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The Hercynian Unconformity in Saudi Arabia - Quantification of Erosion and the Associated Uncertainty through Monte-Carlo Analysis of Maturity Profiles

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Abstract

Uplift and erosion is an important process in a sedimentary basin as it may dramatically affect subsurface properties, such as temperature and pressure (Allen&Allen, 2005). Among the various methods that exist to quantify the amount of missing section, the analysis of maturity profiles using the method of Yamaji (1986) is most widely used. This method is based on the intercept of a line of best fit through the vitrinite reflectance data and the baseline of immature vitrinite at 0.2 % R_0, as shown in figure 1. While this method provides a realistic estimate of the mean value of the amount of missing section, the range of uncertainty is not considered.

In petroleum systems modeling, the thickness of sedimentary layers as well as their eroded thickness is a key input parameter. Today, stochastic simulations of basin evolution are the standard. This requires the definition of ranges of uncertainty of input parameters such as the eroded thickness.

The method presented here uses a Monte-Carlo simulation to determine the probability distribution of eroded thickness for vitrinite reflectance data and the associated standard deviation values. A Matlab®-tool has been developed to perform a stochastic curve fit of depth vs. log-scaled R_0 data, whereby the actual curve fit is performed numerous times. Each curve fit varies the R_0 data with a probability according to the mean and standard deviation. The difference between the intercept of the fitted curves with the baseline of immature vitrinite reflectance at 0.2 %R_0 and the depth of the unconformity yields the amount of missing section. The stochastic variation of input parameters results in a systematic variation of erosion data. Characteristic properties such as the mean, the P_{10} and the P_{90} probability of erosion are determined by fitting a normal or log-normal distribution to the erosion data.

The example shown here is from the Paleozoic of Saudi Arabia. The maturity of Silurian sediments suggest a significantly higher heat flow prior to the Hercynian unconformity compared to the present day heat flow, as shown in figure 1 (Marshall, 1995). The decrease of the post-Hercynian heat flow is so strong that the post-Hercynian burial did not overprint the Silurian maturity profile. Therefore, the method of Yamaji (1986) for the calculation of missing section is viable and gives an eroded thickness of 610 m, a value also reported by Marshall (1995). Figure 2 shows the application of the stochastic approach. It yields a normal distribution of erosion thicknesses for the well NYYM-2 in central Saudi Arabia. The mean value of 650 m of erosion is associated with an uncertainty of 500 m (P10) and 790 m (P90). This information may directly be used in basin modeling to evaluate the impact of erosion and the associated uncertainty, e.g. on the timing of the petroleum system.