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SEQUENCE STRATIGRAPHY OF A FLUVIAL-LACUSTRINE SUCCESSION IN THE TRIASSIC LOWER CHINLE FORMATION, CENTRAL UTAH, USA

Timothy M. Demko
Department of Geological Sciences
University of Minnesota Duluth
Duluth, MN 55812
tdemko@d.umn.edu

ABSTRACT

The Shinarump, Monitor Butte, and Moss Back Members of the Upper Triassic Chinle Formation, exposed near White Canyon, UT, represent an incised-valley fill succession in a continental depositional setting. Although incised valleys, and the sequence stratigraphic architecture of their sedimentary fill, have been documented in marginal-marine settings, valley-fill successions from continental settings, updip from any base-level influence of sea level, have not been evaluated from a sequence stratigraphic perspective. These three members of the Chinle Formation fill paleotopographic valleys cut into the underlying Lower Triassic Moenkopi Formation. The basal valley surface is a sequence-bounding unconformity. It is marked by truncation of underlying Moenkopi units and extensive pedogenic modification, especially in interfluve areas. The Shinarump Member fills the lowest portions (incised channels) of the valleys. It is a trough-cross bedded conglomeratic sandstone, interpreted to have been deposited as bars within amalgamated fluvial channels. The top of the Shinarump is an extensive lacustrine flooding surface, and therefore the fluvial succession between the basal sequence boundary and this surface is a lowstand systems tract. Greenish-gray mudstones and brown, rippled sandstones of the Monitor Butte Member overlie the lacustrine flooding surface. The Monitor Butte is interpreted as a highstand systems tract, deposited as a prograding lacustrine delta complex that was fed by a rapidly aggrading fluvial system. The top of the Monitor Butte is a sequence boundary, marked either by an erosional surface at the base of the discontinuous Moss Back Member sandstone where it is present, or a well-developed paleosol characterized by distinctive red coloration and carbonate nodules. The Moss Back Member is a trough cross bedded sandstone characterized by large-scale lateral accretion beds. It represents a smaller, inset incised valley cut into the underlying Monitor Butte lacustrine valley fill. The tripartite fluvial-lacustrine-fluvial succession in the lower Chinle valley fill is reminiscent of other documented lacustrine basin fills (rift basins, etc.). However, this valley fill setting is unique and may be a model for other ancient lacustrine deposits not associated with active tectonics.

BACKGROUND AND SETTING

The Chinle Formation was deposited in a broad, fully terrestrial, cratonic basin on the western margin of Pangea, interpreted by (Lawton, 1994) as a dynamic basin created by subsidence due to viscous flow in the mantle associated with the subduction of the Farallon plate and flexure due to supracrustal loading by the associated volcanic arc (Figure 1). The lower part of the Upper Triassic Chinle Formation in the Colorado Plateau region was deposited in an incised-valley system (Stewart and others, 1972; Blakey and Gubitosa, 1983, 1984). In the Four Corners area the Chinle is more than 500 m thick (Dubiel, 1989b). Sediments deposited in the Chinle basin came from source areas in the remnants of the ancestral Rocky Mountains to the east of the basin (Blakey and Gubitosa, 1983; Dubiel, 1994), uplifted Paleozoic rocks and possible arc-related volcanic rocks to the south (Stewart and others, 1972, 1986), and as wind-transported volcanic ash from contemporaneous arc-related eruptions to the southwest and west of the basin (Stewart and others, 1986). Sedimentological evidence, including vertic paleosols and cyclic lacustrine deposits suggest that the paleoclimatic setting of the Chinle basin was characterized by strong seasonality of precipitation, that is, distinct wet and dry seasons (Dubiel and others, 1991).

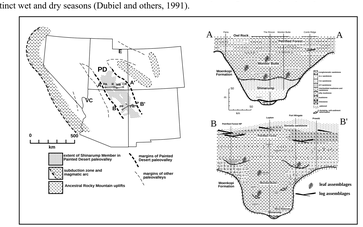

Figure 1. Paleogeographic and stratigraphic setting of the lower part of the Upper Triassic Chinle Formation. Paleovalleys: PD - Painted Desert, VC - Vermilion Cliffs, E - Eagle (after Blakey, 1989, Lawton, 1994, and Dubiel, 1994) . Schematic cross-sections across the Painted Desert paleovalley showing stratal relationships of members of the Chinle to the valley-fill succession (Demko, 1995 and Demko et al., 1998).

