Provenance of the Ludlow and Tongue River sand deposits, Fort Union Formation (Paleocene), Southeastern Montana: Constraints on the Timing of the Bighorn Uplift.

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Introduction

The Williston Basin covers most of North Dakota and parts of western South Dakota, southern Canada and eastern Montana. This intracratonic basin experienced tectonic movement during the Laramide Orogeny along its southwest margin in eastern Montana. During the Cretaceous and into the early Paleocene, the Laramide Orogeny produced thick-skinned thrusts of basement uplifted blocks which are now the Bighorn Mountains and the Black Hills (Beck and others, 1988). This tectonic movement disrupted the southwest margin of the Williston Basin and formed the intramontane Powder River Basin between the Bighorn block and the Black Hills block (Beck and others, 1988). The field area for this project is located 100 km northwest of the Black Hills and 170 km northeast of the Bighorn Mountains, on the southwest margin of the Williston Basin. Sediment eroded from either of these two uplifts was deposited in this area during the Paleocene. Choosing this area enabled me to study the debris eroded from these uplifts. Sandstones from the river channels were analyzed for paleo-current directions (see B. Cole, this volume). By combining this paleo-current information with my analysis of the composition of the Paleocene channel sands, I hope to show the provenance of these channel systems and to give some insight on the timing of the uplift of the Bighorn Mountains.

Methods of Investigation

Samples of sand deposits were collected for petrographic analysis from fluvial systems of the older Ludlow Member and younger Tongue River Member of the Fort Union Formation. Thin sections were prepared for the sand samples and 500 counts per thin section were made from these samples. The point counted data was plotted using the ternary plot diagrams of Dickinson, 1979 as well as my own configurations. Another important distinction in this study is in grain identification. Groups of biotite grains connected in "booklets" were counted as metamorphic fragments (Whipkey and others, 1991). SEM analysis and compositional comparison were also undertaken. The results were then entered into ternary plot diagrams (see figures 1,2,3). These plots include: total quartz- total feldspar- total fragments (Dickinson, 1979), total monocrystalline quartz- total feldspar- total all stable and unstable fragments (Dickinson, 1979) and total volcanic fragments- total sedimentary fragments- total metamorphic and plutonic fragments (this report).

Results and Discussion

Field data collected by Barret Cole and myself, indicate that the rivers of the Ludlow Member were trending in a northeast direction. This result agrees with northeast paleo-current directions collected on the Ludlow Member in the Cave Hills District of western South Dakota (Goodrum, 1983). Pollen dating done by Doug Nichols suggests that the upper coals of the Ludlow Member in southeastern Montana is late Puercan to early Torrejonian in age. This places the Ludlow Member in Ekalaka in the early Paleocene and approximately 50 meters above the Cretaceous/ Tertiary boundary (see correlation chart by Hicks and Belt in Belt's discussion of the January Workshop, this volume).

Paleo-currents for the Medicine Rocks sandstone of the Tongue River Member (late Torrejonian) show this system to be trending to the southeast. There is also an angular unconformity separating the Ludlow and the Tongue River Members in the field area (see abstracts by Clark, Robertson and Lambert, this volume). If the paleo-current trends with their time information are valid, then there should be a compositional difference and possibly a provenance difference between the river systems of the Ludlow Member and the river systems of the Tongue River Member.

Preliminary petrographic results (see figures 1,2,3) show that there is a compositional difference, although a minor one, between the Ludlow and Tongue River sands. In all three ternary plots there is a distinct separation between the Ludlow and the Tongue River. The most distinct separation occurs between the amount of total quartz. The data shows that the Tongue River sands have less quartz grains than the Ludlow sands while maintaining similar levels of feldspar. The data also displays that the Tongue River Medicine Rocks sandstone contains a higher percent of sedimentary fragments than the Ludlow sands.

Conclusions

Based on the petrographic and paleo-current data the provenance of the Ludlow Member fluvial systems is the Bighorn Uplift to the southwest. With the documented paleo-current trends to be northeast during the Ludlow, this would place the rivers of Ludlow time flowing from the Bighorn Mountains towards the Williston Basin. The relative large amount of metamorphic and plutonic fragments in the Ludlow indicate that a basement core is being eroded during the deposition of the Ludlow (see discussion Hansley and Brown, 1992 and Lindholm and Merin, 1984). Paleo-current directions indicate the Bighorn Mountains were the source of this basement core erosion. The petrographic results (see figure 2) of the presence of first cycle metamorphic and plutonic fragments illustrate that the Bighorn core was eroding at this time.

Petrographic results (see figures 1,2) and paleo-current trends suggest that the provenance of the Tongue River Medicine Rocks system is from a different source area. The paleo-current data shows that its source must lie northwest of Ekalaka. The petrographic data shows that in three different analysis there is a clear separation in composition of the Ludlow and the Tongue River Member which also suggests that the source area is different. Also, sedimentary (recycled) fragments dominate the lithic fragments in contrast to the Ludlow. This evidence indicates strongly that there is a provenance difference. The source area for these rivers, however, does contain eroded basement grains of plutonic and metamorphic origin. The only possible source area based on paleo-current information is the Sevier overthrust in western Montana.

