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Review of the History of Usage of the Gallup Sandstone and Related Units, Southern and Western San Juan Basin, New Mexico

By

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

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INTRODUCTION

Even from a cursory review of the literature on the Cretaceous of the San Juan Basin, significant problems with both the original definition and the subsequent interpretations of the Gallup Sandstone are obvious. Most of these problems will become apparent as one reads through the following sections concerning the historical interpretation of the Gallup Sandstone and the distribution of lithologic units within it. However, a brief statement of these problems may help to focus the readers' attention during the examination of the data presented.

Sears (1925), in his original definition of the Gallup Sandstone as a unit containing multiple lithologies, did not describe a type section. This lack of an adequately measured and described type section, later misinterpretations and miscorrelations, and extension of the name "Gallup Sandstone" out of Sears' study area have led to a "Gallup Sandstone" that now includes much more than Sears' original definition.

Finally, the Gallup Sandstone consists of a variety of very distinctive lithologic units (see fig. 19). Although technically acceptable under the Code of Stratigraphic Nomenclature, this results in unnatural and awkward boundaries. Ill-defined contacts and the combination of lithologic units has forced earlier and current workers alike to obscure and to misrepresent what we think are significant geologic relationships.

These problems lead us to the conclusion that the Gallup Sandstone is in need of an accurate definition, with well-defined boundaries that are both useful and natural. Furthermore, some way must be found to show satisfactorily the various lithologic units within this interval of rocks, so as to better represent the important geologic relationships that their distribution demonstrates.

We will summarize these problems at the end of these notes. Figure 1 illustrates the correlation of Cretaceous rocks and the general Cretaceous section within the San Juan Basin. Figure 2 is a Gallup Sandstone outcrop mapand location map.

DEFINITION AND HISTORICAL INTERPRETATION

The original definition of the Gallup Sandstone Member by Sears (1925) is examined along with the subsequent interpretation by various other workers in the Gallup-Zuni, Acoma, and San Juan Basins. The material is presented chronologically by date and author, with the bulk of the text being a paraphrasing or summary of each author's work. We have attempted in all cases to make our editorial comments obvious and separable from the facts as presented by each author.

Sears--1925

The Gallup Sandstone Member of the Mesaverde Formation was named by Sears (1925, p. 17) for exposures in the vicinity of Gallup, New

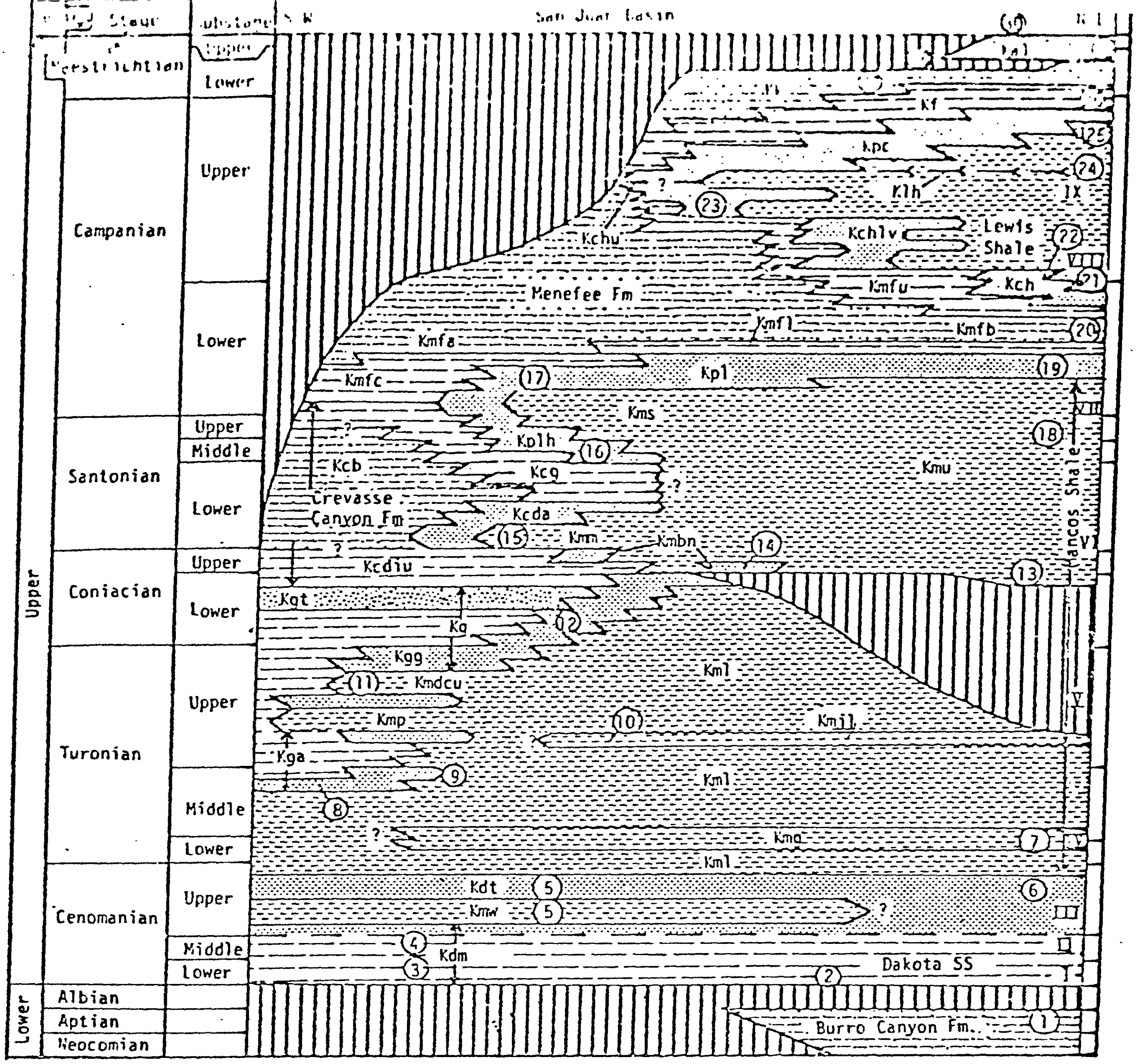


Figure 1. Correlation of Cretaceous rocks along the west side of the San Juan Basin with standard stages of the Cretaceous System. Numbers refer to notes in the Appendix. Roman numerals along right side indicate transition from transgressive to regressive parts of transgressive-regressive cycles described in the text. Not to scale. Units are: Dakota Sandstone: (Kdm) main body; (Kdt) Twowells Sandstone Tongue; Mancos Shale: (Kmw) Whitewater Arroyo Shale Tongue; (Kmg) Greenhorn Limestone Member; (Kmjl) Juana Lopez Member; (Kmp) Pescado Tongue; (Kmdcu) upper part of D-Cross Tongue; (Kmbn) basal Niobrara sandstones; (Kmm) Mulatto Tongue; (Kms) Satan Tongue; (Kml) lower part of Mancos Shale; (Kmu) upper part of Mancos Shale; Gallup Sandstone: (Kga) Atarque Member; (Kg) Gallup Sandstone of type area; (Kgg) Gallego Sandstone Member; (Kgt) Torrivio Sandstone Member of Molenaar (1973, p. 98); Crevasse Canyon Formation: (Kcdiu) Dilco Coal Member; (Kcda) Dalton Sandstone Member; (Kcb) Bartlett Barren Member; (Kcg) Gibson Coal Member; Point Lookout Sandstone: (Kpl) main body; (Kplh) Hosta Tongue; Menefee Formation: (Kmfc) Cleary Coal Member; (Kmfa) Allison Member; (Kmfl) lower coal member; (Kmfb) middle barren member; (Kmfu) upper coal member; Cliff House Sandstone: (Kch) main body; (Kchlv) La Ventana Tongue; (Kchu) upper part (Chacra Sandstone Member of Mesaverde Formation of Dane, 1936, p. 101); other units: (Kpc) Pictured Cliffs Sandstone; (Kf) Fruitland Formation; (Kk) Kirtland Formation; (Kal) lower or Cretaceous part of Animas Formation (includes McDermott Member and lower part of upper member); (Klh) Huerfanito Bentonite Bed of Lewis Shale.

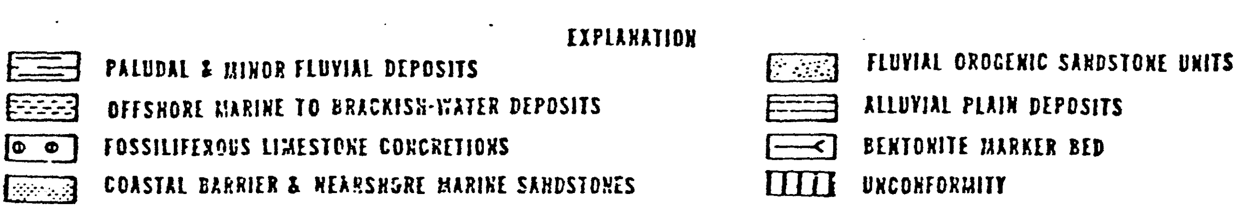


Figure 1.--Generalized geologic section of Cretaceous rocks of the San Juan Basin, New Mexico (from Peterson and Kirk, 1977).

(Note: Atarque Member should be Atarque Member of Molenaar)

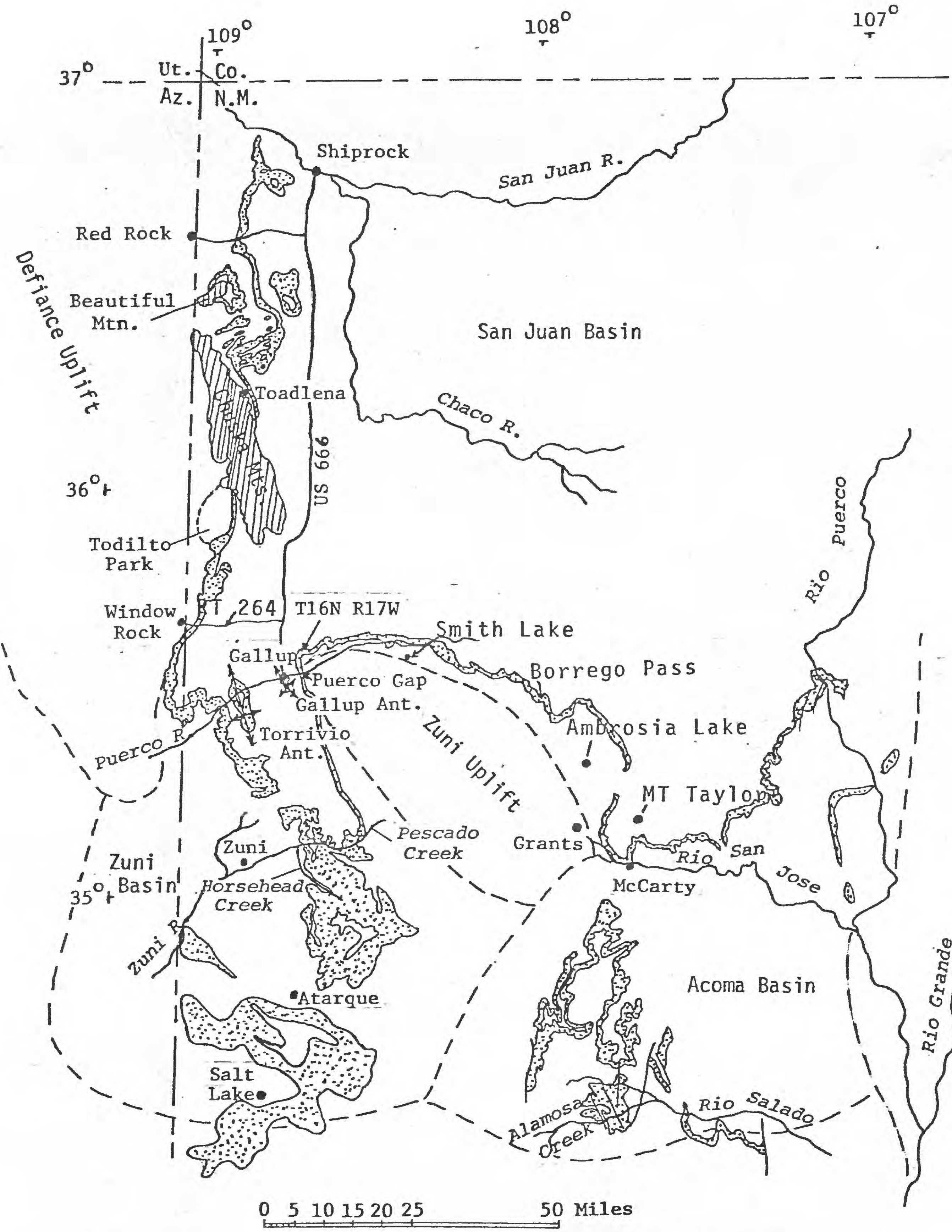
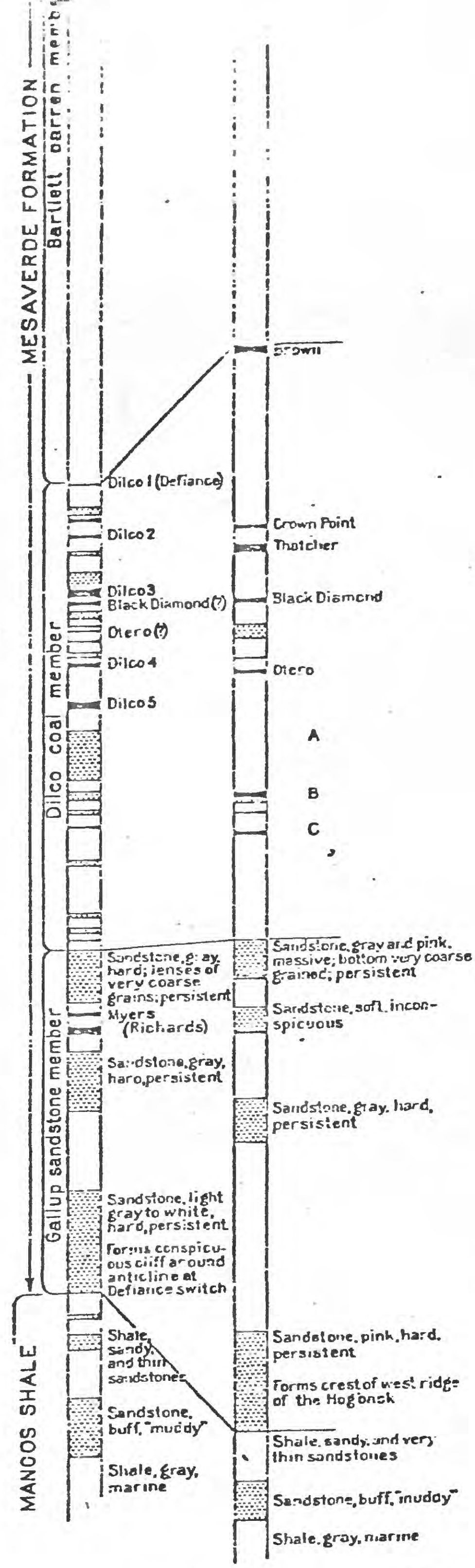


Figure 2.--Map showing approximate outcrop (stippled pattern) of the Gallup Sandstone and the Gallup-Zuni, Acoma, and San Juan Basins (modified from Dane, Bachman, and Reeside, 1957; and Molenaar, 1973).

