# THE ROSEBUD PROBLEM REVISITED

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ABSTRACT

For at least a century, questions have continued concerning which lithostratigraphic units constitute the Rosebud Formation of Gidley and how they correlate with other regional Arikareean deposits. The correlation of the Rosebud Formation has been known as the Rosebud Problem, popularized by the late James Reid Macdonald from the 1960s through the 1980s and has continued to be a major geological problem in South Dakota and surrounding states. Essentially, the Rosebud Formation has been considered by some workers as having been deposited during the early Arikareean North American Land Mammal Age in its type area on the Rosebud Indian Reservation in south-central South Dakota; others have correlated the Rosebud Formation with formational entities farther west in southwestern South Dakota that were accumulated during the entire Arikareean Age. Much of the problem is historical, based upon the designation of several units by W.D. Matthew as the upper and lower Rosebud Formation in southwestern South Dakota. Macdonald recognized the greater temporal extent and additional lithostratigraphic units in this area. He designated the lower Rosebud unit as the Sharps Formation, extended names from Nebraska for the succeeding Monroe Creek and Harrison formations, and the upper Rosebud has been retained in southwestern South Dakota. However, many workers, especially this author, have referred to the upper Rosebud unit as "Rosebud" Formation. Relatively few diagnostic fossils have been recovered from the type area of the Rosebud Formation, but those few specimens suggest an early Arikareean Age. Now, numerous fossils have been secured from the Turtle Butte Formation that overlies the Rosebud Formation in south-central South Dakota. The Turtle Butte assemblage indicates a late early Arikareean time of deposition. As a result, the nomenclature of those units to the west requires revision. The "Rosebud" Formation requires a new formational name (Black Bear Formation) because this reddish sandy siltstone/claystone is lithologically distinct from the Sharps Formation, the type Rosebud Formation in central South Dakota, and the equivalent Anderson Ranch Formation in Nebraska. Moreover, the late Arikareean assemblage from the "Rosebud" Formation indicates a significantly later time of deposition than the early Arikareean type Rosebud Formation. The type Rosebud Formation lies over a major regional disconformity that may be correlated to the west with the Godsell Ranch channels described by Macdonald, although paleofaunal similarities may indicate correlation with the slightly younger Monroe Creek Formation.

Additional studies are required for substantiation of alternatives of type Rosebud Formation correlation.

Keywords

Correlation, Oligocene, Miocene, Rosebud Formation, Godsell Ranch beds, Black Bear Formation

## INTRODUCTION

For over a hundred years, a major problem in the lithostratigraphy of southern South Dakota has persisted. The problem has been so pervasive that it was even called the "Rosebud Problem" in these Proceedings by the late James Reid Macdonald (1988). The Rosebud Problem persisted during production of the geological map of South Dakota (Martin et al. 2004) resulting from different ages ascribed to the Rosebud Formation between south-central and southwestern

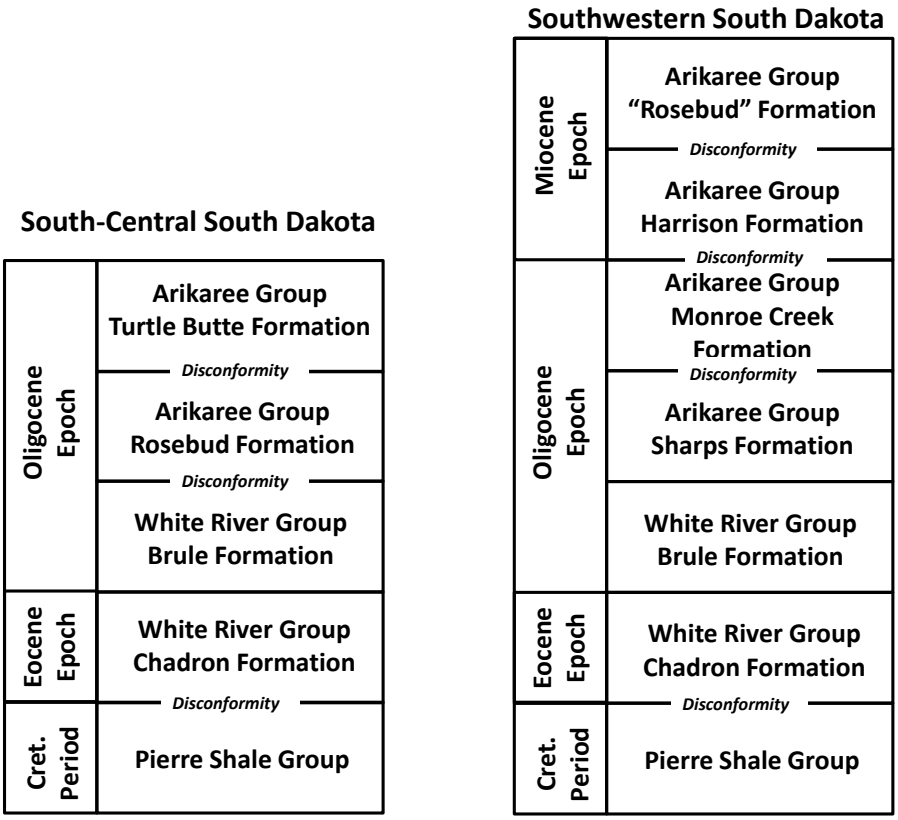


*Figure 1. Lithostratigraphic relationships of late Paleogene-early Neogene formations in south-central and southwestern South Dakota. Composite section in south-central South Dakota based upon Skinner et al. (1968) and in southwestern South Dakota on Harksen and Macdonald (1969).*

South Dakota. Although questions remain, enough data are now available to address major aspects of the Rosebud Problem.

