Geologic Map of the Samson Lake 7.5-Minute Quadrangle, McKinley County, New Mexico

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September 2024

New Mexico Bureau of Geology and Mineral Resources
Open-File Geologic Map OF-GM 312

Scale 1:24,000

https://doi.org/10.58799/OF-GM-312

This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program under STATEMAP award number G22AC00601, 2022. Additional support was made possible by the 2023 Technology Enhancement Fund provided by the New Mexico Higher Education Department. Funding is administered by the New Mexico Bureau of Geology and Mineral Resources (Dr. Nelia W. Dunbar, Director and State Geologist (2023); Dr. J. Michael Timmons, Director and State Geologist (2024); Dr. Matthew J. Zimmerer, Geologic Mapping Program Manager).

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Report on Geology of the Samson Lake Quadrangle McKinley County, New Mexico

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Introduction

The geology of the Samson Lake quadrangle is dominated by rocks deposited in or just inland of the Western Interior Seaway during late Cretaceous (~100.5–66 Ma) time (**FIGURE 1**). We will begin our discussion with the oldest rocks deposited in this area and then move forward in time to the present.

Shale, limestone and sandstone are often found associated with each other. They are a prime example of what is known as Walther's Law, which states that any rocks deposited in a conformable succession in a geologic sequence were once found in adjacent environments (**FIGURE 2**).

In the case of the marine rocks found on the Samson Lake quadrangle, limestones are usually deposited furthest from shore (the grey area in figure 1) in areas that receive very little sediment (no limestones are found on the Samson Lake quad but associated limestones are known to the northeast where the deeper parts of the Cretaceous seaway were found); shales like the Mancos Shale are deposited closer to shore where fine sediments carried to sea by rivers slowly settle out on the seafloor, often with some contributions from shelled animals; and sandstones such as the Gallup Sandstone are from relatively nearshore environments such as barrier islands, beaches, and/or nearshore bars. This sequence is continued 'landward' by the stratigraphically higher continental rocks of the Crevasse Canyon and Menefee Formations, which represent lagoon, estuarine, swamp and river (or fluvial) sediments and are composed of sandstones and terrestrial shales with highly variable amounts of interbedded coal lenses.

As sea level rose and fell during the late Cretaceous, these environments migrated to the southwest (as sea level rose) and northeast (as sea level fell) across the Samson Lake area. Since this area was down-dropping at this time, the sediments from each environment were preserved within the San Juan Basin (more below) in the vertical succession we presently see.

Overview of units, geologic history and description of relations

MANCOS SHALE

The Mancos Shale was originally named for Mancos, Colorado (Cross and Purington, 1899) and this unit covers or underlies vast areas in the western United States including part of Utah, Colorado, Wyoming, Montana, New Mexico, Texas and Arizona. As mentioned above, this type of shale is deposited far enough from shore that it is composed mainly of silt and clay that slowly settled to the seafloor after entering from rivers—in this case rivers flowing out of mountains to the west and southwest. Marine organisms living in these seas contribute varying amounts of shelly material, producing shales that are on a spectrum from lime free (at least at present since lime can be 'leached' from rocks after deposition) to shaly limestone. The age of the Mancos has been determined through evolutionary changes in, for example, Ammonites contained within shale layers (**FIGURE 3**). By this reasoning the Mancos is as old as 95 Ma, regionally. Only the uppermost part is exposed here, and since the overlying Gallup sandstone is thought to be Turonian (Tschudy, 1976) the upper Mancos here is probably 93–92 Ma* (Figure 4). In the Samson Lake area this unit is the oldest rock exposed, and the upper contact is gradational with the overlying Gallup Sandstone, which represents sands deposited as the 'beach' (and then coastal rivers) moved over this part of New Mexico during a drop in sea level (*a regression*).

*Since age ranges of these rocks are based on regional relations, there is some overlap in their *age ranges* based on biostratigraphy, but all rocks are still necessarily younger than those they overlie.

