# PETROGRAPHIC ANALYSIS OF THE TULLOCK MEMBER OF THE PALEOCENE FORT UNION FORMATION IN THE POWDER RIVER BASIN, SOUTHEASTERN MONTANA

Genga T. Nadaraju
Department of Geology
The College of Wooster
Wooster, OH 44691

The Tullock Member of the Fort Union Formation in southeastern Montana was deposited by rivers flowing east to southeast. Channel sands in the Tullock consist of, in order of decreasing abundance, lithic fragments, quartz, and feldspar. Quartz, chert, and feldspar decrease eastward from Miles City while lithic grains of shale, siltstone and carbonate increase.

## Field Study

The Fort Union Formation in the Powder River Basin is composed of (from lowest to highest) the Tullock, Lebo and Tongue River Members. All three Members are Paleocene in age. Sand samples of the Tullock Member were collected for petrographic analysis from outcrops between 23 and 37 meters below the contact of the Tullock Member with the overlying Lebo Member. The 11 sample sites lie between Signal Butte (near Miles City) and Locate Road, an east-west distance of 40 km (Fig. 1). All samples of sand are from paleochannel deposits. Measured sections (BN1, BN2 and B-37) at three of the sites display a fining upward sequence. Cementation was normally moderate (can be easily disaggregated without breaking grains; Pettijohn et. al., 1973) at all sites. The sand is light gray in color and medium to fine grained. Cross-beds and some ripple laminae, indicative of paleocurrent directions, are characteristic throughout the channels of the Tullock Member.

## Petrographic Analysis

Thin sections at 9 sites have been examined using 300 or more detrital framework grains, excluding matrix. Grains observed were grouped into 12 categories: monocrystalline quartz, polycrystalline quartz, chert, quartz-mica aggregate, quartz-mica tectonite, volcanic lithic, carbonate lithic, potassium-feldspar, plagioclase, sedimentary lithic fragments (siltstone, shale), opaque and other lithic fragments (heavy minerals, muscovite, biotite, chlorite). Additional petrographic observation of the samples included extinction angle, maturity of grains, sorting, grain alteration, recycled grains, overgrowths and the presence of heavy minerals.

## Results

Grains observed in thin section were on average moderately sorted and submature. Point counting revealed a predominance of lithic fragments (40-50%). Major lithic fragments were shale and siltstone. Minor lithic fragments include volcanic lithic, carbonate lithic, quartz-mica aggregate, quartz-mica tectonite and phyllite. Monocrystalline and polycrystalline quartz form about 20-30% of the sand. Feldspar (plagioclase and potassium-feldspar) averages 10-20%, and other minor constituents (muscovite, chlorite, biotite, zircon, glauconite and opaque) were less than 5% of the sand.

Both shale and siltstone lithics occur either as large elongate rock fragments or finer grains that resemble, and blend into, the matrix. Other lithics (phyllite and schist) appear as fine grained argillaceous fragments. Most of the lithic fragments appear squashed, deformed and molded about the more competent grains such as quartz. Carbonate lithics appear rounded with abraded boundaries. Most have undergone alteration and exhibit two-directional rhombic cleavage. Volcanic lithics (10%) are mostly fresh. Monocrystalline quartz (Qm) is more abundant than polycrystalline quartz (Qp). Quartz displays both undulose and straight extinction. Grains generally range from angular to sub-angular. A great variety of quartz was found, including monocrystalline quartz with inclusions, quartz chalcedony, myrmekite, quartz with overgrowths, euhedral monocrystalline quartz and strained quartz. Occurrences of the above varieties, however, were less than 1%. Polycrystalline quartz includes either microcrystalline quartz, megacrystalline quartz, or a combination of both. Most chert appears as detrital grains and displays uniformly microcrystalline quartz crystals. Feldspars present include varieties of plagioclase, orthoclase and microcline. Potassium-feldspar is dominant over the plagioclase. Zoned plagioclase, perthitic tecture and albite twins were among the other varieties observed. Both fresh and altered feldspars occur.

