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CORRELATION OF THE GALLUP SANDSTONE AND ASSOCIATED FORMATIONS, UPPER CRETACEOUS, EASTERN SAN JUAN AND ACOMA BASINS, NEW MEXICO

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INTRODUCTION

The Gallup Sandstone of northwestern New Mexico has been of interest to stratigraphers for many years for several different reasons. In the 1920's and 30's when general mapping was being done in the southern San Juan Basin, it was studied because of the economic interest in the overlying coal beds. In the forties it was one of the units involved in working out the principles and relationships of transgressive and regressive sedimentation and large scale intertonguing of the total Upper Cretaceous sedimentary sequence, which is so well exemplified across the San Juan Basin. In the late fifties and early sixties, it was of great interest because of its relationship to oil discoveries made in the San Juan Basin. Since then several papers have discussed correlations and depositional environments of the Gallup Sandstone in local areas on the northwest side of the basin.

In 1973 the Four Corners Geological Society published a memoir entitled *Cretaceous and Tertiary Rocks of the Southern Colorado Plateau* (Fassett, 1973). Included in it was a paper by the author on the sedimentary facies and correlation of the Gallup Sandstone and associated formations in the western and southern San Juan Basin and the major portion of the Zuni basin. The present paper is a continuation of the study of these strata extended to the eastern and southeastern side of the San Juan Basin, the Acoma basin to the south and the Carthage area southeast of Socorro, New Mexico (Fig. 1). These areas have been covered in part by Pike (1947), Dane, Wanek and Reeside (1957), Gadway (1959) and Dane (1960). In the present paper more details are added and some of the units are correlated differently.

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MAJOR FACIES AND DEPOSITIONAL ENVIRONMENTS

The major facies and depositional environments of the Gallup and associated formations have been discussed in some detail in a recent paper by the author (Molenaar, 1973, p. 86). That discussion also applies to the area of this paper. To avoid repetition, only generalities and different aspects will be noted here.

Generally, the Gallup Sandstone consists of northeastward

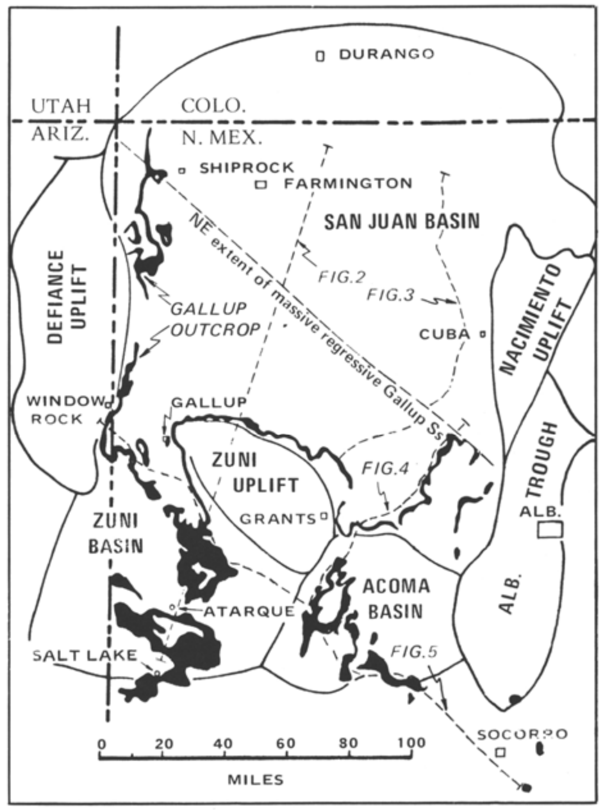


Figure 1. Index map showing Gallup outcrops and cross section locations.

prograding coastal barrier strandplain or delta front sandstones that grade seaward into offshore marine mudstones of the Mancos Shale and intertongue with, or have landward equivalents of nonmarine or brackish coastal plain deposits of the Dilco Member of the Crevasse Canyon Formation. These latter deposits consist of paludal mudstone, some fluvial channel sandstones and minor coal beds. The Gallup Sandstone on the west side of the San Juan Basin displays considerable lithofacies variation owing to a major fluvial system which contributed sediments; abrupt stratigraphic rises are also present. However, on the southeast side of the basin, fluvial sandstones are minor and abrupt stratigraphic rises are not present. The Gallup in this area is interpreted to be the result of a rather uncomplicated northeastward prograding strandplain. Barrier island bars, where present, are thought to have evolved into the strandplain as the back barrier lagoons filled up with sediments and the barriers accreted seaward. In the area of the type section near Gallup, New Mexico, a nonmarine fluvial sandstone unit (Torrivio Sandstone—Molenaar, 1973, p. 98) and associated paludal shales were included in the Gallup. However, on the southeast side of the San Juan Basin the top of the Gallup is placed at the top of the regressive coastal barrier sandstone.