GALLUP SANDSTONE

The lower part of the Gallup Sandstone, as mapped, is composed of marine sandstones deposited as a relative sea-level decline brought near-shore sands into the Samson Lake area. This unit contains few fossils but is known to be between ~93 and 89 million years old, regionally, based on the age of overlying and underlying rocks. The base of the formation in this area is mapped at the lowest continuous sandstone found above mixed sandstone and shale of the Mancos. This alternating sequence of sandstone and shale at the top of the Mancos indicates that relative sea level rose and fell several times before finally rising to deposit the Gallup Sandstone proper. The top of the Gallup Sandstone in this area, as mapped, is coarser than the fine- to medium-grained sands found in the marine part of the rocks and has been interpreted as fluvial sands that were deposited near the coast—and that presumably provided the 'raw material' for the marine sands of the lower Gallup. This upper, fluvial sandstone has sometimes been mapped separately and has been named the Torrivio Sandstone after Torrivio Mesa which is partly located in the southeast corner of the Samson Lake quadrangle. Because the whole body of the Gallup Sandstone, as mapped here, is relatively thin and because a characteristic pinkish color sometimes noted in the Torrivio Sandstone is irregular in this area, we have lumped the Torrivio Sandstone with the Gallup Sandstone on the Samson Lake quadrangle.

CREVASSE CANYON FORMATION and MENEFEE FORMATION

As sea level continued to fall, this area began to accumulate lagoon, swamp, estuary, and fluvial sediments deposited between highlands to the southwest and the shoreline, which continued to move northeastward with episodic small-scale, sea-level rises creating a complexly interbedded sedimentary sequence. Various members of the Crevasse Canyon and Menefee Formations were deposited in these low-lying, mostly coastal areas in complex and laterally variable combinations of sandstone, shale, siltstone and coal (**FIGURE 4**). The Crevasse Canyon and

Menefee Formations were originally defined (and divided from each other) in an area where a marine sandstone (the Point Lookout Sandstone) separated them. The Point Lookout Sandstone pinches out about 25 miles northeast of Gallup and the associated sea-level rise never reached the altitude of the Samson Lake area (**FIGURE 4**) and so division of the Crevasse Canyon and Menefee Formations is somewhat problematic here.

The oldest member of the Crevasse Canyon is named the Dilco Member and consists of mostly fine-grained sediments with lesser amounts of fine- to fine-grained sandstone. Originally called the Dilco Coal Member to distinguish it from the 'barren' (of coal) members such as the Bartlett and Allison Members, in the Samson Lake area coal is more variably present, and found in generally thinner lenses in most units than in the type areas. For example, The Gibson Coal Member of the Crevasse Canyon Formation was originally defined by the presence of coal seams >14 in.thick (e.g. Dillinger, 1990) but on the Big Rock Hill quadrangle (just east of Gallup), coal seams in the Gibson are mostly less than 14 in. but up to 3 m thick (Kirk and Zech, 1987).

The next younger unit above the Dilco Member, The Bartlett Barren Member of the Crevasse Canyon Formation, is, in general, coarser-grained than the Dilco Member, but in the absence of the characteristic thicker coal beds found elsewhere in the Dilco, the placement of the contact between them becomes somewhat arbitrary. We have tried to place this contact near the first more-or-less continuous sandstones (often forming low mesas) above the generally lower-lying shale and siltstone-rich rocks of the Dilco. This scheme for defining the contact between these members (as well as other members described below) is far from ideal but is a natural consequence of the highly variable nature of near-coastal environments where sea levels are rising and falling (and the climate is changing) on multiple time scales. Active tectonics (the subsidence of the San Juan Basin) during deposition of these rocks adds additional lateral variability to the resultant sediments. These considerations, combined with the gradational and interfingering nature of the contacts between most late Cretaceous continental rocks, results in contacts that can only be placed in a generalized way. These contacts should therefore not be regarded as definite.

Above the Bartlett Barren Member, a mapping unit composed of a combined Gibson Member of the Crevasse Canyon Formation and Cleary Coal Member of the Menefee Formation is found. Again, these two units were originally distinguished from each other by the presence of the marine Point Lookout Sandstone, which is not present in this area. The Contact between this combined unit and the underlying Bartlett Barren Member is once again defined at the top of the last more-or-less continuous, commonly mesa-forming sandstones.

