Abstract

A High-Latitude Signature Evidenced by Distinctive, Recurring Facies and Sedimentary-Pedogenic Structures in the Late Cretaceous Prince Creek Formation, North Slope of Alaska, USA

Peter P. Flaig[1], Paul J. McCarthy[2], Anthony R. Fiorillo[3], Dolores, A. van der Kolk[1], Susana Salazar[2]

[1]University of Texas at Austin, Bureau of Economic Geology, Jackson School of Geosciences, Austin, TX, USA
[2]Department of Geology and Geophysics, and Geophysical Institute, University of Alaska, Fairbanks, AK, USA
[3]Perot Museum of Nature and Science, Dallas, TX, USA,

The Late Cretaceous (Maastrichtian) Prince Creek Formation (Fm) is a dinosaur-bearing coastal-plain to lower delta-plain succession that crops out in bluffs along the Colville, Kogosukruk, and Kikiakrorak Rivers of northern Alaska. The Prince Creek Fm preserves an Arctic greenhouse succession deposited at 80-85° north latitude, making it a true paleopolar ecosystem. Herein we suggest that a combination of distinctive, recurring facies and sedimentary-pedogenic structures, found consistently throughout the Prince Creek Fm, are evidence of a high-latitude signature on this low-gradient, muddy coastal plain.

Strata of the Prince Creek Fm record deposition in tidally influenced meandering trunk channels and meandering and fixed (anastomosed) distributary channels, as well as associated floodplain sedimentation (Flaig et al. 2011). Spatial relationships between channels and floodplains indicate that the bulk of deposition in the Prince Creek Fm occurred on crevasse–splay complexes adjacent to trunk channels. Crevassing was common with splay complexes constructed on organic-rich floodplain deposits by the lateral migration of meandering distributaries and the vertical filling of anastomosed distributaries. The reason for frequent crevassing in the Prince Creek Fm distributary system is unknown; however, high concentrations of suspended load due to an abundance of mud and volcanic ash may have been a contributing factor. Floodplain deposition occurred in lakes, ponds, swamps, marshes, and mires and on levees and crevasse splays. Abundant compound and cumulative, weakly developed paleosols similar to modern aquic subgroups of Entisols, Inceptisols and potential acid sulfate soils developed on the margins of lakes and swamps as well as on levees and splays. Ashfall tuffs were also common.

IHS composed of rhythmically repeating, coarse-to-fine couplets of current-rippled sandstone and siltstone or mudstone is found in all channels, and carbonaceous root traces are preserved on both the IHS and on crossbed sets within these channels. The rhythmic and repetitive nature of these coarse-to-fine couplets (IHS) together with relatively thick, muddy fine-grained members in couplets was initially thought to primarily reflect tidal effects in channels (Flaig et al. 2011). Further investigations suggest that the ubiquitous roots on the IHS and on crossbeds may also be evidence for a flashy system and/or a system that experienced regular and possibly drastic reductions in discharge.

Hyperpycnites have recently been identified by van der Kolk et al. (in review) in prodelta deposits of the genetically-linked shallow-marine sediments of the Schrader Bluff Fm. Thick mud drapes on point-bar surfaces (IHS), the presence of abundant fixed (anastomosed) channels, and thick successions of fine-grained floodplain facies found stratigraphically above, below, and interfingering with these channels suggest that channels of the Prince Creek Fm were suspended-load channels (e.g. Smith 1983, Flaig et al. 2011). Estimates of channel dimensions and discharge suggest that these channels fall within the range of other suspended load systems in the Cretaceous Western Interior Seaway that typically produce hyperpycnites (Bhattacharya and MacEachern 2009). The presence of hyperpycnites associated with channels of

the Prince Creek Fm suggest that river systems routinely experienced large seasonal floods and dramatic fluctuations in discharge, possibly related to seasonal climate changes, intense storms, or snowmelt freshets.

Several well-documented dinosaur bonebeds found on floodplains of the Prince Creek Fm exhibit a recurring facies pairing and bipartite division of flow that is consistent with deposition by fine-grained, viscous hyperconcentrated flows (Flaig et al. in press). Hyperconcentrated flows are turbid, two-phase flows intermediate in suspended sediment concentration between streamflows and debris flows (Sohn et al. 1999, Pierson 2005). The addition of even a small amount of clay (e.g. 1-4 weight %) into a streamflow permits electrostatic forces acting between clay particles to increase the viscosity and transform a streamflow into a non-Newtonian hyperconcentrated flow with measurable yield strength (Costa 1988). We believe that exceptional discharge events, possibly generated by seasonal snowmelt from the nearby ancestral Brooks Range and/or large storm events, entrained mud and ash stored on point bars and floodplains, increasing suspended sediment concentrations in rivers and generating recurring erosive hyperconcentrated flows that transported the remains of dinosaurs onto floodplains adjacent to distributary channels (Flaig et al. in press).

Entisols, Inceptisols and potential acid sulfate soils of the Prince Creek Fm are typically drab-colored and contain abundant organic matter, carbonaceous root traces, Fe-oxide depletion coatings, and zoned peds (soil aggregates with an outermost Fe-depleted zone, darker-colored Fe-rich matrix, and lighter-colored Fe-poor center) indicating periodic waterlogging, anoxia, and gleying, consistent with a high water table. In contrast, Fe-oxide mottles, ferruginous and manganiferous segregations, bioturbation, and rare illuvial clay coatings indicate recurring oxidation and periodic drying of these same soils. There is no evidence of cryogenic processes in Prince Creek Fm paleosols. Pedogenic features in compound and cumulative paleosols of the Prince Creek Fm indicate that floodplains were dynamic, and that soil-forming processes were repeatedly interrupted by alluviation, resulting in weakly developed soils. Paleosols of the Prince Creek Fm also contain abundant pedogenic illite/smectite resulting from the illitization of original smectite derived from the abundant volcanic ash deposited on floodplains. Pedogenic clays such as these typically form in a soil environment subject to alternating wetting and drying. Abundant evidence of repeated wetting and drying and frequent influx of alluvial material into paleosol horizons suggests a relationship to a nearby alluvial system with variable discharge that is perhaps affected, at least in part, by seasonal flooding and/or frequent storms.

There is no modern analogue for an ecosystem, such as the one found in the Prince Creek Fm, which experienced relatively warm temperatures under a polar-light regime (Spicer 2003). Although the recurring facies trends and sedimentary-pedogenic structures discussed here, when looked at individually, do not necessarily exhibit a high-latitude signature, when taken as a group of characteristics they most likely indicate a flashy system, with the flashy nature of this system likely driven by extreme seasonally or frequent storms. This fact is probably a reflection of the latitudinal position of Alaska during the Late Cretaceous greenhouse (80-85° N) and its paleopolar light regime. The high-latitude light regime may have allowed for periods of relative inactivity of the distributary system, allowing plants to occupy most channels and soils to become drier. At other times seasonal snowmelt in the Brooks Range and/or seasonal storms triggered floods, which subsequently produced hyperconcentrated flows and hyperpycnites, carved splay channels, and inundated floodplain paleosols with water and sediment. We believe that all of these characteristics are the high-latitude signature in the Prince Creek Fm of northern Alaska.

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