In the southern half of the Acoma basin, a lower tongue of Gallup (Atarque Member) is present below the main or upper Gallup. The facies and environments in this unit arc similar to those previously discussed (Molenaar, 1973, p. 95), except that the main body of nonmarine paludal shales grades directly into marine Mancos Shale without an intervening coastal barrier sandstone. The absence of a coastal barrier sand body might be attributable to insufficient wave energy in the shallow Mancos sea.

Marine sandstones and shales that are related to the basal Niobrara (Coniacian) transgression overlie the regressive deposits of the Gallup-Dilco interval. These basal Niobrara sandstones are genetically unrelated to the regressive Gallup, but many geologists have included them with the Gallup in the more seaward localities. Other geologists have referred to them as basal Niobrara sandstones, Tocito Sandstone, transgressive Gallup and "Stray sandstone." For a full discussion of this nomenclature problem, refer to Molenaar (1973, p. 100). In this paper they will be referred to as basal Niobrara sandstones.

Two types of basal Niobrara sandstones have been differentiated on the west and south sides of the San Juan Basin by Molenaar (1973, p. 100). These are (1) the transgressive on lap sandstones exposed along the northwest side of the basin and (2) the transgressive offlap sandstones exposed in the outcrops along the south side of the basin (Borrego Pass Lentil or "Stray sandstone"). A third type is recognized in the outcrops around Mesa Prieta and near Guadalupe and Casa Salazar on the southeast side of the basin. These are the regressive-appearing offshore bars which are lenticular sandstone bodies ranging up to 30 feet in thickness. They consist of an upward coarsening sequence of highly burrowed and bioturbated very fine- to fine-grained sandstone and are usually capped by a thin one- to five-foot thick, medium- to coarse-grained transgressive sandstone. This sandstone could easily be mistaken for the regressive Gallup.

DETAILS OF CORRELATION

The purpose of this paper is to show the details of correlation of the Gallup Sandstone and associated formations in the eastern San Juan Basin and extending south into the Acoma basin. A composited regional cross section from the Zuni basin through the central San Juan Basin from Molenaar (1973, Fig. 2) is included for comparison. The eastern San Juan Basin Acoma basin section is shown on two stratigraphic cross sections; one based on subsurface control (Fig. 3) and the other based on surface control (Fig. 4). The cross section shown in Figure 5 correlates the Zuni basin section with the Acoma basin section and is extended southeastward along depositional strike to the Cretaceous outcrops at Carthage, fifteen miles southeast of Socorro. In order to correlate these sections with the type area of the Gallup Sandstone near Gallup, New Mexico, where many of the units were originally named, the reader is referred to the various cross sections of Molenaar (1973). The cross sections and the control points listed here are numerically continuous with those of the 1973 paper. Also, the various sandstone units that have been informally designated A through F in the 1973 paper are similarly designated here. Locations of all surface and subsurface control points are listed in Table 1.

The correlations shown on the various cross sections are based primarily on the relationships of depositional facies and environments and are substantiated where feasible by lateral tracing of beds. The transition zone between the Mancos Shale and the massive Gallup Sandstone is included with the Mancos Shale on all surface sections. The correlations are straightforward and little additional discussion is necessary. A few points for clarification can be made though, especially where correlations are in disagreement with those of previous workers.

The age of the various units associated with the Gallup Sandstone has been discussed by Molenaar (1973). In general, the base of the lower Gallup in the southern Acoma basin-Carthage area is early Carlile (mid-Turonian) in age. The upper part of the regressive Gallup to the north may be as young as earliest Niobrara (latest Turonian-earliest Coniacian). The basal Niobrara sandstones are early Niobrara (early Coniacian).

Lower Gallup (Atarque Member)—Juana Lopez—D Cross Shale Interval

The Juana Lopez Member of the Mancos Shale (referred to as Sanostee by many geologists), which consists of thinly interbedded calcarenite, very fine-grained sandstone, siltstone and shale, and is a widespread marker bed throughout the San Juan Basin area, correlates directly with the nonmarine portion of the Atarque Member of the Gallup in the Acoma basin. This relationship was demonstrated by Molenaar (1973, p. 94) along the Nutria monocline on the west side of the Zuni uplift. Dane's (1960, p. 49) correlation of the Juana Lopez with the basal sandstone of the Atarque Member is considered to be too low. This basal sandstone at its most seaward point is equivalent to, though not necessarily continuous with, the Semilla Sandstone, a lenticular offshore marine sandstone that underlies the Juana Lopez at its type locality south of Cuba (Dane, Kauffman and Cobban, 1969). The correlation of the Semilla Sandstone or equivalent marker is shown on the subsurface cross section (Fig. 3).

