Geologic Map of the Gallup West 7.5-Minute Quadrangle, McKinley County, New Mexico

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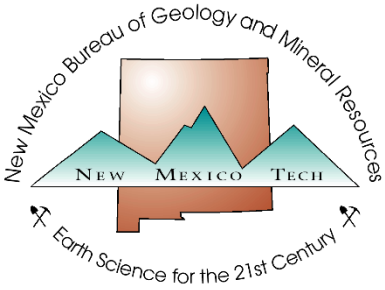

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Report on Geology of the Gallup West Quadrangle McKinley County, New Mexico

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Introduction

The Geology of the Gallup West 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 Gallup West quadrangle, limestones are usually deposited furthest from shore (in the grey area in **FIGURE 1**) in areas that receive very little sediment and so sediment is composed mostly, or almost entirely, of the shells of marine organisms (no limestones are found on the Gallup West 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 marine organisms; and sandstones such as the Gallup Sandstone are deposited in 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.

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 Gallup West 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 settle 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 Gallup West 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 Gallup West 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 southwest corner of the Gallup West 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 Gallup West quadrangle.

CREVASSE CANYON FORMATION and MENEFEE FORMATION

As sea level continued to decline, 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 Gallup West 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 medium-grained sandstone. Originally called the Dilco Coal Member to distinguish it from the 'barren' (of coal) members such as the Bartlett Barren and Allison Members, in the Gallup West 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, in general, coarser 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/lense 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 Gallup West 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 **FIGURE 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 Gallup West 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.

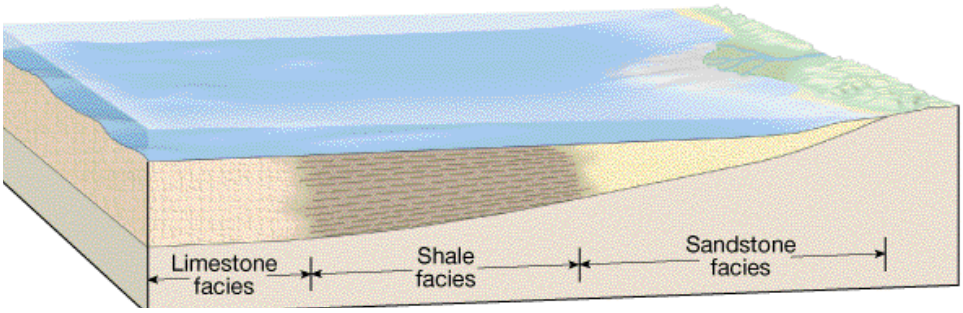

FIGURE 2. Schematic showing common distribution of rock types in a shallow marine environment. Rising and falling sea levels result in these various types being deposited in vertical successions like the rocks found on the Gallup West Quadrangle. (public domain)

