom hole temperatures, maturity (%Ro), pressure, porosity, and permeability (Figure 1).

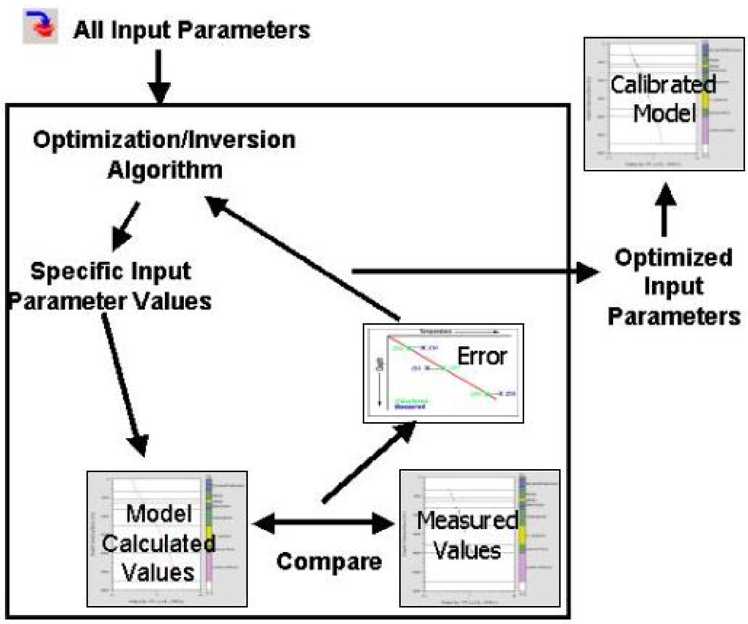

Figure 1: The optimization process in petroleum system modelling: Input parameters (porosity, thermal conductivity, etc.) are selected; limits on the values of the parameters can be incorporated; model values are calculated based on the parameters selected and compared with the measured values; an error is determined and, using the ASA method the process iterates looking for the global error minimum. Once determined, the optimized model is available.

The error calculated by this process is a quantitative measure of the magnitude of difference between modelled and observed data. For 'n' input parameters, the error surface is an (n+1) dimensional surface $y = f(x_1, x_2, \ldots, x_n)$, where $x_1, x_2, \ldots, x_n$ are the input parameters, and y is the error. The inversion algorithm iteratively adjusts values of forward model parameters (e.g. lithologic, thermal, stratigraphic, diagenetic) to improve the match between predictions and observations until a best match (global minimum error) is located (Figure 2).

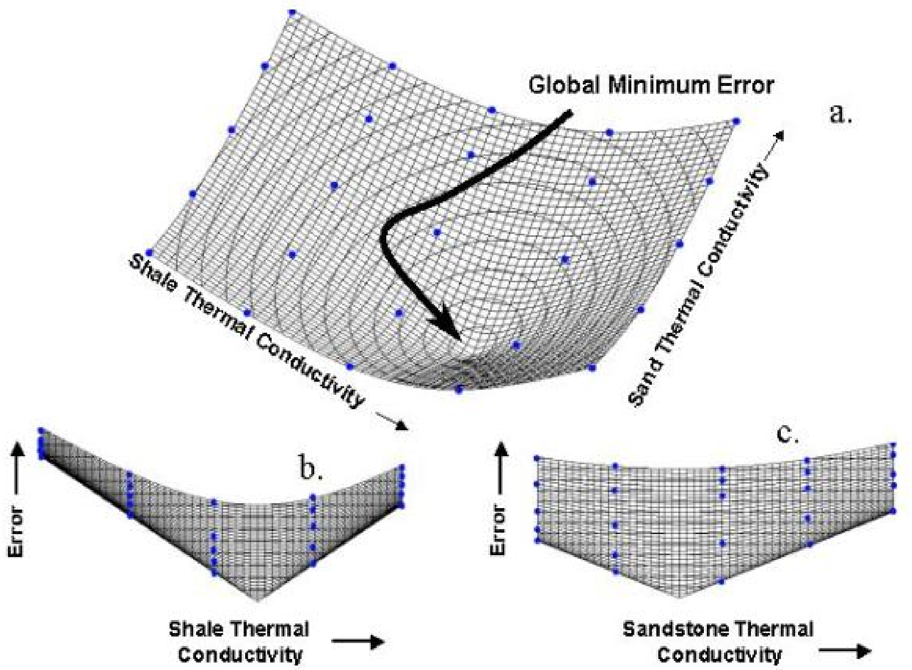

Figure 2: An error surface for a two parameter model – shale thermal conductivity and sand thermal conductivity. (a.) A three dimensional view of the surface. The vertical axis is 'Error'. The global minimum error is represented at the top of the arrow. (b.) A cross-section through the surface with the axes 'Error' and 'Shale Thermal Conductivity ' displayed. The shale conductivity value providing the minimum error is at the apex of the figure. (c.) A cross-section through the surface with the axes 'Error' and 'Sandstone Thermal Conductivity' displayed. Again, the value yielding minimum error is evident. This optimization model has a unique solution for these two parameters, hence the cone 'error' surface.

We use a well set from the North Sea for which there are a variety of measured data (including temperature, maturity, porosity, and pressure). The inversion calculation yields optimized values of thermal parameters such as heat flow and thermal conductivity, which provide a good match of calculated to measured data. We then use the process to calibrate pressure data in the area. Computerized optimization streamlines the calibration process and enables quantitative determination of default parameters affecting the petroleum system model.