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Explanation of Geologic Map Units for use with University of Nebraska-Lincoln Conservation and Survey Division Open-File Maps Nos. 53-65.

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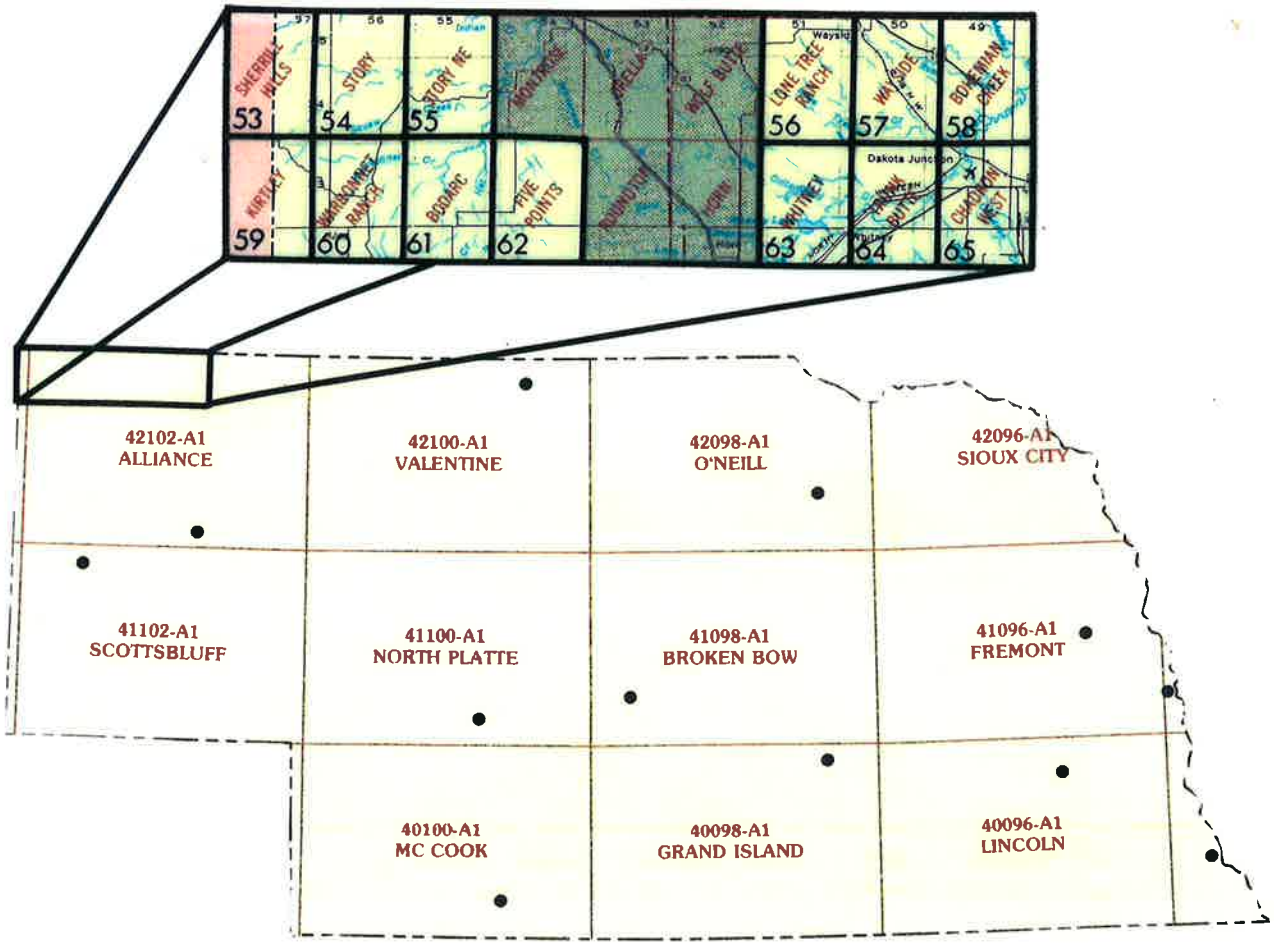

University of Nebraska-Lincoln Conservation and Survey Division (IANR) state map project (USGS Alliance 1°x2° Geologic Quadrangle)

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INTRODUCTION

This explanation of geologic map units is intended for use in conjunction with the following University of Nebraska-Lincoln Conservation and Survey Division Open-File 7.5' (1:24,000) Geologic Maps [Table 1: see also LaGarry and LaGarry (1997a-m)]:

TABLE 1. Open-file (OF) maps with which to use this explanation of geologic map units.

OF # NAME	OF # NAME
No. 53 Sherrill Hills (Wyoming-Nebraska)	**No. 60 Warbonnet Ranch (Nebraska)**
No. 54 Story (Nebraska)	**No. 61 Bodarc (Nebraska)**
No. 55 Story NE (Nebraska)	**No. 62 Five Points (Nebraska)**
No. 56 Lone Tree Ranch (Nebraska)	**No. 63 Whitney (Nebraska)**
No. 57 Wayside (Nebraska)	**No. 64 Trunk Butte (Nebraska)**
No. 58 Bohemian Creek (Nebraska)	**No. 65 Chadron West (Nebraska)**
No. 59 Kirtley (Wyoming-Nebraska)	****** Horn (Nebraska)[1]**

1. The Horn (Nebraska) Geologic 7.5' Quadrangle map was prepared separately as part of LaGarry and LaGarry (1997n), and has not been assigned an individual open-file map number.