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

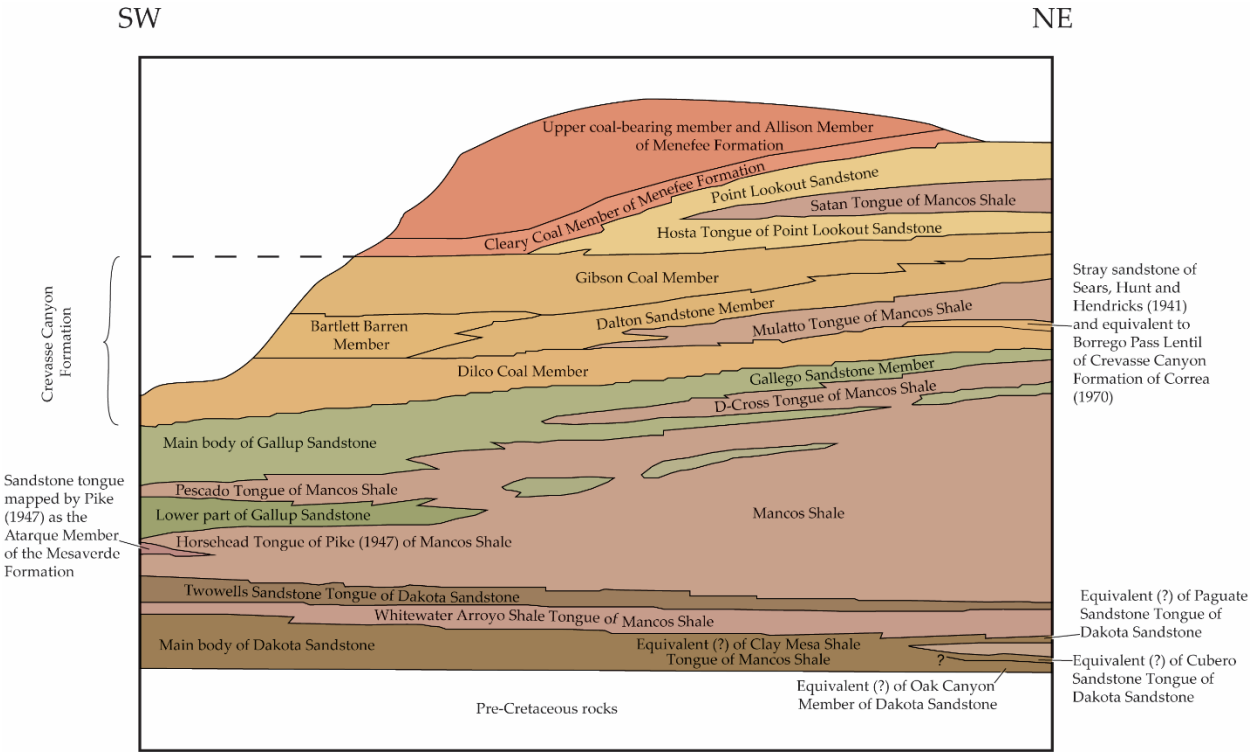

FIGURE 4. Stratigraphic relations of Cretaceous units in the Gallup area from Hackman and Olson (1977).

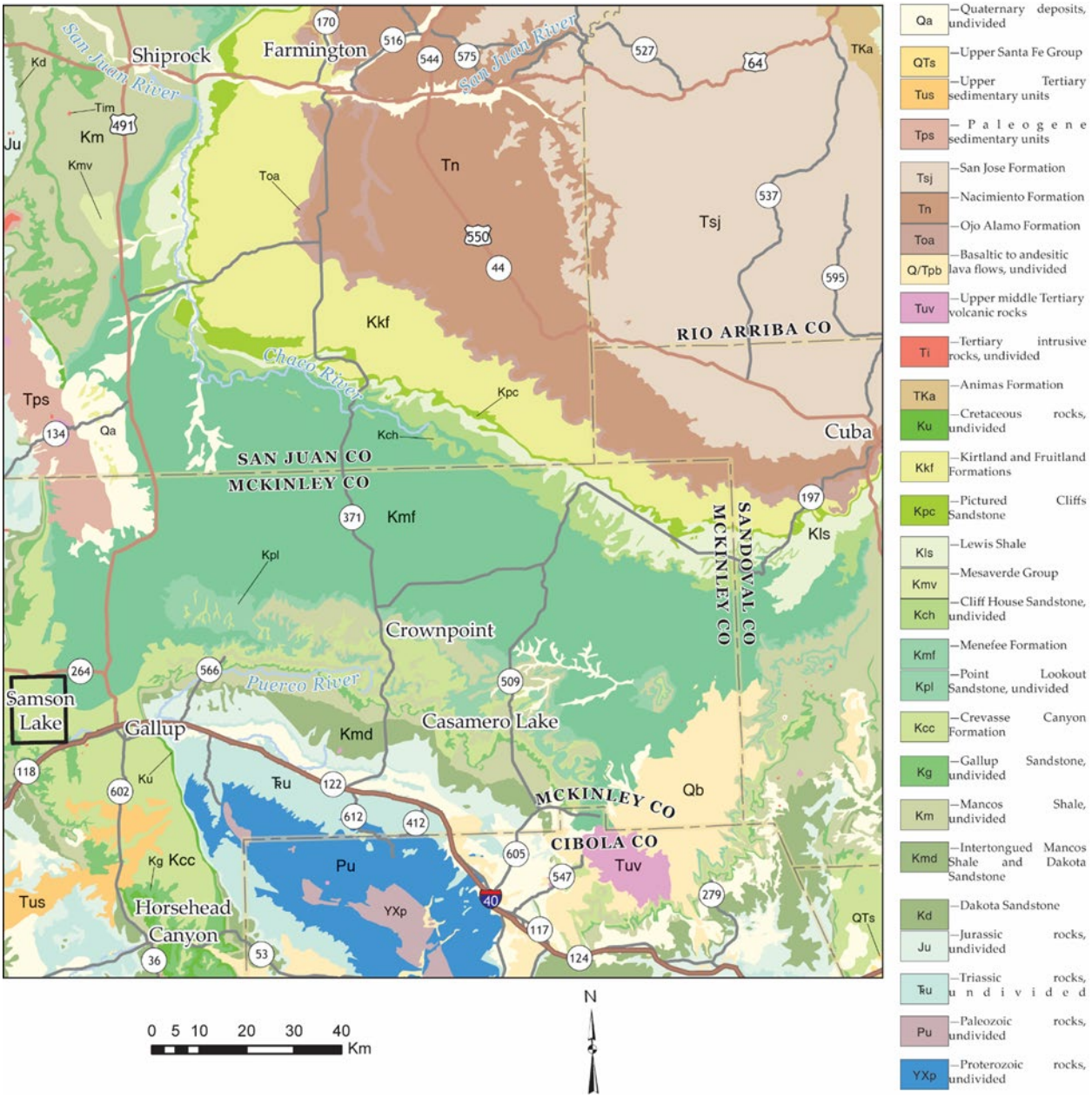

FIGURE 5. A simplified geologic map of northwest New Mexico showing the Samson Lake quadrangle location in relation to the concentric structure of the San Juan Basin (Anderson and Jones, 1994). Crownpoint, Casamero Lake, and Horsehead Canyon (**FIGURE 4**) are also shown. Geology from the Geologic Map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