The point count constituents were plotted on various ternary diagrams (Fig. 2; Dickinson and Suczek, 1979) to study variations both stratigraphically, with the overlying Lebo and Tongue River Members (using point count data of Wong, 1988), and geographically, within the Tullock Member and correlative Ludlow Member of North Dakota (using point count data of Velbel, in prep.). The results show some significant changes in the number of various constituents geographically within the Tullock Member. Eastward from Miles City (Fig. 1) the following were observed : decrease in quartz (especially polycrystalline quartz), chert and feldspar; increase in shale and siltstone lithics, carbonate lithics, and opaques. No major changes were observed in the number of volcanic lithics between Miles City and the Locate Road area but a decrease occurs in the Spring Draw area (T1 & T2). Other constituents show no significant changes. No significant stratigraphic variations of constituents of the Tullock Member were observed. This is because of the narrow sampling interval, from 23 to 37 meters below the overlying Lebo Member.

Paleocurrent data (Fig. 1) show a southeasterly trend at the locations of samples T1, T2, and T10 and a southwesterly trend at "Practice Butte" near the location of samples T3 and T9.

Discussion

Regional comparison with the Ludlow samples of North Dakota (Velbel, in prep.) shows the following differences in the Ludlow samples: increase in quartz (10-15%), decrease in feldspar (18-20% - feldspars present are mostly weathered), and an increase in lithics mainly due to quartz-mica aggregate (5%). Paleocurrent directions in the Ludlow study area trend northeasterly. Provenance study of Tullock Member in northeast Wyoming and southeast Montana (Whipkey and Cavaroc, 1987) showed a framework of 80% quartz with feldspars and lithics making up the remainder. Paleocurrent directions here trend northeasterly. Framework and sedimentation patterns of the Tullock Member in southeastern Montana (Brown, 1987) show a westerly to northwesterly transport of sand associated with interfluvial zones of flood plains and swamps.

Local comparison stratigraphically with the overlying Lebo and Tongue River Members reveals the following differences: increase in quartz with the increase greater in the Lebo Member (10-15%); Lebo feldspars increase by approximately 5%, but the Tongue River feldspars decrease by approximately 10% compared to the Tullock. Lithic fragments decrease from the Tullock to the Lebo Member but increase from the Lebo to the Tongue River Member (Tongue River lithics primarily consist of carbonate fragments). Volcanic lithics decrease from the Tullock to the Tongue River Member. Paleocurrent directions in the Lebo Member in the Pine Hills area (Fig. 1) show a east to northeast trend.

The Tullock Member sands in the study area are composed primarily of lithic fragments and quartz. Quartz grains are common detrital constituents of most sedimentary rocks and also occur in many igneous and metamorphic rocks. Different varieties of quartz (based upon inclusions, overgrowth, etc.) were assigned to igneous, metamorphic and sedimentary source rocks (Pettijohn et. al., 1973). However, undulose extinctions of quartz crystals are typical of stress during and after the crystallization of igneous and metamorphic rocks (Ehlers and Blatt, 1982). The polycrystalline quartz detrital fragments are elongated which suggests they originated in a nonhydrostatic stress field during metamorphism (Ehlers and Blatt, 1982). Shale lithics suggest a rip-up origin. Tullock Member shale lithics show a low degree lithification and are elongate grains. The increase in sedimentary lithic fragments from the Miles City area towards the east suggests a intrabasinal source. Other lithic fragments indicate source rocks of igneous and metamorphic nature (Ehlers and Blatt, 1982). The frequency of feldspar occurrences were orthoclase > plagioclase > microcline > perthite where perthite is the least common type. The decrease in feldspar and increase in weathered feldspar towards the east indicates increasing transport distance. The presence of volcanic lithics, quartz-mica aggregrates, and unweathered feldspars are indicative of first cycle grains (Ehlers and Blatt, 1982). Volcanic lithics could have been derived from a volcanic area or unroofed basement, the unweathered feldspars from a volcanic area, and the quartz-mica aggregates from unroofed basement. Most of the heavy minerals (zircon, epidote, rutile) originated from metamorphic rocks. Carbonate, with its two-directional cleavage, could be from an older sedimentary environment.

Given the above petrographic evidence, the source area of the Tullock Member sediments could be either igneous or metamorphic with metamorphic being more likely. A volcanic source area could be another possibility since volcanic activity is known in western Montana during the Late Cretaceous (Steven et. al., 1972, p. 229). The increase in lithic fragments and weathered feldspars and decrease in fresh feldspars and polycrystalline quartz towards the east coincides with the southeasterly trending paleocurrent direction. Therefore the Tullock Member sediments could have been transported by a paleochannel or paleochannels flowing from a source to the west or northwest. Also the presence of some unweathered feldspar and heavy minerals near the Miles City area is indicative of a source area not too far to the west.