While compiling the geologic map unit descriptions in this supplement, every effort was made to adhere to guidelines for the use of provisional and formal lithostratigraphic units as defined within the North American Stratigraphic Code (NACSN, 1983). As yet, no formal lithostratigraphic names are applied to Quaternary units in the mapped area, and they are characterized by simple genetic descriptions. An exception to the aforementioned adherence to the North American Stratigraphic Code (NACSN, 1983) is the weathered zone below the post-Cretaceous, pre-Eocene unconformity. This zone has traditionally been described as a separate entity from its parent material, and this practice is continued here. Ages assigned to map units are from Stout and others (1961), Hunt (1985), Swinehart and others (1985), Tedford and others (1985, 1996), Prothero and Swisher (1992), and Evans and Terry (1993). Because this explanation applies to several maps, units or characteristics of units unique to individual quadrangles are referred to in the unit descriptions, followed by the name of the quadrangle on which they may be found. Likewise, many of the units in this explanation may not apply to individual maps. However, because of extensive revision, redefinition, and redescription of many of the mapped units, we include them all in the overall discussion of the mapped quadrangles. Provisional unit names are in quotes (" "), and unit names new to northwestern Nebraska are in italics. For more detailed descriptions of these units, see LaGarry and LaGarry (1997n).

EXPLANATION OF MAP UNITS

QUATERNARY SYSTEM

Holocene Series

(Qa1) ***Alluvium*** - This unit consists of trough and planar crossbedded epiclastic sediments deposited in modern stream channels. Its clasts are derived from local bedrock and surface deposits and typically range from clay to cobble sized. This unit is generally <2 m thick overall, and is mapped in all drainages where present in recognizable amounts. This unit lies unconformably on older deposits.

(Qa2) ***Clayey alluvium***- This unit consists of laminated clays deposited in modern and ancient floodplains. It corresponds in part to T^0 of Schultz and Stout (1945). Where covered by vegetation, this unit is mapped based on the distribution of clayey alluvial land (Ragon and others, 1977). This unit is generally <3 m thick, and is mapped in all drainages where it is present in recognizable amounts. This unit lies unconformably on older deposits, usually bedrock.

Holocene and Pleistocene Series undifferentiated

(Qa3) ***Older alluvium 1***- This unit consists of trough and planar crossbedded epiclastic sediments deposited in modern and ancient channels and floodplains. Its clasts are derived from local and distant bedrock and surficial sources, and range from clay to cobble sized. This unit typically contains at least three depositional sequences corresponding in part to T^1 and T^2 of Schultz and Stout (1945). Individual sequences have one or more weakly developed paleosols and/or rhythmically bedded clays. Plant macrofossils are common in the paleosols and rhythmically bedded clays. Snails are frequent in the laminated silts. Vertebrate fossils, typically *Bison*, are rare and poorly preserved within the sands and gravels. The thickness of this unit varies depending on the number of depositional sequences present, but is generally 2-20 m. This unit is distinguishable from Qa1 and Qa2 based on its thickness, the presence of paleosols, and its fossil content. Where covered by vegetation, its mapped distribution is based on exposures in cut banks, and the occurrence of soils of the Tripp-Haverson-Glenberg soil association and loamy and gravelly alluvial land (Ragon and others, 1977). This unit lies unconformably on older deposits, usually bedrock, and intertongues with adjacent Qr2 and Qr3.

(Qa4) ***Older alluvium 2***- This unit consists of crossbedded and crosslaminated epiclastic sediments preserved as erosional remnants on isolated hilltops surrounding Whitney Lake [Whitney (Nebraska)7.5' quadrangle]. Its clasts are derived from local and distant bedrock and surficial sources, and range in size from clay to coarse gravel. This unit lacks paleosols or buried soils, and consists of a single depositional sequence. Vertebrate fossils, typically *Bison*, are rare and poorly preserved in the sands and gravels. This unit is 2-5 m thick, and is distinguishable from Qa1 and Qa2 based on its thickness, fossil content, and topographic position, and from Qa3 based on the absence of paleosols and lack of cobble-sized clasts. Where covered by vegetation, its mapped distribution is based on exposures in cut banks and the occurrence of soils of the Tripp-Haverson-Glenberg soil association and loamy and gravelly alluvial land (Ragon and others, 1977). This unit lies unconformably on bedrock.

(Qr1) ***Clayey residuum***- This unit consists of residuum and soils derived from the weathering of the Pierre Shale and minor amounts (10-15%) of alluvial and colluvial clay sediments. This unit is mapped based on exposures in cut banks and the distribution of soils of the Pierre-Kyle-Samsil association (Ragon and others, 1977). Residuum or soil < 5 cm thick is mapped as Pierre Shale. This unit typically has a gradational contact with adjacent Qr2 and Qr3.

(Qr2) ***Silty residuum***- This unit consists of residuum and soils derived from the weathering of White River Group silty claystones, clayey siltstones, and sitstones, and minor amounts (10-15%) of alluvial and colluvial silty clay sediments. This unit is mapped based on exposures in cut banks and the distribution of soils of the Bufton- Orella-Norrest association, parts of the the Kadoka-Keith-Mitchell association, and the Epping series (Ragon and others, 1977). Residuum or soil < 5 cm thick is mapped as bedrock. This unit typically has a gradational contact with adjacent Qr1and Qr3.

(Qr3) ***Sandy residuum***- This unit consists of residuum and soils derived from the weathering of sandy siltstones, silty sandstones, and sandstones of the White River and Arikaree Groups, and minor amounts

(10-15%) of alluvial and colluvial silt and sand deposits. This unit is mapped based on exposures in cut banks and the distribution of soils of the Canyon-Alliance-Rosebud and Canyon-Budget-Oglala associations (Ragon and others, 1977). Residuum or soil < 5 cm thick is mapped as bedrock. This unit typically has a gradational contact with adjacent Qr1and Qr2.

