The Depositional History of the Arikaree Formation in the Ekalaka Hills, Carter County, Montana

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INTRODUCTION

The Arikaree Formation is a widespread uppermost Oligocene to lower Miocene sandstone unit (Frazier and Schwimmer, 1987). It was first named by Darton in 1899, who described the exposures along the Niobrara River in northwestern Nebraska and southwestern South Dakota (Denson and Gill, 1965). The formation extends northward from Nebraska to South Dakota and westward into southeastern Montana and Wyoming. It was once a widespread unit throughout the Williston Basin, but with erosion in the Pliocene and Pleistocene much of it has been removed (Denson and Gill, 1965). The general stratigraphy in this area consists of the following units in ascending order: the Cretaceous Hell Creek Formation, the Paleocene Fort Union Formation, the Eocene Golden Valley Formation, the Oligocene White River Group, and the Arikaree Formation (Figure 1).

THE ARIKAREE FORMATION IN THE EKALAKA HILLS

The Arikaree Formation forms prominent cliffs of light green sandstone in the Ekalaka Hills, just south of Ekalaka, southeastern Montana. In 1945 Mylan Stout and G.E. Lewis identified rodent (*"Hystricops" senrudi*) and equid (*Parahippuss* or *Miohippus*) fossils in the Arikaree Formation in the Chalk Buttes area, making the formation Miocene in age (Denson and Gill 1965). The general stratigraphy of the sections I measured in the Ekalaka Hills comprised, in ascending order, channel sands of the Tongue River Member of the Fort Union Formation, a green mudstone, a buff channel, and the greenish sandstone of the Arikaree Formation (Figure 2). I was unable to determine whether the green mudstone and the buff channel were part of the Paleocene strata or whether they were part of the Miocene, since no fossil evidence was available. Also, no distinct unconformity was recognizable. The Arikaree is easily recognizable because it caps many of the buttes in the area and commonly forms resistant cliffs.

PURPOSE AND METHODS

Through field observations and petrographic analysis (including point counts), I am hoping to gain some understanding of the environment of deposition of the Arikaree Formation. Thirteen stratigraphic sections were measured and an effort was made to try and correlate the sections over a few kilometres. Unfortunately, this effort was not successful as often it was very difficult to establish a base line from which to correlate the rest of the strata. Therefore, five main sections were studied in which the exposures of the Arikaree were relatively well preserved and approachable (refer to USGS 7.5" Stagville Draw Quadrangle, Montana). I tried to correlate these five sections with measured sections of Paleocene strata to the north of Ekalaka, but this was also unsuccessful . Through the thin-section work I am making comparisons to determine if there are any major differences in the petrography of similar units that are from different locations. When point counting, I included cement in the total count (500 points per thin section). When plotting the compositions, however, I excluded the cement and normalized the percents of quartz, feldspar, and lithic fragments. I also included the chert fragments in the lithic fragment percent.

PRELIMINARY RESULTS

The five sections that were studied in relative detail were:

1) Stagville Springs Section (NE 1/4 SW 1/4 sec. 21, T. 1 N., R. 58 E.)
2) Sugarbowl Valley Section (North center of SW 1/4 sec. 34, T. 1 N., R. 58 E.)
3) Opechee Road Section (North center of SW 1/4 sec. 10, T. 1 N., R. 58 E.)
4) Lambert Spring Section (South center of SW 1/4 sec. 9, T. 1 N., R. 58 E.)
5) Rimrock Carter Road Section (North center of NE 1/4 sec. 34, T. 1 N., R. 58 E.)

The Sugarbowl Valley and Rimrock Carter Sections show the stratigraphic succession described above most clearly (Figure 2). In the other three sections the buff channel sandstone is missing. Tan to gray channel sands of the Tongue River Member (Fort Union Formation) occur at the base of all the sections. These are fine-grained sandstones and in the Sugarbowl Valley Section, the unit becomes even finer-grained toward the top. In thin section the grains tend to be subangular and have slightly undulatory extinction. Sedimentary structures include trough cross-bedding with paloecurrents varying from 140° to 150°. In the Opechee Road Section, some dewatering structures such as convolute lamination were also present.

Overlying the Tongue River Member sandstones is the green mudstone. On fresh surfaces it has a purple tint. The contact between the two units was usually covered but digging readily revealed it. The mudstone is a non-calcareous rock with about 60-65% microcrystalline quartz. A green marl at the Opechee Road Section may be a correlative of the green mudstone. This mudstone unit was thickest (over ten metres) in the Sugarbowl Valley Section. Here, it is cut by the overlying buff channel in some places, but is continuous on either sides of the channel in others. Directly below the channel in this section there is a slip plane in the mudstone unit; the channel cutting into the mudstone caused a rotational block to slip along this plane.