The Allison Member of the Menefee Formation overlies the combined Cleary/Gibson rocks, usually contains little or no coal, and is dominated by sandstone. The placement of this contact is, in a stratigraphic sense, arbitrary, because the level at which coal becomes absent (or nearly absent) changes laterally and a *strict* definition in compliance with the North American Stratigraphic Code is not possible. As far as possible, the lower contact of the Allison Member is placed near the top of the last coal bed/lens in the Cleary/Gibson map unit. Nevertheless, the change to clearly sand-dominated and coal-free sedimentation indicates changes in either climate, source-area conditions, fluvial dynamics or some combination of these variables.

SAN JUAN BASIN

All the rocks exposed on the Samson Lake quadrangle were deposited in the San Juan Basin (SJB), a structural basin that formed between ~80 and 40 Ma during the Laramide Orogeny (or mountain-building event, see **FIGURES 5** and **6**). Compression of western North America during this time caused complex deformation over a large area and in what would become the SJB, long-term subsidence resulted in the preservation of sediments deposited in both marine and terrestrial environments as sea level rose and fell across this area (Cather, 2004).

Subsequent erosion of this 'bowl-shaped' basin resulted in a roughly concentric exposure of rocks that are progressively older away from the center of the basin (**FIGURE 5**). The Samson Lake quadrangle lies on the southwest side of this basin and therefore, in general, progressively older rocks are exposed as one moves southwest across the area. The Laramide compression that created the SJB also caused faulting and folding on smaller scales and this deformation resulted in the broad folds apparent on the map and probably also the one north-south-striking fault seen on the eastern half of the map.

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Appendix A: Figures

FIGURE 1—The Western Interior Seaway and Campanian paleogeography (Sampson et al., 2023). Parts of the Mancos Shale and most of the Menefee Formation were deposited at this time.

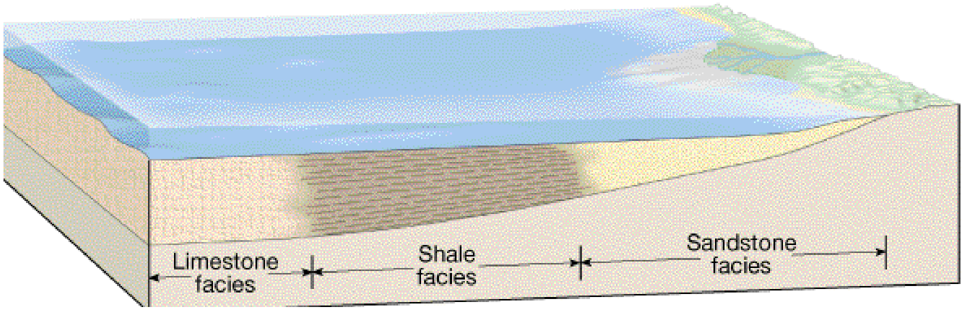

FIGURE 2—Schematic showing common distribution of rock types in a shallow marine environment. Rising and falling sea levels result in these various types being deposited in vertical successions like the rocks found on the Samson Lake Quadrangle. (public domain)

FIGURE 3—Artist's rendering of a late Cretaceous Ammonite. (public domain)