The lithostratigraphy of the late Paleogene-early Neogene units of southern South Dakota and northwestern Nebraska has been somewhat controversial over the years, principally owing to historical development. One of the most controversial units has been the Rosebud Formation, originally named by J.W. Gidley (1904) for deposits near the Rosebud Indian Agency in Todd County, south-central South Dakota (Skinner et al. 1968; Macdonald and Harksen 1968). Later, when W.D. Matthew (1907) began collecting vertebrate fossils in southwestern South Dakota, he transferred the name Rosebud to these rocks, noted some temporal differences among the units, and introduced the terms lower and upper Rosebud Formation. J.R. Macdonald began extensive investigations in the 1950s, and with J.C. Harksen, formalized the stratigraphic succession in southwestern South Dakota (Figure 1). Meanwhile, investigators in Nebraska had formulated a stratigraphic succession of equivalent deposits across northern Nebraska. Much of this nomenclature was based upon that of researchers from the Carnegie Museum, University of Nebraska, and the American Museum of Natural History. This stratigraphic nomenclature was summarized by Peterson (1906) and McKenna (1965), and correlations to South Dakota were outlined by Harksen and Macdonald (1969), Martin (1976, 1983, 1985) and Martin and Green (1984).

In central South Dakota, the Oligocene Brule Formation of the White River Group is typically overlain by the Rosebud Formation of Gidley (1904). However, the Rosebud Formation may overlie a variety of formations, indicating a major sub-Rosebud unconformity. The Rosebud Formation is in turn disconformably overlain by the Turtle Butte Formation of Skinner et al. (1968) in southern Tripp County, South Dakota, which is disconformably subjacent to strata of the Miocene Ogallala Group. The Turtle Butte Formation is localized, and the Ogallala Group normally disconformably overlies the Rosebud Formation in south-central South Dakota.

In southwestern South Dakota, the lithostratigraphic succession is more complex. The Sharps Formation, deposited during the early Arikareean (Ar1) North American Land Mammal Age (NALMA) (Tedford et al. 2004) with the Rockyford Ash Member at its base (Macdonald 1963, 1970), overlies the Brule Formation of Whitneyan NALMA. Within the Sharps Formation, as mentioned by Macdonald (1963), Harksen (1974), and Martin (1985), lies a major disconformity demarked by very deep channels incised into the underlying pink lower Sharps Formation and even down into the Brule Formation (Harksen 1974). Macdonald (1963, 1970) referred to these channels as the Godsell Ranch channels in Shannon County, and Harksen (1974) and Parris and Green (1969) noted similar channels in the Cedar Pass area of Jackson County, South Dakota. The paleofaunal assemblages of these channel deposits are slightly more derived than those from the lower Sharps Formation (Macdonald 1963; Parris and Green 1969). The silty, vertically weathered Arikareean (Ar2) Monroe Creek Formation is suprajacent to the Sharps Formation and is in turn succeeded by the gray, sandy Harrison Formation. Both names were extended into South Dakota from the panhandle of Nebraska. Overlying the Harrison Formation is a pink, silty,

very fine-grained sandstone that has been termed variably as the upper Harrison, upper Rosebud, or "Rosebud" Formation (Peterson 1906; Macdonald 1963; Martin 1983, respectively). In 1967, I found the Black Bear Quarry II Local Fauna (Green 1972; Martin and Green 1984) in this unit that indicates a latest Arikareean (Ar4) time of deposition. The "Rosebud" Formation is disconformably overlain by the Batesland Formation, a large channel system that was incised into the pink "Rosebud" Formation (Harksen and Macdonald 1967; Martin 1976). Based upon current definitions (Tedford et al. 2004), the Batesland Formation was deposited during the earliest Hemingfordian NALMA.

Paleofaunal assemblages from each of the southwestern South Dakota formations indicate a succession of Arikareean deposits beginning with the earliest Arikareean (Ar1) Rockyford Ash Member of the Sharps Formation through the latest Arikareean (Ar4) "Rosebud" Formation. Unfortunately, the units in south-central South Dakota have been much more poorly known. Only a few fossils have been recovered from the type Rosebud Formation including the oreodonts: *Leptauchenia, Desmatochoerus (Paradesmatochoerus)* (reviewed by Skinner et al. 1968), and *Megoreodon hollandi* (Bailey 2004), as well as the horse *Parahippus* (Bailey 2004). In the late 1960s, Morton Green and I made a large collection of microvertebrates from the Turtle Butte Formation, which overlies the Rosebud Formation. These fossils remained undescribed until recently. In the meantime, Bailey (2004) made a collection consisting of four small mammalian taxa upon which he based a late early Arikareean time of deposition for the Turtle Butte Formation. Now, one of my students, Karew Schumaker (2008), has described the large assemblage from Turtle Butte, consisting of 25 small mammalian taxa and seven larger taxa.

