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WAS THE LOWER PERMIAN ABO FORMATION, NEW MEXICO, DEPOSITED BY DISTRIBUTIVE FLUVIAL SYSTEMS?

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Abstract—The lower Permian strata of the Abo Formation consist of siliciclastic red beds found across much of New Mexico. Deposition of most of these red beds took place on an extensive alluvial plain across which paleoflow was southward to the shoreline of the Hueco seaway. The overall geometry of the Abo Formation deposits in parts of northern and southern New Mexico fits the distributive fluvial system (DFS) model, with coarse upland alluvial fan deposits giving way downgradient to much finer-grained strata, and with coarser-grained strata overlying finer-grained strata in the basin as a likely result of the DFS lengthening and prograding basinward.

INTRODUCTION

The lower Permian strata of the Abo Formation are siliciclastic red beds found across much of New Mexico, and similar, correlative strata are found in adjacent states. Deposition of most of these red beds on an extensive alluvial plain across which paleoflow was southward to the shoreline of the Hueco seaway has long been agreed on (e.g., Seager and Mack, 2003; Kues and Giles, 2004; Lucas et al., 2013; Fig. 1). This alluvial plain was >570 km long in a N-S direction and >600 km wide in an E-W direction. The primary source areas for Abo sediments were the Zuni uplift in the northwest, the Uncompahgre and San Luis uplifts in the north, and the Pedernal uplift in the east (Kues and Giles, 2004; Fig. 1). The Abo deposits were among the first sediments that covered Ancestral Rockies highlands in New Mexico during the early Permian. Biostratigraphic correlations indicate that strata of part of the Supai Formation/Group in Arizona, Cutler Group strata in the Four Corners, and Wichita Group strata in north-central Texas are correlative to the Abo and represent similar fluvial depositional systems. Sedimentation of these red beds took place under a dry monsoonal climate with alternating dry and wet seasons (Mack, 2003). Here our focus is on the Abo Formation.

Three aspects of the Abo fluvial deposits merit explanation: (1) the overall stratigraphic architecture, which at most Abo outcrops can be divided into a lower, mudrock-dominated interval (Scholle Member of Lucas et al., 2005) and an upper interval with numerous extensive sheets of sandstone (Cañon de Espinoso Member of Lucas et al., 2005); this signature is typical of prograding DFS, and the outcrops of Abo Formation well exposed along the Jemez and Guadalupe Rivers in the southwestern Jemez Mountains show this architecture (Lucas et al., 2012a); (2) the generally fine-grained nature of most Abo outcrops, which are mudstone, siltstone, and very-fine to fine sandstone; and (3) the local presence of very thick and very coarse-grained (conglomeratic) Abo sections along the flanks of Ancestral Rocky Mountain uplifts; a good example of a very coarse-grained (conglomeratic) Abo section is in the northern Sacramento Mountains (Lucas et al., 2014; Fig. 1).

The Abo strata are thus composed of conglomerate, sandstone, nodular limestone (calcrete), and mudstone lithofacies that can be combined into three principal architectural elements: (1) sandstone sheets formed by amalgamated broad, shallow channels of a low-sinuosity river system (or of amalgamated meandering channels; Hartley et al., 2010) and/or by unchannelized flow; (2) sandstone lenses and bodies that represent minor fluvial channels, unchannelized flow, and sheet splays; and (3) siltstone/mudstone with pedogenic carbonate that represents deposits of floodplains. Lucas et al. (2013) summarized the prevailing view that Abo deposition took place on an extensive alluvial plain in which well-defined, bedload river channels within extensive muddy floodplains were succeeded by sandstone sheets formed by low-sinuosity river deposits

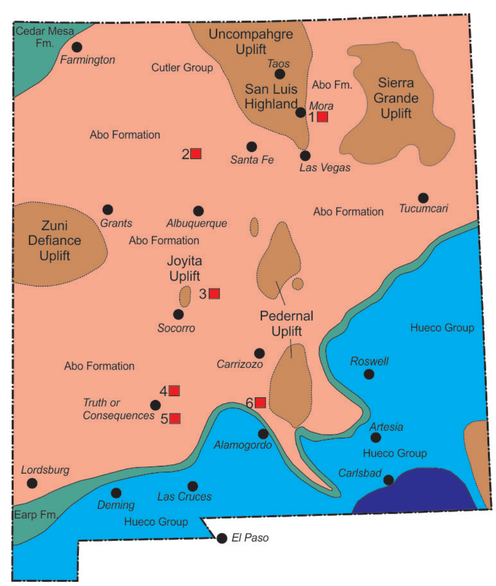

FIGURE 1. Paleogeographic map of the Cutler-Abo depositional basin (modified from Kues and Giles, 2004). Numbered locations: 1 = Mora River; 2 = Jemez Springs; 3 = Type Abo section; 4 = Fra Cristobal Mountains; 5 = Caballo Mountains; 6 = Sacramento Mountains.

subject to episodic avulsion and sheetflooding. They attributed this change in stratigraphic architecture to tectonic changes in which falling base level (relatively rapid subsidence) during deposition of the lower Abo was followed by episodically stable base level (slower subsidence) during deposition of the upper Abo. However, it may also be possible to model Abo deposition by distributive fluvial systems (DFSs).

