Early and Mid-Paleocene Paleodrainage Analysis and Implications for Regional vs. Local Allogenic Processes, Ekalaka Area, SE MT

Barret S. Cole
Department of Geology
Amherst College
Amherst, MA 01002-5000

Introduction

During the Paleocene, Eastern Montana was occupied by a vast alluvial plain which received sediment from Western Montana and Wyoming, as well as from Laramide basement-cored uplifts such as the Bighorn Mountains and the Black Hills to the south of the study area. This study concentrates on the fluvial systems responsible for the deposition of the Ludlow and Tongue River strata. Since this sequence and the sequence at the Cave Hills locality in South Dakota contain more sand than is present elsewhere in the Paleocene and there are Paleocene slump structures beneath an unconformity, it is evident that there have been tectonic or eustatic events resulting in base level change.

Stratigraphy

The Cretaceous Hell Creek Formation is conformably overlain by the two members of the Paleocene Fort Union Formation which are in turn unconformably overlain by the Miocene Arikaree Formation in the Ekalaka area (see Belt-Workshop Review Figure 1, this volume). This area is shown by Belt's introduction figure 1.

The lower of the two members, the Ludlow, consists of 50 meters of greenish-grey siltstones, grey clayey shales, unconsolidated sandstone that weathers yellow, and lignite beds. To the east in South Dakota, it is 150 meters thick and interfingers with the marine Cannonball Member (see Belt-Workshop Review Figure 1, ibid). The Ludlow fluvial environment contains minor river systems with flood plains that showed some swamps and ponded water in poorly drained areas (Belt et al.,1992). The Tongue River Member is 35 meters thick. It is dominated by sandstones, most of which are semi-lithified. It contains tan and buff, medium-grained, massive bedded, locally cross-bedded sandstone with thinner interbeds of grey claystone. The Tongue River Member was deposited by major river systems and flood plains. A schematic cross-section has been produced to show the relationship between the lithologic units that make up the Ludlow and Tongue River Members in the study area (Figure 1).

The Tongue River Member is represented by the Medicine Rocks Sandstone. This is a multi-storeyed, trough cross-bedded sandstone up to 30 meters thick in some localities. It is medium-grained with a high sand/mud ratio and has a distinct pitted weathering characteristic.

Beneath the unconformity and above the Ludlow lies a fine-grained, ripple-bedded, and burrowed lithology believed to be lacustrine in origin. Although this lithology was included within the Tongue River by Bergantino (1980), it remains un-named. There are distinct zones where this lithology has been deformed (Figure 1). The Ludlow Member underlies the un-named lithology and consists of flood plain deposits with interbeds of carbonaceous shale and coal as well as some small channel belt sands. As Figure 1 shows, there is a three-fold stratigraphy rather than the previously documented two-fold stratigraphy for this area (Bergantino, 1980).

Sedimentology

The Medicine Rocks Sandstone seems to have distinct edges of a meander belt to the north and south rather than a blanket geometry that is common to braided systems. Trough cross-beds with ripple beds occur only at the top of the uppermost storey of this multiple storey sandstone. This shows that the ripple beds of the lower storey sands had been removed by the erosive action of migrating meanders and that only the fining up sequence of the top storey is preserved. The erosive contacts at the bases of each storey are marked by a basal conglomerate that is relatively continuous. In addition, multiple discontinuous erosive contacts were noted. No mud drapes are present within the Medicine Rocks sandstone bodies indicating a relatively stable level of water as opposed to differing stages. There were a few lateral accretion surfaces fully identified, but the lack of preservation of fine-grained facies as well as the lack of overall mud in the system made this distinction difficult.

Crustal subsidence during the deposition of the Medicine Rocks Sandstone seems likely to have been at a slower rate since sandstones of this thickness are lacking in the Tongue River Member in any other part of SE Montana. Since the rate of floodplain aggradation normally parallels the rate of crustal subsidence over long

periods of time, a slow rate of aggradation can be assumed for the floodplain of the river system that deposited these sandstones.

Bridge and Leeder (1979) have produced computer simulated models for alluvial stratigraphy that resolve some of the factors responsible for increased "interconnectedness" of sand bodies within a meander belt. The factors they found to be most conducive to higher ratios of "interconnectedness" were a slower rate of floodplain aggradation and a longer avulsion periodicity. Since the multiple discontinuous erosive surfaces in the Medicine Rocks mark a high degree of "interconnectedness," the floodplain of the Medicine Rocks Sandstone must have aggraded relatively slowly and the periodicity of avulsion must have been relatively long.