At the southwestern end of cross section No. 6 (Fig. 4), the gradation of the nonmarine paludal shale into marine Mancos Shale is shown schematically. The correlation of the E and F sandstones differs somewhat from that of Pike (1947, p. 68) and Dane, Wanek and Reeside (1957, p. 188). Units cannot be physically traced with certainty between control points 56, 60, 61 and 53 because of slumping and tree cover along Cebollita Mesa and the physical gap in outcrops between Cebollita Mesa and Rinconado Canyon. The lower sandstone at Rinconado Canyon is thought to be an offshore bar that is laterally equivalent to the F sandstone to the south. The E sandstone is a southeastward projecting marine bar that had a landward connection west and south of Gallup (Fig. 5). This bar pinches out into marine shale both southeastward and to the south in the western part of the Acoma basin in addition to the normal northeastward pinchout (Figs. 4 and 5). It divides the D-Cross Shale Tongue into two tongues to the northwest

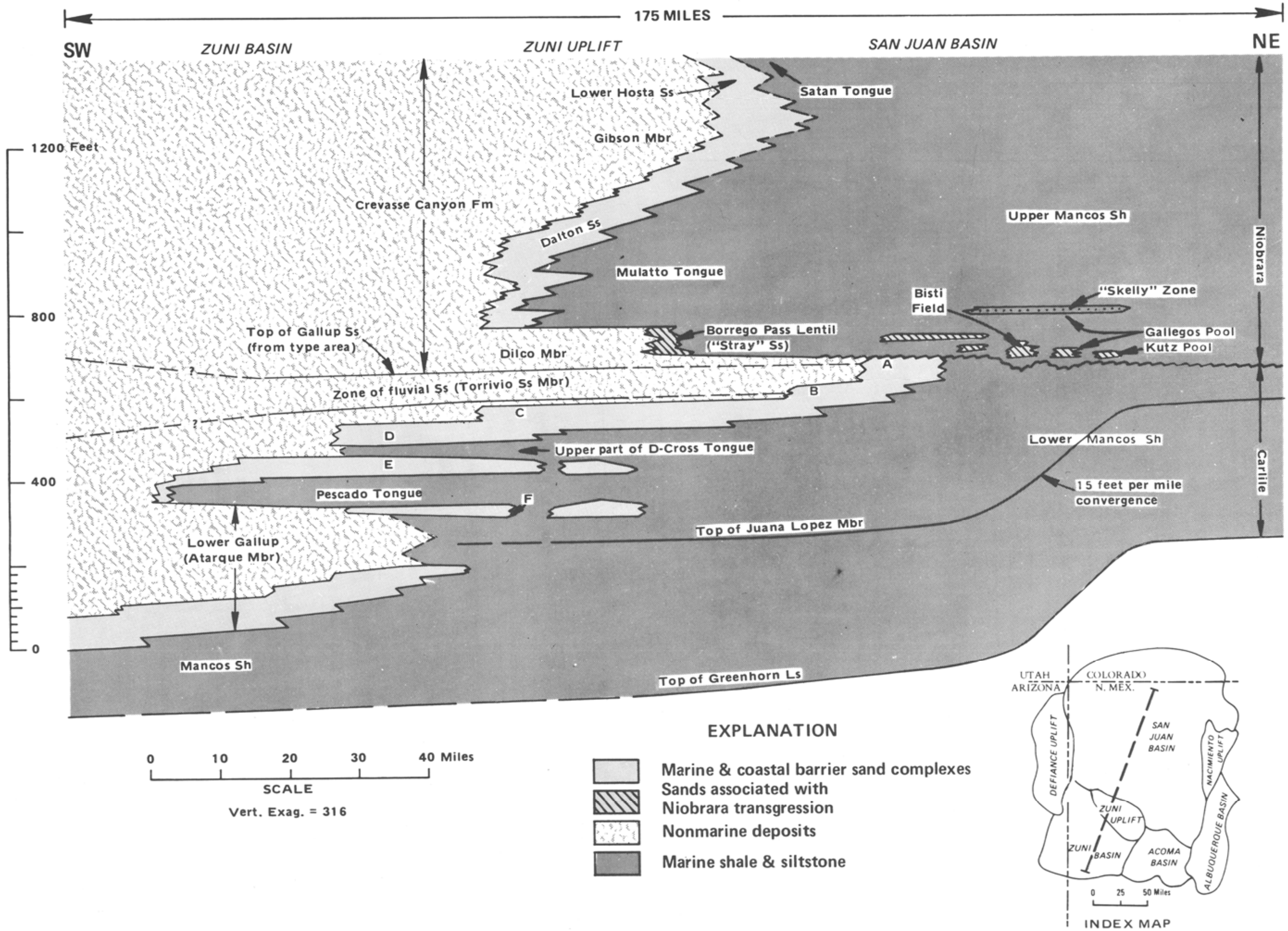
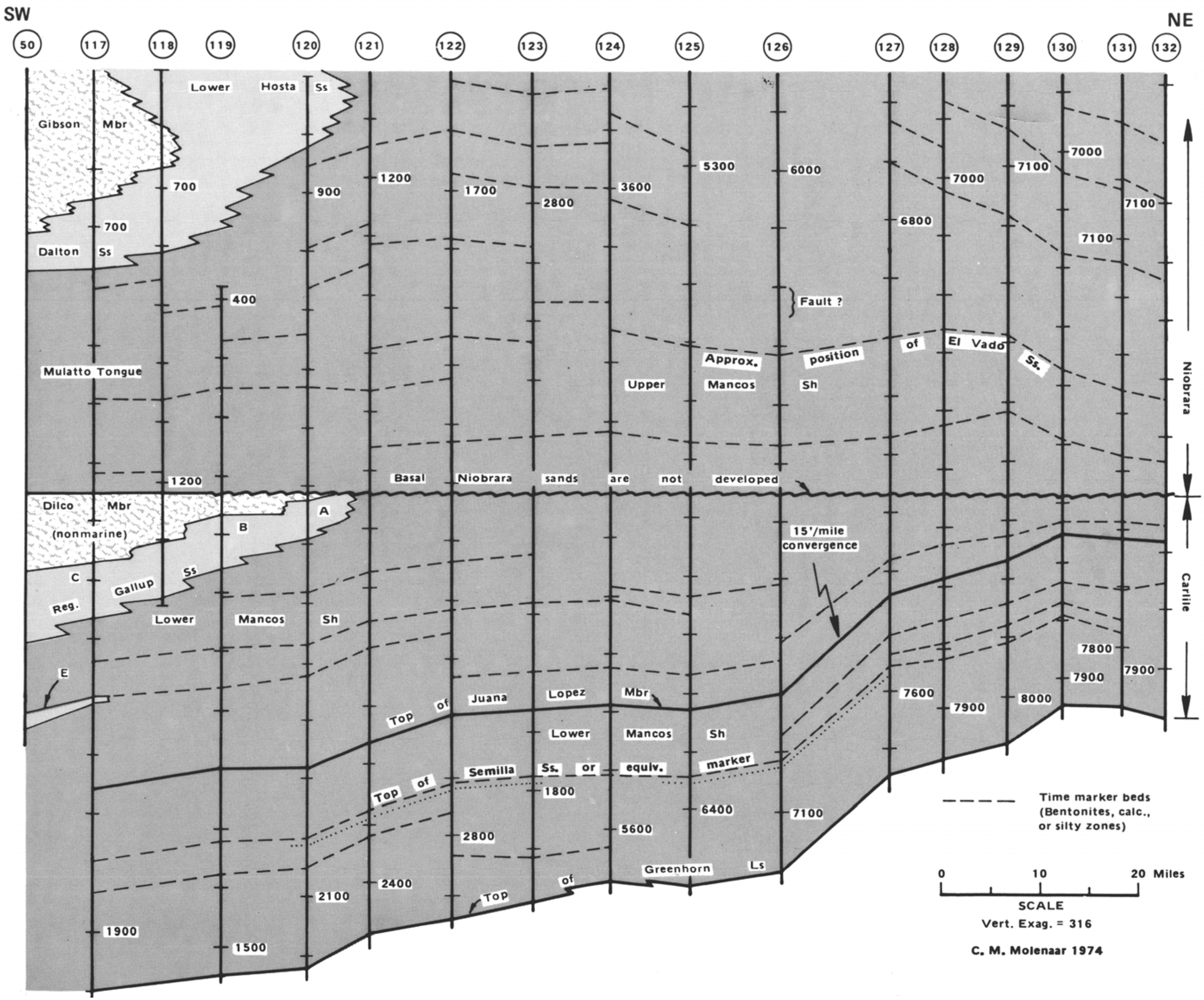