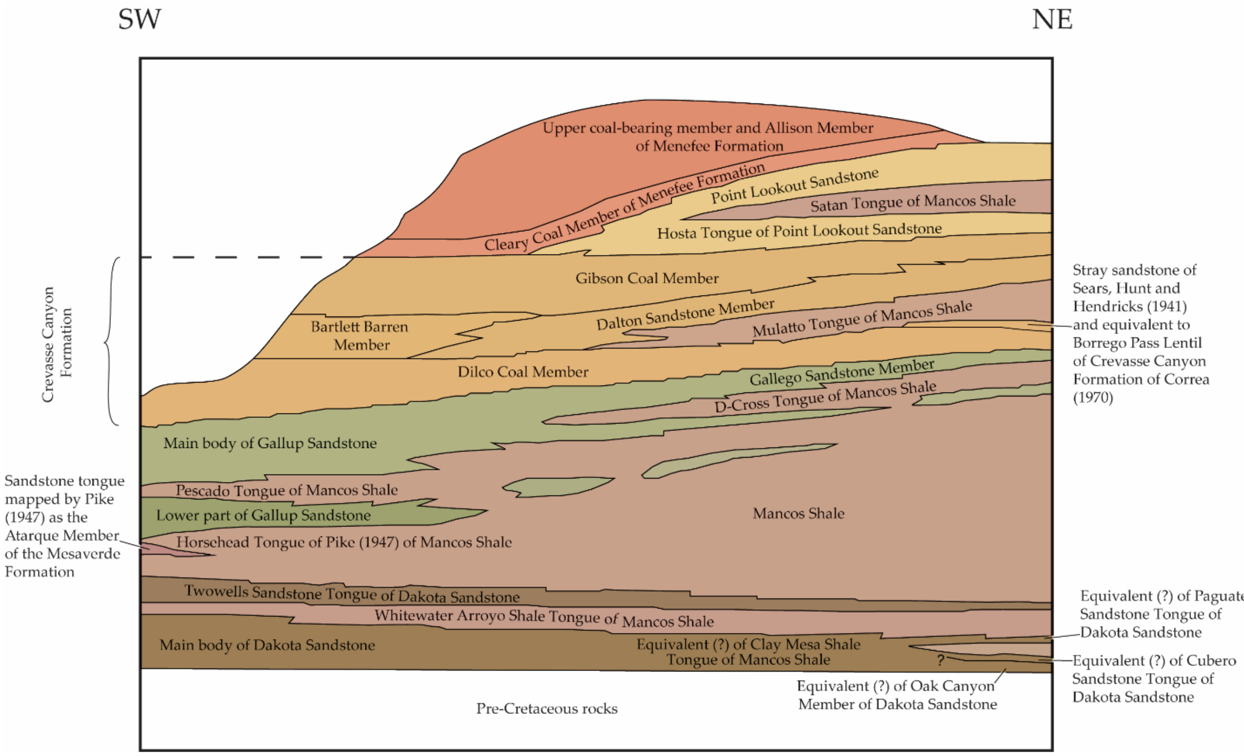

FIGURE 4—Stratigraphic relations of Cretaceous units in the Gallup area from Hackman and Olson (1977).