DFS MODEL

The DFS model is well explained by Hartley et al. (2010) and Weissmann et al. (2010). In contrast to tributary (axial, dendritic) fluvial systems, distributive (downstream bifurcating) fluvial systems are analogous to large deltas; they are often fan-shaped with "decreasing discharge down-flow and transitions from proximal, channelized to distal, unconfined flow" (Nichols and Fisher, 2007, p. 75). A DFS is defined as deposits of a fluvial system with the following general characteristics (Weissmann et al. 2010, 2013; Hartley et al. 2010): (1) radial distributive pattern of channels away from the apex where the river enters the basin; (2) decrease in channel size downgradient; (3) decrease in grain size downgradient and increase in the amount of fine-grained floodplain deposits; and (4) lack of lateral channel confinement for river activity depositing sediment on the open DFS.

The complete architecture of modern DFSs includes proximal, medial, and distal regions radially spanning tens of kilometers or more, apex to toe. Proximal deposits are characterized by the coarsest-grained sediments in amalgamated channel-fill deposits (facies) with little floodplain material. These form at the sedimentary basin margin. They converge to an apex (often in a confined valley) from which channels radiate in the medial portion of the DFS to distribute sediment down depositional gradient. Much of the coarse-grained sediment is dropped at the apex or in the proximal reaches of the distributary channels. Downgradient, the medial portion of the DFS preserves an increasing proportion of overbank material and decreasing clast size within channel fills. Distal reaches are mudstone dominated (floodplain facies) with thin sheet sands usually resulting from unconfined flow. Channel deposits make up a small percentage of the distal facies, with channel dimensions becoming progressively smaller (Nichols and Fisher, 2007) and channel belt spacing at its greatest (Weissmann et al., 2010). Basinward progradation of the proximal and medial portions of the DFS can result in coarser-grained deposits overlying finer grained deposits—a coarsening upward to amalgamated channel-belt deposits (Weissman et al., 2013).

ARGUMENTS FOR A DFS MODEL FOR THE ABO FORMATION

Abo sediments can readily be understood within the DFS model, particularly the three aspects that merit interpretation listed above. In two places (Fig. 1), on the Mora River in northern New Mexico (Baltz and Myers, 1999, fig. 69) and along the western flank of the Sacramento Mountains in southern New Mexico (Lucas et al., 2014, fig. 3), thick sections of the Abo Formation are very coarse grained with many conglomeratic beds. On the Mora River, sediments called Sangre de Cristo Formation by most workers clearly belong to the Abo lithosome (Darton, 1928; Baltz and Myers, 1999; Lucas and Krainer, 2023). Here the Abo is 785 m thick, with many beds of conglomerate and coarse sandstone and with relatively little mudstone. The formation thins and fines southward. Soegaard and Caldwell (1990) interpreted these strata as high-gradient upland deposits along the edge of the Ancestral Rocky Mountains Uncompahgre uplift and as analogues of the Kosi fan in India, which is now considered a characteristic DFS (Weissmann et al., 2010, 2013).

In the Sacramento Mountains, similar Abo deposits (Coyote Hills Member of Lucas et al., 2014) are ~ 400 m thick. Speer (1983a, b) and Lucas et al. (2014) interpreted these as upland deposits with basement clasts and coarse sandstone derived from the adjacent Ancestral Rocky Mountains Pedernal uplift, with paleoflow to the west and southwest. Down depositional gradient, across the paleobasin floor to the west, Abo Formation strata in the Fra Cristobal and Caballo Mountains (Fig. 1) are much finer grained and display the two-part architecture characteristic of the Abo—a lower, mud-dominated interval overlain by an upper interval with many sandstone sheets (Lucas et al., 2012b).

Thus, the overall geometry of the Abo Formation deposits in some parts of northern and southern New Mexico is suggestive of the DFS model, with coarse upland alluvial fan deposits giving way downgradient to much finer-grained strata, and with coarser-grained strata overlying finer-grained strata in the basin as a likely result of the DFS lengthening and prograding basinward. Thus, several smaller rivers entered the extensive alluvial plain (exorheic basin) from the different uplifts, each forming a DFS. The Abo alluvial plain thus was formed by several laterally interfingering DFSs. Nevertheless, more data and analysis are needed to better elucidate the possible role of DFS in deposition of the Abo Formation.

Red beds of the Abo Formation show a transition from dominantly channelized flow with fewer overbank deposits in the more proximal part to dominantly unconfined flow with high amounts of floodplain deposits in the distal part where deeper incision of channels is absent. A characteristic feature of the distal facies is thick overbank deposits with intercalated sand sheets that formed by unconfined flow, subordinately showing erosive bases indicating the formation of local channels. For example, in the Caballo Mountains the distal facies overbank fines constitute 70–87% of the succession (Lucas et al., 2012b). This distal facies is best seen in the Abo Formation at the type section at Abo Pass and in the Fra Cristobal and Caballo Mountains (Lucas et al., 2005, 2012b, 2013; Fig. 1).

DISCUSSION

The main weakness of the inference of Abo deposition by DFS, though, is the lack of documentation of the proximal DFS in the Abo outcrop belt, though upward coarsening within the Abo is consistent with prograding DFS. In northern New Mexico, outcrops that should allow that exist (Lucas et al., 2014), but it has not been attempted. In southern New Mexico, those outcrops are buried under the Cenozoic fill of the Tularosa basin. DFS may also be present in Abo correlative strata from northern Arizona to north-central Texas, but more study is needed to establish this.

Clearly, the overall stratigraphic architecture of the Abo Formation, the generally fine-grained nature of most Abo outcrops, and the local presence of very thick and very coarse-grained (conglomeratic) Abo sections along the flanks of Ancestral Rocky Mountains uplifts are suggestive of DFS. Hopefully additional research will be undertaken to further evaluate this possibility.

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Outcrop of Midde Pennsylvanian Sandia Formation—quartz-rich sandstones and conglomerates—at Mesa Venado in the Sierra Nacimiento.
Photo by Spencer G. Lucas