Tertiary Uplift in the Northern National Petroleum Reserve in Alaska (NPRA) - Geology, Timing, and Influence on Petroleum Systems

Houseknecht, David W.[*1]; Bird, Ken J.[2]; Burruss, Robert C.[1]; O'Sullivan, Paul [3]; Connors, Christopher [4]
(1) USGS, Reston, VA.
(2) USGS, Menlo Park, CA.
(3) Apatite to Zircon, Inc., Viola, ID. (4) Geology, Washington and Lee University, Lexington, VA.

A broad, post-mid-Cretaceous uplift is defined in northern NPRA by truncation of Cretaceous strata beneath the Plio-Pleistocene "Gubik unconformity," stratal dip, thermal maturity patterns, and amounts of exhumation. Progressively older strata are truncated westward beneath the unconformity, from the Paleogene Sagavanirktok Formation at the Colville River delta to the Albian uppermost Torok Formation at Point Barrow. The uplift extends westward beneath the Chukchi shelf along an axis that trends 290-295° and is more than 100 miles wide (south-north). Stratal dip and the truncation pattern of topset seismic reflections in the Albian Nanushuk Formation indicate that the uplift is asymmetrical, with a steeper northern limb. Nanushuk beds dip 0.5-1° on the south flank (north of the foothills fold-thrust belt), 1-2° on the east flank, and 4-7° on the north flank, where a clearly defined angular unconformity between Plio-Pleistocene and Cretaceous-Paleogene strata is evident on seismic data just below the sea floor of the inner Beaufort shelf.

Estimates of the amount of uplift and erosion range from less than 1,000 ft at the Colville River delta to perhaps more than 7,000 ft along the northwestern coast of NPRA, between Point Barrow and Peard Bay. These exhumation estimates are based on analysis of regional stratigraphy, compaction curves derived from sonic logs, vertical and lateral thermal maturity trends, and apatite fission-track (AFT) data. AFT analysis of samples from three wells (South Meade, Topagoruk, and Ikpikpuk) across the eastern flank of the uplift indicates Tertiary cooling in two pulses. Cooling was initiated at 75-65 Ma and continued through the Tertiary, with accelerated cooling starting at 35-15 Ma.

The origin of the uplift is enigmatic. Although it overlaps older positive structural elements (Barrow high, Meade arch, Alaska rift shoulder, and Barrow arch), evidence of a genetic link is lacking. Nor is the geometry and magnitude of the uplift consistent with a flexural origin related to Brooks Range tectonic loading. The uplift appears to form the eastern end of a huge area of elevated basement and thin to absent Cretaceous-Tertiary strata extending west-northwestward to the North Chukchi High, and the timing of the uplift is coincident with right-lateral trans-tensional faulting in the Hanna wrench-fault zone. New marine seismic data north of NPRA reveal growth strata above basement-rooted faults north of the Beaufort shelf edge. Ongoing analysis of these data may provide insights on the origin of the uplift.

The northern NPRA uplift, which post-dates oil generation in NPRA by >10-20 my, significantly influenced petroleum systems. The regional distribution of oil and gas in sub-LCU (Lower Cretaceous unconformity) and older reservoirs, gas isotopic composition, and oil seeps are spatially correlated with uplift magnitude. Uplift and erosion likely caused a decrease in confining pressure on subsurface fluids, resulting in

expansion of free gas and degassing of oil in reservoirs, and degassing of formation water. Moreover, the southeast part of the uplift may have provided northward migration pathways for voluminous gas originating in and beneath the foothills fold-thrust belt, resulting in a “gas flush” through the region of maximum uplift, likely displacing oil from sub-LCU reservoirs. Strata above the LCU do not appear to be influenced in a consistently similar manner, suggesting that shale overlying the LCU acted as a vertical barrier to the gas flush.