Brookian tectonic – sedimentary nexus, Arctic Alaska

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Integration of widely accepted geological inferences with new observations from subsurface and surface studies in the Colville basin provides a basis for interpretation of tectonic influences on Brookian sedimentation. This work considers an area extending approximately 700 miles from the Herald arch to the Canadian Beaufort Sea. The width of the study area ranges from more than 200 miles in the west to about 50 miles in the east, a reflection of the eastward convergence of the Barrow arch and the Brooks Range. Significant links inferred from this work-in-progress are offered as working hypotheses.

During the late Paleozoic and Early Mesozoic, Arctic Alaska, part of the northern margin of North America, was the site of passive-margin sedimentation above a basement composed of highly deformed, mostly metasedimentary rocks. Early phases of passive-margin sedimentation were influenced by synsedimentary, basement-rooted normal faults. Some of these fault systems are oriented approximately parallel to the ancestral continental margin, resulting in abrupt, basinward increases in thickness of passive-margin strata, whereas others are oriented approximately perpendicular to the ancestral continental margin, resulting in grabens and half-grabens that cut across regional strike. Subsequently, some of these fault systems influenced Brookian contractional deformation and/or were reactivated as reverse, transpressional, or transtensional faults during Brookian deformation.

Following an episode of failed rifting in the late Jurassic, Arctic Alaska (including the Chukotka Peninsula of Russia) rifted from North America during the Hauterivian, and a thermally elevated rift shoulder (Barrow arch) developed along the northern margin of the Arctic Alaska microplate. More-or-less simultaneously with rifting, the southern margin of the Arctic Alaska microplate, presumably attached to a southward-subducting slab of oceanic lithosphere, was overridden by one or more oceanic arc terranes, thus initiating the Brooks Range orogeny and the development of a foreland fold-and-thrust belt. The combined effects of subduction flexure and the obduction of arc terranes onto the southern margin of Arctic Alaska initiated the development of the Colville foreland basin into which the earliest Brookian sediments (Okpikruak Formation) were deposited. The apparent concentration of obduction along the southwestern margin of the microplate (western Brooks Range and Chukotka) may have induced far-field peripheral effects expressed as greater uplift along the eastern part of the Barrow arch.

During the Aptian – Albian, voluminous foreland basin deposits accumulated in the western Colville basin (Chukchi Sea and western North Slope), while the hinterland was undergoing extensional uplift, perhaps related to reversal in subduction polarity and subduction rollback. Magmatic belts of this age cut across the accreted terranes of interior Alaska and the Chukotka Peninsula of Russia. Sediment dispersal patterns, which indicate influx from the west and south, and sandstone compositions suggest the bulk of the sediment in the foreland basin deposits was derived from the hinterland, a belt of significant uplift and exhumation. Well-documented uplift in the foreland fold-and-thrust belt during this interval is limited to the Herald arch system, where uplift apparently culminated during the Aptian. Stratal geometries from the Chukchi Sea north of the Herald arch suggest foredeep-type subsidence continued through the Albian and perhaps into the Late Cretaceous. To the east, relatively subtle and indirect evidence of contractional loading along the southern basin margin is provided by stratal geometries of Aptian – Albian foredeep deposits, which record subsidence patterns most likely induced by tectonic loading and which locally suggest the development of syntectonic piggyback basins. Subsidence rates along the southern margin of the basin were sufficiently high that most sediment entering the basin from the south was sequestered in the foredeep, where markedly aggradational stratal geometries indicate high rates of both accommodation and sediment influx. These characteristics contrast with those of coeval strata of the broad foreland, where markedly progradational geometries indicate relatively low rates of accommodation and high rates of sediment influx. A massive shelf-margin failure in the foreland during the Late Albian has been linked to lateral movement along fault systems that originally developed as normal faults during the Late Paleozoic, and may suggest far-field influences of contraction at the southern basin margin.

During the Late Cretaceous and Early Tertiary, the focus of foreland basin sedimentation shifted eastward to the central North Slope. Evidence suggests that the western Brooks Range – Chukotka hinterland continued to be a significant sediment source during the Late Cretaceous, though sediment influx to the Colville basin from this provenance likely was shut off by the extensional opening of the Hope basin during the Early Tertiary. Beneath the Chukchi Sea, north of the Herald arch, Late Cretaceous tephras are likely proximal equivalents of volcanic material that is a significant component of Upper Cretaceous strata of the central North Slope, where Upper Cretaceous stratal geometries suggest sediment influx from the west and south, a continuation of the pattern established during the Aptian – Albian. In Upper Cretaceous strata beneath the central North Slope, massive shelf-margin failures that spatially coincide with thrust fault culminations in underlying strata provide evidence that contractional deformation directly influenced sedimentation northward to within 30-50 miles of the Barrow arch crest. Moreover, stratal geometries immediately basinward of the massive shelf-margin failures suggest that contractional deformation modified accommodation space and caused basinward redistribution of sediment in a pattern resembling lowstand bypass.

During the Tertiary and continuing into the Holocene, Brookian sedimentation shifted farther eastward to the eastern North Slope and adjacent Beaufort Sea and was again initiated in the Chukchi Sea. In the Canning River region, stratal geometries indicate a progressive evolution from predominantly eastward shelf-margin progradation in the Paleocene to predominantly northward shelf-margin progradation in the Miocene. This pattern is inferred to be a consequence of Eocene – Oligocene contractional deformation in the eastern Brooks Range foreland fold-and-thrust belt, and the increased northward influx of sediment from the resulting orogenic highlands. The general timing of this contractional deformation is similar to the relatively abrupt eastward tilt of the Barrow arch that resulted in westward spillage of reservoired oil from Prudhoe Bay, perhaps suggesting a causal relationship. Across the easternmost North Slope, including much of the Arctic National Wildlife Refuge coastal plain and the adjacent U.S. – Canada Beaufort Sea, and starting as early as the Paleocene, a series of north-vergent, thrustcored antiformal ridges that progressively become younger northward have significantly influenced Brookian sedimentation. The synsedimentary growth of these ridges formed trailing piggyback basins filled mostly by shallow marine through nonmarine facies and localized shelf margins along the ridge crests. Tertiary strata in the Chukchi Sea onlap deformed Aptian – Albian strata in sub-basins whose geometries suggest an extensional origin, and the entire stratigraphic column is deformed by transtensional fault systems.

Collectively, these observations suggest that a contractional belt between the hinterland and the foreland basin influenced Brookian sedimentation throughout the Cretaceous and Tertiary. During the Aptian – Albian, the influence was mostly limited to the foredeep, where stratal geometries provide subtle evidence of tectonically induced subsidence. During the Late Cretaceous – Early Tertiary, contractional deformation stepped northward out of the foredeep into the foreland, commonly exploiting fault systems formed during Late Paleozoic extension; these fault systems acted as buttresses and/or lateral stress transfer systems depending on their orientation relative to the contractional belt. As both contraction and sedimentation migrated northward and eastward during the Tertiary – Quaternary, contractional deformation exerted profound and direct influences on sedimentation, as evidenced by piggyback basins and tectonically localized shelf margins in Paleocene – Holocene strata of easternmost Arctic Alaska.