Figure 2. Regional cross section showing stratigraphic relationships of Gallup Sandstone with overlying and underlying rocks, Zuni Basin through central San Juan Basin (after Molenaar, 1973).


SW
NE
50
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
Lower Hosta Ss
Gibson Mbr
Dalton Ss
Mulatto Tongue
700
700
400
900
1200
1700
2800
3600
5300
6000
6800
7000
7100
7000
7100
7100
Fault ?
Approx. position of El Vado Ss.
Upper Mancos Sh
Niobrara
1200
Basal Niobrara sands are not developed
Dilco Mbr (nonmarine)
A
B
C
Reg. Gallup Ss
Lower Mancos Sh
15'/mile convergence
Carlile
E
Top of Juana Lopez Mbr
Lower Mancos Sh
7600
7900
8000
7800
7900
7900
Top of Semilla Ss. or equiv. marker
1800
6400
7100
2800
5600
Top of Greenhorn Ls
2100
2400
1900
1500
Time marker beds (Bentonites, calc., or silty zones)
0
10
20 Miles
SCALE
Vert. Exag. = 316
C. M. Molenaar 1974

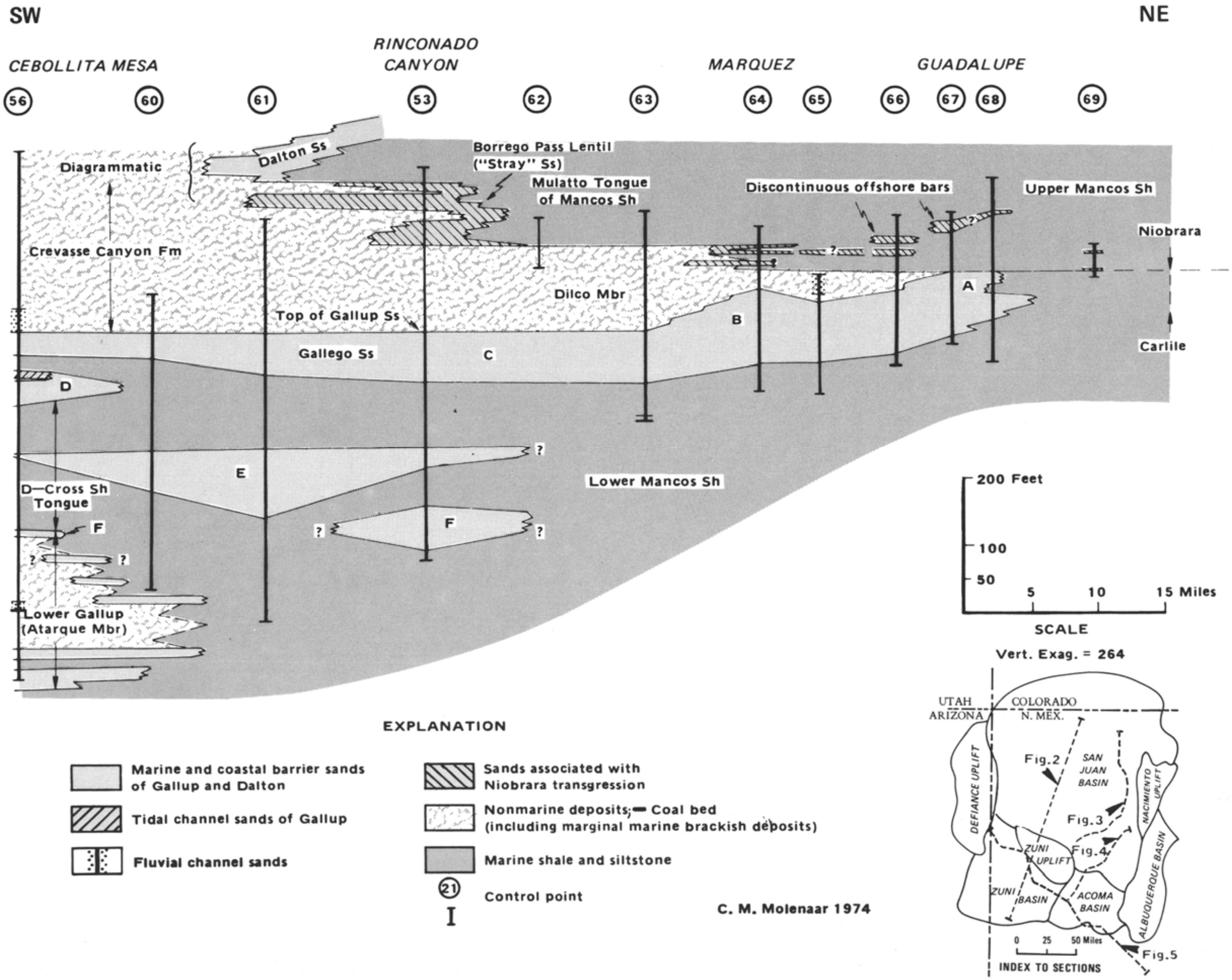


Figure 4. Cross section No. 6: Acoma Basin to southeastern San Juan Basin.

as shown on Figure 5. The lower half is directly equivalent to the Pescado Tongue as defined in the area south of Gallup.

Gallego—Upper Gallup Interval

In the Acoma basin the Gallego Sandstone, which was named by Winchester (1920, p. 6) for a thick sandstone bed northeast of D-Cross Mountain at Pueblo Viejo Mesa in Section 17, T. 4 N., R. 7 W., is thought to consist of both the C and D sandstone. At D-Cross Mountain the Gallego, a few silty streaks in the middle of the thick sandstone, probably represents a transgressive split between the C and D sandstone. In the Puertecito area, which is slightly farther seaward, the two sandstones are split by a 35-foot thick transgressive marine mudstone unit (control points 57 and 58, Fig. 5). A questionable marine mudstone tongue also is present at a similar stratigraphic position at the southern end of Cebollito Mesa (control point 56, Figs. 4 and 5).