## PALEOFAUNAL TEMPORAL INTERPRETATIONS IN SOUTH-CENTRAL SOUTH DAKOTA

In south-central South Dakota, the type Rosebud Formation was considered Arikareean based upon correlations of the collected fossil oreodonts: *Leptauchenia, Desmatochoerus (Paradesmatochoerus)*, and *Megoreodon* (Skinner et al. 1968; Bailey 2004). However, the sample size is small, and biostratigraphic significance is limited at the generic level. *Leptauchenia* is a relatively long-ranging genus and extends from the Orellan NALMA through the early Arikareean NALMA, and perhaps even into the early Hemingfordian NALMA according to Lander (1998:417). However, Bailey (2004:88) disputed any records later than late early Arikareean (Ar2 of Tedford et al. 2004). *Desmatochoerus (Paradesmatochoerus)* is shown by Tedford et al. (1985) as ranging through the early Arikareean Sharps Formation and higher into the late Arikareean. More recently, the taxon has been split into species of *Eporeodon* and *Merycoides* (see Lander 1998), whose ranges extend through the Arikareean into the Hemingfordian. *Megoreodon* is slightly problematical, even if the species is *M. hollandi*. Surprisingly, Tedford et al. (1985) showed its generic range beginning above the Sharps Formation. Also, depending upon accepted taxonomy, the genus has been synonymized with *Merycochoerus*, whose range also extends through the Arikareean into the Hemingfordian (Lander 1998) and has been recorded as *Merycochoerus superbus*

from the Sharps Formation from SDSM Locality V5351 (Macdonald 1970). This species has also been identified from the Turtle Butte Formation (Skinner et al. 1968; Schumaker 2008). Bailey (2004) added the taxa, *Parahippus* and *Megoreodon hollandi*, to the list from near the type area (Bailey, per. comm., 2011) of the Rosebud Formation but provided neither formal systematic taxonomic descriptions nor precise stratigraphic position within the Rosebud Formation.

***Table 1. Mammalian Paleofauna from the Turtle Butte Formation adapted from Schumaker (2008).***

Erinaceidae
- *Hibbarderix* sp. indet.

Proscalopidae
- *Proscalopus* sp. cf. P. *secundus*

Soricidae
- *Domnina* sp. indet.

Omomyidae
- *Ekgmowechashala* sp. indet.

Ochotonidae
- *Gripholagomys lavocati*

Leporidae
- *Megalagus primitivus*
- *Palaeolagus philoi*
- *Palaeolagus* sp. indet.

Aplodontidae
- *Alwoodia harkensi*

Sciuridae
- *Protosciuris* sp. indet.
- *Protospermophilus* sp. nr. P. *kelloggi*
- cf. *Nototamias* sp. indet.

Castoridae
- *Palaeocastor* large sp. indet.
- *Palaeocastor (Capatanka)* large sp. indet.
- *Palaeocastor (Capatanka)* small sp. indet.
- cf. *Capacikala* sp. indet.

Eomyidae
- *Pseudotheridomys* sp. cf. P. *hesperus*

Geomyidae
- cf. *Tenudomys* sp. indet.
- cf. Pleurolicus sp. indet.

Heteromyidae
- *Proheteromys* sp. indet.
- *Schizodontomys harkseni*

Florentiamyidae
- *Sanctimus stuartae*
- *Hitonkala macdonaldtau*

Zapodidae
- *Plesiosminthus grangeri*

Cricetidae
- *Paciculus nebraskensis*

Amphicyonidae
- gen. et sp. indet.

Family indet.
- *Nothocyon* n. sp.

Canidae
- *Hesperocyoninae* gen. indet.
- *Borophaginae* gen. indet.
- *Cynarctoides roii*

Equidae
- *Archaeohippus equinanus*

Merycoidodontidae
- *Merycochoerus superbus superbus*

Both taxa appear in the late early Arikareean and range throughout the Arikareean, with *Parahippus* ranging into the Hemingfordian. Therefore, even though Skinner et al. (1968) considered the Rosebud oreodonts as equivalent to those from the Sharps Formation in southwestern South Dakota, this correlation is not as decisive as once thought. The taxa mentioned by Bailey seem to indicate the type Rosebud Formation may have been deposited in the late early Arikareean NALMA (Ar2), but more specimens are required from throughout the formation to substantiate this contention.

Although few fossils have been recovered from the type Rosebud Formation, numerous specimens have been derived from the disconformably suprajacent Turtle Butte Formation. Since the publication by Skinner et al. (1968), numerous small vertebrates were collected in the late 1960s but remained undescribed until recently. Schumaker (2008) completed a Master's thesis in which she described 32 mammalian taxa (Table 1). Comparisons of these taxa with those known from the Sharps Formation in southwestern South Dakota indicate similarity, including the last North American nonhuman primate, *Ekgmowechashala*, which has been found in early Arikareean assemblages in the Gering Formation of northwestern Nebraska (Swisher 1982; Martin 1973) and the John Day Formation in Oregon (Rose and Rensberger 1983). However, even greater similarity occurs with the assemblages from the Monroe Creek Formation of southwestern South Dakota (Macdonald 1972) and the Gering Formation of Nebraska (Bailey 2004). *Plesiosminthus, Palaeocastor (Capatanka),* and *Palaeocastor (Capacikala)* define the base of the Arikareean (Ar1), and *Pseudotheridomys, Gripholagomys, Pleurolicus, Gregorymys,* and *Alwoodia harkseni* define the base of the late early Arikareean (Ar2) according to Tedford et al. (2004). *Paciculus nebraskensis, Hitonkala macdonaldtau,* and *Schizodontomys harkseni* also appear during deposition of the Monroe Creek Formation on the Great Plains. Therefore, based on first appearances, the Turtle Butte assemblage appears to have been accumulated during the late early Arikareean NALMA (Ar2). The paleofaunal assemblages correlate well with the superpositional relationships indicating that the Turtle Butte Formation was deposited later than the lower Sharps Formation and slightly later than the type Rosebud Formation.