Mexico. Although no type section was designated, his description of the Gallup is as follows:

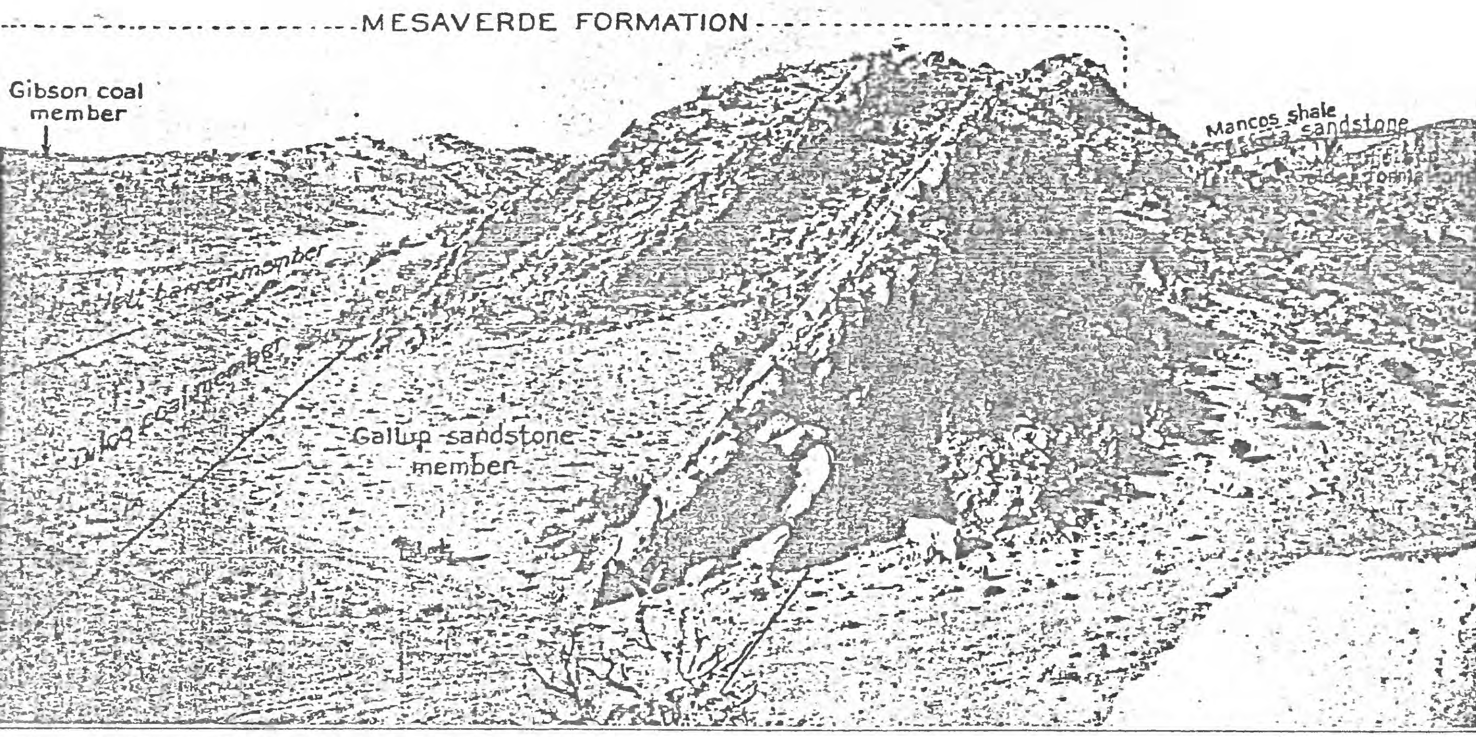
> "Lying conformably upon the Mancos shale is the Gallup sandstone member, 180 to 250 feet thick, comprising three massive sandstone and interbedded shale and coal. The member is named from the town of Gallup, part of which is built upon its uppermost bed of sandstone. The general character of the member is persistent throughout the basin. Along the Hogback (see Pl. V) the upper and lower sandstones are pink and the middle sandstone is light gray; the lower sandstone forms the crest of the west ridge. Only the upper sandstone is exposed in the anticline at Gallup, where it is commonly known as 'the pink sandstone.' The member is well exposed in the Torrivio anticline (see Pl. XII, A), at Defiance Switch; the lower sandstone is the most resistant and makes prominent abrupt cliffs above the shale on both sides of the river. At this place all three sandstones are light-gray to white, but farther south and in the exposure on the west side of the basin the upper bed is at places pink or even brick-red. Lenses of very coarse grains were noted at several localities in the upper sandstone.
>
> "The absence of pink color in the member near Defiance Switch has led to confusion in the correlation, and several workers have regarded the coal beds at the Richards mine as part of the 'lower coal measures' or Dilco coal member. However, detailed study shows beyond doubt that the Myers (Richards) coal beds are equivalent to thin coals lying below the 'pink sandstone' at Gallup and in the Hogback. The relations are well shown in the columnar sections of the east and west sides of the district. (See Pl. I, in pocket)." (Sears, 1925, p. 17.)

This description is graphically supplemented by two idealized columnar sections (Sears, 1925, Pl. 1) from the east and west sides of the Gallup-Zuni Basin (fig. 3), and by a photograph taken by Darton in 1901 (Sears, 1925, Pl. V) (fig. 4) of the gap in the Nutria Monocline about 4 km northeast of Gallup, New Mexico. Sears annotated the upper and lower contacts of the Gallup Sandstone Member on the photograph, excluding a lower sandstone bed poorly exposed in



COLUMNAR SECTIONS SHOWING RELATIONS OF COAL BEDS IN THE GALLUP COAL DISTRICT, NEW MEXICO

Figure 3.--Generalized geologic sections from the east and west sides of the Gallup-Zuni Basin showing correlations in the Gallup Sandstone Member of the Mesaverde Formation (from, Sears, 1925, Pl. 1).



WEST RIDGE OF THE NUTRIA MONOCLINE (THE HOGBACK), SHOWING GALLUP SANDSTONE MEMBER OF MESAVERDE FORMATION AND ASSOCIATED BEDS, 2½ MILES NORTHEAST OF GALLUP, N. MEX.

Photograph by N. H. Darton

Figure 4.--Sears' annotation of the contacts of the Gallup Sandstone Member, Mesaverde Formation, on a photo taken by Darton in 1901 (Sears, 1925, Pl. V).

the talus slope to the east and two lower sandstone beds exposed south of the photographed outcrop. These lower sandstones were described and measured by Dane, Bachman and Reeside (1957, p. 105) and by Molenaar (1973, p. 96).

Sears--1934

The Gallup Sandstone Member was traced eastward from the type area by Sears in 1934. It is in the area immediately to the east of the Nutria Monocline (in T. 16 N., R. 17 W., NMPM) that the relationship of the various parts of the Gallup become most complicated.

The right-hand side of figure 5 is taken from Sears' (1934, p. 15-16) written description of the Gallup Sandstone Member in T. 16 N., R. 17 W., NMPM. The left-hand side of figure 5 shows Sears' Gallup Sandstone Member as defined in 1925. Beaumont (1957, p. 119) noted that both the light-gray and pink upper sandstones are coarse grained in the vicinity of Darton's photograph.

Hunt--1936

In 1936 Hunt extended Sears' correlation of the Gallup Sandstone Member eastward into the Mount Taylor area. He maintained that the sandstone bed mapped as Gallup in that area "* * * is equivalent to the upper and middle sandstones of the type locality" (Hunt, 1936, p. 46) (fig. 6). This correlation represents a misinterpretation of the distribution of the coarse-grained fluvial upper sandstone.

Sears, Hunt, and Hendricks--1941

In 1941 Sears, Hunt, and Hendricks reported upon lateral changes in the Gallup Sandstone Member in their classical paper on

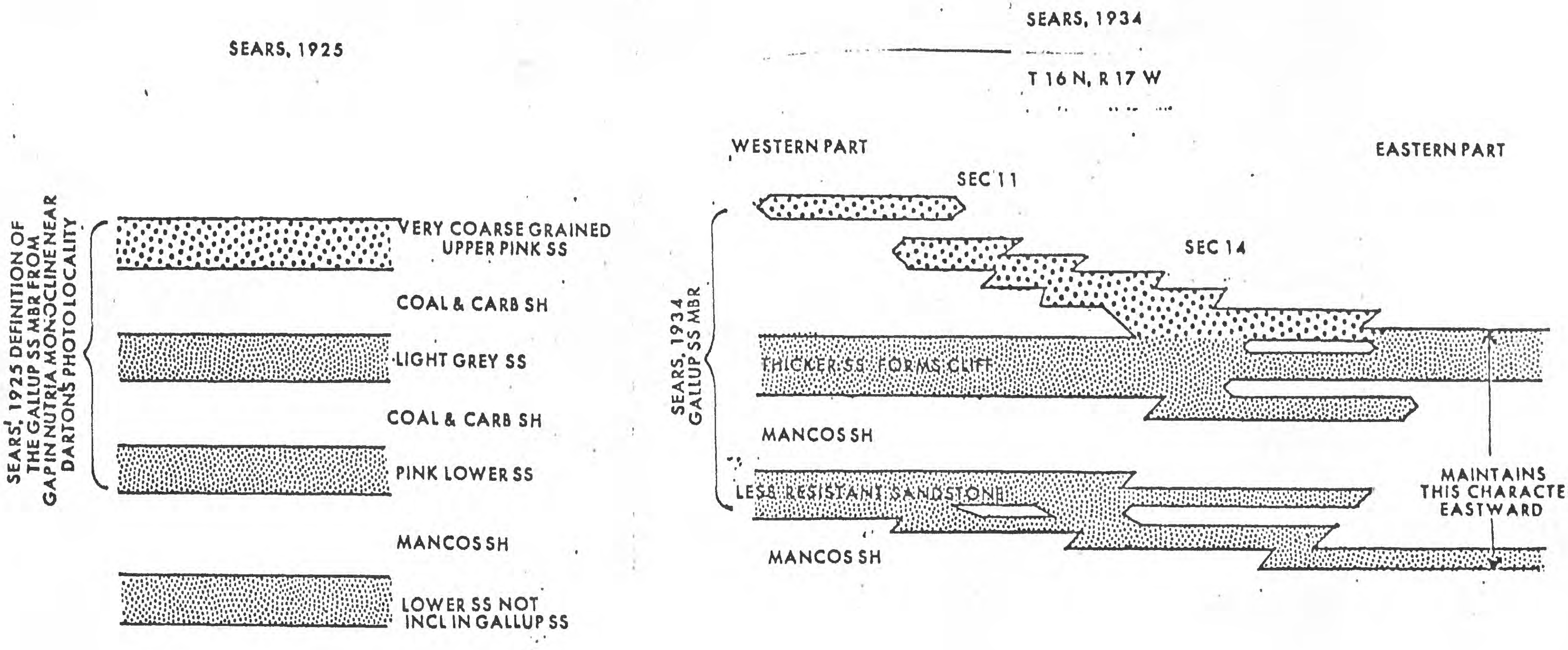


Figure 5.--Sketches prepared from Sears' (1925 and 1934) description of the Gallup Sandstone Member, showing the correlation of beds between the section on the Nutria Monocline at the gap north of the Rio Puerco with those of T. 16 N., R. 17 W., NMPM.

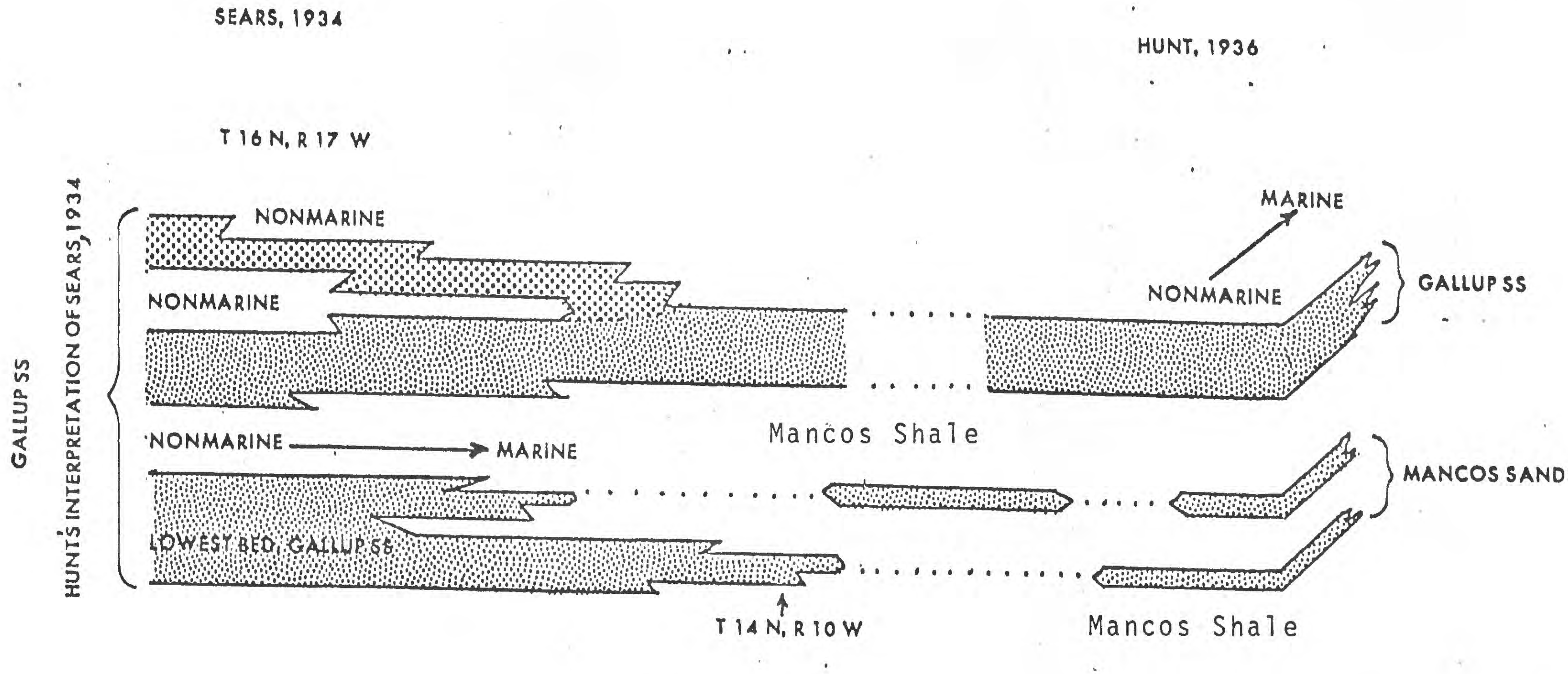


Figure 6.--Sketches prepared from Hunt's (1936) description of the Gallup Sandstone Member in the Mount Taylor area, showing his correlation with the section described by Sears (1934) from T. 16 N., R. 17 W., NMPM.

transgressive and regressive deposits of the Cretaceous of the San Juan Basin. Darton's photograph, annotated by Sears, is reproduced (Sears and others, 1941, Pl. 27B) as a representative section of the Gallup Sandstone Member on the Nutria Monocline, and the various beds are shown on a fence diagram eastward from the Nutria Monocline via the Mount Taylor area to the Rio Puerco (of the east) and northward into the Cabezon and Bernalillo areas (Sears and others, 1941, Pl. 26) (fig. 7). The "lower Gallup Sandstones," although discussed with the main body of the Mancos Shale in their paper (Sears and others, 1941, p. 109-110), are correlated with the Gallup Sandstone Member on their fence diagram. Their interpretation of the relationship between parts of the Gallup Sandstone Member remains essentially unchanged from that presented by Sears (1934) and by Hunt (1936).

Pike--1947

In 1947 Pike extended the Gallup Sandstone Member correlation along the western margin of the San Juan Basin southward from the San Juan River into the Gallup-Zuni Basin and from the south-central part of the San Juan Basin at McCarty, New Mexico, southward into the Alamosa Creek area of the Acoma Basin.