As noted above, the buff channel sandstone is missing at the Opechee Road, Lambert Spring, and Stagville Spring Sections. In the Sugarbowl Valley and Rimrock Carter Sections, however, it is a major unit up to ten mertres thick. It is a fine-grained sandstone and contains intraclasts of the underlying mudstone at the base. The compostion of the rock is similar to the overlying Arikaree Formation (Figure 3). The grains are subangular and show slightly undulatory extinction. The channel has low-angle trough cross-bedding that starts at about two metres from the base of the unit. The buff channel sandstone is characterized by northeast trending paleocurrents (average 100°). Poorly lithified layers alternate with resistant layers, which are cemented with calcite. The top three to four metres contain abundant vertical burrow-like features that are about 0.1 m to 0.5 m in length. They are perpendicular to the bedding; the bedding actually runs through the structures (Moyle, 1993). There is no distinct contact between the channel and the overlying Arikaree; the buff color of the channel grades into the green of the Arikaree. This makes it difficult to determine whether the channel is part of the Arikaree Formation or the older Paleocene strata.

Blanketing the underlying three units is the Arikaree Formation, a green sandstone containing lithic fragments. The sandstone is fine-grained and typically massive, although in some places bedding is recognizable and in these layers the grain size decreases to very fine sands. Low-angle trough cross-bedding with paleocurrents ranging from 110° to 250° are also present. In the Stagville Springs Section, at about 10.5 metres from the base of the exposure, possible hummocky cross-stratification and a poorly preserved reactivation surface occur. The vertical burrow-like features that cut through the beds increase in abundance near the top of the section. At the Opechee Road and Stagville Springs Sections the Arikaree has a few thin (0.5 cm) volcanic ash layers at the base of the unit.

Arikaree sandstones consist of about 45% quartz, 10-15% feldspars and 35-40% lithic fragments (Figure 3). Detrital grains are relatively angular and fresh; even feldspars are relatively unweathered. Many of the lithic fragments and the other detrital grains are volcanic in origin. Quartz grains are subangular and have slightly undulatory extinction. Lithic fragments are angular to slightly rounded and are made of feldspars and mafic minerals, such as muscovite, biotite, and hornblendes. There are detrital hornblende and pyroxene grains present also. The rock is matrix supported; there is abundant calcite and the detrital grains seem to be floating in this matrix. The matrix is relatively coarse grained around the grains and decreases in size away from the grain boundaries. Some grains of quartz and feldspar are embayed by calcite. Some feldspar grains appear to have been split in two by calcite, which seems to have filled in cracks in the grains.

A green, well-rounded mineral, about 2-3 mm in diameter, was identified as possibly glauconite or celadonite. Glauconite is shallow marine in origin; celadonite is an altered volcanic mineral. Positive identification of this mineral is difficult because glauconite and celadonite vary mainly on a structural level, and because there wasn't a great abundance of the mineral in the rock specimens.

System	Series		Group, formation, member
Quaternary	Recent and Pleistocene		
Tertiary	Pliocene or upper Miocene		Flaxville Formation and probable correlatives
	Miocene		Arikaree Formation
	Oligocene	A	Brule Formation
			Chadron Formation
	Eocene		Golden Valley Formation
	Paleocene	B	Sentinel Butte Member
			Tongue River Member
			Cannonball Member; Ludlow Member
Cretaceous	Upper Cretaceous		Hell Creek Formation
			Fox Hills Formation
			Pierre Shale

A - White River Group
B - Fort Union Formation

Figure 1. Generalized stratigraphic section of exposures in eastern Montana, North and South Dakota (after Denson and Gill, 1965). More recent dates show the Arikaree starting in the uppermost Oligocene (Frazier and Schwimmer, 1987).

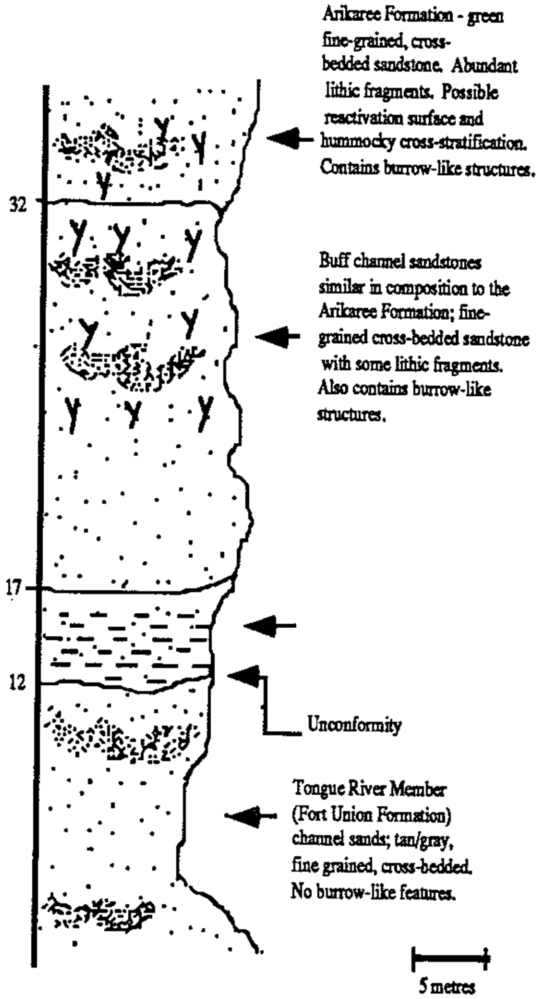

Figure 2. Generalized stratigraphic column of Sugarbowl Valley and Rimrock Carter Sections

DISCUSSION

On the basis of field observations and laboratory analysis, several suggestions about the depositional environment of the Arikaree Formation can be made. Some evidence is consistent with marine influence at the time of deposition of the Arikaree. The green mineral (possibly glauconite?), the hummocky cross-stratification, the reactivation surface, and the burrow-like structures suggest a marine or estuarine environment. Limited biostratigraphic data make it unlikely that the Arikaree in the Ekalaka Hills is marine influenced (Denson and Gill, 1965). It is most likely a terrestrial unit.