(Qe) Loess- This unit consists of massive eolian silt. It is generally 3-20 m thick and frequently contains snails. Local concentrations of vertebrate fossils, typically *Bison*, are rare but important because of their association with paleoindian artifacts and hearth sites. At least one, but typically two, paleosols are present. The paleosols frequently contain plant macrofossils. Preliminary drafts of geologic maps of the Montrose (Nebraska), Orella (Nebraska), Roundtop (Nebraska), and Horn (Nebraska) 7.5' quadrangles overstated the distribution of this unit (LaGarry and Hunt, 1994). The revised distribution of this unit is based on exposures in cut banks and the occurrence of soils of the Mitchell series (Ragon and others, 1977). This init lies unconformably on older deposits, usually bedrock, and intertongues with adjacent Qac1, Qac2, and Qal.

(Qac1) *Undifferentiared silty alluvium and colluvium*- This unit consists of alluvium and colluvium derived from the weathering of White River Group clayey siltstones and silty claystones. Upland occurrences are primarily colluvium, and form prominant "grass tables" that mantle shallower slopes. Occurrences on foot slopes are typically 10-15%, but usually not more than 50%, stratified alluvium. This unit is mapped based on exposures in cut banks and the distribution of the Bufton silty clay loam (Ragon and others, 1977). This unit is generally 0.1-10 m thick. This unit lies unconformably on older deposits, usually bedrock, and intertongues with adjacent Qr2, Qr3, Qe, Qac2, and Qal.

(Qac2) *Undifferentiated sandy alluvium and colluvium*- This unit consists of alluvium and colluvium derived from the weathering of silty sandstones and sandy siltstones of the Arikaree Group. Upland occurrences are primarily colluvium (lithic gravels or conglomerates) capping isolated buttes. Occurrences on foot slopes are typically 10-15%, but usually not more than 50%, stratified alluvium. This unit typically contains one or more stone lines where >1m thick. This unit is mapped based on the distribution of soils of the Busher-Tassel-Vetal association and the Kadoka silt loam (Ragon and others, 1977). It is generally 0.1-15 m thick. This unit lies unconformably on older deposits, usually bedrock, and intertongues with adjacent Qr2, Qr3, Qe, Qac1, and Qal.

(Qal) *Undifferentiated older alluvium and loess*- This unit consists of thinly interbedded silty alluvium and colluvium, sandy alluvium and colluvium, and reworked loess mantling some exposures of the White River Group in the Roundtop (Nebraska) and Five Points (Nebraska) 7.5' quadrangles (see also LaGarry and LaGarry, 1997n). This unit contains as many as five depositional sequences separated by paleosols containing plant macrofossils and paleoindian hearth sites (see Stout and others, 1961; Whitten and others, 1997). Reworked Eocene and Oligocene fossils are common within the alluvium and colluvium. The alluvium and loess contain scattered occurrences of *Bison,* and the loess contains snails. The thickness of this unit varies depending on the number of depositional sequences present, but is generally 2-22 m. Upland occurrences form "grass tables" mantling some slopes. Lowland occurrences Include some T^1 and T^2 of Schultz and Stout (1945). This unit was mapped by LaGarry and LaGarry (1997n) on the Roundtop (Nebraska) 7.5' quadrangle where it is well exposed by dissecting streams. It also occurs in small amounts on the Horn (Nebraska) 7.5' quadrangle, but was not recognized elsewhere. This unit is distiguished from Qe based on the presence of stratified alluvium, and from Qa3, Qa4, Qac1, and Qac2 based on presence of loess. The distribution of this unit is mapped based on exposures in cut banks and the occurrence of soils of the Mitchell series (Ragon and others, 1977). This unit lies unconformably on older deposits, usually bedrock, and intertongues with adjacent Qe, Qac1, and Qac2.

TERTIARY SYSTEM

Miocene Series

ARIKAREE GROUP

(Tau) Upper Harrison Formation- This unit consists of up to 18 m of yellowish to grayish brown, fine to medium grained, thin to medium bedded (0.2-5 m), massive or weakly crossbedded volcaniclastic sandstones containing abundant fine rhizoliths, root molds, and voids suggesting subterranean insect galleries. This unit is best exposed in the Kirtley (Wyoming-Nebraska) 7.5' Quadrangle. In the Chadron West

(Nebraska) 7.5' quadrangle, exposures of this unit are obscured by dense vegetation and it was mapped based on outcrop and bore-hole data (Swinehart and others, 1985; Swinehart, 1996, written communications). The upper contact was not observed. The lower contact, however, occurs at a prominent regional unconformity above a silcrete developed within fine to medium grained, often poorly indurated brown volcaniclastic sandstones of the underlying Harrison Formation. Although vertebrate fossils occur within this unit (Hunt, 1985), none were observed during this study.