Finally, dating of the Ludlow Member to be earliest Paleocene (corresponding to Tullock age) by Nichols (written communication, 1993) and the presence of metamorphic and plutonic fragments suggests that the Bighorn Uplift commenced no later than the Cretaceous/ Tertiary boundary. This conclusion agrees with Hansley and Brown's (1992) interpretation of the Tullock Member sands in central Montana. A petrographic study done on the sands of the late Cretaceous (Maestrictitian) shows rivers trending to the east across this area and that the sediments show no signs of the commencement of the Bighorn uplift. The evidence from the Paleocene and late Cretaceous necessitate the uplift to have occurred at the K/T boundary.

Problems

One of the most unclear parts of this study is the question of how volcanic lithic fragments are present in the Ludlow Member sands. Based on paleo-current data in Ekalaka (this report) and work done in Livingston, Montana on the Cretaceous Elkhorn Volcanic sequence (see Dripps, 1992) the presence of volcanics from the Elkhorn sequence in the Ludlow sands was predicted. However, new information from Hansley and Brown (1992) and preliminary petrographic results from this report indicates that the Bighorn uplift had commenced by the beginning of the Paleocene. Therefore the uplifted Bighorn block should have blocked the drainage from Livingston keeping volcanic fragments absent from the Ludlow sands. Explaining the presence of volcanic fragments in the Ludlow has not yet been accomplished.

Another problem still unresolved is to determine if the fragments in the Ludlow sands or the Tongue River sands are first cycle. The petrographic results suggest strongly that the Ludlow sands contain first cycle fragments and the Tongue River sands contain predominantly second cycle fragments. This problem is directly connected with the necessity to find a probable source area for the Tongue River sands. Since the Sevier overthrust is documented primarily as a thin-skinned thrust, it would be unlikely to find first cycle basement grains in the Tongue River sands (Beck and others, 1988). It is vital, then, to determine if the Tongue River fragments are recycled. Classification of the correct cycle of lithic fragments will pinpoint the provenance of the Tongue River sands.

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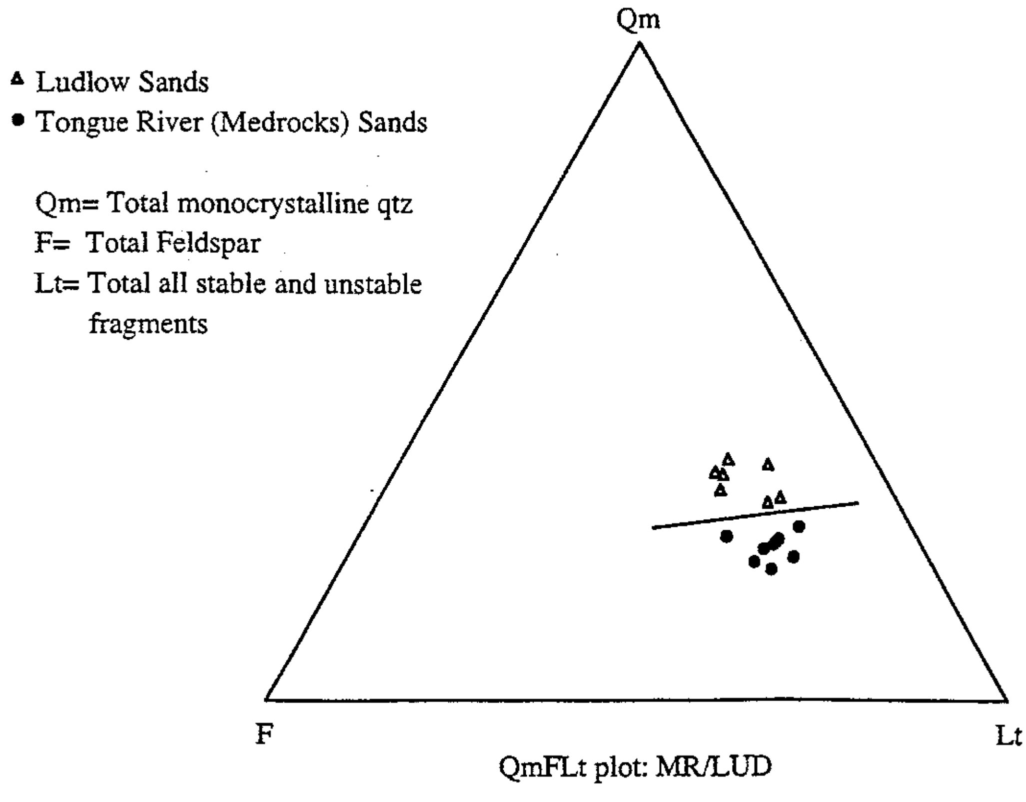

FIGURE 1: Qm-F-Lt ternary plot (Dickinson and Suczek, 1979).