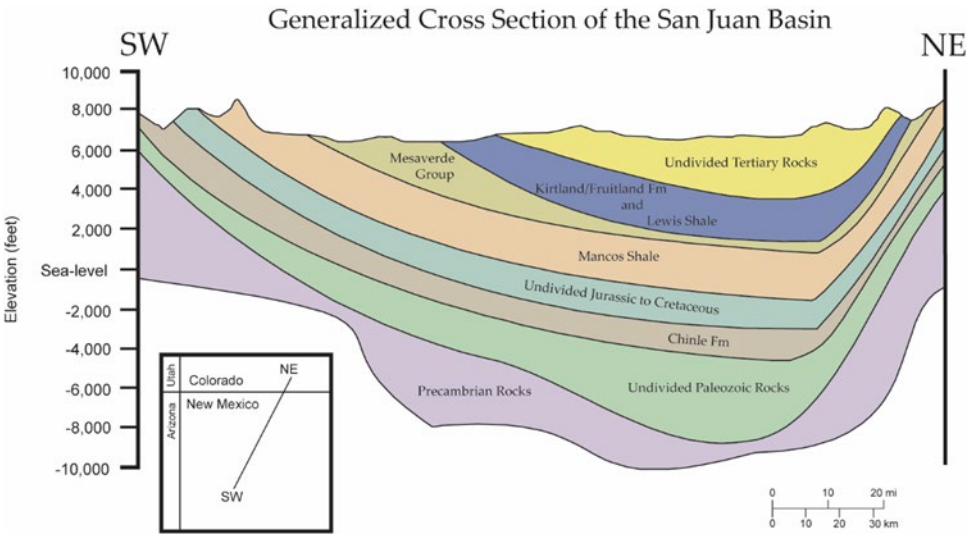

FIGURE 6. Generalized geologic cross section of the San Juan Basin (Guiffre, 2016). The Gallup West Quadrangle is underlain by rocks of the Mesaverde Group (Gallup Sandstone and Crevasse Canyon and Menefee Formations) and the Mancos Shale.

Appendix B: Description of Units

Explanation of descriptive terms and ages.
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. Chronologic ages are taken from the most recent International Chronographic Chart (Cohen et al, 2023). Geologic ages (e.g. Campanian) for individual units are taken from regional biostratigraphic evidence (e.g. Tschudy ,1976) and may not represent their exact chronologic ages on the Gallup West Quadrangle.

SUMMARY
The Gallup West 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)

Sand and gravel that has been moved, excavated, or otherwise modified by humans for construction purposes.

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. Commonly at least 5–10 m thick. Contacts for this map unit are mapped as "approximately located" due to poor exposure except along incised channels. Mapped where >≈1 m thick.

Short

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, silty sandstone, silt and clayey silt. Commonly at least 5–10 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.

Short

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 240 m thick on the Gallup West quad but the top has been eroded and the unit is at least 600 m thick, regionally.

Short
The Allison Member is 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 sandstone. The unit also contains substantial proportions of less well-exposed, loose, fine-grained sandstone, siltstone and shale. Coal comprises a relatively small proportion.

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). Dillinger (1990) reports coal beds up to 6' thick in the **Cleary** 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 50 to 90 m.

Short

Sandstones are yellowish- to brownish-weathering, very fine- to coarse-grained, lenticular, poorly to well-sorted and comprise a majority of the unit. Shale and siltstone comprise up to 50%(?) of the unit in this area 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.

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/**Cleary** Members (see above).

Short

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.

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. The lowest ≈60 ft of the Dilco Member is a distinctive, pinkish, feldspathic sandstone interpreted as a braided stream deposit (Anderson, 1990).

Short

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.

Kg
Gallup Sandstone

Well-exposed, very fine- to medium-grained, well-sorted, cross-bedded, thin to thick-bedded cliff-forming sandstone. 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. Composed of transgressive/regressive marine and marginal marine sandstones with uncommon silty/shaley and coal beds. 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 Torrivio Sandstone, which is distinctive for its pinkish color and the presence of feldspar (Thacker, in press Geologic map of the Bread Springs quadrangle). Because the characteristic pinkish color is not prominent in the limited exposures on the Gallup West

quad we have included the Torrivio Sandstone with the main body of the Gallup Sandstone here.

Short
Well-exposed, very fine- to medium-grained, well-sorted, cross-bedded, thin- to thick-bedded cliff-forming sandstone.

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 Gallup West quadrangle.

Short
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 Gallup West 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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