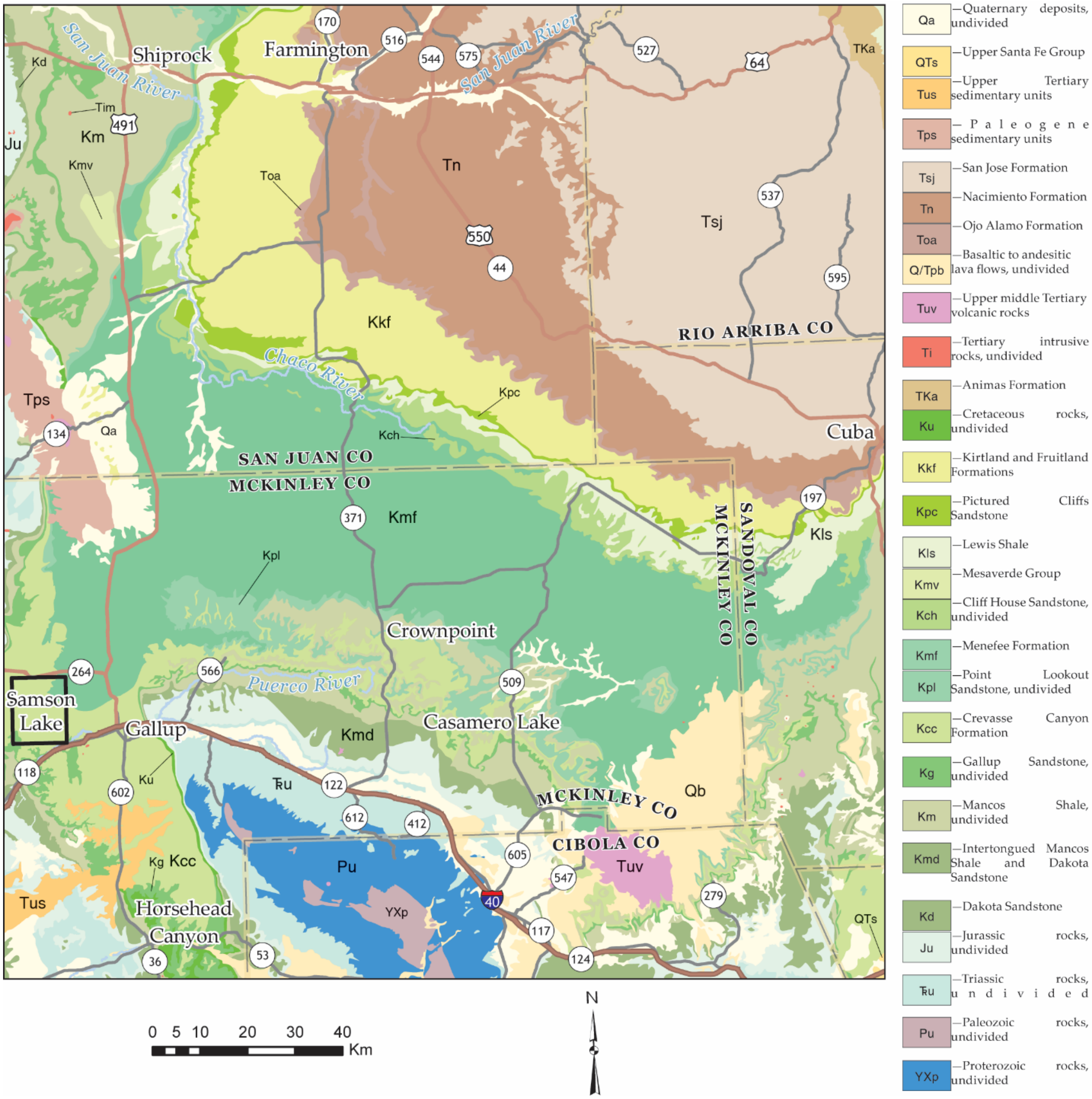

FIGURE 5—A simplified geologic map of northwest New Mexico showing the Samson Lake quadrangle location in relation to the concentric structure of the San Juan Basin (Anderson and Jones, 1994). Crownpoint, Casamero Lake, and Horsehead Canyon (**FIGURE 4**) are also shown. Geology from the Geologic Map of New Mexico OFGM-304. Unit descriptions can either be found in this publication or from the geologic map-unit descriptions in OFGM-304.

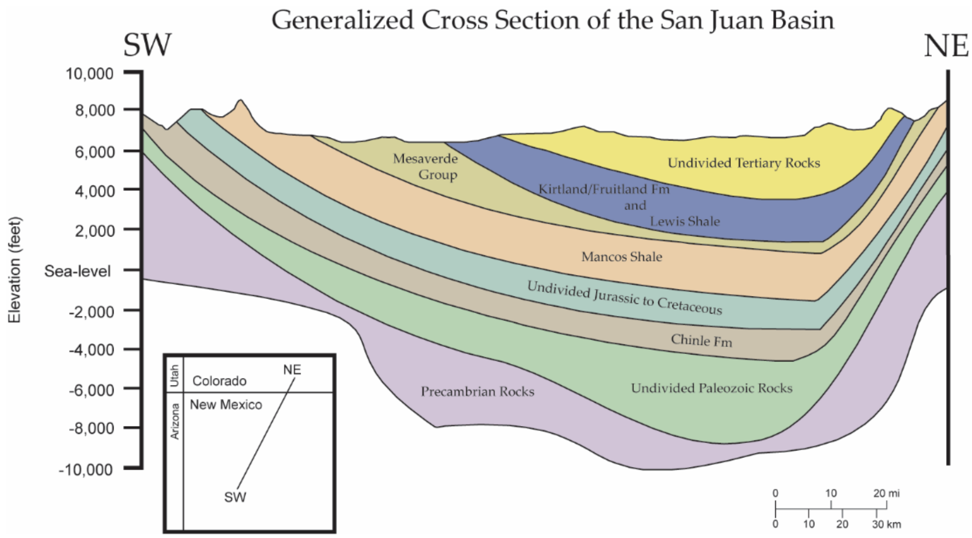

FIGURE 6—Generalized geologic cross section of the San Juan Basin (Guiffre, 2016). The Samson Lake Quadrangle is underlain by rocks of the Mesaverde Group (Gallup Sandstone and Crevasse Canyon and Menefee Formations) and the Mancos Shale.

Appendix B: Description of Units

Explanation of descriptive terms.

Colors (e.g. rocks, outcrops) are subjective; strength, sorting, angularity, grain/clast size, and hand-sample descriptive terms after Compton (1985); sedimentary terms after Boggs (1995). Queries (?) after descriptors indicate uncertainty in interpretation and/or identity and/or persistence of descriptor.