In the Ludlow Member of North Dakota, smaller amounts of feldspars and greater amounts of quartz-mica aggregate with a northeasterly paleocurrent direction could be due to a different source area entirely. Provenance study of Tullock Members by Whipkey and Cavaroc (1987) and J. Brown (1987) was done south of my study area in the Powder River Basin. Paleocurrent directions at these two areas show trends different from those in my study area. Therefore sediments in these areas could be from different source areas. In the overlying Lebo and Tongue River at Pine Hills (Wong, 1988), mineral constituents are approximately the same. Lithic fragments decrease and feldspar and polycrystalline quartz increase stratigraphically in the Lebo Member. This suggests that the Lebo sediments are not as far travelled as the Tullock Member sediments. In addition, a northeasterly paleocurrent direction in the Lebo Member suggests different source areas for Lebo and Tullock sediments. As for the Tongue River sediments, the increase in lithic fragments is mainly from within the basin as opposed to the Tullock lithics, most of which have an extrabasinal source (Fig. 2).

References Cited

Brown, J. (1987), Framework and sedimentation patterns of Tullock Member of Fort Union Formation, east central Powder River Basin, Montana and Wyoming: American Association of Petroleum Geologists Bulletin, v. 71, p. 1001-1002.

Dickinson, W. and Suczek, C.A., (1979), Plate tectonics and sandstone composition: Association of American Petroleum Geologists Bulletin, v. 63, p. 2164-2182.

Ehlers, E.F., and Blatt, H., (1982), Petrology: Igneous, sedimentary and metamorphic: San Francisco, CA, W.H. Freeman and Company, 732 p.

Pettijohn, T.J., Potter, P.E., and Siever, R., (1973), Sand and sandstones (1st edition): New York, Springer-Verlag, 618 p.

Steven, T. A., et al., (1972), Upper Cretaceous and Cenozoic igneous rocks, p. 229 in Geologic atlas of the Rocky Mountain region, United States of America: Rocky Mountain Association of Geologists, Denver, Colorado: A.B. Hirschfeld Press, 331 p.

Velbel, M., in prep., Petrology and provenance of sandstones from the Ludlow Member, Fort Union Formation, southwestern North Dakota: 44 p.

Whipkey, C.E., and Cavaroc, V.V., (1987), Provenance of Tertiary Powder River Basin sandstone units, northeast Wyoming and southeast Montana: Geological Society of America Abstracts with Programs, v. 19, p. 136.

Wong, B., (1988), Preliminary petrography and provenance of sands from the Lebo and Tongue River Members of the Fort Union Formation, Montana: Senior Integrative Exercise, Department of Geology, Carleton College, Northfield, Minnesota, 66 p.

