MONTANA PROJECT

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EARLY PALEOCENE FLUVIAL SEDIMENTOLOGY, PALEOBOTANY, AND PALEOMAGNETISM

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Geologic setting of the Montana project:

The area lies in the High Plains, 200 miles east of the Rocky Mountains (Figure 1). The strata examined (Figure 2) are exposed within badland topography on either side of the Powder River. The plateau beyond is underlain by a resistent material (clinker) formed when a thick coal seam burns. The plateau forms uplands where cattle graze. All strata other than clinker are unconsolidated and easily exposed by shovelling away surface wash.

Because no faults or folds interrupt the original horizontality of the strata, and because the vegetation is sparse, this is an ideal region for student studies. Correlation from one measured section to another can be physically walked out in many instances, thereby assuring the sort of control rarely found in sedimentary sequences. Each student learns to measure sections, identify various fluvial depositional environments, and collect specific samples for laboratory analysis.

Geologic studies on Late Cretaceous and Early Paleocene strata in western Williston Basin have been in progress since 1981 (Belt et al., 1984; Belt and Rockwell, in press). The initial objectives were to develop a 3-dimensional control on facies so that actualistic paleogeographic maps could be made. These maps enable the researcher to define river channel parameters, such as channel pattern, width/depth ratio, sinuousity, percentage of lateral accretion to channel bottom facies within the channelbelt. Flood basin features such as coal beds and their relationship (if any) to the channel deposits can be accurately diagnosed. Nearly 100 surface outcrop sections within a 45-square mile region near Miles City, Montana (MC, Figure 1) were measured by Belt and his students prior to 1987. This resulted in 15 different paleogeographical horizons within the 100 meter thick sequence of the Lebo Member (Figure 2).

However, paleogeography was not the only matter of interest. A strong affinity of certain clay minerals to the channels and for other clay minerals to the floodplain became apparent from the facies mapping. The composition of sand from the channel deposits can reflect source area contributions, and perhaps distant tectonic effects. Finally the actual age relationships of the strata in the western Williston Basin are poorly known. Previous age relationships were based on little or no fossil data in the area (Figure 2) yet long-ranged correlations were made from North Dakota to eastern Montana.

That was the way matters stood when the opportunity arose of KECK funding for the summers of 1987 and 1988. During the first summer, we extended the previous paleogeographic map coverage to the north and east of the original area, nearly doubling the size of the region investigated.

The enclosed abstracts show the range of projects: paleohydraulics, paleomagnetism, sand provenance, paleobotany, clay mineralogy, and regional aspects of a key marker horizon. These are now put into a context emphasizing the common thread that runs through all of them.

Results of the 1987 field season:

All projects had successful outcomes, although some will have more far-reaching influence than others in the years to come. One of the many advantages of Keck is the opportunity for students to try out a line of research that would otherwise be considered risky. The usual funding for professors makes them more conservative in the type of project they take on.

The provenance study by Bonnie Wong has yielded evidence of the rise of nearby ancestral rocky mountains during the time Lebo and Tongue River Members (Figure 2) were being deposited. Her work must be considered in conjunction with another Carleton student: Laura Sloan. Laura wrote a thesis on thin sections collected four years ago from the Lebo Member. She also studied the petrography of the late Cretaceous Hell Creek Formation (thinsectgions from David Murphy). Both Bonnie and Laura agreed independently on Lebo composition. The surprise was that Hell Creek was also of very similar composition. The particular feldspars (fresh perthites) suggest unroofed basement in a nearby rocky mountain, possibly the Bighorn Range. If this proves to be the case, it would be the earliest evidence of Laramide orogeny in the area.

The project of Beth Williams concentrates on paleobotany. Beth's collection of leaf fossils from the Lebo Member has excited Dr. Leo Hickey of Yale Peabody Museum because: (a) it is the oldest occurrence of modern families of leaves and (b) the stratum can be independently dated by fossil bone (mostly turtle, crocodile, fish). Beth's find supplies a missing link in the evolutionary history of plant fossils.

The projects of Lynn Metcalf and JR Robinson concentrated on paleohydraulics of Lebo Member stream channels. They showed that meandering is a likely pattern for the Lebo channels and thus when channel dimensions, grain size, and primary structures are measured, the discharge of the Lebo streams can be calculated. This gives us an important clue as to the type of climate at the time, and ought to be testable by paleobotany. The meandering nature of the channels was apparent in the field because the channels penetrated several buttes and could be mapped in the flat-lying strata.

The project of Connie Hayden involved the types of clay minerals associated with the various facies: channel, levee, crevasse lobe, flood basin. She was able to show that more kaolinite occurs on the flood plain than in the channels and on the levee. The key question is whether a particular clay mineral speicies is authigenic or detrital. Further work is necessary, but if a general association of clays to particular facies can be developed, it will be possible for us to use this tool in the subsurface, especially in the Powder River Basin of Wyoming. That region contains vast coal reserves and the depositional environments there are the subject of recent controversy. Clay mineral studies also indicate the type of climate to be expected in the basin as well as the source area of sediment.