STRATIGRAPHY OF INCISED VALLEYS IN THE STUDY AREA

Three major paleovalley systems at the base of the Chinle Formation are recognized in the Colorado Plateau region: 1) the Painted Desert paleovalley (a part of which is discussed in detail this poster); 2) the Vermilion Cliffs paleovalley; and 3) the Eagle paleovalley (Blakey and Gubitosa, 1983; Dubiel, 1994) (Figure 1). In addition several major tributaries to these systems have also been identified and named including the White Canyon, Cottonwood (Blakey and Gubitosa, 1983), Moab, and Temple Mountain paleovalleys (Dubiel, 1994). The major incised valleys were cut into the underlying Moenkopi Formation over most of the Colorado Plateau, and into the Permian and older rocks near the eastern margin of the Chinle depositional area (Stewart and others, 1972). The paleovalley systems are up to 150 km wide and 120 m deep, and individual valleys in these systems are up to 90 m deep and 8 km wide (Blakey and Gubitosa, 1983, 1984). Lawton (1994) has suggested that this period of incision was initiated by dynamic uplift on the western edge of the North American craton and continued due to a downward base-level shift caused by overspill from the adjacent dynamic basin into a back-arc basin. The youngest rocks below the unconformity at the base of the Chinle are Middle Triassic (Anisian) (Stewart and others, 1972) and the oldest rocks above the unconformity are Upper Triassic (Carnian) (Litwin and others, 1991, a lacuna of 25 million years. The Shinarump, Monitor Butte, Moss Back, and part of the Petrified Forest Members of the Chinle Formation represent the paleovalley infill sequence of the Painted Desert paleovalley system (Blakey and Gubitosa, 1983, 1984; Blakey, 1989) (Figure 2). Although the Shinarump Member is most commonly the lowest stratigraphic unit in the infill sequence, an interval of pedogenically modified older rocks and basal Chinle, informally called the "mottled strata", is often present near the base of the formation (Stewart and others, 1972). The mottled strata represent a period of non-deposition and/or sporadic and patchy deposition between the time of paleovalley incision and infill. Color mottling and the presence of crayfish burrows in this unit are evidence of fluctuating water tables and gleying during pedogenesis (Dubiel and others, 1991).

The Shinarump Member is typically composed of two distinct units of quartzose sandstone: 1) a lower conglomeratic sandstone characterized by crude trough and tabular cross beds that infill the lowest channels of the paleovalleys, and 2) an overlying medium- to coarse-grained sheet sandstone characterized by tabular cross beds, that is more regionally extensive (Davidson, 1967; Blakey and Gubitosa, 1984). The Shinarump also contains variable amounts of interbedded siltstone and mudstone beds, in some instances making up 60% of the unit, but more typically <10% (Blakey and Gubitosa, 1984). The thickness of the Shinarump ranges from more than 90 m near the deepest parts of the paleovalleys to zero where it pinches out against the paleovalley walls (Stewart and others, 1972). The Shinarump sandstones have been interpreted to have been deposited in bed-load dominated low-sinuosity streams (Blakey and Gubitosa, 1983; 1984; Pierson, 1984; Dubiel, 1987), although some outcrops of conglomeratic sandstone in the lowest parts of paleovalleys do have evidence of significant deposition by lateral accretion (Blakey and Gubitosa, 1984).

The Monitor Butte Member overlies the Shinarump Member and is predominantly composed of olive-gray to greenish gray smectitic mudstone and siltstone, but also contains fine-grained tuffaceous sandstone, laminated carbonaceous mudstone and shale (Stewart and others, 1972). In the White Canyon area of southeastern Utah, the Monitor Butte also contains thin limestones and coal seams (Dubiel, 1989a; Dubiel, 1993) (Figure 4). It ranges from more than 80 m thick to zero where it pinches out against the margins of the paleovalley (Stewart and others, 1972). Distinctive sedimentary features in the Monitor Butte include: 1) delta foreset beds (Figure 5); 2) thin, broad channels; and 3) contorted and slumped strata (Stewart and others, 1972; Dubiel and others, 1993). Large-scale scours at the base of the Monitor Butte in southeastern Utah cut out some or all of the underlying Shinarump Member (Stewart and others, 1972; Dubiel, 1994). The Monitor Butte has been interpreted as having been deposited in fluvial, lacustrine, lacustrine delta, and paludal environments (Stewart and others, 1972;Dubiel, 1987).