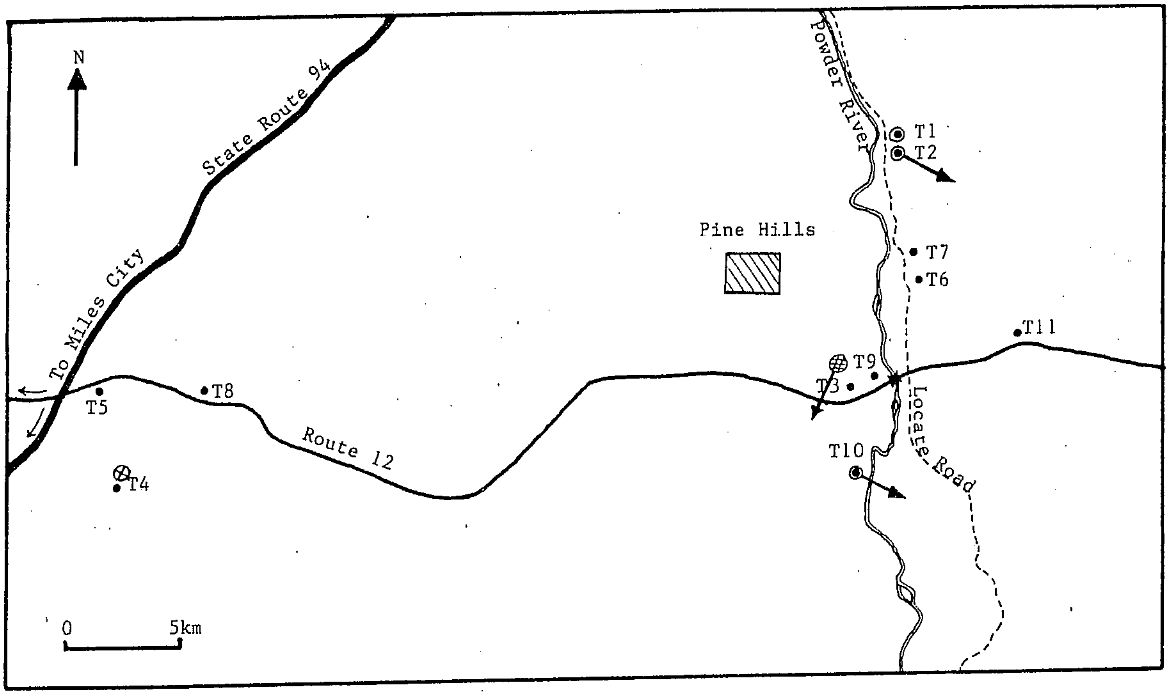


**Figure 1 :** Locations of sand samples collected in the Tullock Member of the Paleocene Fort Union Formation in the Powder River Basin, southeastern Montana.

Measured Sections

BN1 is at T1
BN2 is at T2
B-37 is at T10

Legend

- Locality of sand sample
- Locality of sand sample with measured section
- Paleocurrent direction
- Practice Butte
- Signal Butte

QFL

Q = all quartz
F = all feldspars
L = all lithic fragments and carbonate

QmFLt

Qm = monocrystalline quartz
F = all feldspars
Lt = all lithic fragments, carbonate, and polycrystalline quartz

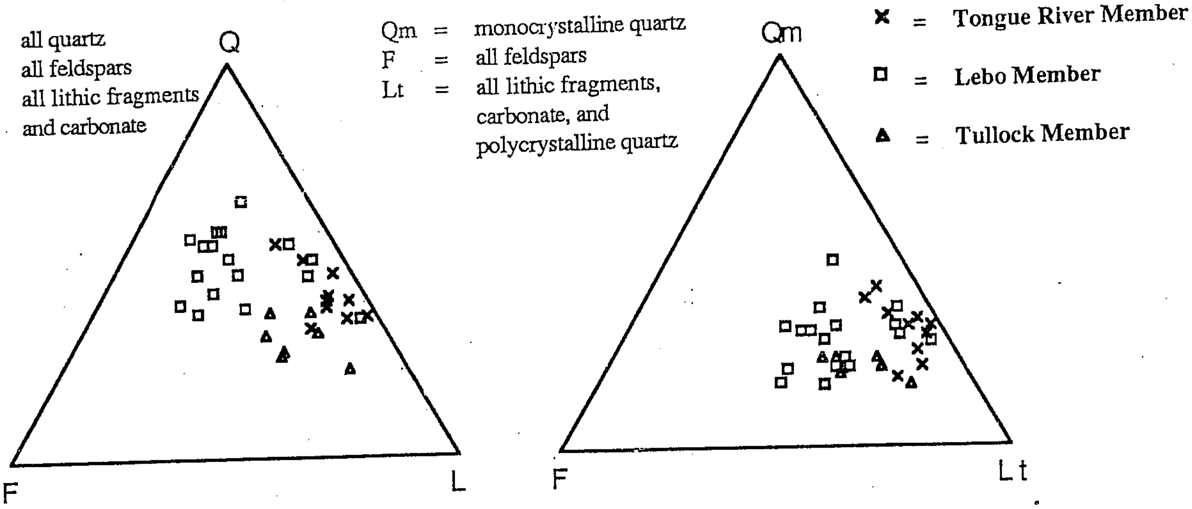


**Figure 2 :** Ternary diagrams of sand samples from the Tullock Member (this study), plotted with data of Wong (1988) from the Lebo and Tongue River Members in the Pine Hills.