Oligocene Series

(Tah) Harrison Formation- This unit consists of brown and gray, fine to medium grained, massive or weakly bedded, often poorly indurated volcaniclastic sandstones having prominent, rhizolithic silcretes 2-10 m thick in its upper 75 m. Fine siliceous and calcareous rhizoliths, root molds, and voids suggesting subterranean insect galleries are common within the upper part. These beds are well exposed along the flank and top of the Pine Ridge Escarpment. The upper boundary is an abrupt contact with overlying yellowish or grayish brown fine grained sandstones of the Upper Harrison Formation. This contact is a regional unconformity overlying a widespead silcrete that weathers into a prominent, flat bench that can be traced accross the region. Hunt's (1985) disconformable contact between this unit and the underlying Monroe Creek Formation was observed within Monroe Canyon [Warbonnet Buttes (Nebraska) 7.5' quadrangle], but no discernable lithologic change occurs at this disconformity and it could not be traced outside the of Monroe Canyon. In most areas no recognizable lithologic contact between this unit and the underlying Monroe Creek Formation was observed, in which case these units were combined (Tah/Tam) following Swinehart and others (1985). Alternately, the contact was placed at the base of the lowest rhizolithic silcrete, giving this unit an overall thickness of 75-95 m. Below this alternate contact the sandstones are gray or buff rather than brown and were assigned to the underlying Monroe Creek Formation. *Daimonelix* are present throughout the uppermost 75 m of this unit, and vertebrate fossils, while present as isolated occurrences or local concentrations (Hunt, 1985), were not observed during this study.

(Tam) Monroe Creek Formation- This unit is a 155-185 m thick (see below) sequence of brown, buff, and gray volcaniclastic silty sandstone, fine to coarse grained volcaniclastic sandstone, and thin (< 0.5 m) tabular and lenticular interbeds of massive or crossbedded brown sandstones and conglomerates. The base of the sequence consists of about 20 m of thickly bedded, unindurated, massive brown sandstone having 0.2-0.5 m thick interbeds of unindurated, crossbedded fine grained brown sandstone and conglomerate. This sequence is well exposed on the south side of Roundtop and southward [Roundtop (Nebraska) 7.5' quadrangle: LaGarry and LaGarry (1997n)]. These beds are in turn overlain by 125-135 m of massive, indurated, fine to medium grained gray and buff sandstones frequently containing "pipey" or "potato" concretions (see Schultz, 1941), infrequent lenticular interbeds of massive or crossbedded brown sandstones, fine rhizoliths, root molds, and voids suggesting subterranean insect galleries. Vertebrate fossils are rare, and only fragments of tortoise carapace were recovered during this study (see also LaGarry and Hunt, 1994; LaGarry and LaGarry, 1997n). The lower boundary of this unit is either an intertonguing contact with underlying crossbedded conglomeratic sandstones of the *"Ash Creek beds"*, or a sharp, erosional contact with the underlying White River Group (*Horn Member* of the Brule Formation). On the noth flank of Roundtop [Roundtop (Nebraska) 7.5' quadrangle: LaGarry and LaGarry (1997n)] this latter contact occurs at a 0.3 m thick dark brown, crossbedded conglomeratic sandstone. In most areas no recognizable lithologic contact between this unit and the overlying Harrison Formation (in the sense of Hunt, 1985: see above) was observed, in which case these units were combined (Tah/Tam) following Swinehart and others (1985). Alternately, the contact was placed 20-30 m higher in the section at the first prominent rhizolithic silcrete, above which the volcaniclastic sandstones are generally brown rather than buff or gray. This unit corresponds to LaGarry and Hunt's (1994) and LaGarry and LaGarry's (1997n) "Arikaree Group undifferentiated".

(Taa) *"Ash Creek beds"*- This provisional lithostratigraphic unit (LaGarry and LaGarry, unpublished data) is named for exposures on the tops and flanks of isolated buttes along Ash Creek, West Ash Creek, and East Ash Creek north of the Pine Ridge in the Chadron West (Nebraska) 7.5' quadrangle. This unit consists of 0-35 m of brown and dark brown, indurated, trough and planar crossbedded conglomeratic sandstone beds 0.2-5.2 m thick overlain by up to 20 m of brown and gray, medium bedded, fine grained to conglomeratic sandstones. At least two sequences can be distinguished within the lower sandstones. Within the lowest of these sequences, the gravel-sized and larger clasts consist of angular

fragments of massive pinkish gray, buff, and brown volcaniclastic siltstone presumably eroded from the underlying White River Group (*Horn Member* of the Brule Formation). Subsequent sequences contain progressively fewer lithic clasts and increasing amounts of smaller, well rounded crystalline clasts from source areas far to the west. The uppermost 20 m of this unit occasionally contains this lithic gravel. These beds were deposited within an east-west paleovalley generally parallel to the Pine Ridge that incised into the underlying *Horn* and Whitney members of the Brule Formation. These sandstones and conglomerates also cap the Sherrill Hills [Sherrill Hills (Nebraska) 7.5' quadrangle] and the Warbonnet Buttes [Sherrill Hills (Nebraska) and Warbonnet Buttes (Nebraska) 7.5' quadrangles]. The intertonguing upper contact with the Monroe Creek Formation is marked by a progressive change from well indurated, crossbedded conglomeratic sandstones to buff or gray massive volcaniclastic sandstones. These beds were previously assigned to the Gering Formation (Schultz, 1938; Vondra and others, 1969: see also Hunt, 1985). However, Swinehart and others (1985) and Swinehart and Diffendal (1995) demonstrated that the Gering Formation consists primarily of pumaceous sandstones and conglomerates restricted to an east-west trending paleovalley in the southern panhandle of Nebraska.