Pike (1947, p. 28-29) described the Gallup Sandstone Member at the San Juan River in the northwestern part of the San Juan Basin as consisting of a 3.6-m-thick coarse-grained quartzose sandstone that in a short distance southward changes character to an even-bedded marine sandstone (Gallup Sandstone Member, Pike's designation). It is overlain by an interval of thin irregular sandstones, shales, carbonaceous shales, and thin coals (Dilco Coal Member) and a coarse-

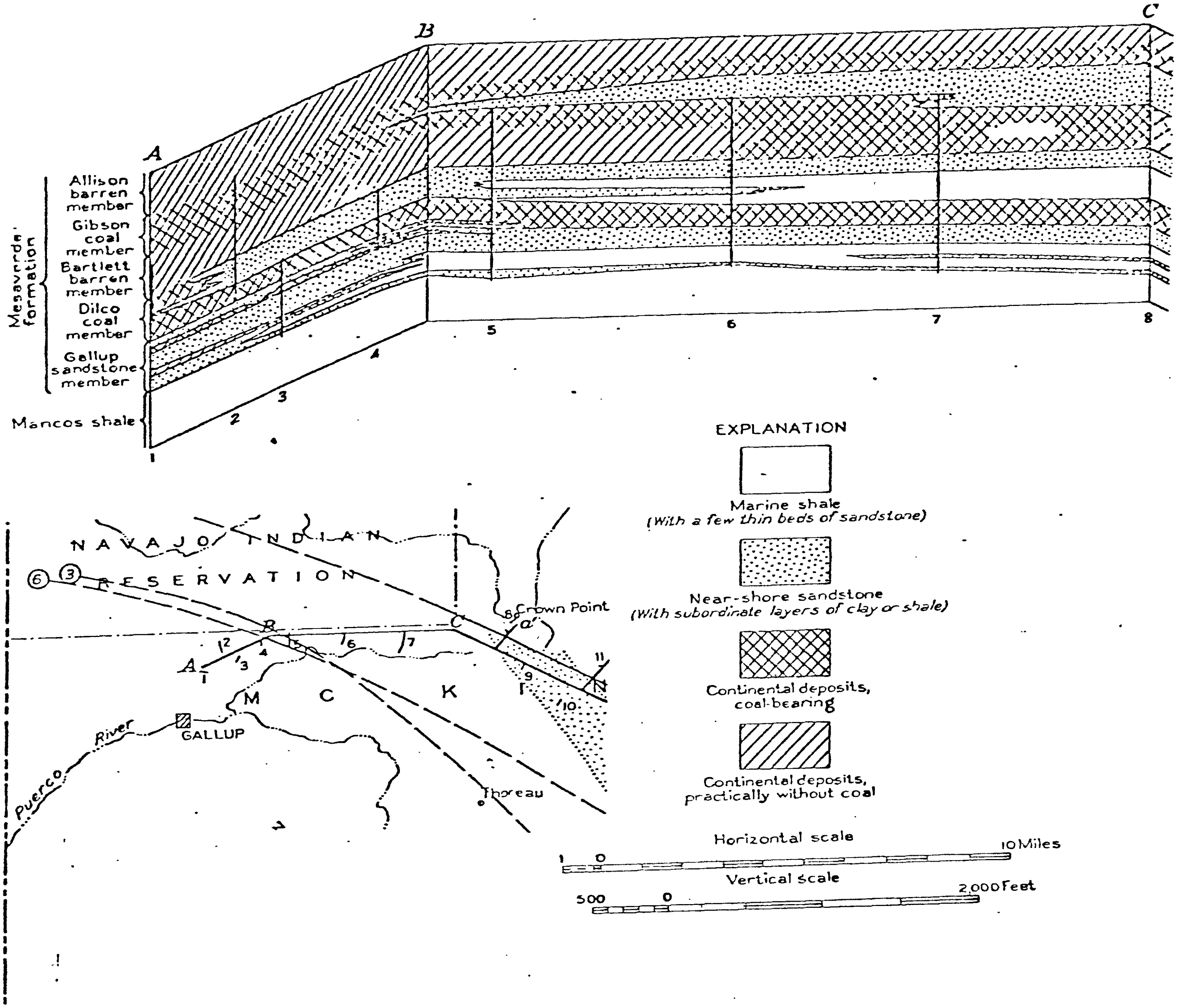


Figure 7.--Correlation of the Gallup Sandstone Member and adjacent units in the southwestern part of the San Juan Basin (Sears, Hunt, and Hendricks, 1941, Pl. 26).

grained highly crossbedded sandstone ("stray" sandstone of Sears and others, 1941) (fig. 8). All of these beds previously constituted the Tocito Sandstone Lentil of the Mancos Shale of Reeside (1924, p. 8). Pike suggested that the name "Tocito" be dropped (1947, p. 29).

In discussing the area from the Chuska Mountains to the southern border of the Navajo Reservation, Pike (1947, p. 30-33) described the Gallup Sandstone Member as a lower 30-m thick massive sandstone overlain by a 15-m-thick, coarse-grained, thin, slabby quartzose sandstone zone that is highly crossbedded. This coarse-grained sandstone, where present, was considered by him to be the top of the Gallup Sandstone Member. It is overlain by the Dilco Coal Member (Pike, 1947, p. 34).

South from the Navajo Reservation into the Gallup-Zuni Basin, Pike (1947, p. 33-36) described and defined the units from top to bottom: the Pescado Tongue of the Mancos Shale; a lower part of the Gallup Sandstone Member of the Mesaverde Formation, which underlies the Pescado Tongue and consists of Mesaverde type rocks coming into the section from the south; the Horsehead Tongue of the Mancos Shale; and the Atarque Member of the Mesaverde (consisting of nonmarine deposits including sandstone, shale, carbonaceous shale, and thin coal seams) (fig. 9). The Atarque Member is the lowest stratigraphic member of the Mesaverde in this area. (Note: From figure 9, Pike clearly includes lower marine sands in the Atarque Member.)

Pike (1947, p. 62-71) also extended the San Juan Basin nomenclature and stratigraphy into the McCarty-Alamosa Creek area (Acoma Basin). His stratigraphic section in the area (fig. 10) may

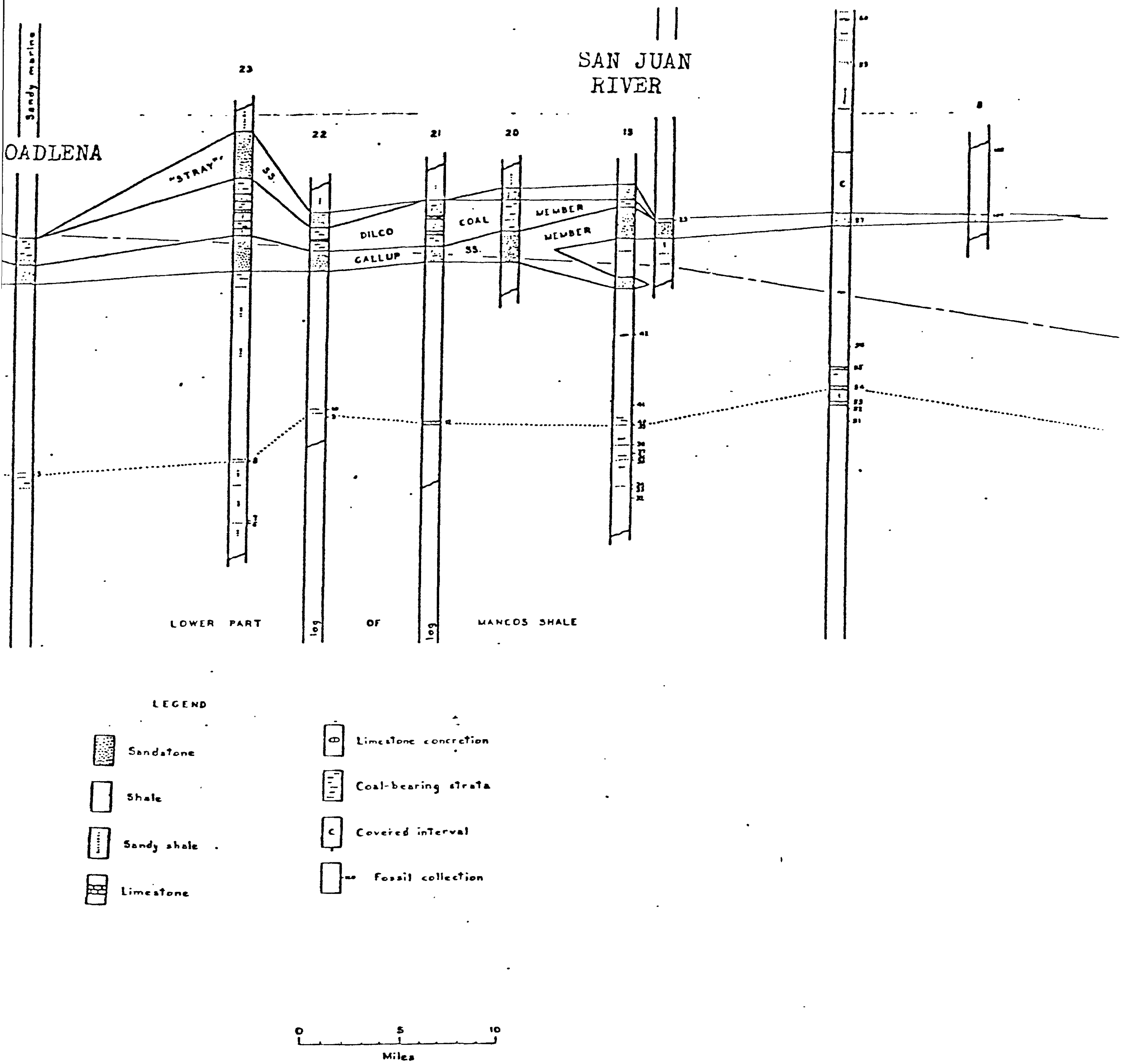


Figure 8.--Pike's (1947) correlation of the Gallup Sandstone Member and adjacent units north of the Chuska Mountains on the west side of the San Juan Basin (Pike, 1947, Pl. 11).

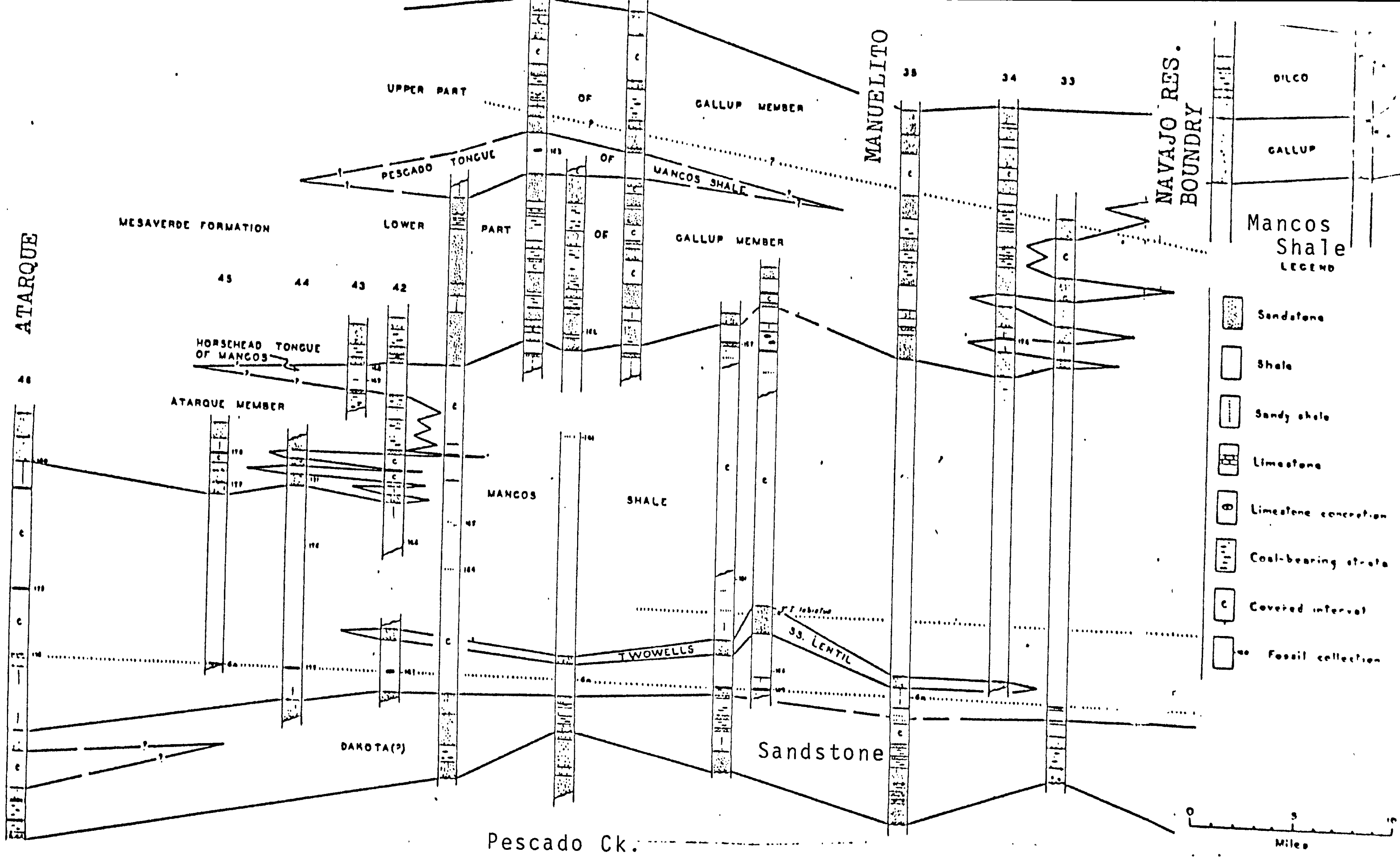


Figure 9.--Pike's (1947) correlation of the Gallup Sandstone Member and adjacent units from the Chuska Mountains southward to Atarque, N. Mex., southwestern San Juan Basin and Gallup-Zuni Basin (Pike 1947, Pl. 11).

be summarized as consisting of a lower part of the Gallup Member composed of sandstone, shale, and carbonaceous shale; the Pescado Tongue of the Mancos Shale; an upper part of the Gallup Sandstone (equivalent to the Gallego Sandstone Member of the Miguel Formation of Winchester, 1920); and an overlying Dilco-lower Gibson undivided (of the Crevasse Canyon Formation).

Allen and Balk--1954

In 1954 Allen and Balk examined the geology of the Fort Defiance and Tohatchi quadrangles in the southwestern San Juan Basin. They described the Gallup interval east of Todilto Park as consisting of two massive cliff-forming sandstones each of which are 25 m in thickness separated by 4.3 m of interbedded gray carbonaceous shale and a 15-cm coal seam. The upper sandstone is homogeneously colored and the lower is banded gray and orange. They are both described as containing poorly sorted fine-grained to coarse-grained sandstone (75-90 percent) with clay and minor feldspar. Northward these sandstones split and interfinger with thin units of medium-grained poorly sorted sandstone; variegated red, gray, chocolate brown, and black siltstone; silty shale; and thin coals. The entire interval thins to 30 m. Southward the Gallup divides into three and then four sandstone beds near the southern boundary of the Navajo Reservation with the next to lowest being 30 m thick and the others ranging from 7.5 to 12 m with interbedded thin sandstone, siltstone, shale and thin coal seams bringing the total thickness to about 90 m (Allen and Balk, 1954, Pl. 11).