## RESULTANT PROPOSALS

The confinement of the type Rosebud Formation in south-central South Dakota to the early Arikareean has ramifications concerning the lithostratigraphic nomenclature in southwestern South Dakota. No longer is Macdonald's concept tenable that the Rosebud Formation correlates with the Sharps Fm., Monroe Creek Fm., Harrison Fm., and "approximately 250 feet of pinkish silts which the writer believes to be a western extension of Gidley's Rosebud Beds" (Macdonald 1988). These pinkish silts are what have been considered as the "Rosebud" Formation (Martin 1983, 1985). However, this unit must be considered differently now that the age of the type Rosebud Formation is better known. The type Rosebud may be a correlative of the lower Sharps Formation in southwestern South Dakota. However, based upon the additions of Bailey (2004), the type Rosebud Formation may be more likely a correlative with the upper Sharps, that

portion characterized by the Godsell Ranch channels (Macdonald 1963; Martin 1983; 1985) and the Monroe Creek Formation. The lower Sharps Formation appears to be a continuation of regional sedimentation of the White River Group. Subsequently, a regional change in fluvial energy occurred, as evinced by the Godsell Ranch channels. The resultant sequence (Figure 2) is composed of the upper Sharps Formation and the overlying Monroe Creek Formation and may represent the initiation of the deposition of the Arikaree Group. Therefore, the name Sharps Formation should be restricted to the lower Sharps Formation (that portion from the Rockyford Ash Member to the Godsell Ranch/Cedar Pass channels). Until additional investigations can be undertaken, the upper Sharps Formation is herein informally termed the Godsell Ranch beds in southwestern South Dakota (Figure 2). The Godsell Ranch beds are best exposed in sections 11 through 14, T.40N., R.44W., Shannon County, SD (see photograph in Harksen 1974, p. 6). The term includes the Cedar Pass channels (Parris and Green 1969; Harksen 1974) exposed to the east in sections 22 and 23, T.3S., R.18E., Jackson County, SD.

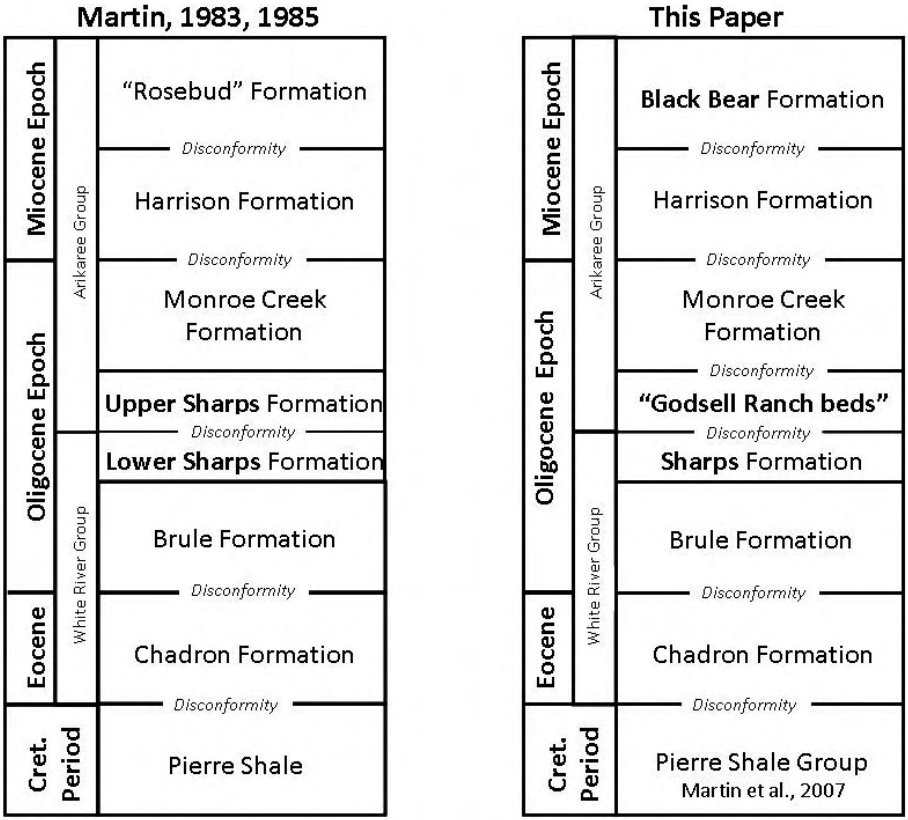


***Figure 2. Suggested nomenclature for southwestern South Dakota. Units in separate fonts are altered from previous designations. Subdivisions of the Arikareean NALMA (Ar1 to Ar4) of Tedford et al. (2004) are on the right side of the figure.***

Based upon paleofaunal correlation, the Turtle Butte Formation appears equivalent to the Monroe Creek Formation, and the type Rosebud appears to have been deposited just prior, although disconformably, to the Turtle Butte Formation (Figure 3). Both units appear to have been deposited in the late early Arikareean (Ar2) based upon known mammalian fossils, although additional specimens from the type Rosebud Formation are desirable. Based upon sequence stratigraphy (Figure 3), these correlations are less obvious. The basal Rosebud Formation disconformity is widespread, representing a major unconformity and the initiation of a major lithostratigraphic sequence. This unconformity would likely correlate with the major disconformity that occurs at the base of the upper Sharps Formation represented by the "Godsell Ranch beds" (Figures 2-3) and Cedar Pass channels. However, this correlation contradicts the biostratigraphic evidence and indicates additional investigations are required to understand the complex cut and fill Cenozoic lithostratigraphy. Radiometric dates on tephras from the Turtle Butte Formation and other units could help remedy these correlations.