WHITE RIVER GROUP

BRULE FORMATION

(Twbh) *Horn Member* - This provisional lithostratigraphic unit (Swinehart, unpublished data) is named for the small community of Horn 16 km northwest of Crawford, Nebraska [Horn (Nebraska) 7.5' quadrangle]. It consists of massive to weakly stratified buff, pinkish gray, or pale brown volcaniclastic siltstone, volcaniclastic silty sandstone, and volcaniclastic sandy siltstone. At its proposed type section at the head of Whitehead Creek near Roundtop [Roundtop (Nebraska) 7.5' quadrangle: LaGarry and LaGarry (1997n)], this unit is about 55 m thick, but thins to 5-10 m thick to the west [Sherrill Hills (Wyoming-Nebraska) 7.5' quadrangle] and to 13 m thick to the east [Chadron West (Nebraska) 7.5' quadrangle]. In the western part of the mapped area [Sherrill Hills (Wyoming-Nebraska) 7.5' quadrangle] this unit is distinctly thinly bedded. This unit erodes into vertical cliffs or rounded ledges having a highly fractured appearance and occasionally contains small (2-10 cm), irregularly shaped nodules or concretions in discontinuous zones 1-10 m thick. A prominent volcanic ash, the Nonpareil Ash Zone (NPAZ) of Swinehart and others (1985), occurs 5-33 m above the base of the unit. This ash has been $^{40}Ar/^{39}Ar$ dated at 30.050 $\pm$ 0.19 Ma (Swisher and Prothero, 1990). Vertebrate fossils are locally abundant at its base, and include oreodonts, rhinoceroces, and tortoises. This unit has a sharp erosional contact with the overlying Arikaree Group. Below the east-west trending Arikaree Group paleovalley (see above), this unit is incised by the *"Ash Creek beds"*. Elsewhere, this unit is overlain by the Monroe Creek Formation. The lower contact with the Whitney Member is either gradational or an erosional unconformity where this unit fills valleys and depressions in the underlying Whitney Member. This unit corresponds to the basal part of Schultz and Stout's (1955) and Meehan's (1994) "Gering Formation" [Roundtop (Nebraska) 7.5' quadrangle: see LaGarry and LaGarry (1997n)], and the "Roundtop member" of the Brule Formation of Terry and others (1995).

(Twbw) Whitney Member- This unit consists of massive, nodular, buff-colored volcaniclastic siltstone. The nodules are 1-8 cm in diameter and occur in discontinuous zones 0.5-10 m thick. Two prominent 1-2 m thick volcanic ashes occur 33 m ("upper Whitney ash") and 56 m ("lower Whitney ash", lwa) above the base of the unit. The upper ash has been $^{40}Ar/^{39}Ar$ dated at 31.85 $\pm$ 0.02 Ma (Prothero and Swisher, 1992), and the lower ash has been $^{40}Ar/^{39}Ar$ dated at 31.24 $\pm$ 0.06 Ma and 31.29 $\pm$ 0.06 Ma (Deino, 1996, written communication). Worm casts associated with the lower ash likely indicate a weakly developed paleosol with this horizon. Well preserved vertebrate fossils frequently occur in 10 m zones adjacent to the volcanic ash layers. The common taxa include camels, antelope, rhinoceroses, oreodonts, and tortoises. About 2.5-5.5 m above the base of this unit, at the level of Schultz and Stout's (1955) "white bed", is a relatively widespread horizon 0.1-6 m thick consisting of crossbedded conglomeratic channel sandstones towards the west [Sherrill Hills (Wyoming-Nebraska) and Bodarc (Nebraska) 7.5' quadrangles] and laminated silts in the central part of the study area [Roundtop (Nebraska) 7.5' quadrangle: see Lagarry and LaGarry (1997n)]. This horizon is thickest where it fills valleys and depressions in the underlying massive siltstone. Sheet sandstones 0.01-0.1 m thick having a striking bluish green color are common in the lower 5 m of this unit in some areas [Roundtop (Nebraska), Five Points (Nebraska), and Bodarc (Nebraska) 7.5' quadrangles: see LaGarry and LaGarry (1997n)]. The overall thickness of this

unit is 18-88 m, and it weathers into high, smooth slopes having a highly fractured appearance. It has a sharp, undulating, erosional upper contact with the overlying *Horn Member,* except where the *Horn Member* fills deeper valleys and depressions within this unit. This unit has an intertonguing lower contact with the underlying Orella Member, except where the channel sandstones near the base of this unit have incised into the Orella Member. This unit is equivalent to Schultz and Stout's (1955) Whitney Member in addition to their underlying "Orella D".