Allen and Balk (1954, p. 88) recommended raising the Mesaverde

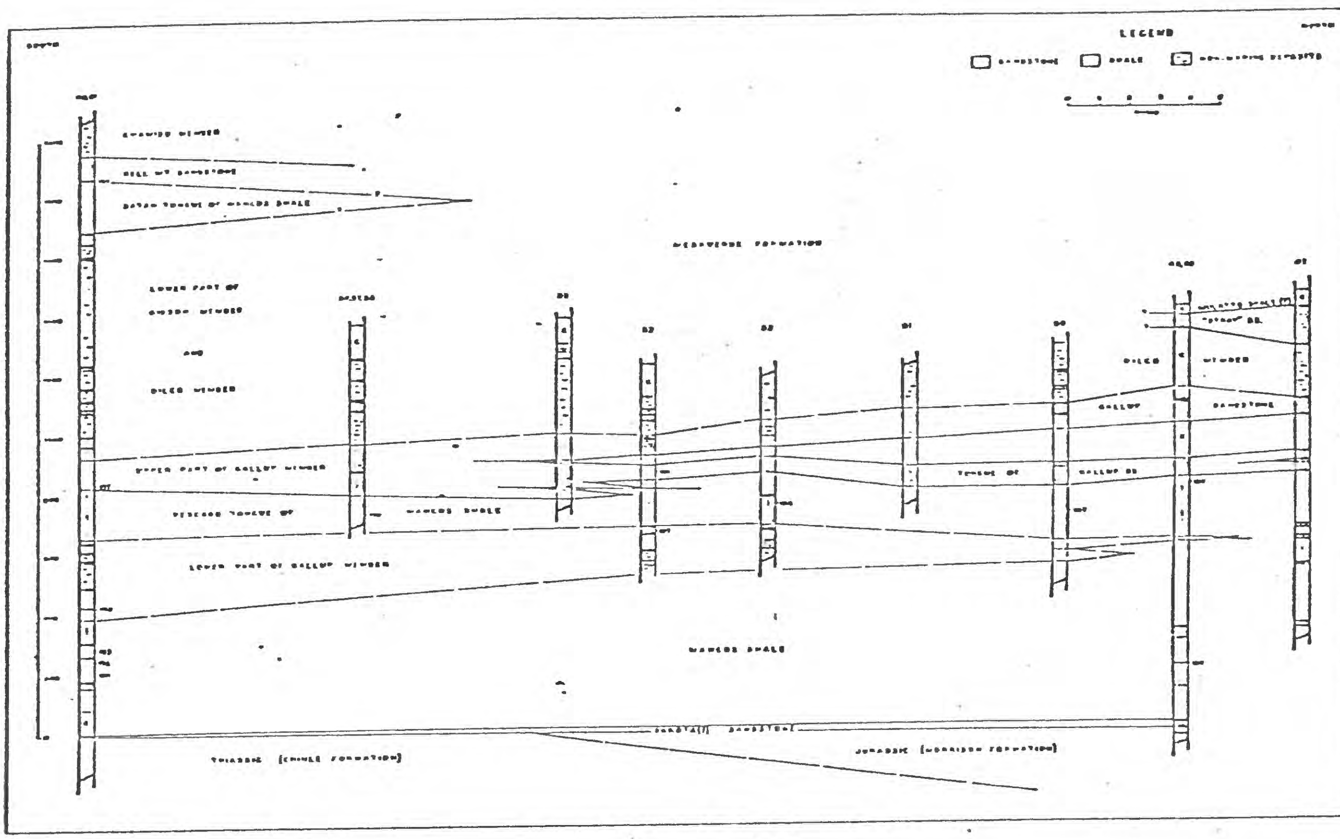


Figure 10.--Correlation of the Gallup Sandstone Member and associated formations from the McCarty-Alamosa Creek area, New Mexico (Pike, 1947, Fig. 6, p. 68).

from formation to group status and the Gallup Sandstone Member to formation status. In addition they recommended that the overlying Dilco Coal Member be considered a member of a new formation, which they named the Crevasse Canyon Formation. These changes were supported by Beaumont, Dane, and Sears (1956) in their revised nomenclature of the Mesaverde Group. Neither paper comments on the status to be given the "lower part of the Gallup Member," the Atarque Member, or the Pescado Tongue of the Mancos Shale, described by Pike (1947) from the Gallup-Zuni Basin or the Alamosa Creek area. This revised nomenclature has remained essentially unchanged since 1956.

Beaumont--1957

In 1957 Beaumont reexamined the character of, and lateral changes in, the Gallup Sandstone along the western side of the San Juan Basin. At the Torrivio Anticline, Beaumont (1957, p. 116) described the Gallup Sandstone as consisting of a lower cliff-forming, light-brown-weathering, fine-grained to medium-grained sandstone which is overlain by four poorly sorted, fine-grained to very coarse-grained sandstone and granule conglomerate beds separated by carbonaceous shale, claystone, coals, and minor amounts of sandstone. From there the Gallup Sandstone thickens northward to the vicinity of Window Rock and then thins northward to a pinch-out near the San Juan River. Near Todilto Park, according to Beaumont (1957, p. 116), the basal sandstone unit of the Gallup merges with a higher sandstone to form a massive 30-m sequence. (Note: Actually the two continue to be separable, see Beaumont, 1957, fig. 2, and Pike, 1947, Pl. 11, measured section #27.) The upper sandstone loses thickness northward by intertonguing with the overlying Dilco Coal Member, resulting in a 15-m slabby sandstone zone at the top of the Gallup Sandstone. From Sanostee north, Beaumont described (1957, p. 118) a three-part division of the Gallup similar to that of Pike (1947), a lower fine-grained massive sandstone separated from a coarse-grained slabby sandstone by a unit containing carbonaceous shale and coal. This entire interval is considered Gallup by Beaumont (1957). Near the Rattlesnake Oil Field, the lower Gallup Sandstone pinches out into marine shale, and north of the San Juan River the upper coarse grained sandstone thins rapidly to a 1.5- to 3-m-thick coarse-grained sandstone(fig. 11).

Dane, Wanek, and Reeside--1957

In 1957 Dane, Wanek, and Reeside reproduced eight sections in the McCarty-Alamosa Creek area, pointing out some miscorrelations made by Pike (1947) and realigning some of his earlier sections duplicated by faulting. In addition, they recommended abandonment of some names proposed by Winchester based on correlations of these units with their equivalents in the San Juan Basin. However, they proposed retention of the name Gallego Sandstone as the upper sandstone of the Gallup Sandstone, and they proposed the name D-Cross Tongue for an upper tongue of the Mancos Shale (below the Gallego Sandstone), believing this tongue to be younger than the Pescado Tongue of the Mancos. The remainder of the correlations in the Gallup interval may be seen on figure 12.

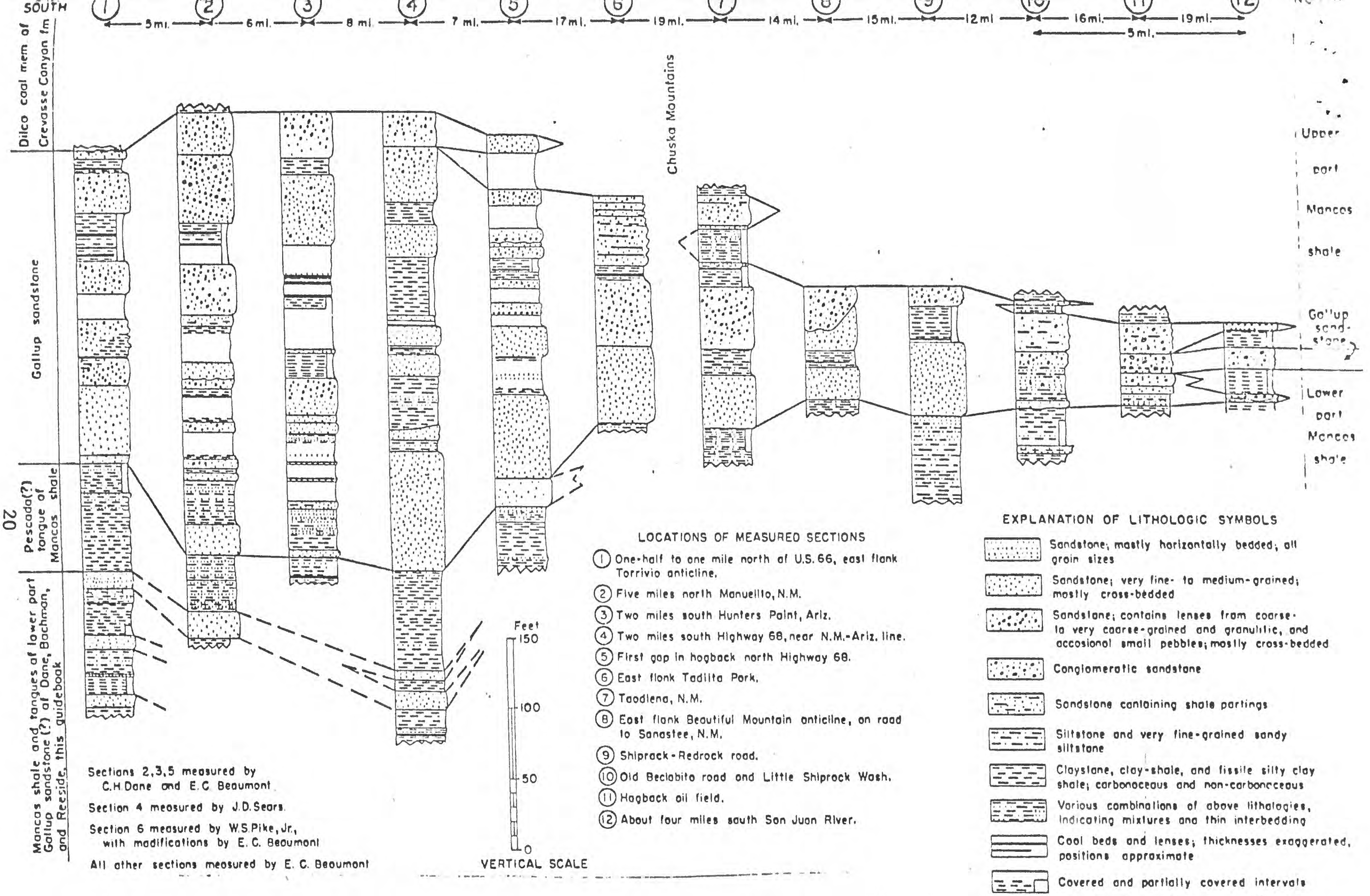


Figure 11.--Stratigraphic sections of the Gallup Sandstone and associated rocks between U.S. Highway 66 and the San Juan River, New Mexico and Arizona from Beaumont, 1957, Fig. 2, p. 117).

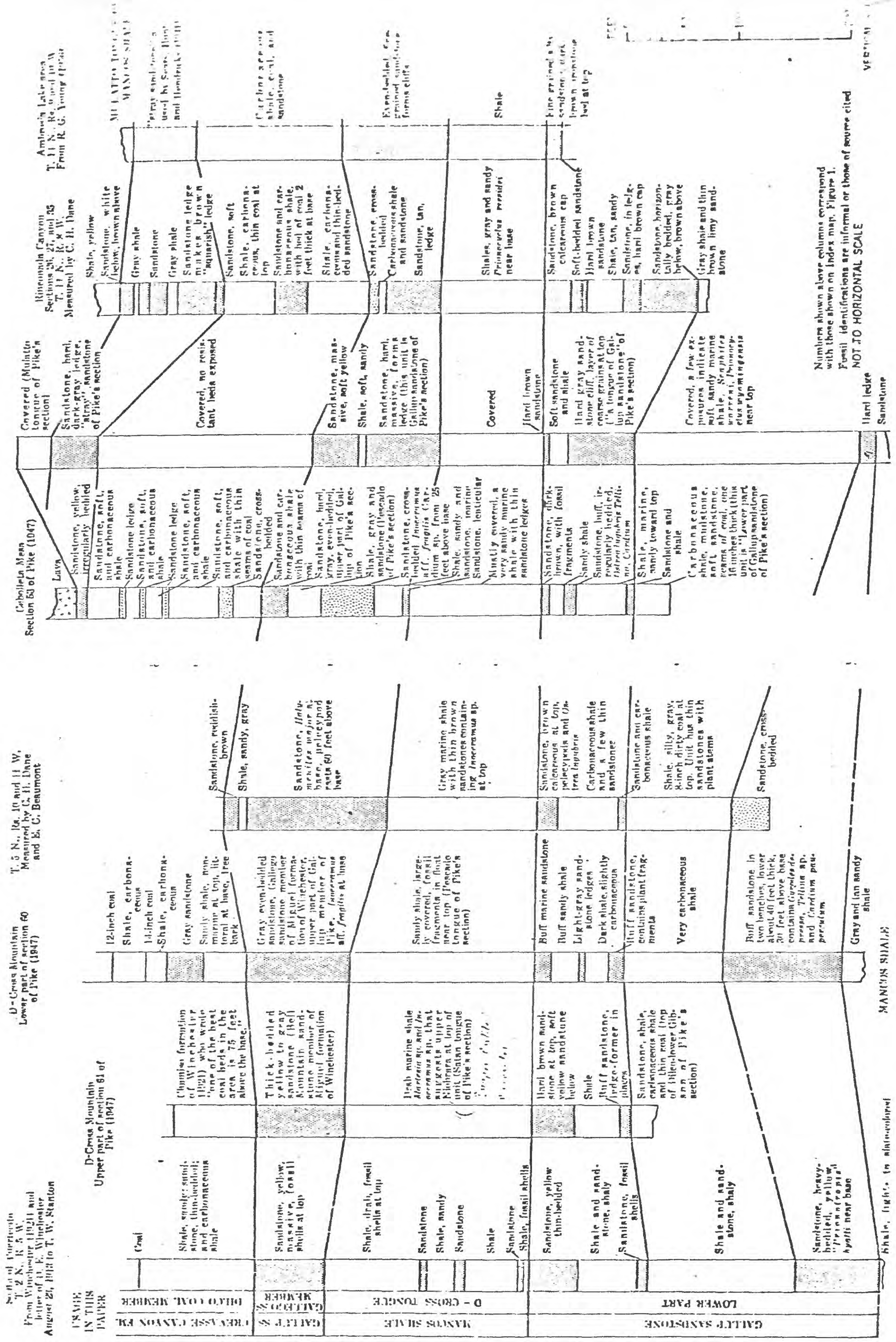


Figure 12.--Correlation of the Gallup Sandstone and associated formations in the McCarty-Alamosa Creek area, New Mexico (portion of diagram from Dane, Wanek, and Reeside, 1957, Fig. 2, p. 188-189)

Dane, Bachman, and Reeside--1957

In 1957 Dane, Bachman, and Reeside presented a detailed correlation of the Gallup Sandstone from Pescado Creek to its type area and from there eastward to the Ambrosia Lake area (Dane, Bachman, and Reeside, 1957) (fig. 13). They also measured a section at the Puerco gap east of Gallup, N. Mex. (Dane and others, 1957, p. 99-101) (see fig. 14), which we consider to be the first detailed description of the Gallup Sandstone in the type area.

Thaden--1967

Geologic mapping in the Ambrosia Lake area led geologists to divide the Gallup Sandstone into an upper main body and two lower tongues, B and A. (See for example: Thaden and others, 1967.) These lower tongues of the Gallup were considered sandstones in the Mancos Shale by Hunt (1936) and were later correlated by Sears, Hunt, and Hendricks (1941) with tongues of what they considered the lowest sandstone of the Gallup in T. 16 N., R. 17 W., NMPM, east of the Nutria Monocline.