The A, B and C coastal barrier sandstones on the southeast side of the San Juan Basin and south into the Acoma basin are not separable as they are on the west side, and appear to be one uniformly prograding strandplain sequence where the outcrops are continuous enough to permit lateral tracing. This is possible between control points 63 and 64 (Fig. 4). Even though the nonmarine Dilco thickness decreased from 126 feet to 30 feet between these points, there is no abrupt rise in the Gallup Sandstone. Part of the Dilco thickness change between these points is attributable to a stratigraphic rise of the transgressing Mulatto Tongue. Similarly, the section between control points 66 and 67 shows no abrupt rise except for one 5- to 10-foot rise just north of control point 66. This may represent the back side of a barrier island bar development. This part of the basin is interpreted as a non-deltaic or interdeltaic depositional site, as opposed to the more deltaic character of the west side of the San Juan Basin. Channel sandstones in the nonmarine Dilco facies are minor, suggesting a uniform shoreface accretion of the coastal barriers. The subsidence causing the abrupt stratigraphic rises on the west side were probably localized pulses in the overall subsiding geosyncline. Such pulses may have been associated with deltaic loading and (or) shifting.

Basal Niobrara Sandstone—Upper Mancos Shale Interval

Two transgressive offlap rises are shown on Figure 4. The sandstone buildup near Rinconado Canyon (control point 53) is correlated with the Borrego Pass Lentil ("Stray sandstone") (Molenaar, 1973, p. 97). The buildup in the vicinity of Marquez (control point 64) consists of three 3- to 8-foot thick sandstone beds separated by dark gray, fissile shales of slightly greater thicknesses. Grain size of the sandstone beds coarsens slightly upward from very fine to fine. The units are generally flat-bedded with some small scale cross-bedding. Ripple marked surfaces and burrows are common. The sequence is interpreted to have been deposited in a somewhat restricted environment in front of the transgressing Niobrara sea. These are probably the sandstones that are oil productive in the recently discovered Miguel Creek dome field 20 miles northwest of Marquez.

The transgressive onlap sandstone lenses that crop out on the northwest side of the San Juan Basin are oil productive in the north-central part of the basin (Bisti, Gallegos, and others). They become thinner and finer grained to the southeast and are not developed sufficiently in wells on the subsurface cross section to stand out on electric logs (Fig. 3). However, some thin lenses are present which frequently yield oil "shows" in drilling wells. Oil has been produced from these basal Niobrara sandstones at Media field (just north of control point 123). In the El Vado area on the northeast side of the basin, a lens of basal Niobrara coarse-grained sandstone about 3 feet thick has been named the Cooper Arroyo Sandstone Member of the Mancos Shale (Landis and Dane, 1967, p. 7).

In areas where the lenticular basal sandstones are not present, the base of the transgression is usually marked by a zone of medium to coarse quartz grains scattered in the basal few feet of the upper Mancos Shale. Glauconite is also common. These criteria usually are good for recognizing the contact in areas northeast of the seaward extent of the regressive Gallup where the contact is shale on shale. An example of this contact is seen in a road cut along New Mexico Highway 44 about 21 miles south of Cuba and 0.4 mile north of the junction with the dirt road to San Luis and Cabezon. (The first road cut about 0.3 mile south of this junction is in the Juana Lopez Member and the next cut 0.8 mile south of the junction is the Semilla Sandstone.) At this road cut the difference can be seen between the non-fissile silty mudstone of the lower Mancos Shale (Carlile) and the interbedded fissile shale and thinly bedded siltstone to very fine-grained sandstone of the upper Mancos Shale (Niobrara). The actual contact is marked by a poorly sorted, very glauconitic zone with scattered medium to coarse sand grains. A few feet above is a thin resistant, upper fine- to medium-grained sandstone bed.

Because the basal Niobrara sandstones are thin or absent in the northern San Juan Basin, the basal transgressive contact is difficult to detect in the subsurface. It is inferred by reference to electric log markers above and below. The contact as shown on the northern half of Figure 3 could be as much as fifty feet high.

Most of the so-called Gallup tops reported by operators of drilling wells in the eastern and northern San Juan Basin are arbitrarily picked at various electric log "kicks" and have no relationship to the actual basal Niobrara sandstones or to the Gallup equivalent interval. These reported tops are usually 200 to 500 feet above the basal Niobrara transgression and mark various sandy zones in the upper Mancos Shale. Some of these zones correlate with the El Vado Sandstone Member of the Mancos Shale, which was named by Landis and Dane (1967, p. 8) for a 100-foot thick resistant unit consisting of interbedded very fine-grained sandstone, siltstone and shale that crops out near El Vado Reservoir on the northeast side of the basin. The approximate position of the El Vado Sandstone is shown on the subsurface cross section (Fig. 3).

