Estimation of the amount of eroded section in the partially exhumed Colville Basin of the Alaska North Slope using geophysical logs

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Burial and thermal history modeling of partially exhumed sedimentary basins requires estimation of the amount of section deposited and later eroded. For the Colville Basin in northern Alaska, we have developed a method for estimating erosion based on porosity-depth trends observed in well data. Commonly, vitrinite reflectance and fission-track thermochronologic data are used for estimating exhumation, and both data types have been used in this region. However, differences between multiple vitrinite data sets for the same well and scatter in individual data sets, including apparent vitrinite recycling, often result in large uncertainties in erosion estimates, and the available fission-track data are too sparse for regional interpolation. Moreover, reliance on thermal techniques creates interdependence between the amount of eroded section and the thermal parameters used for modeling, thereby complicating the modeling process by increasing the number of dependent variables.

As an alternative to thermal methods, we estimated erosion in the Colville Basin from porosity-depth trends in porosity measurements on core and in porosity logs derived from sonic and gamma ray logs. Initially, we analyzed porosity data from coastal and offshore wells where minimal erosion has occurred since the maximum depositional thickness was attained at the end of Brookian foreland deposition. Porosity reduction, assumed to incorporate both compaction and cementation, was defined as a function of burial depth and lithology by fitting exponential curves to the porosity logs, subset by lithology. Subsequently, these porosity reduction functions were applied to wells in parts of the basin that have undergone significant erosion since the maximum depositional thickness was attained. For each well, modeled porosity values based on our porosity reduction functions were compared to the porosity log from the well. We minimized the misfit between the modeled and observed porosity values by varying the amount of section assumed to have been eroded from the top of the sedimentary column. The result is an estimate of denudation at the well location since the time of maximum accumulation of the Brookian sequence.

The estimated amounts of denudation for the North Slope range from more than 10,000 feet in parts of the southern foothills to ~4000-8000 feet in the northern foothills and southern coastal plain, ~1000 feet along the northeast coast of the National Petroleum Reserve-Alaska, and 0 feet in the northeastern state lands adjacent to the Arctic National Wildlife Refuge. We estimate the uncertainty of these values to be better than +/- 10% in the majority of wells assessed. Where fission-track and reliable vitrinite data are available, thermal-based estimates provide a check on our erosion estimates, and comparison shows close agreement. However, the relatively large number of sites assessed with our method provides a higher spatial resolution of denudation estimates than was previously available. In addition, our erosion estimates are based on data that are independent of the thermal evolution of the basin, allowing implementation in thermal history modeling as independent variables.