The paleomagnetism project of Linden Rhoades was perhaps the most ambitious. New information is at this moment (March) still being collected by Linden in spite of the difficulty of finding an unoccupied cryogenic magnetometer somewhere. The remanent magnetism in the Lebo and Tongue River Members was so weak that a normal magnetometer (of the type at Franklin and Marshall College) was not sufficiently sensitive for making the measurements required. The ultimate goal is to achieve the beginnings of a magnetostratigraphy in eastern Montana.

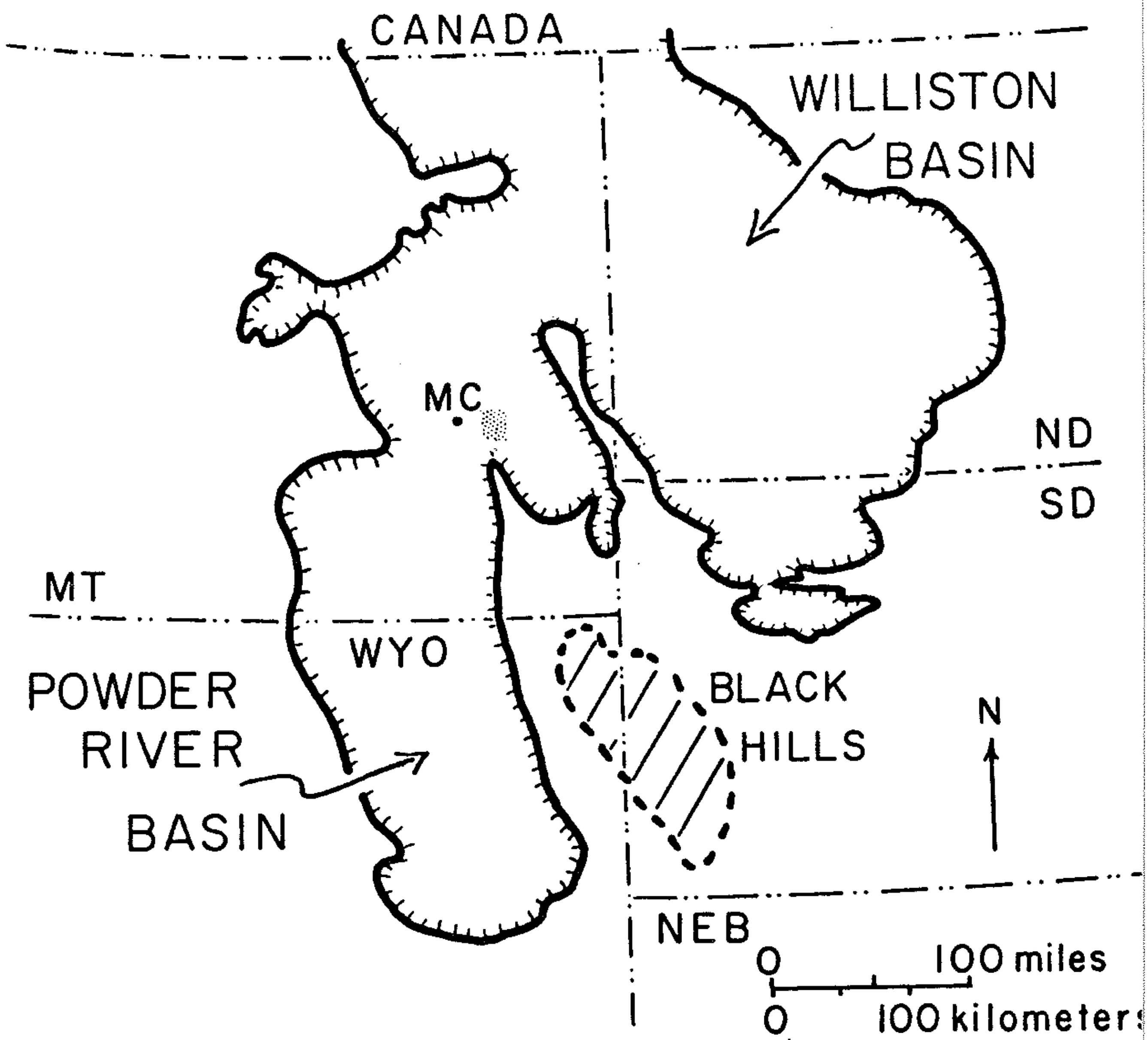
The project of Kevin Ellingwood showed that a very widespread fine-grained yellow sand lying between two widespread thin coal seams was an excellent horizon for correlation, but that its depositional environment was very difficult to determine. More work on this unit will be done in the summer of 1988.