O'Sullivan and others--1972

Much of this earlier work is very well summarized in a paper by O'Sullivan and others (1972, p. 25-31), describing the Cretaceous and Tertiary rocks of the Navajo and Hopi Reservations. Darton's photograph is again reproduced as annotated by Sears (O'Sullivan and others, 1972, fig. 12), and in the caption it is stated that the shales above the basal Gallup Sandstone (in the photo) grade into marine shale to the north and east. Their only other recommended revision to earlier work was that Pike's (1947) original designation

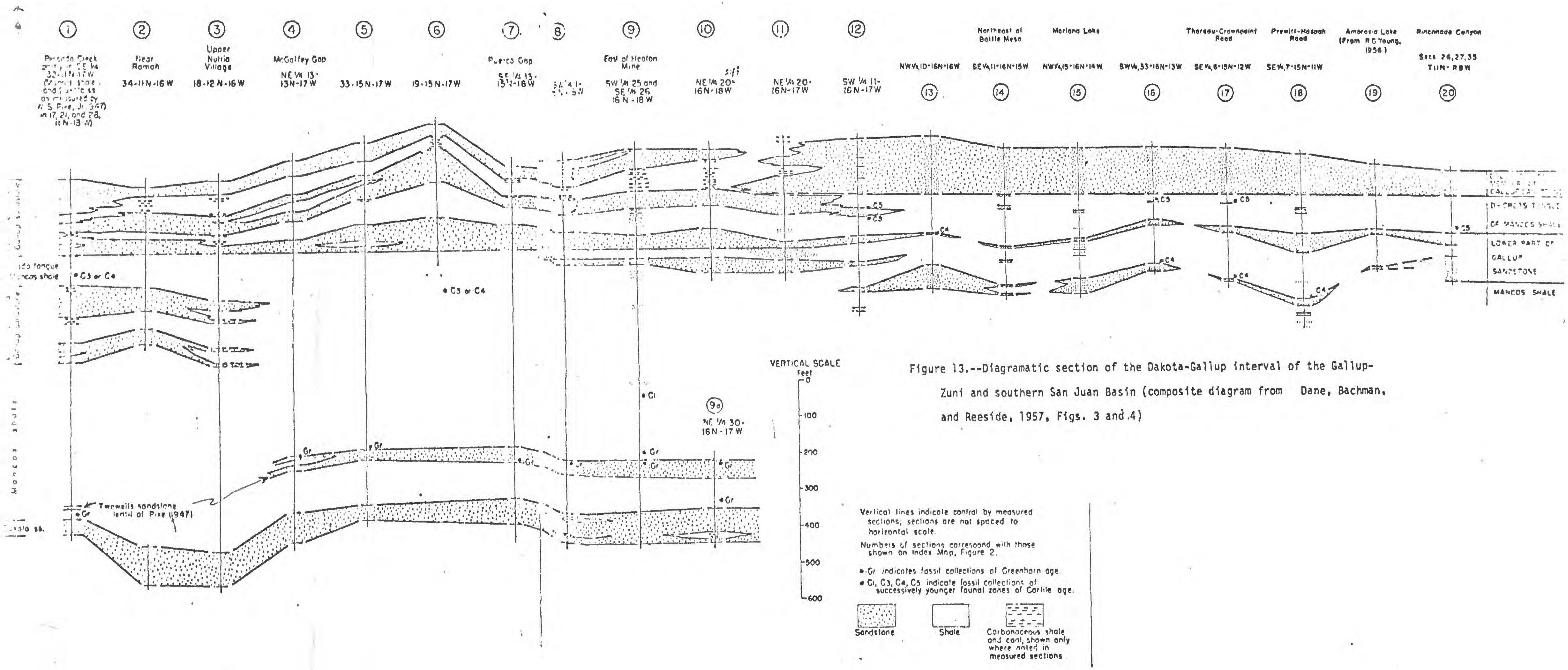
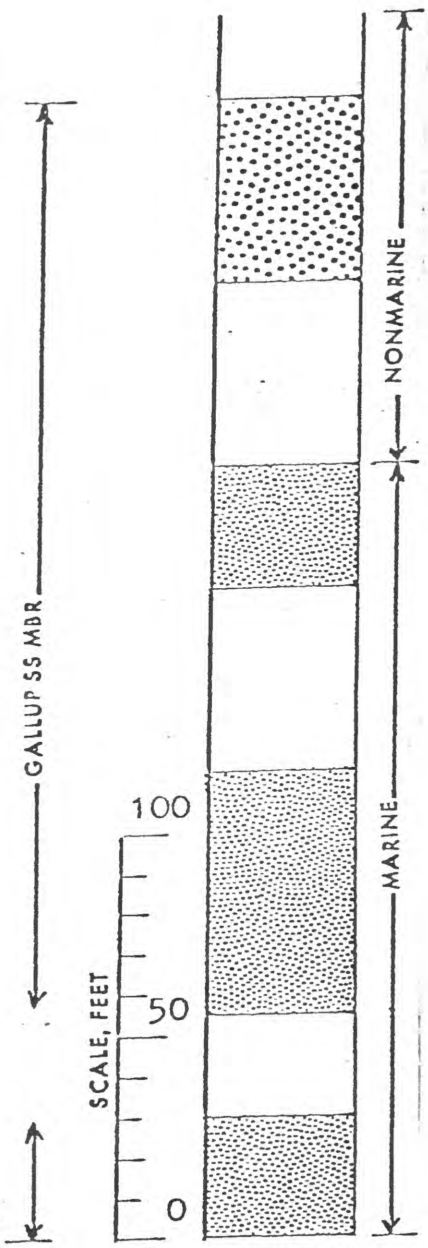


Figure 13.--Diagramatic section of the Dakota-Gallup interval of the Gallup-Zuni and southern San Juan Basin (composite diagram from Dane, Bachman, and Reeside, 1957, Figs. 3 and 4)



DILCO COAL MEMBER, CREVASSE CANYON FORMATION

GALLUP SANDSTONE

Pink coarse grained arkosic sandstone

Carbonaceous soft shale, soft irregular bedded sandstone, one or more coals, wood stems and fragments

Gray to white, fine-to medium-grained, cross-bedded sandstone

Siltstone, shale, thin-bedded soft sandstone, gray or tan, rippled and burrowed; spheriodal brown carbonate concretions; some carbonaceous shale in the upper part

Pink or buff, fine-to medium-grained, thick-bedded, partly crossbedded sandstone; upper part rippled

MANCOS SHALE

Fine grained sandstone, appears 3 miles north of the Puerco Gap section

Figure 14.--Sketch of the Gallup Sandstone prepared from described section at the Puerco Gap, east of Gallup by Dane, Bachman, and Reeside (1957, p. 99-101).

of the three-fold division of rocks in the Gallup interval north of the Chuska Mountains be reinstated (i.e. Gallup Sandstone, Dilco Coal Member, and "stray" sandstone of Sears and others, 1941).

Molenaar--1973 and 1974

Two papers by Molenaar (1973, 1974) represent truly monumental pieces of work showing the various facies relationships of the Gallup Sandstone through correlation diagrams compiled from measured sections and drill-hole logs across the southern and western margins of the San Juan Basin, including the Gallup-Zuni Basin and the Alamosa Creek area (Acoma Basin). Two of his correlation diagrams are reproduced below (figs. 15 and 16).

Molenaar described the Gallup Sandstone as consisting of "* * * a series of northeastward prograding coastal barrier or delta front sandstones that grade seaward into more offshore marine mudstones of the Mancos Shale and intertongue landward with nonmarine coastal plain deposits consisting of paludal mudstones, fluvial channel sandstones and minor coal beds" (Molenaar, 1973, p. 86).

In the Gallup-Zuni Basin, Molenaar examined several of Pike's (1947) earlier correlations. He noted Pike's "lower part of the Gallup Sandstone," which lies below the Pescado Tongue of the Mancos Shale and had been assigned by Pike to the Mesaverde. Farther south Pike described the Horsehead Tongue of the Mancos Shale with Mesaverde-type rocks below it, which he called the Atarque Member of the Mesaverde. Molenaar (1973, p. 94) concluded that the Horsehead Tongue of the Mancos Shale was misidentified by Pike and was probably either some nonmarine beds of the Atarque Member or was the Pescado

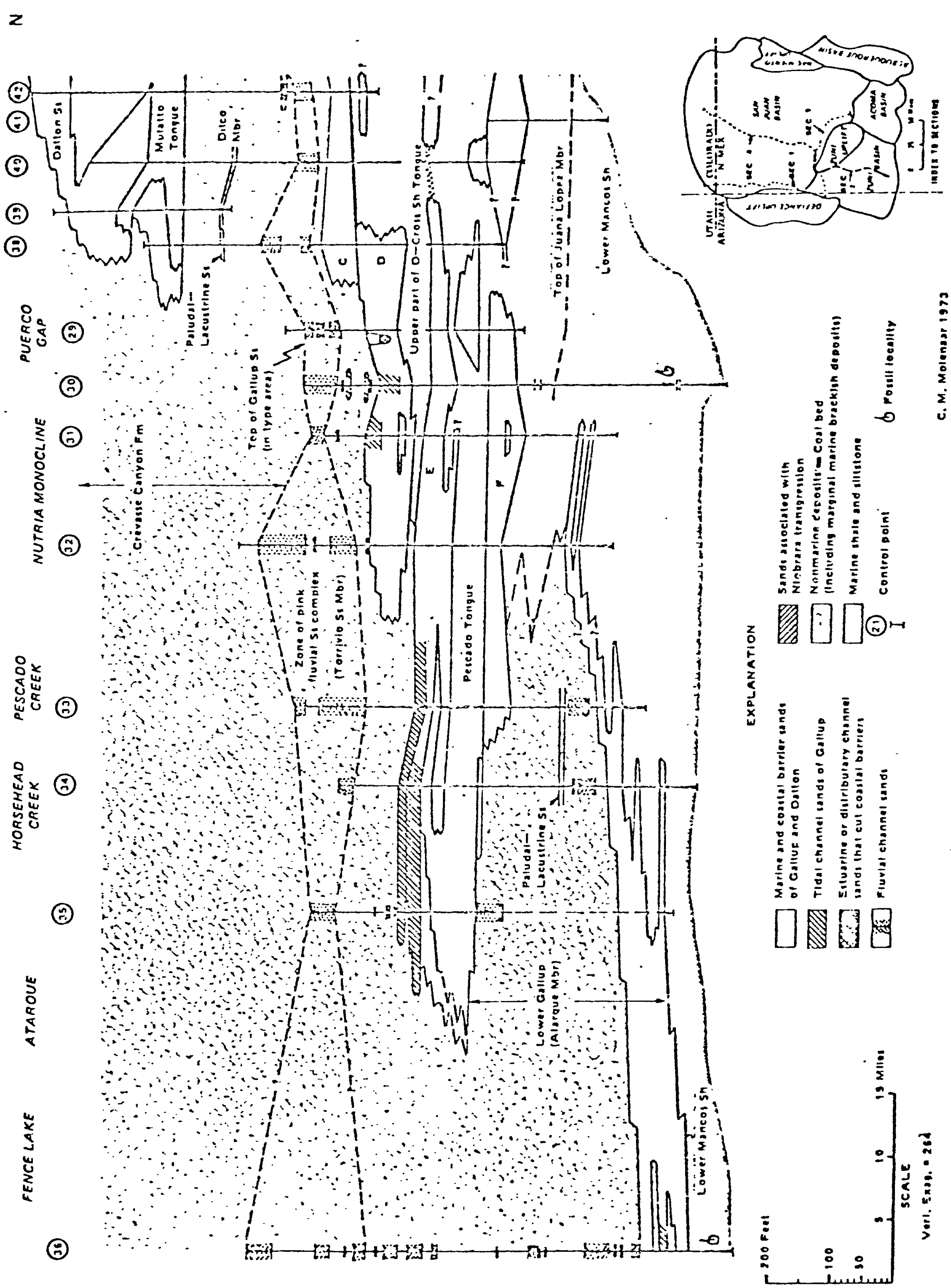


Figure 15.--Cross section of Gallup Sandstone and associated units Gallup-Zuni Basin to San Juan Basin. From Molenaar (1973, p. 95, Figure 9).

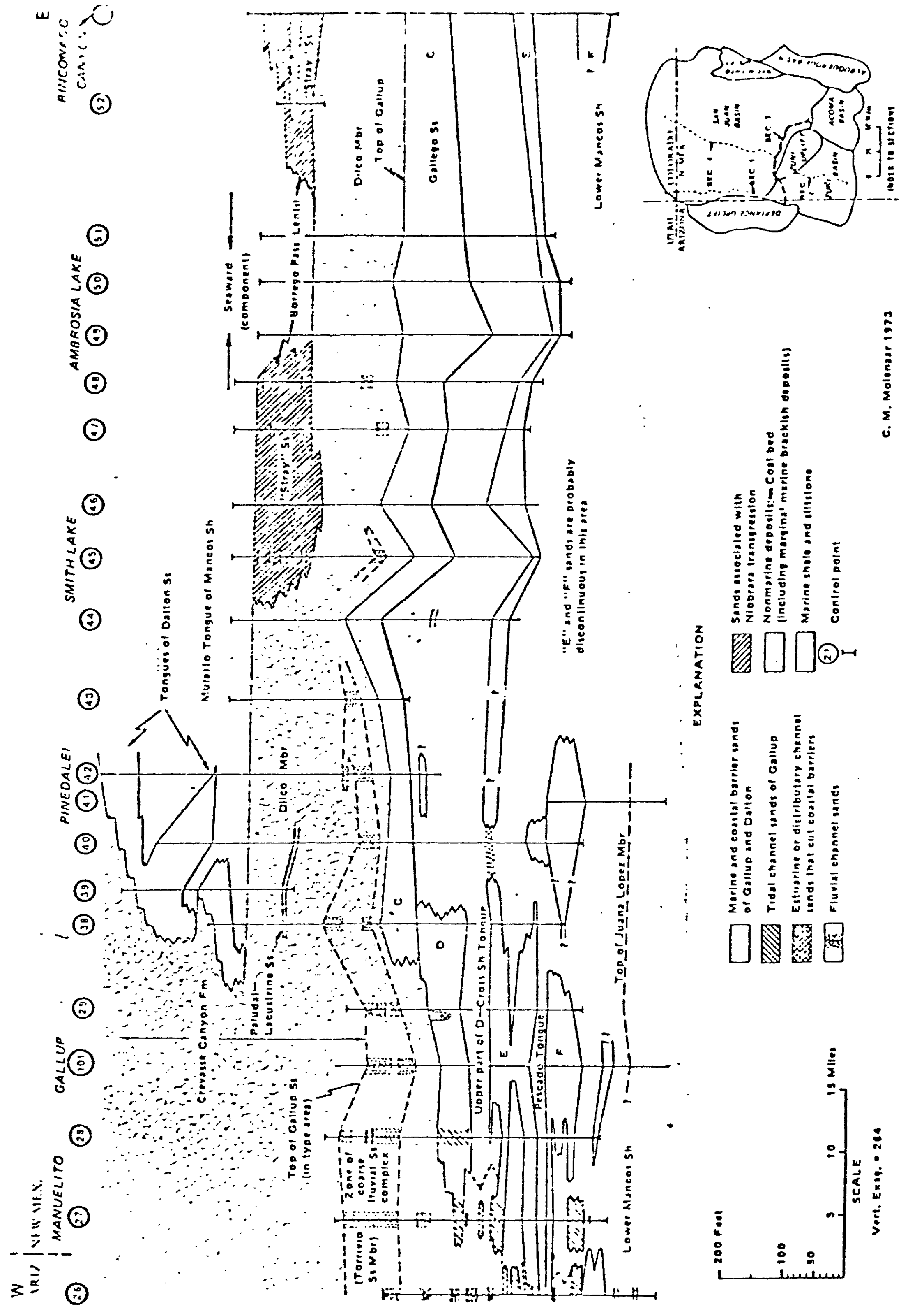


Figure 16.--Cross section of the Gallup Sandstone and associated units, southern San Juan Basin. From Molenaar (1973, p. 97, Fig. 10).

Tongue of the Mancos Shale. (No measured section of Pike includes both the Pescado and Horsehead Tongues.) Because of this Molenaar recommended dropping the name Horsehead Tongue and calling the lower part of the Mesaverde in this area the "Atarque Member of the Gallup Sandstone" (Molenaar, 1973, fig. 9, p. 95). As described, the Atarque Member would include a lower regressive coastal-barrier sandstone sequence and 30 to 60 m of carbonaceous mudstones, minor thin coals, and a few fluvial sandstones; locally it would be capped by another marine sandstone unit (Molenaar's F sandstone, Molenaar, 1974) (figs. 15 and 16). The nonmarine deposits locally grade seaward into offshore-marine deposits without an intervening coastal barrier sandstone (fig. 16).

East of Gallup, on the Nutria Monocline, Molenaar showed that his F sandstone lies below the type Gallup as described by Sears (1925) and that it is separated from it by 6 m of Pescado Tongue of the Mancos Shale (Molenaar, 1973, p. 96). The F sandstone pinches out about 7 km to the northeast of the Puerco Gap. Farther east it again crops out as a series of discontinuous lenses (offshore bars, Molenaar, 1973, p. 96) and was called the lowest part, unit A, of the Gallup Sandstone by Thaden, Santos, and Raup (1967) in the Grants Quadrangle. These lower tongues of Gallup Sandstones do not extend far to the northeast in the subsurface (Molenaar, 1973, fig. 11, p. 99).