(Twbo) Orella Member- This unit consists of thinly interbedded brown, orange, and buff volcaniclastic clayey siltstones, volcaniclastic silty claystones, discontinuous medium to coarse grained, crossbedded and massive, brown sheet sandstones, and multistoried basal channel sandstones. The clayey siltstone, silty claystone, and sheet sandstone beds usually occur as couplets <0.5 m thick, with each couplet consisting of a thin, discontinuous sheet sandstone and an associated pedogenically altered clayey siltstone or silt claystone. The only pedogenic features with the silty claystone and clayey siltstones consist of chalcedony-filled root voids and insect tunnels. Terry and others (1995) described these weakly developed paleosols as "entisols". The distribution of the discontinuous sheet sandstones is controlled by a complex overlapping cut-and-fill geometry (see Wells, 1994; Wells and others 1994, 1995; Terry and others, 1995; LaGarry and LaGarry, 1997n). The sheet sandstones are thinnest, poorly developed, or absent in th basal one-third of the paleovalley fills (Wells, 1994; Wells and others, 1995). Common sedimentary structures within these sheet sands include soft sediment deformation, fluid escape structures, planar crossbeds, mudcracks or subaqueous shrinkage cracks, and invertebrate trace fossils (Terry and others, 1995; Wells and others, 1995). As these sheet sandstones are exposed and subjected to weathering, the mudcracks propogate through them giving a "nodular" appearance (Terry and others, 1995). These "nodular" appearing sheet sands were interpreted as pedogenic nodules by earlier wotkers (Schultz and Stout, 1955; Schultz and others, 1955). A 0.01 m thick volcanic ash bed (the "Serendipity Ash") occurs 16 m above the base of the unit at the level of Schultz and Stout's (1955) "*Diplolophus insolens* bench". The basal multistoried channel sandstone (the "Toadstool Park Channel complex" of Schultz and Stout, 1955) is 0-9 m thick, and consists of overlapping paleochannels with trough and planar crossbedded, medium to coarse grained, clay matrix-supported sandstones having a gravel lag, thinly bedded and laminated green sandstones, and trough crossbedded conglomeratic sandstones having a gravel lag that contains small fragments of vertebrate bone and turtle carapace. These basal sandstones contain a suite of sedimentary structures consistent with a "mixed" braided/meandering river system, including trough crossbeds and lateral accretion surfaces (Terry and others, 1995). They are exposed intermittently within the Roundtop (Nebraska), Horn (Nebraska), Bodarc (Nebraska), and Warbonnet Buttes (Nebraska) 7.5' quadrangles (see also LaGarry and LaGarry, 1997n). The uppermost surface of the "Toadstool Park Channel complex" contains abundant vertebrate and invertebrate trace fossils, including tracks and trails of worms, insects, crustaceans, birds, rhinoceroces, entelodonts, camels, rodents, lagomorphs, oreodonts, and ?carnivores (Nixon and LaGarry-Guyon, 1993a, 1993b; Terry and others, 1995). Vertebrate fossils are common within the silty claystones and clayey siltstones. The overall thickness of this unit is 26-29 m, and it weathers into steep, step-and-riser badlands. This unit thins to the east [Chadron West (Nebraska) 7.5' quadrangle] and west [Sherrill Hills (Wyoming-Nebraska) 7.5' quadrangle] to 2-4 m of thinly bedded buff or brown siltstone. This unit has an intertonguing contact with the overlying Whitney Member, except where incised by paleochannels within the lower Whitney Member. It has an intertonguing contact with the underlying *"Big Cottonwood Creek member"* of the Chadron Formation, except where the underlying Chadron Formation is incised by the "Toadstool Park Channel complex." This unit is equivalent to Schultz and Stout's (1955) "Orella B" and "Orella C."

Eocene Series

Chadron Formation

(Twc1) *"Big Cottonwood Creek member"*- This provisional lithostratigraphic unit (Terry and LaGarry, 1994, 1995) is named for prominent exposures along Big Cottonwood Creek near Toadstool Geologic Park [Roundtop (Nebraska) 7.5' Quadrangle: LaGarry and LaGarry (1997n); see also Terry and others (1995)]. It consists primarily of pedogenically altered volcaniclastic silty claystones and minor amounts of interbedded claystone, pedogenic carbonate, lacustrine carbonate, massive lenticular sandstone, cross and planar bedded sandstone, diagenetic and sedimentary gypsum, volcanic ash, and a multistoried basal channel sandstone. Weakly developed paleosols in its uppermost 20 m give this unit a

characteristic banded appearance; common colors are yellow, buff, pink, tan, green, and red . The lowermost 15-20 m has less paleosol development, with common colors being green, yellow, and red. In addition to carbonates (typically calcretes), pedogenic features within this unit include ped structures, cutans, and root traces (Terry, 1995b). The pedogenic carbonates are <0.5 m thick and lenticular or tabular. Many contain fossilized dung rolled into balls by insects prior to deposition. The lacustrine carbonates are thin (<0.3 m thick), tabular, and discontinuous, and contain algal laminae, ostracodes, plant macrofossils, and fish remains (see also Welzenbach and Evans, 1992). Lacustrine carbonates with a high silt or clay content are considered marls (Terry and others, 1995; LaGarry and LaGarry, 1997n). The massive and planar bedded sandstones have a wide geographic distribution (see LaGarry and Terry, 1997). However, most of the diagenitic gypsum (often occurring as psuedomorphs) and all of the sedimentary gypsum (beds 0.2-0.6 m thick) are restricted to the Wolf Butte (Nebraska) 7.5' quadrangle (LaGarry and LaGarry, 1997n). The gypsum, sandstone, limestone, marl, and claystone beds are most common within the in lower 15-20 m of the unit. Multistoried basal sandstones 2-5 m thick occur locally [Sherrill Hills (Nebraska), Story (Nebraska), and Story NE (Nebraska), and Roundtop (Nebraska) 7.5' quadrangles: see also LaGarry and LaGarry (1997n)]. At least five pominent volcanic ashes are present throughout this unit. The uppermost ash, Schultz and Stout's (1955) "upper purplish-white layer" is locally widepread marker bed. The next lower ash, Schultz and Stout's (1955) "lower" or "second purplish-white layer" is less widespread, and often only slightly more vitric than the adjacent volcaniclastic silty claystones. The lower three ashes are lenticular and areally restricted, occurring within paleovalleys incised into the underlying *Peanut Peak Member* . The lowermost 20 m of this unit typically occurs as isolated erosional remnants within these paleovalleys [Horn (Nebraska) 7.5' quadrangle]. This unit is calcareous in zones, giving it a nodular (5-10 cm diameter) appearance. It is also highly fossiliferous, containing abundant fossil vertebrate and infrequent fossil invertebrate remains. The overall thickness of this unit is 22-40 m; it is thickest where it has incised into the underlying *Peanut Peak Member.* This unit typically weathers into smooth, near vertical faces and badlands. It has an intertonguing contact with the overlying Brule Formation, except where it is incised by the "Toadstool Park Channel complex" of the Orella Member of the Brule Formation. It has an intertonguing contact with the underlying *Peanut Peak Member* , except where this unit incises or fills valleys and depressions in the underlying *Peanut Peak Member.* This unit is equivalent to Schultz and Stout's (1955) "Chadron B^{3}", "Chadron B^{4}", "Chadron C", and "Orella A." This unit does not occur east of the Trunk Butte (Nebraska) 7.5' quadrangle, where this stratigraphic position is occupied by the *"Trunk Butte member"* of the Chadron Formation.