The terrestrial origin of the Arikaree may be explained in two ways. First, the sandstone of the Arikaree may represent a lacustrine facies deposited on an erosion surface. Unfortunately, no fossil evidence was available for dating from either the Arikaree or the buff channel sandstone units. Such evidence would have resolved whether the channel is part of the Arikaree (Miocene), or part of the Fort Union Formation (Paleocene). I believe that the buff channel is part of the Arikaree Formation because of the similarities in grain size, composition, sedimentary structures, and burrow-like features of the two units (Figure 3). Differences in the colors of the two units may be due to leaching. Channels were first filled in by the buff sands and later deposition took place in more of a blanketing nature. The hummocky cross-beds and the reactivation surface suggest a change in lake levels and the presence of wave/tidal action. The abundant calcite in the rocks seems to be a secondary replacement feature. Perhaps the calcite replaced mud that would be expected in a lake environment, but which is missing in the rocks studied here (Reineck and Singh, 1980).

Second, if the lithic fragments in the rock are fragments of tuff, the Arikaree in the Ekalaka Hills may be a tuffaceous sandstone unit, such as those in southeastern Wyoming and western Nebraska. Valleys may have filled with "fluvial fine-grained volcaniclastics" (Hunt, 1990); when streamflow in the region decreased, fluvial deposition decreased. Subsequent deposition took place in the form of air-fall debris deposited in the inter-valley areas. A possible source of these volcaniclastics may be in western Montana. Winds may have carried pyroclastic debris and deposited it in the southeastern part of the state as a blanketing tuffaceous sandstone.

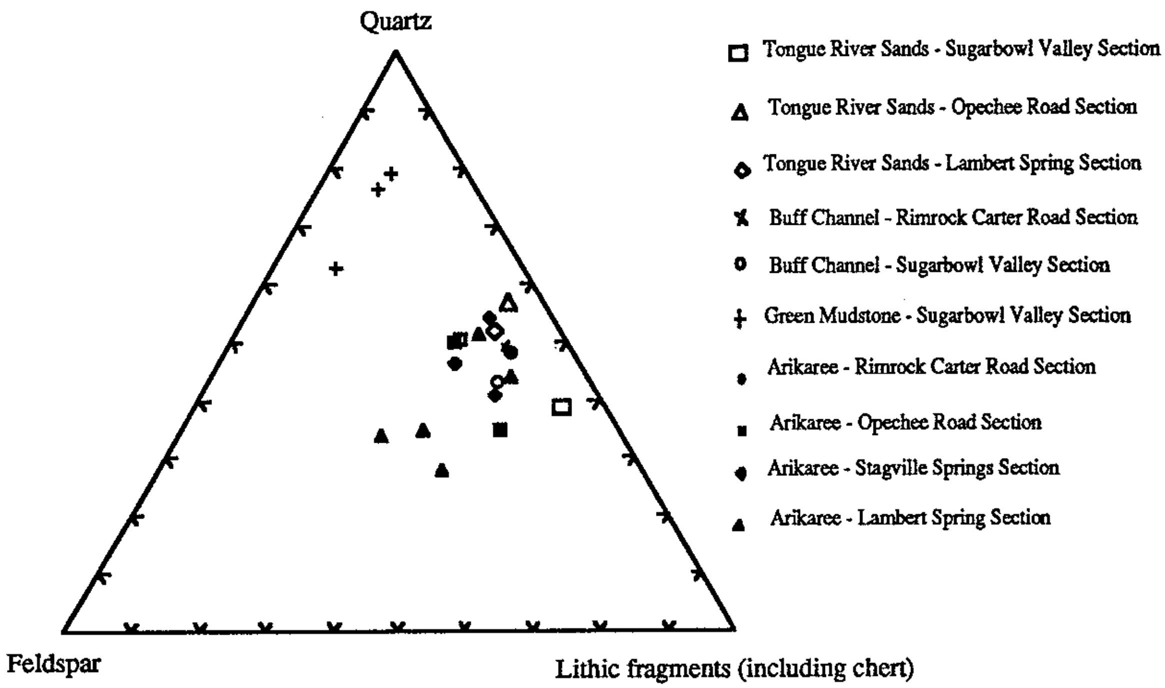

Figure 3.. Composition of Tongue River Member sands, green mudstone, buff channel, and Arikaree Formation from several sections.

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