Pike (1947, p. 70) correlated the Pescado Tongue of the Mancos Shale with the D-Cross Tongue of the Mancos Shale in the Alamosa Creek area. Dane, Wanek, and Reeside (1957, p. 195), believing the

Pescado Tongue to be older, separated it from the D-Cross Tongue of the Mancos Shale. Molenaar (1973, p 96) correlated the Pescado Tongue of the Mancos Shale with the lower half of the D-Cross Tongue, but would apply the name Pescado Tongue only where the D-Cross Tongue is divided by the E sandstone. Thus the name D-Cross Tongue would be retained where the E sandstone was absent and for the tongue of the Mancos lying above the E sandstone (figs. 15 and 16). In the area to the southwest of Gallup, N. Mex., as well as the area east of Window Rock, Ariz., he showed that the upper part of the D-Cross Tongue grades laterally into nonmarine rocks with no intervening coastal-barrier sandstone (figs. 16 and 17).

Molenaar (1973, p. 96) stated that along the Nutria Monocline east of Gallup the E sandstone splits at the Puerco gap but recombines to the north near the gap photographed by Darton. Northward from this gap the E sandstone again splits, causing Dane, Bachman, and Reeside (1957) to misidentify this lower split as a separate lower tongue of Gallup Sandstone (Molenaar, 1973, p. 96). South of the Puerco gap, the lower tongue of the E sandstone pinches out into the Pescado Tongue and the D sandstone pinches out into nonmarine units. The D sandstone bed, correlated on the basis of stratigraphic position with the section east of Window Rock, Ariz., may also be seen to pinch out into nonmarine rocks 1.5 km north of NM Route 264 (Molenaar, 1973).

The top sandstone bed of the Gallup in the type area is a pink fine- to coarse-grained fluvial sandstone, which Molenaar named the Torrivio Sandstone Member of the Gallup Sandstone using a type section located immediately north of the Puerco Gap east of Gallup (Molenaar, 1973, p. 109). The name is taken from Torrivio Mesa 13 km west of Gallup. The Torrivio Sandstone Member ranges in thickness from 0 to 30 m and is interpreted by Molenaar (1973) to be a fluvial complex deposited by low-gradient braided streams and consisting of a crossbedded fine- to coarse-grained feldspathic sandstone containing commonly angular granule-size quartz grains. Individual sandstone units are lenticular and usually are separated by, or grade into, carbonaceous mudstones. (Molenaar's measured type section includes the interbedded carbonaceous mudstone in the Torrivio Sandstone Member.) The Torrivio can be traced northward along the outcrop to the Red Rock Highway where it merges with the coastal-barrier sandstone. Eastward from the Nutria Monocline, the Torrivio Sandstone Member thins, becomes discontinuous, and pinches out. This correlation differs from the correlation of Dane, Bachman, and Reeside (1957) as they show this upper coarse-grained Gallup Sandstone as equivalent to the massive coastal-barrier sandstone to the east (Molenaar, 1973, p. 96). To the north the nonmarine rocks below the Torrivio Sandstone Member are replaced by the coastal-barrier A, B, and C sandstones of the Gallup Sandstone (Molenaar, 1973, fig. 8, p. 93).

Hackman and Olson--1977

The most recently published work involving the nomenclature of the Gallup Sandstone is on the Gallup $1^{o}x2^{o}$ sheet (Hackman and Olson, 1977). A copy of their schematic diagram of stratigraphic relationships is reproduced in figure 17. To a large extent their

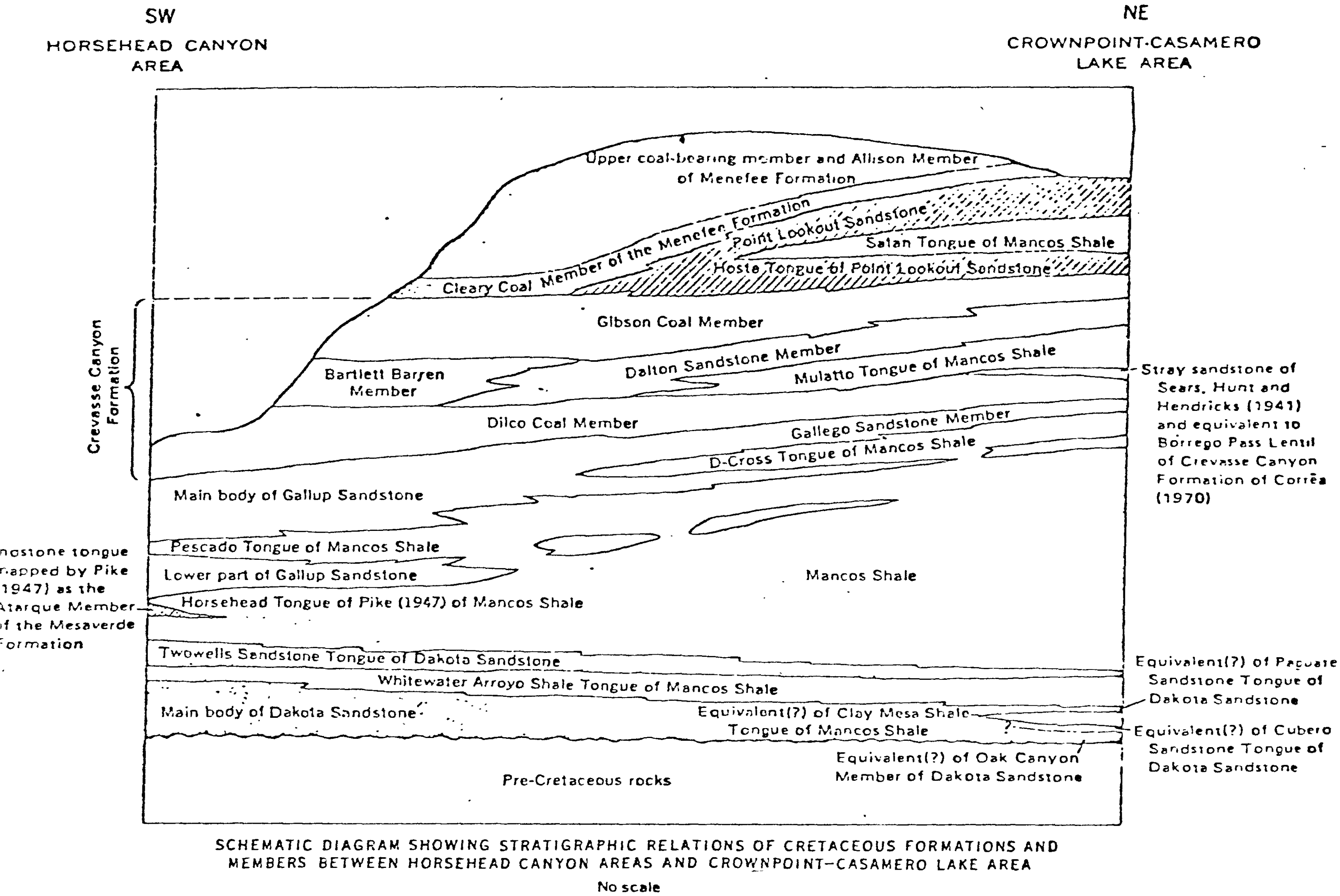


Figure 17.--Schematic diagram showing stratigraphic relations of Cretaceous formations in the Gallup-Zuni and southern San Juan Basin (Hackman and Olson, 1977).

nomenclature follows that of Pike (1947). Many of their geologic units were combined with adjacent units because of the small scale of their mapping. However, they delineate, describe, and define the relationships of the following units: D-Cross Tongue of the Mancos Shale pinches out into continental beds east of Gallup and on the East Defiance Monocline south of Todilto Park; Pescado Tongue of the Mancos Shale, shown mapped with the lower part of the Gallup Sandstone, joins the main body of the Mancos Shale north of Upper Nutria Village, N. Mex., and south of Window Rock, Ariz., and thins to the southwest; and the Horsehead Tongue of the Mancos Shale of Pike mapped with Atarque Member of the Mesaverde Formation, joins the main body of the Mancos Shale southeast of Zuni reservoir and pinches out just south of their map area.

Recent U.S. Geological Survey work

Continuing work by the USGS over the last several years involving geologic mapping (1:24,000 scale) and stratigraphic and uranium studies along the southern and western margins of the San Juan Basin has resulted in the following map publications and open-file preliminary maps: Green and Jackson, 1975a, 1975b, 1976; Huffman, 1976; Kirk and Sullivan, 1976; Kirk and Zech, 1976a, 1976b, and 1978; Robertson, 1974, 1976, 1978; and Robertson and Jackson, 1975. Additional mapping by R. E. Thaden and V. P. Byers is still in progress.

The units A and B nomenclatural designation (Thaden and others, 1967) has been carried from the Ambrosia Lake area westward. (See for example, Robertson and Jackson, 1975; Kirk and Zech, 1976a.)

However, with the appearance of additional intermediate sandstones below the main body of the Gallup Sandstone on the Nutria Monocline, these designations were abandoned. On the monocline these units have been called "lower sandstones" (Green and Jackson, 1976, and Kirk and Zech, 1976b and 1978).

In general, the results of this mapping closely agree with the published cross sections of Molenaar with respect to the distribution of various lithologies within and adjacent to the Gallup Sandstone. We would specifically differ with Molenaar's (1973) interpretation on the following points: (1) the conglomeratic sandstone (Torrivio Sandstone Member of the Gallup Sandstone of Molenaar, 1973) has a more extensive distribution east of the Smith Lake area and has been traced in this direction as far as the Borrego Pass road near sec. 5, T. 15 N., R. 11 W.; (2) there is a minor miscorrelation of lower sandstones of the Gallup in the vicinity of secs. 14 and 15, T. 16 N., R. 17 W., NMPM, between Molenaar's sections numbered 38 and 39 on figure 16. The lower sandstone labeled E on section 44 (fig. 16) probably correlates with the lower tongue of the E sandstone in section 38; and (3) an additional lower tongue of the Gallup Sandstone is exposed in the cliff below Nose Rock in sec. 14, T. 16 N., R. 17 W., between Molenaar's measured sections numbered 38 and 39 and coming into the section between his C and D sandstones (fig. 16).

The authors of these notes have little experience in the Gallup-Zuni Basin or in the Alamosa Creek area and will reserve comment on the correlations of the Gallup Sandstone in these areas. However, there appear to be discrepancies between the report of Molenaar

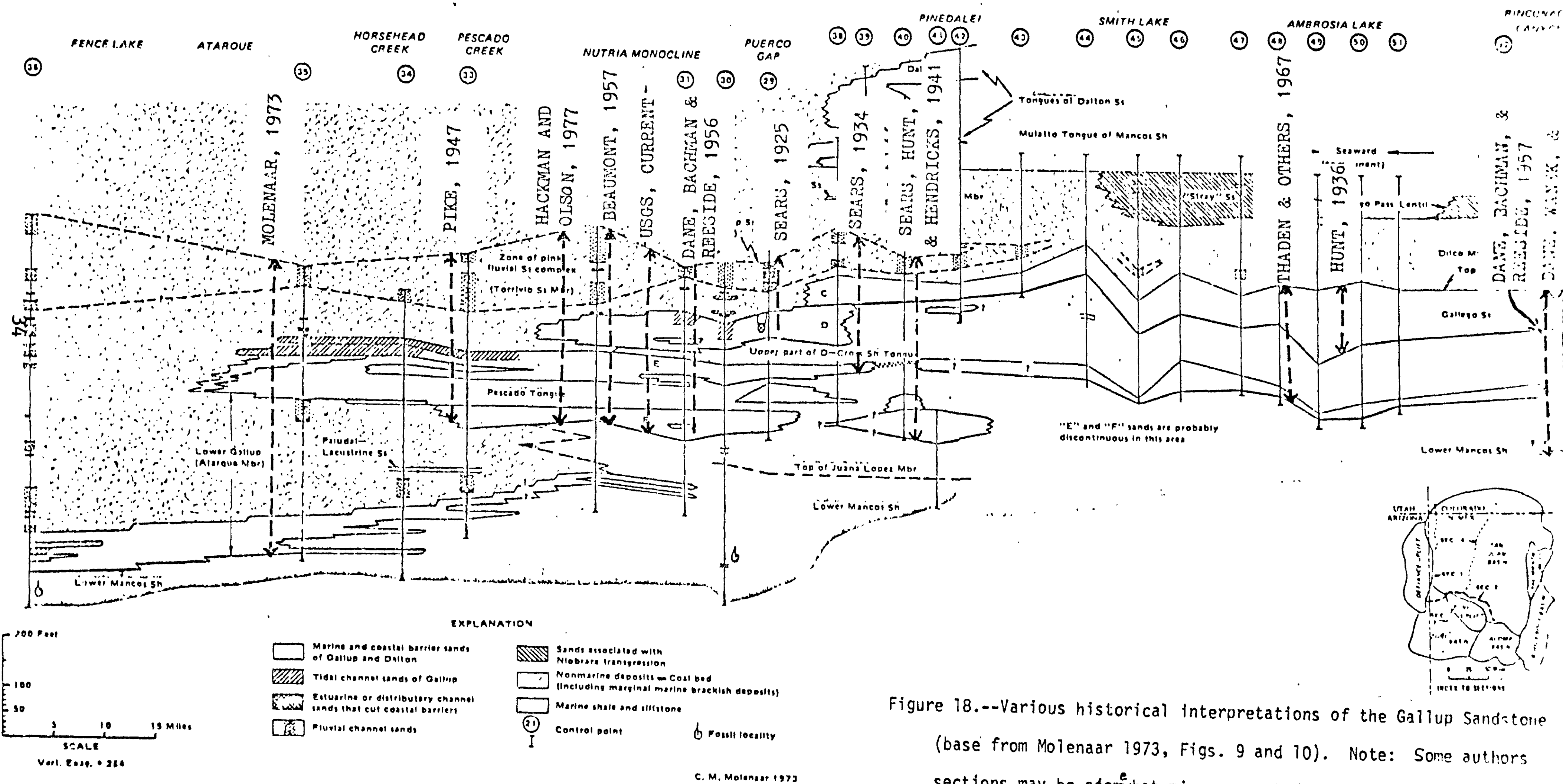


Figure 18.--Various historical interpretations of the Gallup Sandstone (base from Molenaar 1973, Figs. 9 and 10). Note: Some authors sections may be somewhat misrepresented as their sections did not always agree with Molenaar's from the various localities.

(1973) and the recently published 2° sheet by Hackman and Olson (1977) in terms of nomenclature and distribution of lithology in the Gallup-Zuni Basin.

As a means of summary, we have prepared figure 18 to illustrate not only what the original definition of the Gallup Sandstone was but how this was modified and interpreted by the various authors considered in these historical notes. The base for this diagram is taken from Molenaar (1973, figs. 9 and 10) with the assumption that it is very close to the correct distribution of lithologies within the Gallup Sandstone interval. As a consequence, it allows us to place each author's interpretation in the approximate geographic area in which he worked.