With the restriction of the Rosebud Formation to the early Arikareean, the latest Arikareean "Rosebud" Formation of southwestern South Dakota requires nomenclatural revision (Figure 2). The unit is correlative with the gray indurated

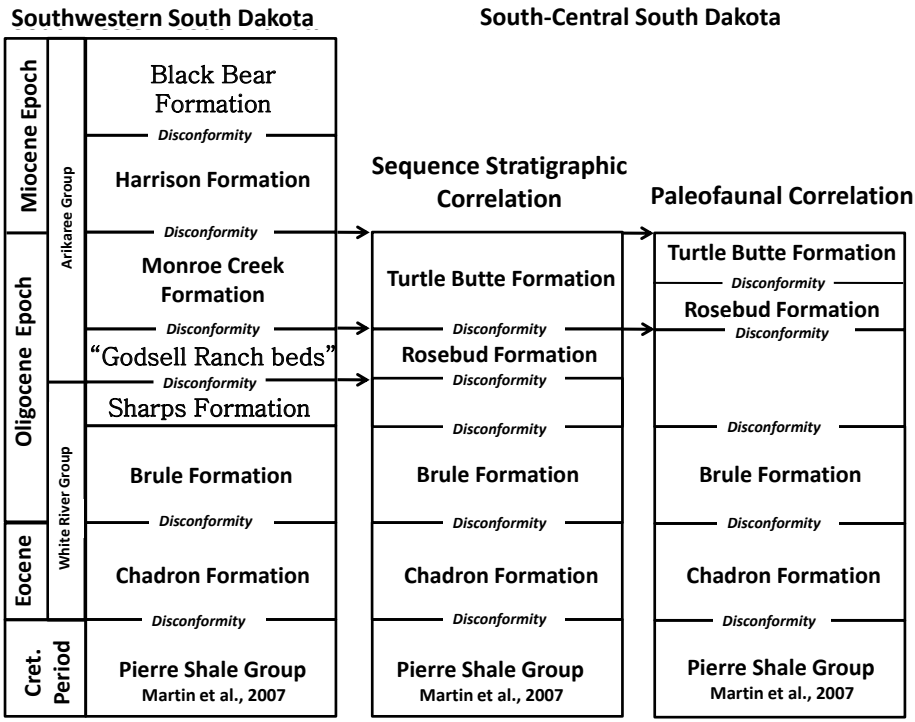


***Figure 3. Alternative correlations of Turtle Butte and Rosebud formations with succession in southwestern South Dakota based upon sequence stratigraphy and paleofaunal correlations. Additional fossils from the Godsell Ranch beds and type Rosebud Formation would aid in clarification of correlation.***