(Twc2) ***Peanut Peak Member***- Terry (1993, 1995a), Terry and LaGarry (1994, 1995), and Terry and others (1995) correlated this unit into Nebraska from southwestern South Dakota. It consists of dark olive, gray, yellow, and red claystones. Most primary sedimentary structure within the claystones (e. g., lamination) are overprinted by pedogenic features, which include root traces, ped structures, cutans, mottling, and calcareous nodules. Discontinuously bedded gypsum, lacustrine limestone and marl, pedogenic calcrete, and sandstone beds occur in different locations and at various stratigraphic levels within the unit . Gypsum beds occur as diagenetically emplaced (0.1-0.5 m thick) and as a result of primary deposition (0.1-0.25 m thick) [Wolf Butte (Nebraska) 7.5' quadrangle: see LaGarry and LaGarry (1997n)]. Lacustrine limestones are tabular (0.05-0.25 m thick), are widespread both geograpically and stratigraphically, and contain algal laminae, ostracodes, plant macrofossils, and fish remains (see also Welzenbach and Evans, 1992). The calcretes are restricted to the Horn (Nebraska), Trunk Butte (Nebraska), and Chadron West (Nebraska) 7.5' quadrangle (see also LaGarry and LaGarry, 1997n; LaGarry and Terry, 1997). The sandstones are calcite-cemented, and occur as basal sandstones and isolated lenses at various stratigraphic positions. The basal sandstones are brown or green, medium to coarse grained, and trough and planar crossbedded. These basal sandstones are up to 4 m thick, multistoried, and resricted to the Sherrill Hills (Wyoming-Nebraska), Story (Nebraska), and Story NE (Nebraska) 7.5' quadrangles (see LaGarry and Terry, 1997). Isolated sandstones are massive, lenticular or tabular, crossbedded, gypsiferous (0.1-1.5 m thick), and occur west of Toadstool Park [Roundtop (Nebraska) 7.5' quadrangle: LaGarry and Terry (1997)]. At least one, and possibly as many as four lenticularly bedded volcanic ashes (0.1-0.3 m thick) are present throughout the unit . This unit has a thickness of 2-17 m. Its contact with the overlying *"Big Cottonwood Creek member"* is intertonguing except where incised by the basal channel sandstones of the *"Big Cottonwood Creek member"* or eroded into paleovalleys. Its lower contact with the underlying *Chamberlain Pass Formation* is a regional unconformity. This unit weathers into smooth, low hummocks, and is equivalent to Schultz and Stout's (1955) "Chadron B^{1}" and Chadron B^{2}", and Clark and others'

(1967) "Chadron Formation undifferentiated" and Peanut Peak Member of the Chadron Formation in the Big Badlands of South Dakota.

(Twc3) *"Trunk Butte member"*- This provisional lithostratigraphic unit (LaGarry and Terry, unpublished data) is named for prominent exposures in the flanks of Trunk Butte, 14.5 km west of Chadron, Nebraska [Trunk Butte (Nebraska) 7.5' quadrangle]. It consists primarily of medium to thickly bedded, pedogenically altered brown, pink, red, green, and olive silty claystone and clayey siltstone microbreccias interbedded with prominent ledge forming calcretes, lenticular pockets of trough crossbedded green silts and fine sand, pedogenically altered brown claystones, and volcanic ash. The calcretes dominate this unit. They are 0.1-5 m thick, and account for as much as 60% of the exposed strata. In addition to the prominent calcretes, pedogenic features include root traces, mottles, peds, cutans, and worm casts and voids. Fifteen meters above the base of the section is a horizon consisting almost entirely of fossil dung rolled into balls by insects prior to burial. Two volcanic ashes are exposed 6 and 13 m above the base of the section. The lower ash is a lens 0-2.5 m thick. The second is only 0.1 m thick, but has a characteristic blue color. Skinner (unpublished field notes 1956-1964, archived at the Division of Paleontology, University of Nebraska State Museum) correlated these ashes to Schultz and Stout's (1955) "lower purplish-white" and "upper purplish-white" layers, respectively. This unit is about 22 m thick at the proposed type section at Trunk Butte, and up to 5 m is exposed within cut banks to the west [Chadron West (Nebraska) 7.5' quadrangle]. Its upper contact is a local erosional unconformity underlying thinly bedded pale brown siltstones of the Orella Member of the Brule Formation. The lower contact is an erosional unconformity where this unit has incised or filled valleys and depressions within the underlying *Peanut Peak Member* of the Chadron Formation. This unit is equivalent to Skinner's *"Trunk Butte member"* of the Chadron Formation, and part of the *"Big Cottonwood Creek member"* as originally defined by Terry and LaGarry (1994, 1995: see LaGarry and Terry, 1997).

