REGIONAL EXPLANATION OF DISTURBED UNITS WITHIN THE EARLY PALEOCENE TONGUE RIVER MEMBER OF THE FORT UNION FORMATION OF SOUTH EAST MONTANA

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INTRODUCTION

The Fort Union Formation covers significant areas in Montana, Wyoming, and North Dakota. In the 1992 KECK study area, located off Montana Route 7 near the town of Ekalaka, the formation includes two units: the Ludlow and Tongue River Members (Figure 1). Much of the Tongue River Member is exposed here with limited exposures of the underlying Ludlow. The focus of the project was threefold: to attempt to identify what caused the shifts in the paleocurrent record; to establish what mechanism triggered the rotation and/or faulting of the lower fine sand unit within the Tongue River Member, and to identify unconformities within the Tongue River Member. The last two points will be discussed here in further detail. It was concluded that the mechanism for deformation could be either loss of lateral support by the cut bank of a meandering river system or regional tectonic forces triggering a decollement along the contact between the Ludlow and Tongue River Members. Two unconformities are suspected to exist within the Tongue River Member although further research is required to pinpoint the exact amount of rock missing.

GEOLOGIC SETTING

During early Paleocene time, the Cretaceous epicontinental sea was retreating as shown by the lateral gradation of the Fort Union Formation into the marine Cannonball Formation to the east in North Dakota. To the west, the Bighorn Mountains rose during Ludlow (early to middle Puercan) time, as evidenced by volcanics and metamorphic materials in the Ludlow Member. Additionally, the Black Hills are thought to have risen during Tongue River (early to mid Torrejonian) time (Belt et al., 1992). Along with these uplifts were the continual development of several large depocenters including the Williston basin, the Bighorn basin, and the Powder River Basin.

Stratigraphy

The Fort Union Formation in SE Montana is bounded below by the Hell Creek Formation and is subdivided into the Ludlow and the Tongue River Members. The Hell Creek Formation consists of calcareous sandstones, siltstones, mudstones and shales. Conformably overlying the Hell Creek is the Ludlow Member of the Fort Union Formation, consisting of easily erodible somber yellow and gray colored clays, and sands with thick lenticular coals. The top of the Ludlow is designated as the last moderately thick and laterally continuous coal horizon. Lying conformably above the Ludlow Member is the lower unit of the Tongue River Member. The lower Tongue River unit consists of fine grained, thinly laminated, ripple bedded sandstone with minor amounts of mud. Contained within this unit are areas where the finely laminated sediments have been faulted and/or deformed. These disturbed areas are in many cases located adjacent to channel sand complexes which contain rip up clasts of the disturbed material at the base. The lower unit is unconformably overlain by the upper Tongue River unit (also called Medicine Rock unit), which consists of widespread cross bedded channel sands. The entire upper unit consists of 95% trough cross beds and lacks fine grained mud size materials and any indications of channel margins. Where the lower unit is deformed an angular unconformity is present between the upper and lower Tongue River units.. However, the contact between the upper and lower units is still clear in areas where the lower unit is not deformed due to the dramatic change in internal structures from finely laminated and occasionally ripple bedded to large cross beds on the scale of a meter.

DISCUSSION

Depositional Environments

The Hell Creek Formation is thought to have been deposited initially in a deltaic system which shifted to an inter-deltaic or coastal plain environment of swamps and mud flats by upper Hell Creek time (Garrett, 1963). The Ludlow Member of the Fort Union Formation was deposited in a low gradient fluvial environment where the coals

and muds represent flood plain and back swamp areas and the sands represent crevasse splay deposits or channel sands (Diemer et al., 1992). The Tongue River Member is interpreted to have been deposited in two distinctly different fluvial systems. The lower Tongue River unit is thought to have been deposited in a low gradient fluvial environment where extensive, shallow lacustrine or paludal type environments existed between channels represented by the finely laminated sands. Due to the scarcity of mud in this deposit, it is suspected that the water in the lacustrine areas was shallow and had a slow drainage system. This would allow the mud sized sediment to be kept in suspension by currents, suspected to begenerated by local winds, and flushed out of the system. The upper Tongue River unit marks a significant change in the fluvial environment. Since the entire unit consists of trough cross bedded sands it is thought to represent an actively meandering river system. Rip up clasts of finer grained sediment have been found at the base of some of the beds suggesting that finer grained material may have existed at one time but was quickly scoured away by another meandering channel. However, the lack of channel margins and fine grained material is problematic.