Summary

The Samson Lake quadrangle is underlain mostly by upper Cretaceous rocks of the Mesaverde Group including the Gallup Sandstone, Crevasse Canyon Formation (Bartlett Barren Member, and a combined mapping unit composed of the Gibson Member of the Crevasse Canyon Formation and the Cleary Coal Member of the Menefee Formation), and the Allison Member of the Menefee Formation. The Cleary Coal and Gibson Members are mapped together in this part of New Mexico because they cannot be distinguished in the absence of the Point Lookout Sandstone, which pinches out east and north of the map area. These rocks represent marine and continental deposits related to late Cretaceous sea level changes (transgressive/regressive sequences). Small outcrops of the marine Mancos Shale are exposed in the southeast corner of the quadrangle. Quaternary alluvium (as 'valley fill') covers large parts of the map area along modern drainages and older Quaternary alluvium covers parts of some uplands. Quaternary alluvium has commonly been incised between 3–15 m, presumably in Historic times (Aby, 2017). Some small areas of Holocene eolian sand have been noted, but not mapped due to their limited extent.

Quaternary Rocks

af

Artificial fill (Recent)

Areas that have been regraded due to mining activities.

Qal

Quaternary Alluvium (late Pleistocene to Holocene).

Well-exposed, poorly sorted, thin- to thick-bedded, brown to pale-tan and yellowish, very fine- to coarse-grained, sometimes pebbly to cobbly, lenticular to tabular sand, silty sandstone, silt, and clayey silt. This unit covers extensive areas along modern valley bottoms and is well exposed along modern drainages where channels have commonly incised 3–15 m in modern times. May contain some eolian and, particularly, reworked eolian material as well as "canyon-mouth" fans. Commonly at least 5–10 m thick and up to 20 m in valley axes. Contacts for this map unit are mapped as "approximately located" due to poor exposure except along incised channels. Mapped where >≈1 m thick.

Qao

Older Quaternary Alluvium (Pleistocene)

Poorly exposed, loose to friable, reddish- to dark-brown, cobbly to sandy alluvium found it high topographic positions.

Cretaceous Rocks

Kmfa

Allison Member of Menefee Formation

The Allison Member (named for Allison, NM; a small community located immediately west of Gallup and on the adjacent Gallup West quadrangle) is most conspicuously composed of well-exposed, yellow- to brownish-weathering, moderately poor to moderately well-sorted, quartz-rich, often feldspathic, carbonate-cemented, thin- to very thick-bedded, indistinctly cross-bedded to planar bedded, friable, broadly lenticular (individual sandstone bodies rarely exceed a half mile in outcrop length (O'Sullivan et al., 1972)) sandstone containing rare channel fills indicating probably northward and northeastward paleotransport. Sandstones sometimes contain rust-colored (ironstone?) concretions >1 m in diameter, particularly to the north of the map area where they are characteristic of some parts of this unit. The Allison Member also contains substantial proportions of less well exposed loose, fine grained sandstone, siltstone and shale. Coal comprises a relatively small proportion of the Allison Member and this has been used to distinguish it from the underlying Cleary Coal Member, with which it is gradational and/or interfingering. Coal beds in the Allison are generally less than 14 in. thick (Sears, 1925; Dillinger, 1990). Since coal beds are discontinuous and variable in thickness, this makes for a vaguely defined lower contact, and the position of this contact is not well constrained in the

Gallup area (mapped contact is probably +/- 30 m stratigraphically in many places). As near as possible we have tried to map this contact at the top of the last coal bed >14 in. within Kmccg. The Allison Member is at least 10–60 m thick, on the Samson Lake quadrangle, but upper contact is eroded and unit is at least 600 m thick, regionally.