DESCRIPTION AND DISTRIBUTION OF LITHOLOGIC UNITS

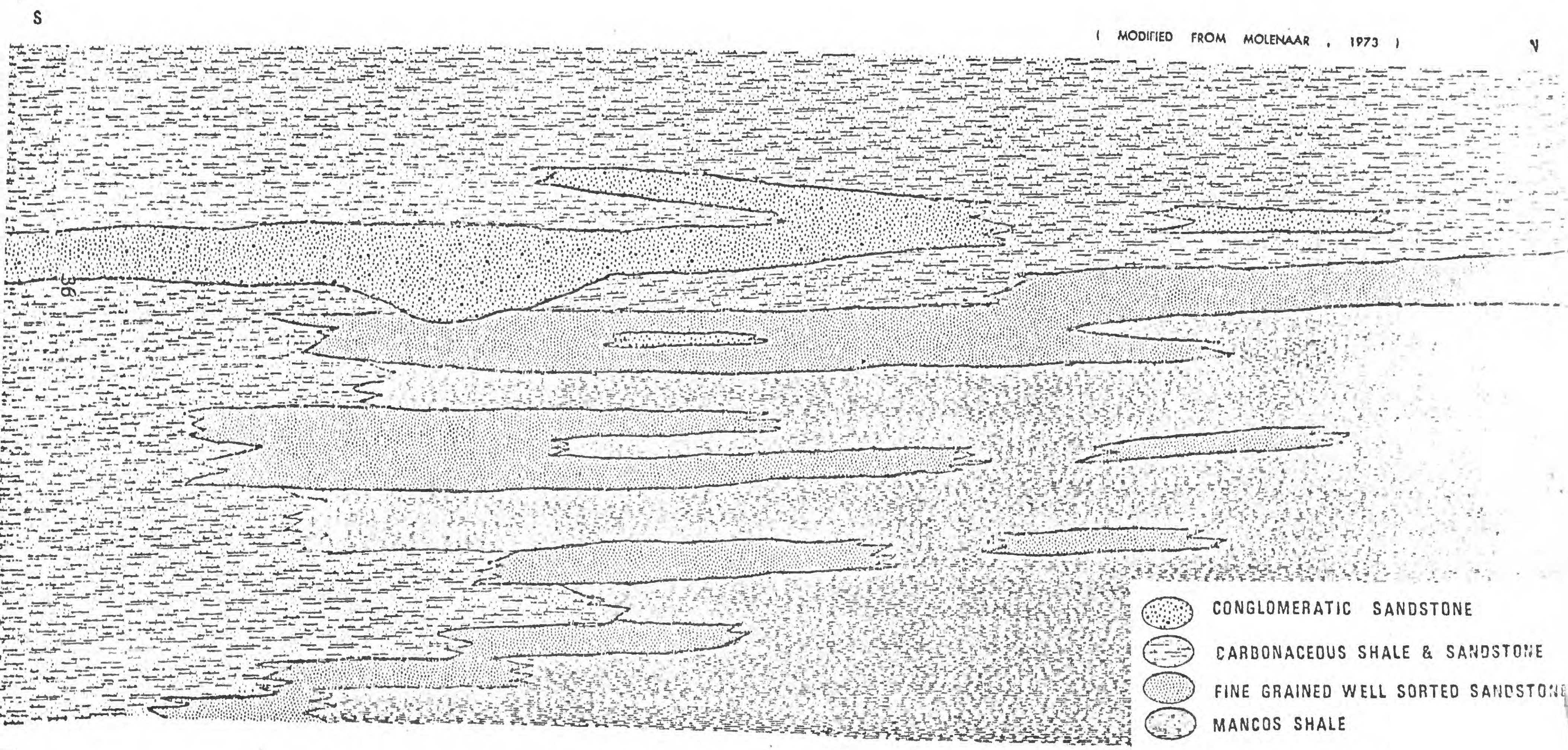
The following are descriptions of what we consider the various lithologic units within and adjacent to the Gallup Sandstone. Figure 19 shows the distribution of these lithologic units on an idealized cross section across the Gallup-Zuni Basin and the southern part of the San Juan Basin.

Mancos Shale

The Mancos Shale involved in this discussion is the part that lies stratigraphically between the Twowells Tongue of the Dakota Sandstone and the main ledge or body of the Gallup Sandstone. It includes the Juana Lopez Member and is intertongued with lower sandstone beds of the Gallup Sandstone. It is mainly light-gray to dark-gray (N7 to N3) shale with thin beds of interbedded siltstone,

Figure 19:

IDEALIZED CROSS SECTION SHOWING DISTRIBUTION OF LITHOLOGIES IN AND ADJACENT TO THE GALLUP SANDSTONE



very fine grained calcareous sandstone, and minor limestone in thin beds that are generally lenticular and discontinuous and in places fossiliferous, and in concretionary zones containing rare septarian nodules as much as 1 m in diameter.

The contact between the Mancos Shale and overlying sandstone beds is generally transitional. The shale and mudstone of the Mancos become yellowish gray (5Y 7/2) and silty upward, interfinger with and grade upward and laterally into thin beds of yellowish-gray (5Y 7/2) to grayish-orange (10YR 7/4), very fine grained, well-sorted sandstone. Marine fossils that have been reported from the Mancos commonly include pelecypods, particularly Inoceramus and Gryphea, and Barroisiceras, Scaphites, and Prionocyclus, among others.

Fine-grained well-sorted Sandstone

This unit consists of grayish-orange (10YR 7/4) to pinkish-gray (5YR 8/1), thick-bedded to very thin-bedded, well-sorted to very well-sorted, subrounded to subangular, very fine grained to fine-grained, locally fossiliferous and calcareous sandstone that occurs in 0- to 30-m-thick sheets, lentils, lenses, and tongues having sharp, commonly iron-stained tops but generally transitional bases with the underlying Mancos Shale. The lower contact is gradational through a zone generally 3-5 m thick.

A generalized section through a major sandstone body displays a recognizable sequence from bottom to top. In the lower part the sandstone is clayey to silty and very fine grained, but it becomes better sorted and coarsens slightly upward. Bedding ranges from thin to very thick, with internal structures varying from obscure stratification to parallel and subparallel lamination and medium-scale hummocky and tangential crossbedding. It typically is bioturbated or burrowed and locally contains small pelecypod shells and shell fragments.

The very fine grained bioturbated sandstone of the lower part is succeeded by fine-grained well-sorted sandstone of the middle part. The contact commonly is sharp with shallow scouring in many places, but also may be gradational. The middle part of the sandstone unit is characterized by small- to medium-scale, low- to moderate-angle trough and wedge-planar crossbedding that commonly displays opposing dip directions; less abundant are parallel-laminated beds. The upper 10 to 50 cm of some crossbedded sets and parallel-laminated beds are burrowed and may include well-preserved trace fossils such as *Ophiomorpha*, and *Thalassinoides*. The middle sandstone commonly constitutes the largest part of a sandstone body.

Capping the sandstone body, but missing at many places, is a fine-grained, very well sorted sandstone unit, 0-5 m thick, that is thin bedded with flat, subparallel, or gently dipping beds. It is commonly burrowed and locally bioturbated by *Scolithos*, *Thalassinoides*, and *Ophiomorpha* among others, Root tubes are abundant in the uppermost 15 cm, where this unit is overlain by carbonaceous shale and mudstone.

The lenses and tongues of sandstone vary in thickness from 0 m at the pinch-out to 30 m. The uppermost sandstones are normally the thickest, with the lower ones commonly ranging from 0 to 10 m thick.

Conglomeratic sandstone

This unit consists of very light gray (N8) to pale red (10R 7/3) and grayish orange (10YR 7/4), medium-scale to very large scale, trough crossbedded, angular to subangular, very poorly sorted to moderately well sorted, very coarse grained to fine-grained feldspathic sandstone. It commonly is composed of 25 percent granule-size quartzose grains, sparse chert and quartzite pebbles, and significant amounts of interstitial clay. Plant debris and carbonaceous material occur on bedding planes and in lenses of conglomerate composed of granules, pebbles, and clay clasts at the base of troughs.

The geometry of the conglomeratic sandstone is a series of troughs, each as much as 5 m thick, that coalesce into lenticular bodies of sandstone, which in turn combine with similar sandstone bodies or intertongue laterally and vertically with carbonaceous mudstone. The contact of the conglomeratic sandstone and the underlying material is everywhere a scour surface. This unit locally scours into, and may intertongue with, the fine-grained well-sorted sandstone.

Carbonaceous shale and sandstone

(Including but not restricted to the Dilco Coal Member, Crevasse Canyon Fm.)

This is a very heterogeneous unit consisting predominantly of light-gray to dark-gray (N7-N3) and minor yellowish-gray (5Y 8/1) and grayish-red (10R 4/3) carbonaceous shale and shales interbedded with grayish-orange (10YR 7/4) to yellowish-gray (5Y 8/1) carbonaceous siltstones and scattered lenticular subbituminous coal beds normally less than 15 cm but rarely as much as 1.5 m thick. Included within this unit is a wide variety of sandstones, most of which can be grouped under three major lithologies: (1) a very light gray (N8) to pale-yellowish-brown (10YR 6/2), thin-bedded to very thin bedded, ripple-laminated, burrowed, moderately well sorted to poorly sorted, carbonaceous, very fine grained silty sandstone with a clayey matrix, which occurs as 1- to 2-m-thick wedge-shaped bodies of limited lateral extent; (2) a very light gray (N8) to pale-yellowish-brown (10YR 6/2), medium-bedded to thin-bedded, high-angle to low-angle trough crossbedded, poorly sorted to moderately well sorted, medium-grained to very fine grained sandstone, which fines upward and occurs as 0- to 10-m-thick lenticular bodies that are commonly ripple laminated at the top; (3) a very light gray (N8) to pale-yellowish-brown (10YR 6/2), thin-bedded to very thin bedded, locally small-scale trough crossbedded, ripple-laminated, bioturbated, well-sorted, fine grained to very fine grained sandstone, which occurs as thin (1-3 m), laterally continuous sheets.

The carbonaceous shale and sandstone unit is interbedded and intertongued with the conglomeratic sandstone and interfingered with the fine-grained well-sorted sandstone.

SUMMARY OF THE GALLUP SANDSTONE PROBLEMS

The diagrammatic cross section modified from Molenaar (1973) and shown in figure 19 illustrates the distribution of lithologies within and adjacent to the Gallup Sandstone. Some general comments concerning this figure will be noted. We have attempted to incorporate all of the observed geologic relationships between various lithologic units in the diagram. However, the intertonguing of the fine-grained well-sorted sandstone with the underlying Mancos Shale is more common than is shown. Also, for the purpose of clarity, the transitional zone between the Mancos Shale and the overlying sandstone is omitted. Finally, it is noted that the scouring of the fine-grained well sorted sandstone by the conglomeratic sandstone is discontinuous both along strike and down dip, and thin carbonaceous shales are present at most places between the two sandstones.

Figures 20 to 25 use the same base as figure 19, with patterns superposed to show the map units that result from regrouping of the various lithologies in and adjacent to the Gallup Sandstone. Figure 20 shows the map units that result from the nomenclature as currently accepted by the U.S. Geological Survey. Figure 21 shows the map units resulting from the nomenclature proposed by Molenaar (1973). Figures 22-25 show the beds between Molenaar's Torrivio and the main body of the Gallup Sandstone as a tongue of the Crevasse Canyon Formation and present other possible ways of grouping these lithologic units. These figures have been placed in decreasing order of what we think are acceptable and desirable.

These alternative groupings are not intended to be exhaustive, but rather present what we consider to be the most reasonable approaches to the problems of accurately mapping the contacts of the Gallup Sandstone and of showing the distribution of the various lithologic units in this part of the Cretaceous.

Figure 20: CURRENT USGS NOMENCLATURE - RESULTING MAP UNITS

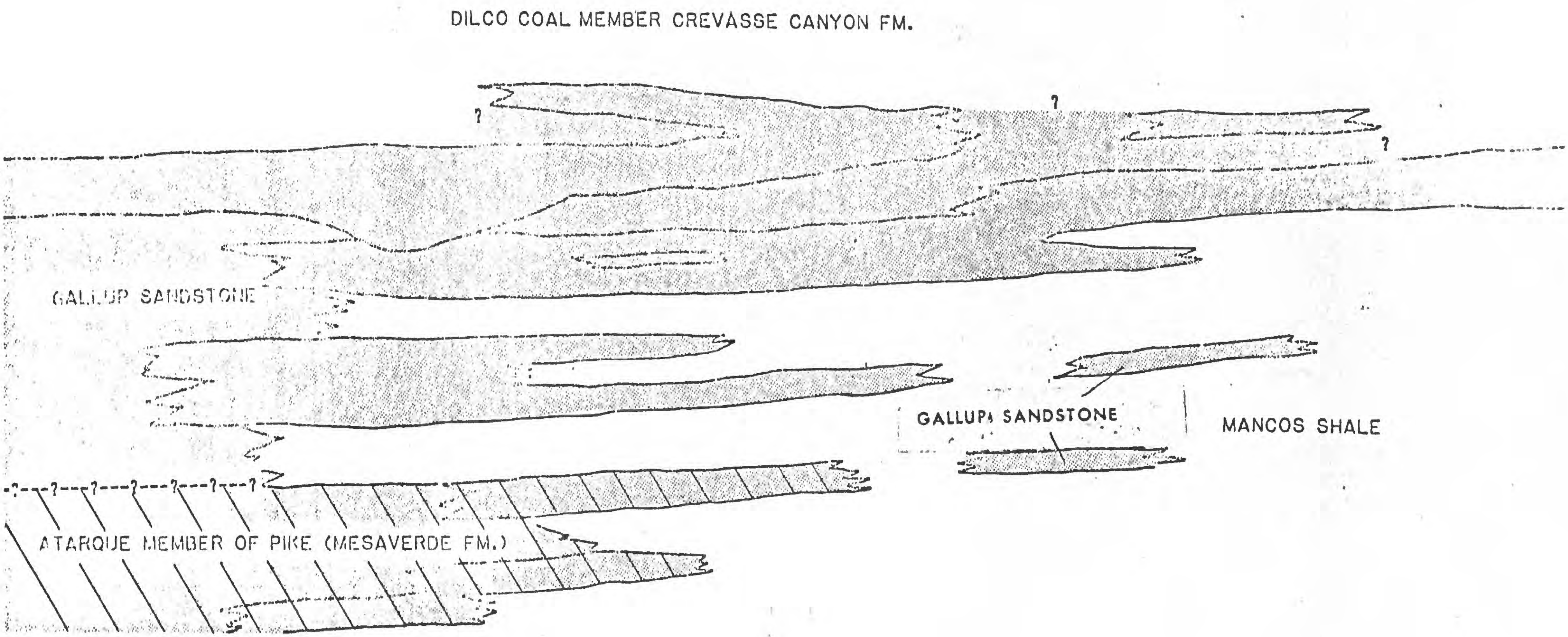
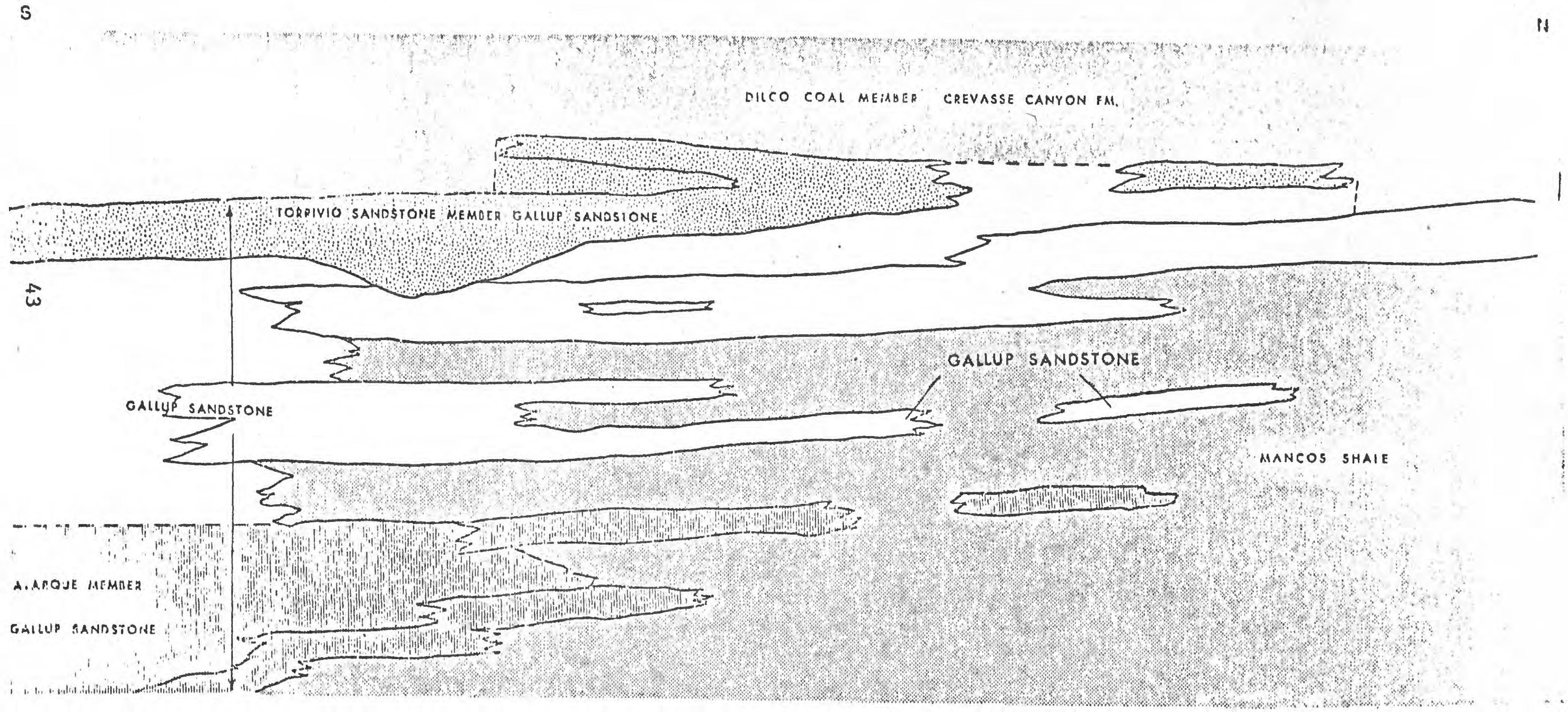