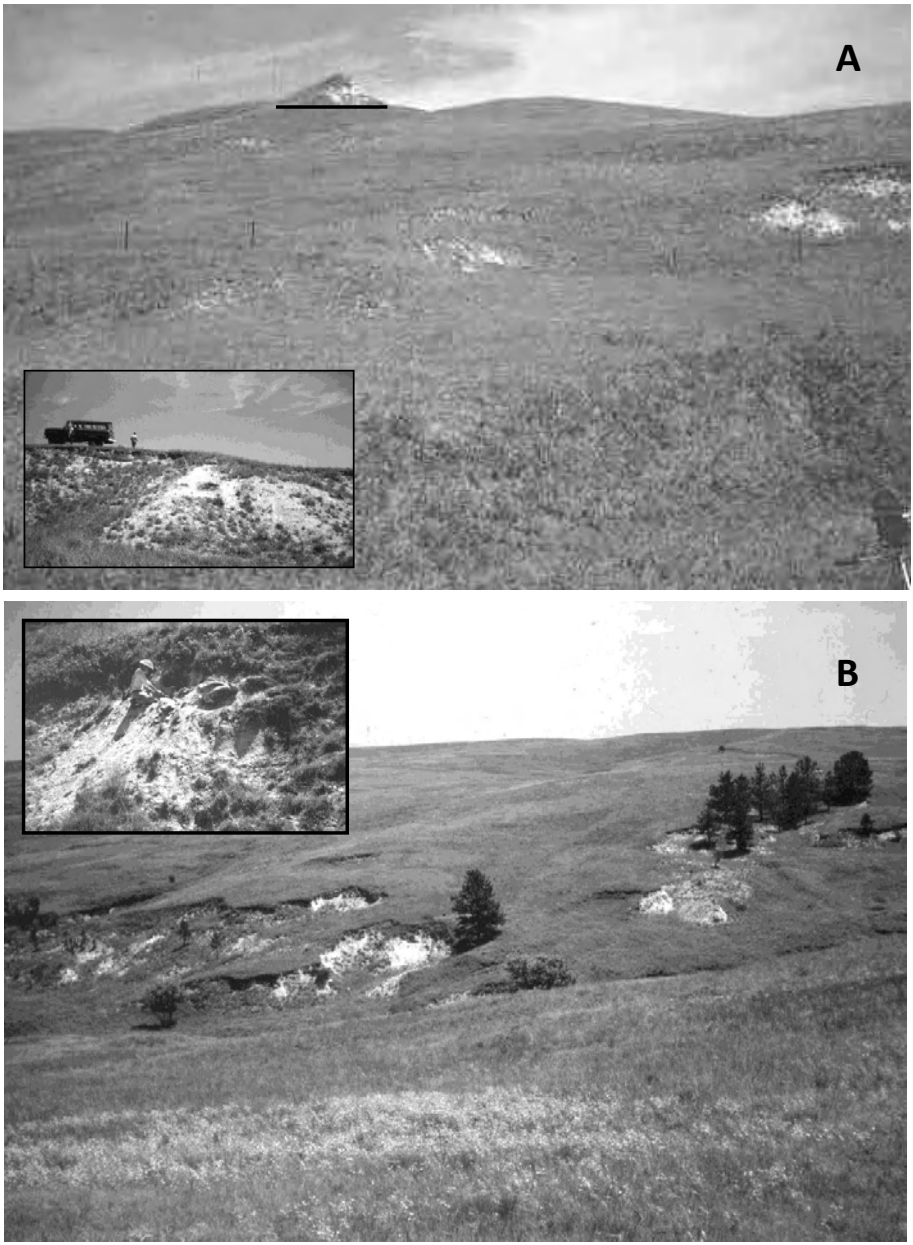


***Figure 4. A) Type section of Black Bear Formation taken from Black Bear Quarry II up to Black Bear Quarry I in suprajacent Batesland Formation. Line demarks top of Black Bear Formation/ base of the Batesland Formation. Inset is photograph of Black Bear Quarry I during excavation. B) View from Black Bear Quarry I down to base of Black Bear Quarry II, which lies below the pine tree in the center of the photograph. The base of the Black Bear Formation lies below the quarry. Inset is photograph of Black Bear Quarry II during excavation.***

sands and clays of the Anderson Ranch Formation of northwestern Nebraska (Hunt 2002) and the Martin Canyon Quarry A assemblage of the gray, sandy Pawnee Creek Formation of northeastern Colorado (See Martin and Green 1984). However the "Rosebud" unit is lithologically distinct, composed of reddish to tan, argillaceous, noncalcareous, very fine-grained sandstone and interbedded claystone and agillaceous siltstone that weather readily, normally form a slope, and are usually well vegetated. Therefore, the name Black Bear Formation is proposed for the disconformably bounded "Rosebud" Formation based upon a type section in the SW1/4, SW1/4, Sec. 8, T.38N., R.40W. (Figures 4-5) in western Bennett County, 48 km west of the town of Martin and approximately 8 km north of the town of Batesland. This 30 m section contains the Black Bear Quarry II Local Fauna (Green 1972; Martin and Green 1984) from a fossiliferous, coarse sand to pebble conglomerate, near the base of the Black Bear Formation. The overlying strata are composed principally of pink siltstone, claystone, and interbedded fine-grained, poorly consolidated, quartz sandstone strata that are normally covered with vegetation. The top of the Black Bear Formation is demarked by the channels of the Batesland Formation that contain Black Bear Quarry I, four meters above the Black Bear-Batesland formational contact (Martin 1976). The Black Bear Formation extends from west of Martin along the Little White River westerly into the Wounded Knee area (Macdonald 1963,

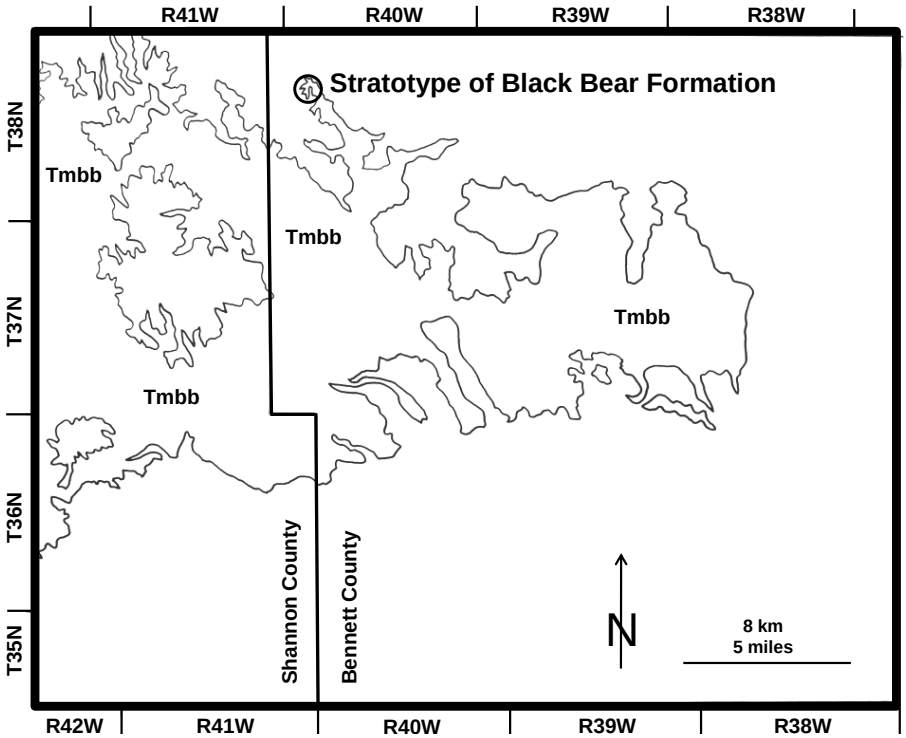


*Figure 5. Outcrop area of Black Bear Formation (Tmbb) in western Bennett and eastern Shannon counties. Adapted from unpublished map by J.C. Harksen.*

1970). In this area, the Black Bear Formation lies disconformably above the Harrison Formation and may reach 75 m in thickness.