Kmccg

Cleary Coal Member of Menefee Formation and
Ks Gibson Member of Crevasse Canyon Formation combined

The Cleary Coal Member of the Menefee Formation and Gibson Member of Crevasse Canyon Formation cannot be divided south and west of the pinch out of the Point Lookout Sandstone, which occurs approximately 12 mi northeast of Gallup (O'Sullivan et al, 1972). This Member is composed of a diverse suite of swamp and fluvial sediments. Sandstones are yellowish- to brownish-weathering, very fine- to coarse-grained, lenticular, and poorly to well-sorted. Shale and siltstone are also present and are generally poorly exposed. The top of this unit is mapped as near as possible to the stratigraphically highest coal bed >14 in. thick (see description of Allison Member). The lower contact is similarly mapped near the lowest coal bed >14 in. thick, but variation in coal thicknesses and the stratigraphic position of thicker coal beds (lenses) make for a somewhat arbitrary lower contact. Dillinger (1990) reports coal beds up to 6 ft thick in the Clearly Coal Member, but coal bed thicknesses are highly variable in the region (e.g. O'Sullivan, et al, 1972), and coal beds are not laterally extensive. Thickness ranges from about 60 to 80 m.

Kcb

Bartlett Barren Member of Crevasse Canyon Formation

The Bartlett Barren Member is composed of mostly poorly exposed, reddish, pinkish, greenish and brownish silt, sandy silt and clayey silt and sandstone. Sandstones are poorly to moderately exposed, loose to friable, thin- to thick-bedded, very fine- to medium-grained, and carbonate-cemented. Interpreted as the landward equivalent of the Gibson/Clearly Members (see above). For discussions of contacts see overlying and underlying unit descriptions. The Bartlett Barren Member is between 21 and 128 m thick, regionally (Kirk and Zech, 1987) and ≈80–100 m on the Samson Lake quadrangle.

Kdci

Dilco Member of Crevasse Canyon Formation

Mostly poorly exposed, light- to dark-gray and brown, thin- to thick-bedded, friable shale and siltstone and poorly to well-exposed, thin- to thick-bedded, very fine- to medium-grained, poorly to well-sorted sandstone. 21 to 67 m thick on the nearby Big Rock Hill quadrangle (Kirk and Zech, 1987). The Dilco Member is ≈80–120 m on the Samson Lake quadrangle.

Kg

Gallup Sandstone

Well-exposed, very fine- to medium-grained, well-sorted, cross-bedded, thin to thick-bedded cliff-forming sandstone. Composed of transgressive/regressive marine and marginal marine sandstones with uncommon silty/shaly and coal beds. The upper part of the Gallup Sandstone is sometimes mapped separately as the Torivio Sandstone, which is sometimes distinctive for its pinkish color, coarse-grained sandstone and the presence of feldspar (Thacker, in press Geologic Map of the Bread Springs quadrangle). Although this unit is locally known as 'the pink sandstone' according to Sears (1925), in the map area it does not always exhibit this characteristic color, although some of the overlying sandstones of the lower Crevasse Canyon Formation do. Because the characteristic pinkish color is not prominent and not always confined to the upper beds on the Samson Lake quad we have included the Torivio Sandstone with the main body of the Gallup Sandstone here. The Torrivio Sandstone is interpreted as a fluvial rock (Anderson, 1990) and its presence, therefore, represents a transition from marine (the Gallup) to continental deposition during a relative sea-level fall. The sandstone is ≈10-50 m thick, regionally (Kirk and Zech, 1987), and ≈50 m exposed here.

Km
Mancos Shale
Poorly exposed, black- to pale-grey, thin-bedded to laminated shale and thick-bedded, yellowish to light-grey sandstone. The Mancos has very limited exposures on the Samson Lake quadrangle. For a discussion of the upper contact of the Mancos, see the Gallup Sandstone description above. Regional thickness is between ≈150–230 m (Dillinger, 1990) but only 30–50 m are exposed on the Samson Lake quadrangle.

Rocks shown only on cross section

Rocks older than the Mancos Shale (Dakota Sandstone (Kd) and Morrison Formation (Jm)) are highly variable in thickness in the region (e.g. Green and Jackson, 1976; Dillinger, 1990; Anderson, 1990; Kirk and Zech, 1987). We have taken average thicknesses from these reports. Cross sections should not be taken at face value and the apparent depth to these older rocks should be viewed with caution as the overall thickness of these rocks is speculative and errors associated with this uncertainty are compounded with depth.

Kd
Dakota Sandstone
Marine sandstone and shale. Approximately 50 m thick.

Jm
Morrison Formation
Terrestrial sandstone, siltstone and shale. Approximately 120–200 m thick.

Xu
Older rocks
Middle Jurassic through Proterozoic rocks. For descriptions of individual units see Hackman and Olson (1977) and Dillinger (1990).

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