THE BASAL NIOBRARA UNCONFORMITY

The basal Niobrara unconformity as shown on the subsurface cross section (Fig. 3) is based on the convergence of marker beds in the Mancos Shale. This unconformity is thought to be well documented by several workers in the northwestern San Juan Basin. However, Campbell (1973, p. 78-84) presents data on the northwestern side of the basin that he interprets as refuting the presence of the unconformity. The present writer still believes there is an unconformity in the northern San Juan Basin because of (1) the convergence noted, (2) the common occurrence of medium to coarse sand grains

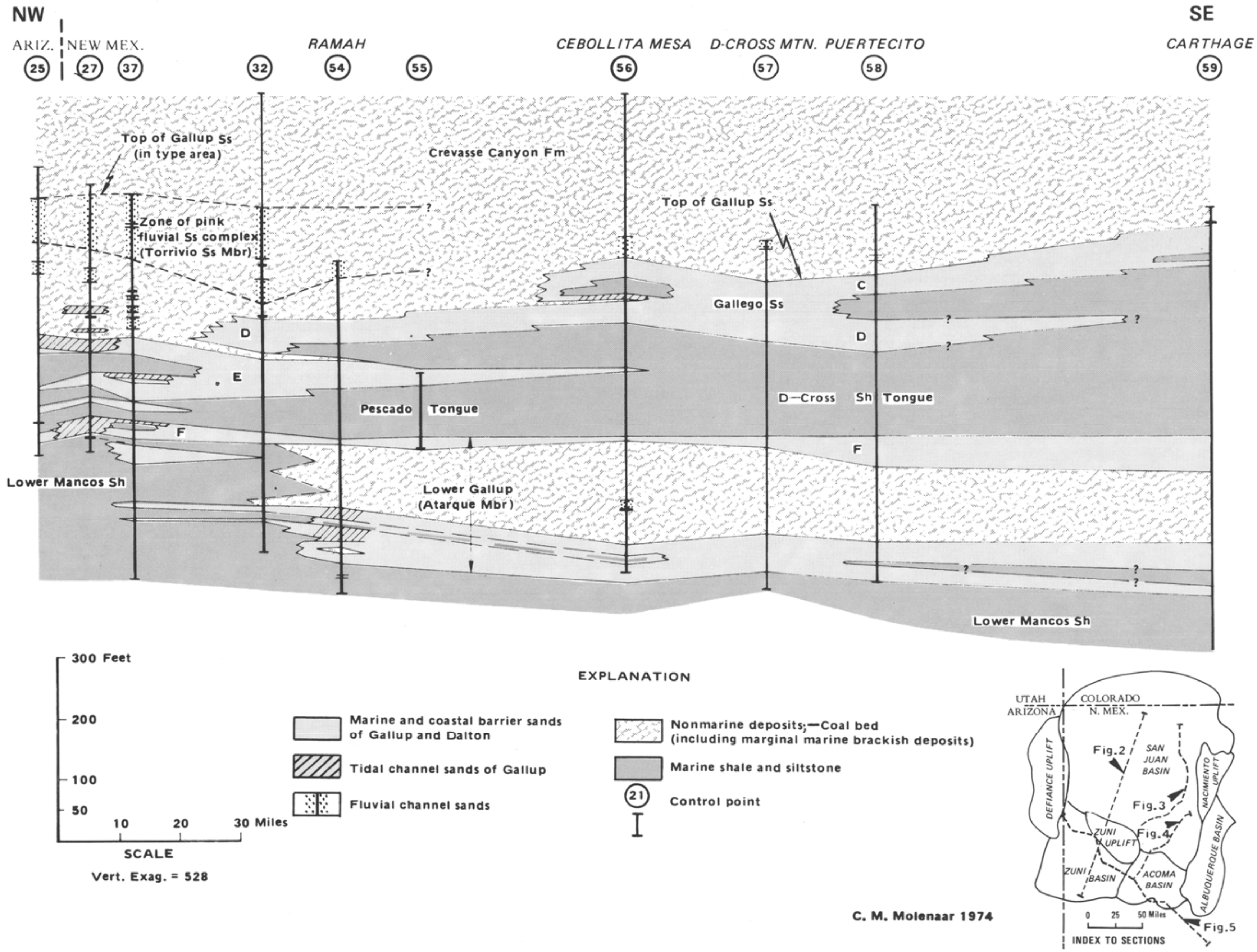


Figure 5. Cross section No. 7: Zuni Basin to Acoma Basin to Carthage, New Mexico.

