SEDIMENTOLOGY OF A THIN, WIDESPREAD SAND HORIZON BETWEEN TWO UPPER LEBO COALS, FORT UNION FORMATION (PALEOCENE), SOUTHEASTERN MONTANA

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The purpose of this study is to examine a two- to three-meter yellow sand and gray mud stratigraphi unit which lies between two regionally extensive upper Lebo coal beds. Because so much of the Lebo consists of interfingering river channel and floodbasin deposits, the presence of a regionally continuous sand body between two equally continuous thin coal beds seems to be incompatible with the rest of the Lebo facies. Could I find information that would shed light on its origin?

The Lebo Member of the Fort Union Formation is Torrejonian in age (see Williams' report, this volume), and in general consists of sand, mud, carbonaceous shale, and lignitic coal. These lithologies interfinger in a complex pattern. Assemblages of these lithologies can be assigned to depositional environments (see Metcalf's report, this volume) such as river channel, levee, flood plain, and crevasse lobe. No marine environments exist in this area, although deltaic deposits of Torrejonian age interfinger with marine deposits 200 miles to the east of the study area (Belt et al., 1984) in North Dakota.

The data collected came from sixteen outcrop sites covering 4 square miles on the Boatwright ranch, 35 miles east of Miles City, Montana. The outcrops occur in a region of badlands topography, and the yel low sand deposit occurs at approximately 800 m (2800 ft) above sea level. In addition, Dr. Belt supplied two measured sections that included the study interval. These sections lay several miles south of the region where I had concentrated my measurements, and extended my knowledge of the yellow sand unit regionally.

The sediments of the yellow marker unit (as I came to call it) consist of sand and mud. Because it was necessary to correlate the yellow marker unit (YMU) over great distances, the two carbonaceous shal and coal horizons, one above and one below the YMU were used for tying the sections down.

The sand commonly was cemented by carbonate to form a sandstone ledge that held up the tops of many buttes. In some cases the carbonate cement replaced the quartz sand and a limestone resulted with all the primary structures of the sands and sandstones which were not replaced by carbonate. Sands contain current ripples (most common structure), osciallation ripples (rare), horizonatal laminae (common), and occasionally megaripples (not large enough to be termed cross beds). The climbing ripple type was locally abundant. Fossil roots and rootlets are also found. On one rare occasion, a burrow, *Planolites* was found. Notable by their absence were cross-stratification that exceeded 20 cm in height. Thus true cross beds are not found.

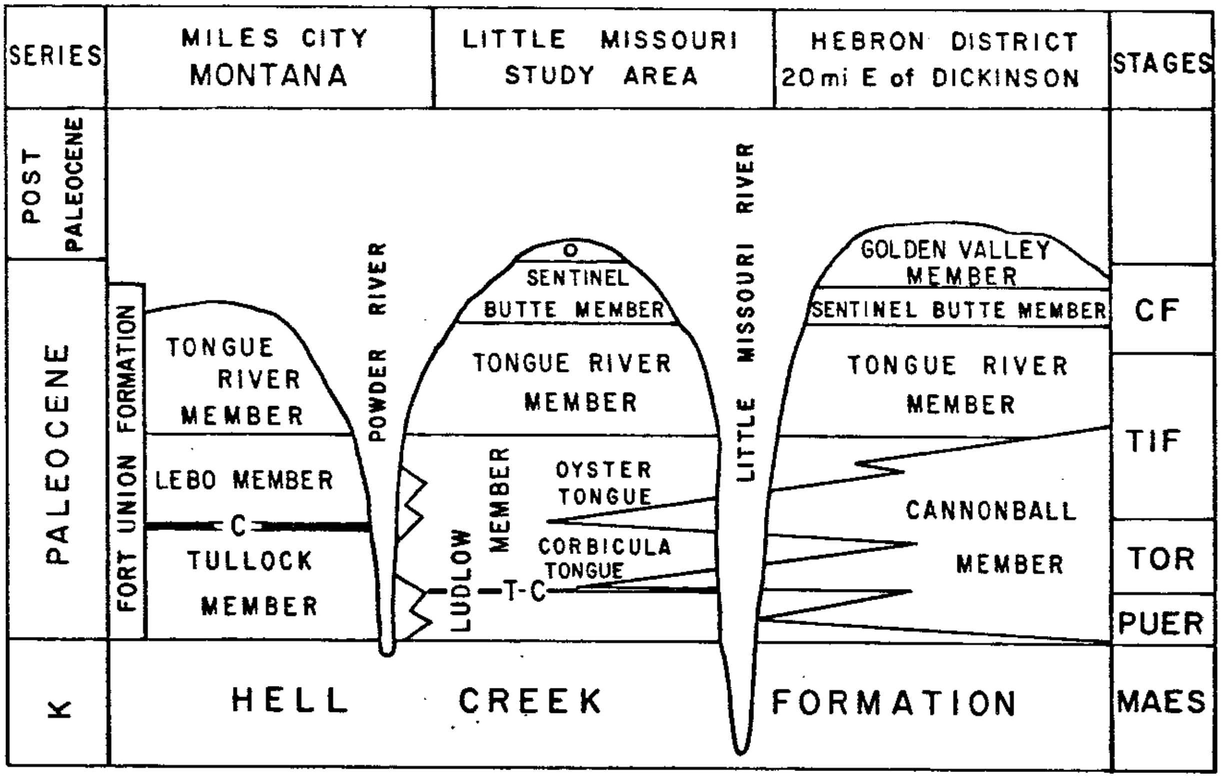
The mud units interbedded with the sand beds are laminated (if not bioturbated) or massive (if disturbed by roots or burrows of invertebrates). These mud beds interfinger with the sand beds to form coa upwards sequences and fining-upwards sequences. Of these two, the coarsening-up sequence is the most common.