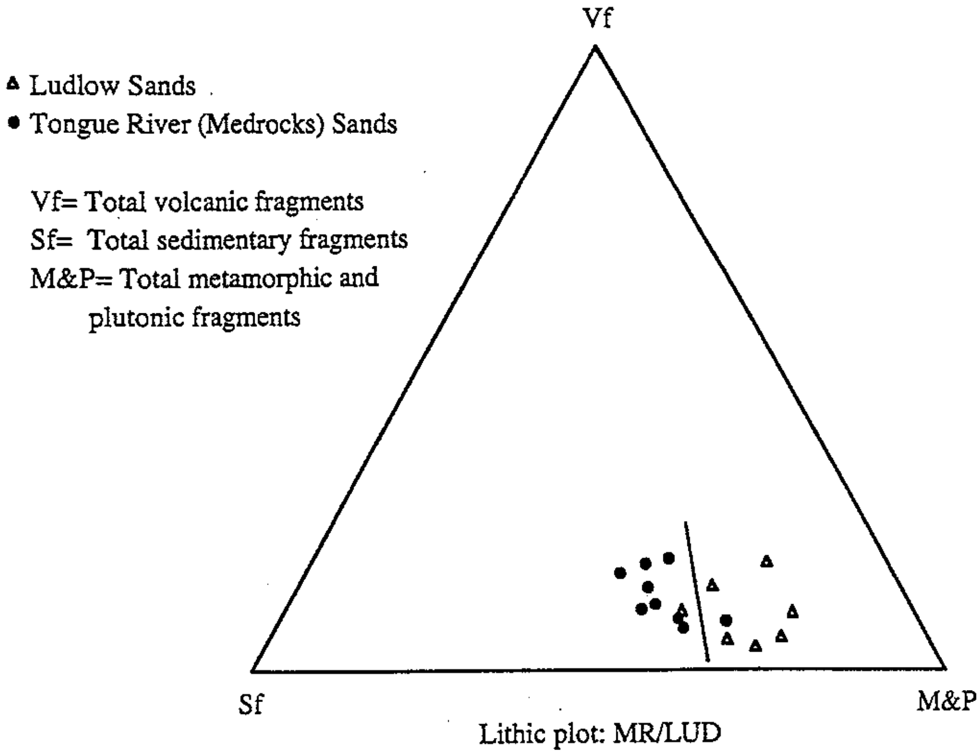

FIGURE 2: Lithic Fragment ternary plot.

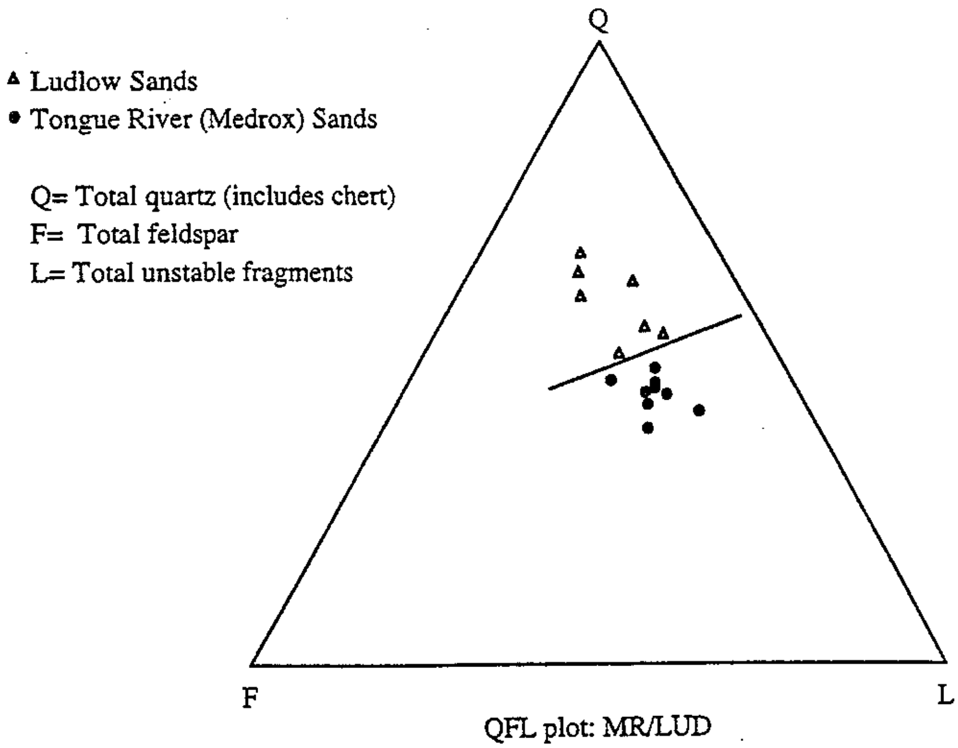

FIGURE 3: Q-F-L ternary plot (Dickinson and Suczek, 1979).