Part I - Surface Control

Control Point	Section		Location T	R	State	Measured By*
25	SE¼	12	25N	30E	Ariz.	CMM
27	S½	31	15N	20W	N. M.	CMM & TDF
32	NW¼	31	13N	16W	N. M.	CMM
37	E½SW¼	34	14N	20W	N. M.	CMM
50		22	14N	9W	N. M.	RWF
53	N½NE¼	2	10N	8W	N. M.	CMM & RLS
54	NW¼	34	11N	16W	N. M.	CMM
55	NW¼	33	9N	15W	N. M.	CMM
56	SE¼17 & NW¼	21	6N	10@	N. M.	CMM
57	20, NW¼29 & NE¼	30	3N	8W	N. M.	CMM & BAB
58	NW¼6 & W½	7	2N	5W	N. M.	CMM & BAB
59	E½8 & NE¼	17	5S	2E	N. M.	BAB & CMM
60	SE¼	5	7N	9W	N. M.	JHE & TRM
61	W½	31	9N	8W	N. M.	JHE & TRM
62	E½	19	11N	6W	N. M.	CMM & RLS
63	E½	4	11N	5W	N. M.	JHE & RK
64		30	13N	4W	N. M.	JHE & RK
65	SE¼	4	13N	4W	N. M.	CMM & TDF
66	SW¼SW¼	7	14N	3W	N. M.	CMM & RLS
67	NE¼SW¼	27	15N	3W	N. M.	JHE & RK
68	E½	10	15N	3W	N. M.	JHE & RK
69	NW¼NW¼	36	16N	2W	N. M.	JHE & RK

* CMM - C. M. Molenaar; TDF - T. D. Fouch; RFW - R. W. Fields; RLS - R. L. Squires; BAB - B. A. Black; JHE - J. H. Elison; TRM - T. R. Magorian; RK - R. Kadwell

Part II - Subsurface Control

Control Point	Well	Sec.	T	R	State
117	R. A. Crane, Jr. No. 1	33	15N	8W	N. M.
118	Crown Cent. Pet. No. 6	9	15N	7W	N. M.
119	Richfield Oil No. 1	4	15N	6W	N. M.
120	Hughes & Hughes No. 1	25	16N	5W	N. M.
121	Refiners Pet. No. 1	29	17N	4W	N. M.
122	Kreatschman & Stowe No. 14	33	18N	3W	N. M.
123	Wiley & Fluid Power Pump No. 3	22	19N	3W	N. M.
124	W. R. Weaver No. 1	8	20N	2W	N. M.
125	Lloyd Smith, Inc. No. 32-1	32	22N	2W	N. M.
126	Magnolia Pet. No. 1-A	18	23N	2W	N. M.
127	Skelly Oil No. 1	30	25N	3W	N. M.
128	So. Union Prod. No. D-10	31	26N	3W	N. M.
129	El Paso Nat. No. 92-2	29	27N	3W	N. M.
130	El Paso Nat. No. 84-2	21	28N	3W	N. M.
131	De Villars No. 21-1	21	29N	3W	N. M.
132	Sunray DX No. 1	34	30N	3W	N. M.

Table 1. Control points used in study.

at the basal contact, and (3) observed angular relationships noted in outcrops on the northwestern side of the basin (Molenaar, 1973, p. 105). The unconformity probably formed in large part under submarine conditions.

Farther south, in the area of Guadalupe along the Rio Puerco, the relationship of the seaward extent of the regressive Gallup to the Niobrara transgression appears to be one of continuous deposition. Still farther south in the basin, little if any truncation is apparent at the base of the Niobrara transgression, and the relationship appears to be merely a transgressive "unconformity" (Fig. 3 and 4).

The convergence of beds high above the basal Niobrara unconformity on the northern half of Figure 3 probably represents paleoslope topography at the time of deposition of the various marker beds or possibly in part, less subsidence to the northeast.

GALLUP OIL PRODUCTION

Estimated ultimate recoveries of between 150 and 200 million barrels of oil have been attributed to the Gallup Sandstone in the San Juan Basin. Of this total only about 8 or 10 million barrels have been found in the regressive Gallup; this being in the structurally controlled Hospah field in the southeastern San Juan Basin, which produces primarily from a channel sandstone in the Dilco interval. Most of the remainder of the reserves have been developed in stratigraphic traps in basal Niobrara sandstones in about 17 fields in the central and northwestern San Juan Basin. These fields range in size from 40 to 50 million barrels, such as Bisti or Horseshoe Canyon fields, to less than a million barrels at the smaller fields. In addition, fracture reservoirs which produce at Boulder and Puerto Chiquito fields on the northeast side of the basin have sometimes been erroneously referred to as Gallup production. These fields produce from fractured reservoirs developed in a zone of shale, siltstone and very fine-grained sandstone in the upper Mancos Shale several hundred feet above the base of the Niobrara transgression. The El Vado Sandstone is probably included in the producing interval.

CONCLUSIONS

In the San Juan Basin and adjacent areas to the south, the character and thickness of the Gallup Sandstone and associated formations change markedly depending on location. An understanding of the sedimentational response to depositional regimens greatly facilitates the correct correlation of these various units within these areas. Knowledge gained by the detailed stratigraphic analyses of surface outcrops when applied to the subsurface, can make the interpretation of subsurface data easier and more meaningful. Lithologic trends, stratigraphic relationships, and strata! geometries can be mapped with considerable confidence. The San Juan Basin, with its surrounding, high quality outcrops, is an ideal area in which to apply this procedure, not only to the Gallup Sandstone but to all the other Cretaceous formations present.

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