Interpretation:

The coal beds indicate the presence of swampy conditions. Immediately above the swamp is laminated mud and rippled sand that indicates ponded water conditions. The swamp must have been drowne by water over a wide area. Because this leads immediately into a coarsening-up sequence, a prograding se quence of sediment filled in the depositional area at that time. The largest-scale cross-laminated ripples (megaripples) are found where sandy units are being deposited that neither coarsen nor fine upwards.

The reconstructed depositional history is not unlike many other sections I measured. There are a few differences here and there, but generally this will suffice as a typical example of the YMU. Because the YMU was walked out over 6 square miles, and can be seen miles to the south from the area studied, the question remains. What is its origin? The answer to that must be intimately linked with the origin of the coal beds that lie above and below this yellow sand and gray mud unit. These coals are equally widespread. What follows are possible environments that were examined that might explain this deposit.

(A) Sandy epicontinental sea. The modern analogue is the continental shelf off the east coast of the United States. The presence of sand and ripples in the YMU would be consistent with a sandy epiconti-



THE LEBO AND TONGUE RIVER MEMBERS AND THEIR AGES WERE STUDIED ON EITHER SIDE OF THE POWDER RIVER

nental sea, but fact that the YMU lies between two coal beds of freshwater origin and the absence of marine fossils in the YMU would eliminate a sandy epicontinental sea.

(B) Vast inland freshwater lake. This would better fit the information we have than an epicontinental sea. Because so many of the sections measured showed rootlet horizons within the middle of the YMU, it would seem that the lake was not persistent at all times over the entire area. The presence of coal would fit the lake model. A vast swampy area became drowned to form a lake, clastics then built out into the lake to form the coarsening-up sands and muds. Lake level might have dropped for plants to root on the sandy lobe, lake level then rose for the muds above the sandy lobe, and then the lake level dropped somewhat for swampy conditions to form again at the top so that a coal bed might develop. This model is very attractive, and might be the best model, provided I can rule out the possibility that this entire deposit resulted from a crevasse lobe associated with a breached levee from a major river.

(C) Is it possible the YMU is a crevasse lobe deposit (Fielding, 1984)? Distinguishing a crevasse lobe deposit from a lake deposit would depend on how widespread the YMU and its two coals can be mapped. Also it is necessary to determine the thickness of the entire sequence when compared with the other Lebo facies which we know have crevasse deposits associated with major fluvial channels. The YMU is much too thin for most normal crevasse lobes found elsewhere (Belt, personal communication, 1988), and so perhaps other factors were at play such as regional water table changes, caused by a decrease in subsidence and sediment retention in the depositional basin. These ideas are speculative. Not enough evidence was gathered to draw appropriate conclusions.

For those who may try this project next summer, they should look for evidence of the termination points for the YMU, plot those termination points up on a map to see the pattern. Also a crevasse lobe ought to have feeder channels that supplied sand to the lobe. No true cross-bedded channel deposits were found this past summer in the YMU. They ought to be sought for next summer. If they are found and if a termination line for the YMU can be plotted, then a crevasse lobe might be a possible viable model. It would be a "proven" case if the YMU can be traced into a major sandy channelbelt perpendicular to the crevasse lobe feeder channel. That might be too much to expect, however.

What about other possible models of deposition? A review of the literature showed the following results.

a) Well-sorted deposits on the trailing margin of a continent (Boggs, 1987) are not likely because the Williston Basin is an intracratonic basin, and none of the Lebo facies are marine. Many similarities exist in the sediments, however.

b) Aeolian deposits (Boggs, 1987) in an interior desert, or coastal dune field next to the sea. This is not likely as aeolian cross bedding is not found (no cross bedding is found in the YMU), and coastal dunes next to the sea ought to be interbedded with marine deposits.

c) Glacial deposits (Boggs, 1987) in a terrestrial environment. These are not likely as the climate was warm-temperate (see report of Williams, this volume), and the abundance of coal seams suggest warm, humid conditions. Not a likely environment for glaciation (to say nothing of no coarse sand or conglomerate anywhere in the Lebo Member).

d) Delta lobes (Coleman and Gagliano, 1964; Morgan, 1970; Saxena, 1976) are a very attractive model. After all, a crevasse lobe is simply a miniature delta lobe (Saxena, 1976), and an interdistributary bay lobe (Elliott, 1974) is but a crevasse lobe that progrades into ponded water on a lower delta plain. It is simply all a matter of scale of the lobe and whether or not one can establish that a delta existed in eastern Montana at the time of Lebo deposition. From previous work, it is clear that a major delta existed 200 miles to the east of the study area in southwestern South Dakota (Belt et al., 1984) and that the Lebo Member in the study area (Metcalf, this volume) and 10 miles southwest of the study area (Belt and Rockwell, in press) is entirely fluvial in origin. Hence the concept of a delta, while very attractive, is not viable given the paleogeographic conditions known to have existed during the time of Lebo deposition in the study area.

So at this time, the issue of model B and C cannot be resolved. Watch this space next year for further developments.

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