(Twcp) *Chamberlain Pass Formation*- Terry (1993, 1995a), Terry and LaGarry (1994), and Terry and others (1995) correlated this unit into Nebraska from southwestern South Dakota. It consists of pedogenically altered red, gray, white, yellowish olive, and olive silty claystones and interbedded lenticular single and multistoried white, gray, yellow, yellowish green, or green trough crossbedded channel sandstones. The claystones ["mudstones" of Evans and Terry (1994) and Terry and Evans (1994)] are laminated or massive and typically 1-3 m thick. The claystones contain Terry's (1993, 1995a) dark red *Interior Paleosol Series equivalent* (see Retallack, 1983) and yellowish olive *Weta Paleosol Series equivalent* (see Evans and Terry, 1994; Terry and Evans, 1994). Most primary sedimentary structures (e. g., lamination) are overprinted by pedogenic features, which include root traces, ped structures, cutans, mottling, pedogenic silcretes, calcareous nodules, and redoxymorphic iron accumulations. Calcareous nodules (2-5 cm diameter) occur in discrete horizons. The sandstones are single (0.5-1.0 m thick) and multistoried (2-8 m thick), fine to coarse grained, pedogenically altered, and usually contain a gravel to cobble sized lag at base. Pedogenic alteration of the sandstones has tranformed their feldspars into kaolinitic clays, an based on the amount of kaolinite within these sandstones, they were likely arkosic when deposited (Terry and Evans, 1994). Individual sandstone bodies are trough crossbedded, fine upwards, and contain pebble stringers, intraclasts, and large blocks of reworked red and yellowish olive claystone and shale incorporated into their base. The overall thickness of this unit is 1-13 m. Its contacts with the overlying Chadron Formation and the underlying *Yellow Mounds Paleosol Series equivalent* are regional inconformities. Along Whitehead Creek in the Five Points (Nebraska), Montrose (Nebraska), and Roundtop (Nebraska) 7.5' quadrangles (see also Terry and others, 1995; LaGarry and LaGarry, 1997n) this unit had incised into underlying unaltered Pierre Shale. The claystones weather into low, smooth hummocks, and the channel sandstones weather into ledges and vertical cliffs. This unit corresponds to the basal gravels and "beds of a bright dark red color" of Darton's (1899) original Chadron Formation, the upper part of Schultz and Stout's (1955) "Interior Paleosol Complex" (*the Interior Paleosol Series equivalent*), and Schultz and Stout's (1955) "Chadron A" or "Yoder" (the channel sandstones: Terry and others, 1995; LaGarry and LaGarry, 1997n).

CRETACEOUS SYSTEM

Campanian Series

MONTANA GROUP

PIERRE SHALE

(Kpy) *Yellow Mounds Paleosol equivalent*- Terry (1993, 1995a), Terry and LaGarry (1994), and Terry and others (1995) correlated this unit into Nebraska from southwestern South Dakota, It consists of pedogenically altered Pierre Shale, and varies in color from yellow to ochre, orange, pink, and white. The original fissility of the parent shale is almost entirely overprinted by pedogenic features, which include root traces, ped structures, cutans, mottling, pedogenic silcretes, calcareous nodules, and redoxymorphic iron concentrations and nodules. Pedogenic limonite frequently occurs 1-2 m below the weathered upper surface. Diagenetic gypsum is also present 1-2 m below the weathered upper surface where overlain by depositional gypsum in the *Peanut Peak Member* of the Chadron Formation [Wolf Butte (Nebraska) 7.5' quadrangle: LaGarry and LaGarry (1997n)]. This unit is 1-15 m thick across the northern part of the study area. Like its parent material, it typically weathers as low hummocks or as steep escarpments in cutbanks of streams. Outcrops of this unit are frequently covered by cobble lag (stippled on maps) remnant of the overlying *Chamberlain Pass Formation*. Its contact with the overlying *Chamberlain Pass Formation* is a regional unconformity. Its contact with the underlying unaltered Pierre Shale is gradational. Although this unit is stratigraphically equivalent to Retallacks (1983) Yellow Mounds Paleosol Series, which was first described in the Big Badlands of South Dakota, it likely represents a different soil series. This unit corresponds to the lower part of Schultz and Stout's (1955) "Interior Paleosol Complex".

(Kp) Pierre Shale- This unit consists of unaltered black, brown, or gray highly fissile marine shale. It contains discontinuous limonitic bands (<0.02 m thick) and nodules (<0.1 m diameter) in zones 0-2.5 m below the exposed upper surface. Exposures in the Wayside (Nebraska) 7.5' quadrangle contain a horizon of lozenge-shaped limonitic concretions up to 3 m in diameter and 0.5 m thick. This unit also contains 0.2-0.5 m thick brown to yellow sandy limestone lense. According to Darton (1899), these limestones occur about 330 m ("1000 feet") below the unconformable upper contact. These limestones contain abundant marine invertebrates, primarily pelecypods [Story (Nebraska), Story NE (Nebraska), Montrose (Nebraska), and Orella (Nebraska) 7.5' quadrangles: see also LaGarry and LaGarry (1997n)]. They occur as the caprock of conical ("teepee") buttes and are a common local source of colluvium (used in road maintenance) within large expanses of otherwise noncolluvial shale. This shale is known to yield fossils of large marine vertebrates. This unit typically weathers as low hummocks or as steep escarpments in cutbanks of streams. Outcrops of this unit are occasionally covered by a cobble lag remnant of the overlying *Chamberlain Pass Formation* (stippled on maps) . As much as 50 m of this unit is exposed within the study area. The upper contact with overlying units is a regional unconformity marked by the *Yellow Mounds Paleosol* unless incised by overlying units. The lower contact is not exposed in the study area.

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