Paleocurrent analysis of the Medicine Rocks Sandstone showed a low to moderate (not exceeding 120 degrees) dispersion of current directions. These readings were measured from well-preserved trough cross-beds. A low dispersion is not typical for a meandering system, although paleocurrent vectors can be destroyed by the downstream migration of meanders and dunes (Allen,1965). More importantly, the trend of the Medicine Rocks Sandstone channels were observed to be southeast except in one area where southwest trends were observed (see Figure 1). This either represents the preservation of one particularly wide sweeping meander or an avulsion event headed towards the floodplain to the southwest.

The southeast trend of the Medicine Rocks channelbelt is important because the Ludlow Member channelbelts trend to the northeast. This indicates that there was a pronounced change in paleodrainage that occurred during the time between the deposition of the Ludlow and the deposition of the Medicine Rocks Sandstone.

Slumped Strata

The deformation of the un-named fine-sandstone unit mentioned earlier consists of small scale extensional faulting and inclined strata. Within these zones of slumping there are rather large areas of scattered angular clasts ranging from pebble to cobble size set in the matrix of the un-named lithology. These are thought to have been syn-slump channelbelts. Work by Clark (this volume) shows that the slump structures were most likely controlled by regional forces rather than local river bank collapse.

Discussion

Although details of the slump structures are beyond the scope of this paper, it is evident that they developed because of a base level change. This base level change was caused by regional tectonic events associated with the Laramide orogeny, while the change in paleodrainage was influenced by global eustacy.

There are several working hypotheses regarding the role of regional tectonism. The two most plausible involve the Laramide orogenic events. A regional tilt may have caused blanket-like slippage of the un-named unit along the weaker, smectite-rich Ludlow producing slump structures or a local uplift on the scale of the present-day Miles City Arch may have caused localized slumping.

These regional tectonic arguments are rooted in the conclusions of Jason Hicks' thesis (1993) involving similar slump features of similar age in the Bighorn Basin. Hicks concluded that these features were the result of regional tectonism rather than global eustacy. A major factor in his decision was the 320 km that separated the Bighorn Basin from the Cannonball Sea, but our study area lies only 80 km from the sea indicating global eustacy may have had some influence.

The northeast trend of the Ludlow rivers has been regionally confirmed by Chris Goodrum (1983) at the Cave Hills locality of South Dakota. These rivers are pre-slumping and thus are unaffected by any tectonic events. The northeast trend is expected since, at the time of Ludlow deposition, the Cannonball Sea was in the Dakotas to the northeast of our study area.

The southeast trend of the Medicine Rocks Sandstone may have been affected by tectonism, but its rivers show eustatic influences. The uplift of the Cedar Creek Anticline may have formed a drainage diversion during the deposition of the Medicine Rocks Sandstone. Belt and others (1984) propose that the Cedar Creek Anticline wasn't a drainage block during the early Paleocene, but may have been by the mid-Tiffanian. Thus, paleodrainage directions in the Ludlow would show no effects, but the Tongue River channels may have been diverted.

A eustatically controlled model for sedimentation in the Williston Basin has been proposed by Cherven and Jacob (1985). They documented an early Paleocene transgression that embodied the lower Fort Union Formation in Montana. This transgression involved a shoreline advance of 135 km that positioned the sea near the Montana border in the central Dakotas. Therefore, the rivers of the Ludlow should flow to the northeast as is observed. Following this transgression, a late Paleocene regression occurred that contains the upper Fort Union Formation in Montana. This regression consisted of a rapid southeastward retreat of at least 240 km. The Tongue River sandstones may have shown southeast paleodrainage directions in response to this retreat.

My conclusion is that regional tectonism caused the slump structures producing the pre-Tongue River unconformity, but acts in combination with global eustacy to cause the switch in paleodrainage. The regional northeastern paleodrainage directions for the Ludlow can be resolved through autogenic processes acting in response to the position of the Cannonball Sea.

However, the southeast paleodrainage directions for the Tongue River sands shows both tectonic and eustatic influences. First, if the slump structures were caused by a slight uplift, it must have eroded by the time of the deposition of the Medicine Rock Sandstone to allow a southeastward paleodrainage. Second, subsidence of the Ekalaka area during deposition of the Medicine Rocks Sandstone must have been fairly slow to cause the amassing of such a large sequence of sand. Third, if the Cedar Creek Anticline were to divert drainage, it seems logical that the diversion would be to the southeast in response to the retreat of the sea in that direction. Progress is presently being made to determine the plausibility of these conclusions.

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FIGURE 1: Schematic Cross-Section of Paleocene Fort Union Formation, Ekalaka Area