The Montana project was designed to include professional advisors to the students. The following advisors, all external to the Keck consortium agreed to advise and also to attend a day-long Winter Workshop with the students in January 1988. Drs. Michael Velbel (Michigan State), Leo Hickey (Yale) and Richard Yuretich (Univ. Mass) put in many long hours not only at the workshop but also agreed to having the students visit them. Kirk Johnson (Yale), Dr. David Fastovsky (Univ. Rhode Island) and J. David Archibald (San Diego State) also helped the students in many ways. The students thereby received advice from professionals who themselves are actively doing research on the same topic, though perhaps in different field areas. However, the high level of student achievement must be attributed to all the advisors particularly those on the home campuses.

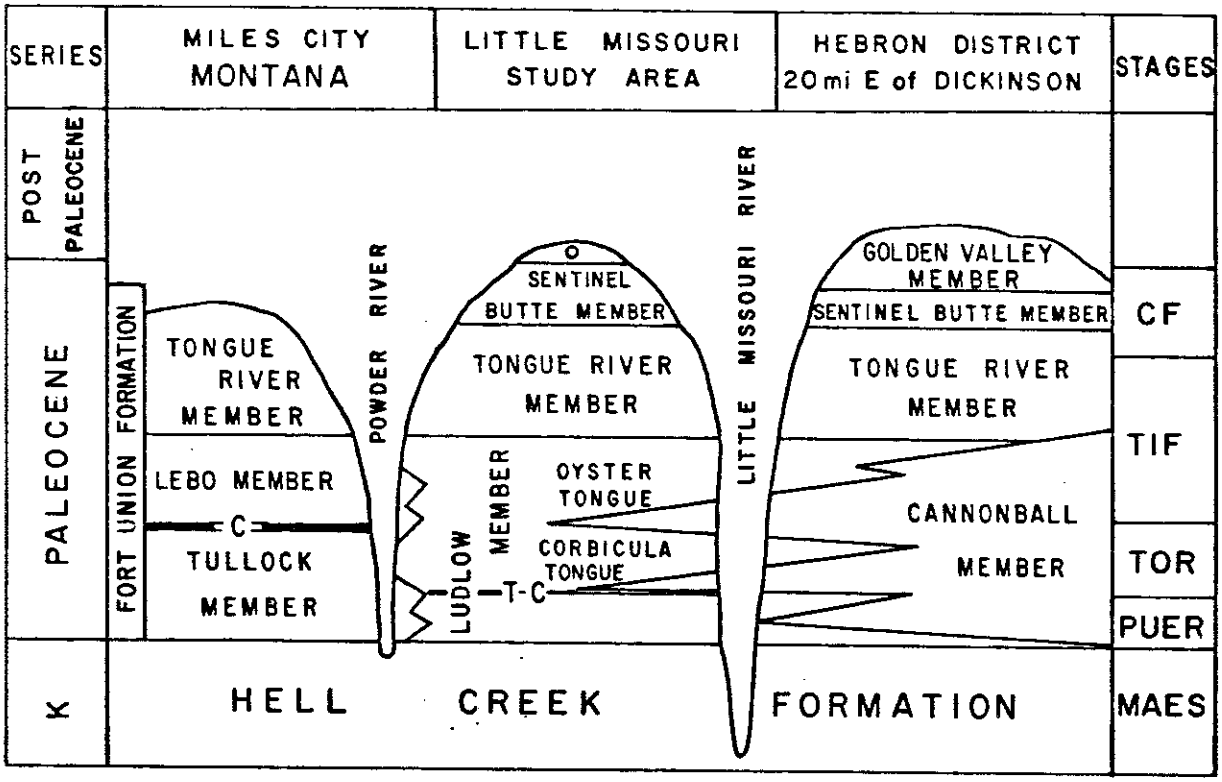
References:

Belt, E. S., Flores, R. M., Warwick, P. D., Conway, K. M., Johnson, K. R., and Waskowitz, R. S., 1984, Relationship of fluviodeltaic facies to coal deposition in the Lower Fort Union Formation (Paleocene), south-western North Dakota: *in* R. A. Rahmani and R. M. Flores, Sedimentology of Coal and Coal-bearing Sequences, International Association of Sedimentologists, Special Publication No. 7, p. 177-195.

Belt, E. S. and Rockwell, B. W., *in press*, Lower Paleocene fluvial deposits, western Williston Basin, Montana: *in*, M.A.Sholes and S. M. Vuke-Foster, editors, Stratigraphy and sedimentology of coal-bearing Early Paleocene deposits from eastern Montana, Montana Bureau of Mines and Geology, Special Publications.



THE STUDY AREAS FOR STUDENT PROJECTS ARE LOCATED JUST EAST OF MILES CITY (MC), MONTANA



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

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 coar 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-