Basin Temperature Modeling using large Bottom Hole Temperature Datasets

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Abstract

Subsurface temperature is a key parameter in development of conventional, unconventional hydrocarbon and geothermal resource plays.

There are two main methods of estimating rock temperature from Bottom Hole Temperature (BHT) datasets data:-

- For small datasets, average temperature gradient is calculated between two or more uncorrected BHT/depth control points. A linear relationship is generally assumed between the ambient surface temperature and BHT temperatures at other depths within the well-bore are determined by interpolation. More advanced techniques use measurements of increasing temperature with increasing time since (mud) circulation (TSC), to extrapolate the temperature at static conditions (eg Horner method).
- For large datasets, regression techniques have commonly been used to correct BHTs and to calculate geothermal gradients. Corrections (usually functions of depth) are applied to raw BHTs to derive "real BHT's". Corrections are based on the relationship between relatively small numbers of fluid flow temperatures (DSTs, RFTs) and the depth average of larger raw BHT datasets. Different depth based equations have been derived for many basins in the Onshore USA.

There a number of problems with the regression based approach:

1. Basins are not flat or lithologically uniform, so there is no reason why corrections should be related to depth alone.
2. The method averages all BHT data with equal weight; short and long TSC data are treated equally
3. The resultant correction, although providing an average temperature which may be acceptable, implies corrected BHT's that are hotter than likely temperatures, which is physically dubious

A new methodology for basin temperature modelling has been developed that utilizes large volumes (~10,000 points) of properly indexed and QC'd BHT data for an onshore basin or area. This methodology honors the observation that borehole temperatures equilibrate, increasing towards formation temperature with elapsed time since fluid circulation. We thus use the maximum BHTs recorded in a layer (normalized for depth) or cell, rather than a corrected average regression based model.

Two methods have been developed to construct a present day temperature geo-cellular volume (cube). In the MaxG cube, we first define a depth varying interval geothermal gradient (IGG) function that defines the maximum envelope of the BHT cloud for each major lithostratigraphic unit. We then construct the temperature cube by stacking the IGGs for all the units in the basin. In the second MaxBHT method, with sufficiently dense data, we use the maximum BHT within each cell to populate the temperature cube. If we are lacking data in a cell, we can infill the voids using the MaxG cube values or a moving average.

The concept is illustrated with examples from the Greater Permian Basin.