Figure 21: MOLENAAR'S TERMINOLOGY—
RESULTING MAP UNITS



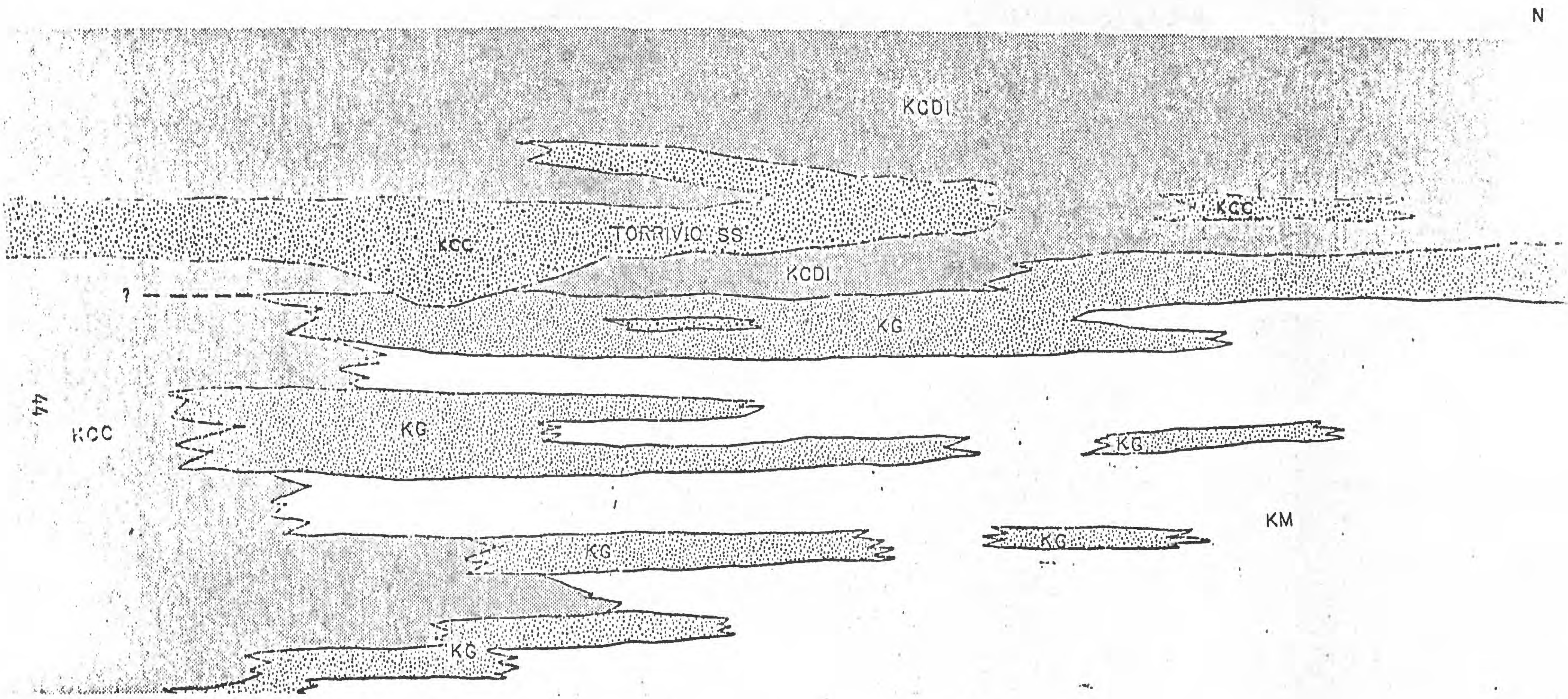


Figure 22.--Conglomeratic sandstone (Torrivio as a mappable bed in the Crevasse Canyon Formation with the underlying carbonaceous shale included in the Dilco Coal Member of the Crevasse Canyon Formation.

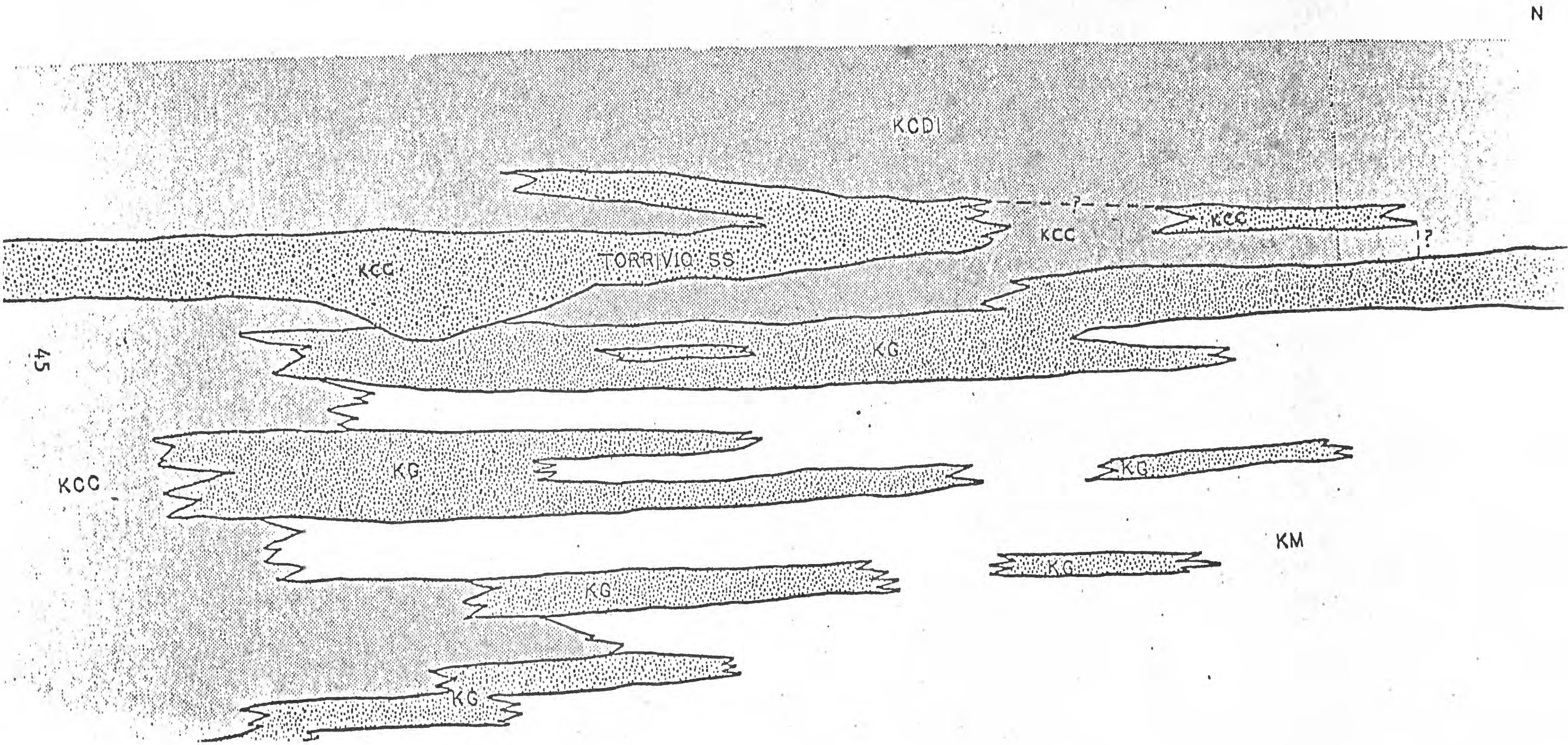


Figure 23.--Conglomeratic sandstone (Torrivio S[illegible] as a mappable bed in the Crevasse Canyon Formation with the underlying carbonaceous shale as an undifferentiated tongue of the Crevasse Canyon Formation.

FIGURE 24

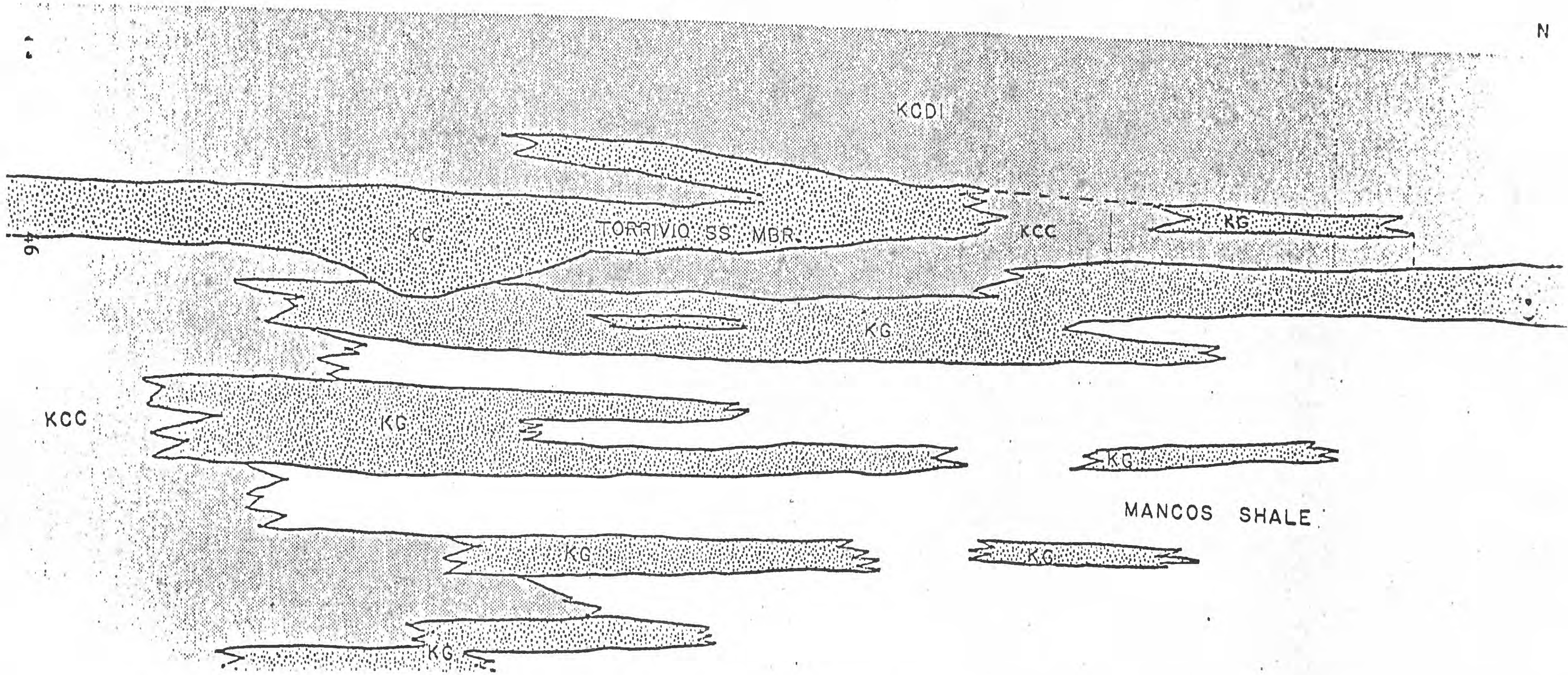
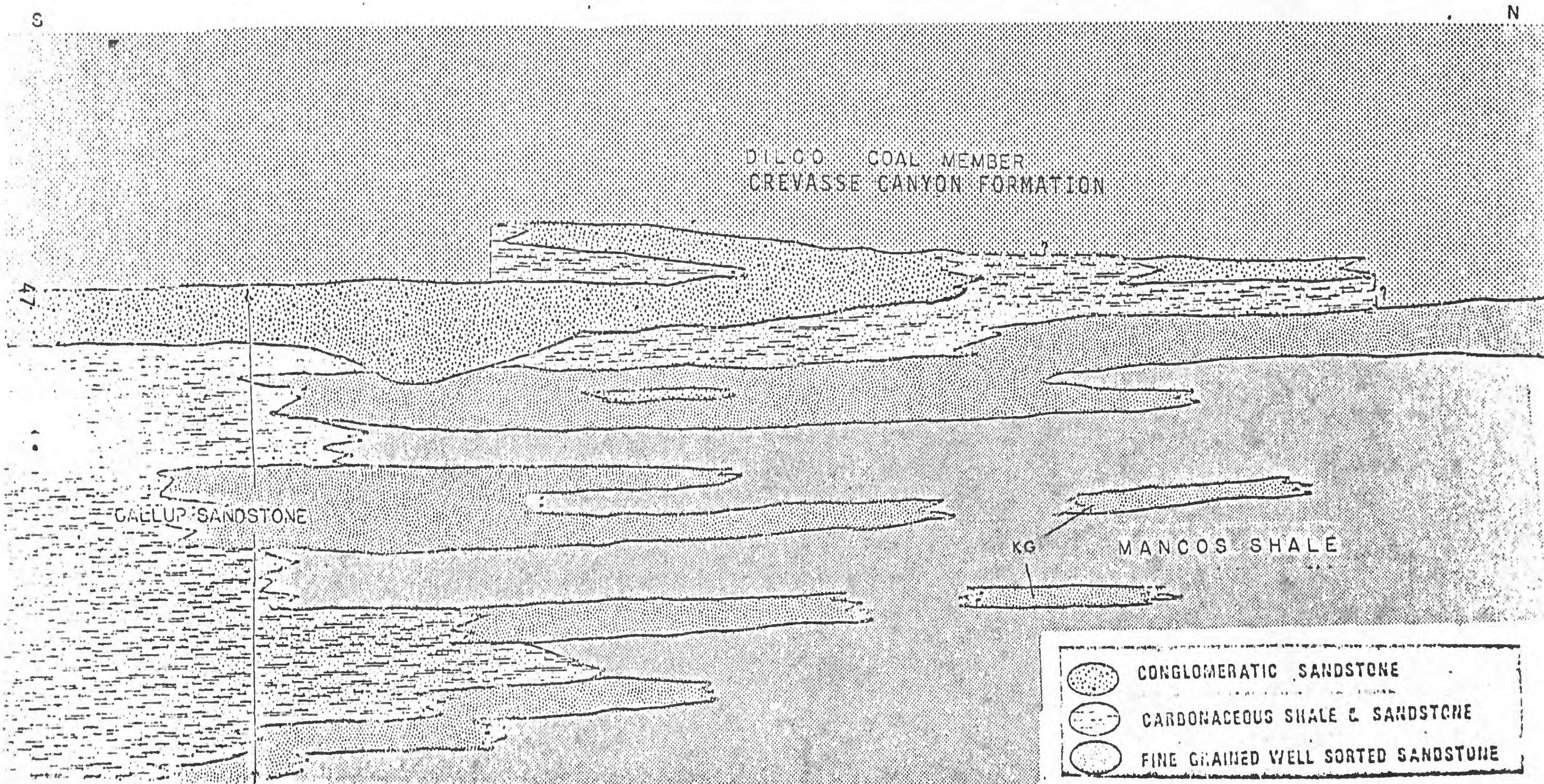


Figure 24.--Conglomeratic sandstone as a member of the Gallup Sandstone with the underlying carbonaceous shale (Kcc) as a tongue of the Crevasse Canyon Formation.

- Figure 25:
MAPPABLE LITHOLOGIES WITHIN AN EXPANDED GALLUP SANDSTONE



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