## CORRELATIONS WITH NORTHWESTERN NEBRASKA

In northwestern Nebraska, the Brule Formation was thought to be overlain by the Gering Formation (e.g. McKenna 1965), a gray, multistoried sandy unit, until the "Brown siltstone" was recognized over the Brule along the Beaver Wall (Tedford et al. 1985). The "Brown siltstone" was correlated with the lower Sharps Formation in South Dakota by Tedford et al. (2004:196) and should be considered as Sharps Formation. These units represent continued deposition of the upper Eocene-Oligocene White River Group sequence. The Gering Formation represents a succession of channel deposits incised into the "Brown siltstone" in Nebraska. The Godsell Ranch and Cedar Pass channels of the upper Sharps Formation may be equivalent to the Gering Formation and all three may represent the initiation of Arikaree Group deposition. The Monroe Creek and Harrison formations occur in both Nebraska and southwestern South Dakota. The Monroe Creek Formation may represent a continuation of the Godsell Ranch beds (upper Sharps) sequence, but the Harrison Formation indicates initiation of another sequence (Figure 2). The Anderson Ranch Formation of northwestern Nebraska (Hunt 2002) appears to be a correlative of the Black Bear Formation in southwestern South Dakota based upon stratigraphic position and paleofaunal similarity. The Runningwater Formation in Nebraska is a channel fill above the Anderson Ranch, and the Batesland Formation is a channel fill incised into the Black Bear Formation in southwestern South Dakota (see Martin and Green 1984); these represent the initiation of another stratigraphic sequence, considered the base of the Ogallala Group in Nebraska.

## CONCLUSIONS

1)The Rosebud Formation of south-central South Dakota was deposited during the early Arikareean NALMA and does not appear equivalent to the entirety of the Sharps, Monroe Creek, Harrison, and Black Bear formations in southwestern South Dakota.

2)The Turtle Butte Formation of south-central South Dakota was deposited during the late early Arikareean (Ar2) and confines the latest time of deposition of the type Rosebud Formation.

3)The precise correlation of the Rosebud Formation with the Sharps-Monroe Creek succession remains questionable, and these various possibilities (Figure 3) serve as models for additional investigation.

4)The Brown siltstone unit in northwestern Nebraska correlates with the sub-Godsell Ranch channel portion of the Sharps Formation and should be considered as Sharps Formation.

5)The upper Sharps Formation represents the initiation of a major lithostratigraphic sequence and is informally designated as the "Godsell Ranch beds" until additional investigations may be completed. The name Sharps Formation should

be restricted to the lower Sharps Formation and include that portion from the Rockyford Ash Member to the Godsell Ranch beds.

6)The "Rosebud" Formation of southwestern South Dakota is renamed as the Black Bear Formation and was deposited during the latest Arikareean NALMA (Ar4).

## ACKNOWLEDGEMENTS

This contribution is dedicated to the late James Reid Macdonald, with whom I shared many great conversations concerning the geology, paleontology, and history of southern South Dakota. He inspired many, and I was impressed that even though he disagreed vehemently with his critics such as Morris Skinner in Nebraska, they remained close friends and committed members of the IOB until the end. We now are challenged to continue these traditions. I thank Mr. Derric Iles of the South Dakota Geological Survey for the opportunity to undertake some of these investigations in the type Rosebud area. I also thank Drs. Morton Green and Robert W. Wilson, who started me on studies of these rocks and fossils. I appreciate the efforts of Ms. Karew Schumaker in preparation of her thesis concerning the Turtle Butte small mammals. The manuscript was enhanced by the reviews of Mr. Bruce Bailey, Dr. Gary Johnson, Dr. Randolph Moses, and Dr. Aaron Wood. I acknowledge the kindness of the late J.C. Harksen, Dr. Laurie Bryant, and the SD Geological Survey for sharing unpublished works. The continued efforts of Dr. Robert Tatina, editor of these Proceedings, are greatly appreciated.

## LITERATURE CITED

Bailey, B.E. 2004. Biostratigraphy and biochronology of early Arikareean through late Hemingfordian small mammal faunas from the Nebraska Panhandle and adjacent areas. Paludicola 4(3):81-113.

Gidley, J.W. 1904. New or little known mammals from the Miocene of South Dakota. American Museum of Natural History Expedition of 1903. Part I, Geological Notes. Bull. Amer. Mus. Nat. Hist. 20-241-246.

Green, M. 1972. Lagomorpha from the Rosebud Formation, South Dakota. Jour. Paleont. 46:377-385.

Harksen, J.C. 1974. Miocene channels in the Cedar Pass Area, Jackson County, South Dakota. SD Geol. Surv., Rpt. Invest. 111:1-10.

Harksen, J.C., and J.R. Macdonald. 1967. Miocene Batesland Formation named in Southwestern South Dakota. SD Geol. Surv., Rpt. Invest. 96:1-10.

Harksen, J.C., and J.R. Macdonald. 1969. Guidebook to the major Cenozoic deposits of southwestern South Dakota. SD Geol. Surv. Guidebook 2:1-103.

Hunt, R.M., Jr. 2002. New Amphicyonid Carnivorans (Mammalia, Daphoeninae) from the Early Miocene of southeastern Wyoming. Amer. Mus. Novitates 3385:1-41.

Lander, B. 1998, Oreodontoidea. *In* Janis, C.M., K.M. Scott, and L.L. Jacobs, editors. Evolution of Tertiary mammals of North America, Vol. I, Terrestrial carnivores, ungulates, and ungulatelike (sic) mammals. Cambridge Univ. Press. 691p.