Evidence of Unconformities

Several features observed in the field indicate that two unconformities are present in the Tongue River Member. Field data indicate that the lower fine grained unit of the Tongue River Member lithified prior to undergoing deformation. The majority of the material is observed to have been faulted and deformed in coherent blocks. The time gap had to have been long enough to allow for significant lithification of the fine grained unit prior to inundation by the meandering channel. This indicates that an unconformity could exist at the contact between the fine grained unit and adjacent local channel sands.

The second unconformity is at the contact between the lower fine grained unit and the overlying cross bedded channel sands. Where the lower unit is deformed an angular unconformity is present. However, the contact between the upper and lower units is still clear in areas where the lower unit is not deformed due to the dramatic change in internal structures. The change from finely laminated and ripple bedded to large cross beds on the scale of a meter is identifiable in the field. How much time these unconformities represent is difficult to establish. There are only two dates to constrain the timing of events in the Tongue River Member. Dating a sample taken from mammal bones found in the upper Tongue River unit established an age of late Torrejoinan (figure 2). Analyzing pollen samples from a coal horizon near the Tongue River-Ludlow contact established an age of late Puercan (Nichols, 1993). Thus there is 1.3 Ma of time with which to place the following series of events: one, the deposition of the fine grained sand unit; two, the lithification of the fine grained unit; three, the deformation of the fine grained unit; four, the subsequent deposition of the overlying cross bedded sands.

Based on initial evidence collected the summer of 1992 it is difficult to evaluate the significance these unconformities. Further work on establishing ages of the adjacent channel sands in the lower Tongue River unit and dates closer stratigraphically closer to the contact between upper and lower units is needed to pinpoint the age gaps.

Mechanisms To Trigger Deformation Of Lower Tongue River Unit

Several working hypothesis both local and regional are currently under consideration for the explanation of deformation in the lower Tongue River unit. Locally, meandering channels cutting through the fine grained lower unit may have removed enough lateral support to cause significant deformation. This theory was first proposed by Garrett in 1963 to explain slump features found in the Ludlow Member farther west and north of the 1992 study area. In many cases the deformed lower unit was found adjacent to local channel sand bodies. However, at other sites no channel sand body could be found in the vicinity of deformed and faulted areas. The second hypothesis takes on a more regional approach. Below the Tongue River Member the Ludlow Member is typically unconsolidated and contains a high percentage of swelling clays. It has be postulated that the contact between the Ludlow and Tongue River Members could provide an adequate decollement surface. Forces large enough to trigger movement along this surface could be provided by the uplift of the Black Hills to the southeast of the study site or earthquakes triggered by Laramide tectonic forces in the area.

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FIGURE 1- Location of study area in southeastern Montana

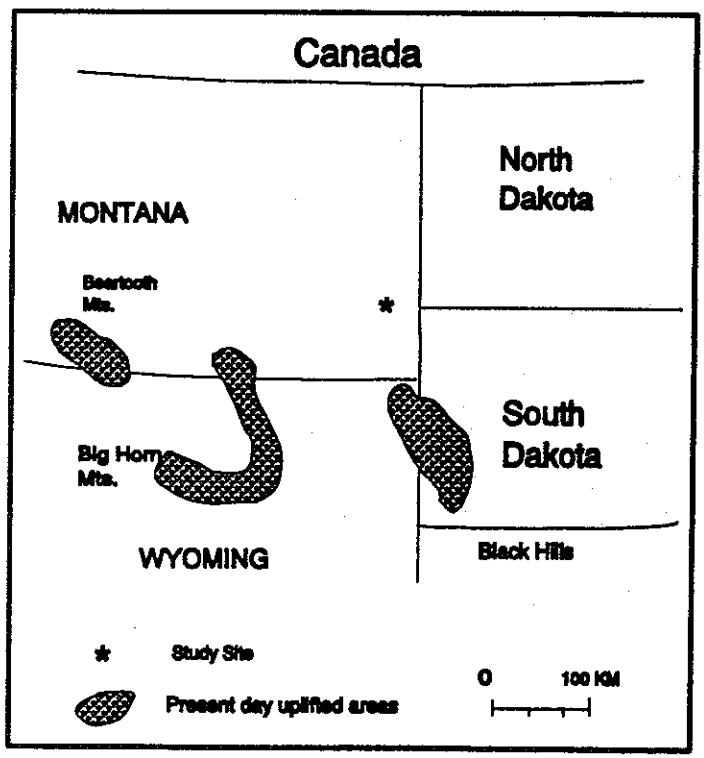

FIGURE 2-
Stratigraphy of the 1992 KECK summer study area and their corresponding ages. The Puercan/Torrejonian boundary is not well defined due to lack of dateable material