The Moss Back Member is a sandstone unit that occurs above the Monitor Butte Member in southeastern Utah (or above older rocks where the Monitor Butte or Shinarump Members are not present) in a belt 80-120 km wide (Blakey and Gubitosa, 1983) in northern New Mexico, southwestern Colorado, and southeastern Utah (Figure 1). It ranges from 50 m thick in the White Canyon area of southern Utah to zero along the margins of the paleovalley (Stewart and others, 1972). The lower part of the Moss Back is characterized by large-scale trough and planar cross bedded, medium-grained sandstone with interbedded carbonate nodule and extrabasinal pebble conglomerates near the base of the unit, and the upper part is characterized by small- and large-scale trough and planar cross-bedded, medium- to fine-grained sandstone (Stewart and others, 1972) (Figure 6). The Moss Back Member has been interpreted to have been deposited in high- and low-sinuosity stream environments. Blakey and Gubitosa (1984) interpret the sandstones in this unit as low-sinuosity, braided stream deposits, whereas Dubiel (1987) viewed them as having been deposited by high-sinuosity, meandering streams.

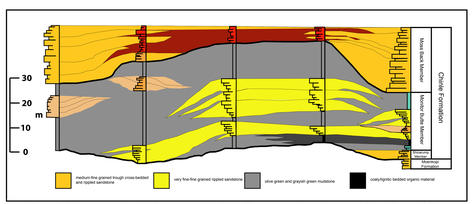

Figure 2. Lithostratigraphy of the lower part of the Chinle Formation in the study area near White Canyon, UT.

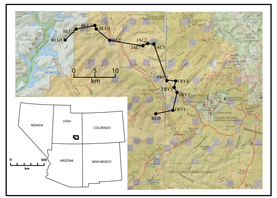

Figure 3. Location of measured section and cross section in the White Canyon, UT area

Figure 4. Allochthonous lignitic coal in the Monitor Butte Member in Blue Notch Canyon, interpreted as a deep lacustrine facies.

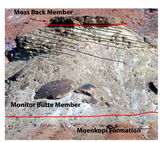

Figure 5. Delta foresets in the Monitor Butte Member in Blue Notch Canyon. Thick red lines mark sequence boundaries above and below.

Figure 6. Fining-upward units in Moss Back fluvial sandstones. Note trough and overturned cross bedding

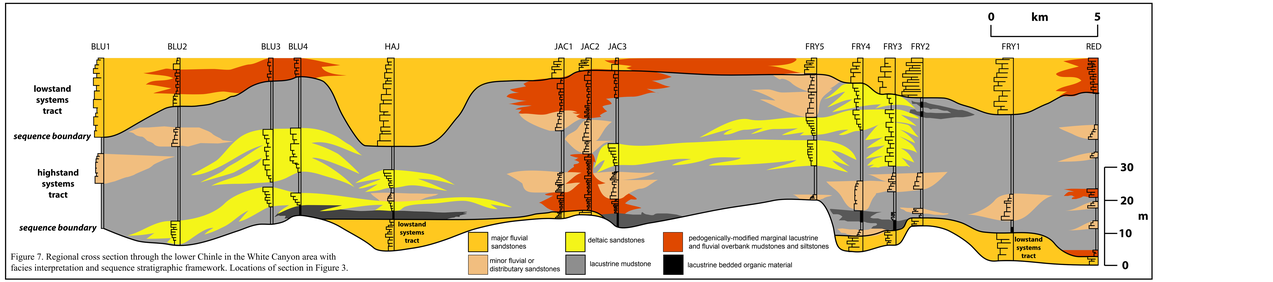

Figure 7. Regional cross section through the lower Chinle in the White Canyon area with facies interpretation and sequence stratigraphic framework. Locations of section in Figure 3.