Macdonald, J.R. 1963. The Miocene faunas from the Wounded Knee Area of South Dakota. Amer. Mus. Nat. Hist., Bull. 125:139-238.

Macdonald, J.R. 1970. Review of the Miocene Wounded faunas of southwestern South Dakota. Los Angeles Co. Mus. Nat. Hist., Bull. 8:1-82.

Macdonald, J.R. 1988. The Rosebud Problem. Proc. SD Acad. Sci. 67:64-68.

Macdonald, J.R. and J.C. Harksen. 1968. Rosebud Formation in South Dakota. SD Geol. Surv., Rpt. Invest. 97:1-13.

Macdonald, L.J. 1972. Monroe Creek (early Miocene) microfossils from the Wounded Knee Area, South Dakota. SD Geol. Surv., Rpt. Invest. 105:1-43.

Martin, J.E. 1976. Small mammals from the Miocene Batesland Formation of South Dakota. Univ. Wyoming, Contr. Geol. 14:69-98.

Martin, J.E. 1983. Composite stratigraphic section of the Tertiary deposits in western South Dakota. Dakoterra, Mus. Geol., SD School of Mines & Tech. 2(1):1-8.

Martin, J.E. 1985. Geological and paleontological road log from Rapid City, through the Oligocene White River Badlands and Miocene deposits, to Pine Ridge, South Dakota. In: Martin, J.E. (ed.) Fossiliferous Cenozoic deposits of western South Dakota and northwestern Nebraska. Dakoterra, Mus. Geol., SD School of Mines & Tech. 2(2):99-119.

Martin, J.E., and M. Green. 1984. Insectivora, Sciuridae, and Cricetidae from the Early Miocene Rosebud Formation in South Dakota. Papers in Vertebrate Paleontology Honoring Robert Warren Wilson.Carnegie Mus. Nat. Hist., Spec. Publ. 9:28-40.

Martin, J.E., J.F. Sawyer, M.D. Fahrenbach, D.W. Tomhave and L.D. Schulz. 2004. Geologic Map of South Dakota. SD Geol. Surv., Map Series, General Map 10, 1:500,000 scale.

Martin, J.E., J.L. Bertog and D.C. Parris. 2007. Revised lithostratigraphy of the Lower Pierre Shale Group (Campanian) of central South Dakota, including newly designated members. In: Martin, J.E. and D.C. Parris. (eds.) Geology and paleontology of the Late Cretaceous marine deposits of the Dakotas. Geol. Soc. Amer., Spec. Paper 427:9-21.

Martin, L.D. 1973. The mammalian fauna of the Lower Miocene Formation of western Nebraska and the early evolution of the North American Cricetidae, Unpubl. Ph.D. Diss., Univ. Nebraska 219p.

Matthew, W.D. 1907. A Lower Miocene fauna from South Dakota. Amer. Mus. Nat. Hist. Bull. 23:169-219.

McKenna, M.C. 1965. Stratigraphic nomenclature of the Miocene Hemingford Group, Nebraska. Amer. Mus. Novtitates 2228:1-21.

Parris, D.C., and M. Green. 1969. *Dinohyus* (Mammalia; Entelodontidae) in the Sharps Formation, South Dakota. Jour. Paleont. 43:1277-1279.

Peterson, O.A. 1906. The Miocene Beds of Western Nebraska and Eastern Wyoming and their Vertebrate Faunae. Ann. Carnegie Mus. 4(1):21-72.

Rose, K.D., and J.M. Rensberger. 1983. Upper dentition of *Ekgmowechashala* (Omomyid Primate) from the John Day Formation, Oligo-Miocene of Oregon. Folia Primatologia 41:102-111.

Schumaker, K.K. 2008. Paleontology, biostratigraphy, and geology of the Turtle Butte Formation (latest Oligocene-early Miocene), Tripp County, South-Central South Dakota. Unpubl. M.S. Thesis, Dept. Geol. & Geol. Eng., SD School of Mines & Tech. 229p.

Skinner, M.F., S.M. Skinner and R.J. Gooris. 1968. Cenozoic rocks and faunas of Turtle Butte, South-Central South Dakota. Amer. Mus. Nat. Hist., Bull. 138:379-436.

Swisher, C.C. 1982. Stratigraphy and biostratigraphy of the eastern portion of the Wildcat Ridge, Western Nebraska. Unpubl. M.S. Thesis, Univ. Nebraska 172p.

Tedford, R.H., J.B. Swinehart, R.M. Hunt, Jr. and M.R. Voorhies. 1985. Uppermost White River and lowermost Arikaree rocks and faunas, White River Valley, Northwestern Nebraska, and their correlation with South Dakota. In: Martin, J.E. (ed.) Fossiliferous Cenozoic deposits of western South Dakota and northwestern Nebraska. Dakoterra, Mus. Geol., SD School Mines & Tech. 2(2):1-367.

Tedford. R.H., L.B. Albright, III, A.D. Barnosky, I. Ferrusquia-Villafranca, R.M. Hunt, Jr., J.E. Storer, C.C. Swisher, III, M.R. Voorhies, S.D. Webb and D.P. Whistler. 2004. Mammalian biochronology of the Arikareean through Hemphillian Interval (Late Oligocene through early Pliocene epochs). In: Woodburne, M.O. (ed.) Late Cretaceous and Cenozoic mammals of North America, biostratigraphy and geochronology. Columbia Univ. Press 391p.

***Editor's note:*** This paper was not presented at the annual meeting, but published as a submitted paper.