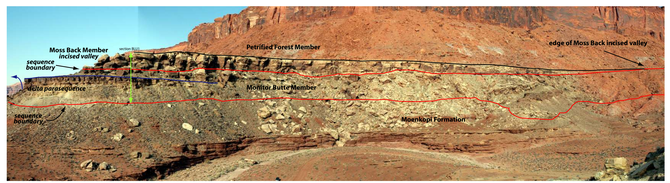

Figure 8. Interpreted photopan of lower Chinle Formation on north wall of Blue Notch Canyon. Note edge of Moss Back incised valley at left. Section BLU1 from Figure 4, see also location in Figure 3.

Figure 9. Interfluve paleosol near edge of Moss Back incised valley. Note well-developed pedogenic carbonate horizon. At Jacob's Chair (JAC1 on Figure 3).

Figure 10. South wall of Blue Notch Canyon showing Moss Back Member incised valley fill thinning to the southeast.

SEQUENCE STRATIGRAPHIC INTERPRETATION

The basal valley surface, at either the base of the Shinarump or Monitor Butte Members is a sequence-bounding unconformity (Figure 7). Truncation of underlying Moenkopi units and extensive pedogenic modification, especially in interfluve areas, are indications of significant erosion and periods of no deposition. The fluvial channel fills and bars of the Shinarump Member fill the incised channels in the base of the valleys. The top of the Shinarump is both another sequence boundary marked by erosion and truncation and an extensive lacustrine flooding surface (flood surface – sequence boundary: FSSB) (Figure 7). It follows that the fluvial succession between the basal sequence boundary and this surface is a sequence consisting of a single lowstand systems tract (LST). Allochthonous lignitic coals (Figure 4), greenish-gray smectitic mudstones and brown, rippled sandstones (Figure 5) of the Monitor Butte Member overlie this lacustrine flooding surface. The Monitor Butte facies succession is interpreted as a highstand systems tract (HST), deposited as a prograding lacustrine delta complex. The top of the Monitor Butte is a sequence boundary, marked either by an erosional surface at the base of the discontinuous Moss Back Member sandstone where it is present, or a well-developed paleosol characterized by distinctive red coloration and carbonate nodules (Figure 9). This dramatic inset incised valley was cut into the underlying Monitor Butte lacustrine valley fill (Figure 7, 8, 10). The Moss Back valley fill succession is comprised of large-scale lateral accretion bar sets of a large alluvial system and a well-drained overbank system (Figure 7).

The fluvial-lacustrine-fluvial succession in the lower Chinle valley fill represents the deposits of series of base-level rise-and-fall (landscape aggradation/degradation) cycles. This is reminiscent of a typical "lacustrine sandwich" tripartite succession in other documented lacustrine basin fills (rift basins, etc..). However, the valley fill setting of the lower Chinle is unique in that no active faults are implicated in the base-level change or subsidence mechanisms. Instead, base-level change controlled the facies succession, stratal stacking pattern, and even the preservation of organic material (Demko et al., 1998) through incised valley cutting and filling.

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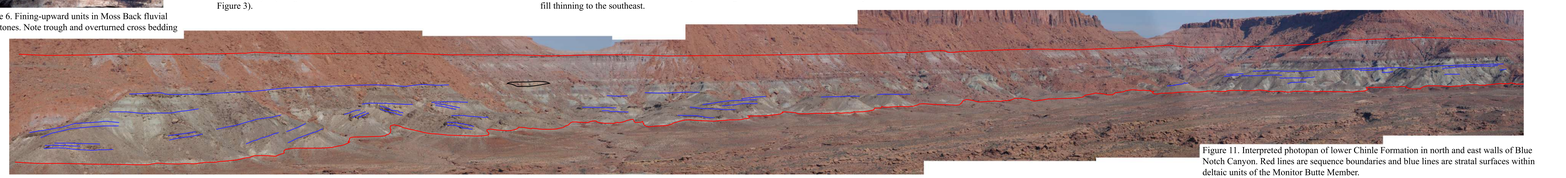

Figure 11. Interpreted photopan of lower Chinle Formation in north and east walls of Blue Notch Canyon. Red lines are sequence boundaries and blue lines are stratal surfaces within deltaic units of the Monitor Butte Member.

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