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The transgressive and regressive relationships between the Upper Cretaceous Mulatto Tongue of the Mancos Shale and the Dalton Sandstone Member of the Crevasse Canyon Formation, Gallup-Pinedale area, New Mexico

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THE TRANSGRESSIVE AND REGRESSIVE RELATIONSHIPS BETWEEN THE UPPER CRETACEOUS MULATTO TONGUE OF THE MANCOS SHALE AND THE DALTON SANDSTONE MEMBER OF THE CREVASSE CANYON FORMATION, GALLUP-PINEDALE AREA, NEW MEXICO

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INTRODUCTION

The Dalton Sandstone Member of the Crevasse Canyon Formation is a coastal-barrier sandstone, which prograded northeastward into the San Juan Basin from a maximum landward position approximately eight kilometers north of Gallup, New Mexico.

The Dalton Sandstone Member was named and defined, the type locality was designated, and its distribution with respect to other members of the Crevasse Canyon Formation was described by Sears (1934, p. 16, 17). Additional correlations of the Dalton on the southern and western sides of the San Juan Basin have been made by Hunt (1936, p. 47, 48), Pike (1947), Sears and others (1941, p. 113-115) and Allen and Balk (1954, p. 92, 93). These have been summarized by O'Sullivan and others (1972, p. E31-E34).

Earlier workers in this area (Sears, 1934, p. 17; Sears and others, 1941, p. 113; O'Sullivan and others, 1972, p. E34; and Molenaar, 1973, p. 97, fig. 10) maintained that the upper and lower units of the Dalton combine in the hogback north of Gallup and that the Dalton pinches out into nonmarine facies farther south. Examination of the environments of deposition, which were not considered in earlier studies, lead to a different interpretation. **[Editor's note: see paper by Molenaar elsewhere in this volume on the Pinedale oil seep.]**

METHOD OF STUDY

Stratigraphic relationships of the Dalton Sandstone Member have been observed in detail most recently during geologic mapping along the southern margin of the San Juan Basin (Robertson, 1975, 1976; Kirk and Sullivan, 1976; Kirk and Zech, 1976a, 1976b; and Green and Jackson, 1976).

For this paper, 13 sections were measured at localities near Pinedale and Gallup, New Mexico. Measured sections include descriptions of all units from the Dilco-Mulatto contact at the base to the Gibson Coal Member at the top. Thickness of the units for three additional sections was determined by use of the PG-2 stereoplotter (fig. 1).

Interpretation of the various sedimentary environments is based on a combination of several geologic parameters: grain size distribution, bedding-surface configuration; the presence of fossils and trace fossils, and vertical and lateral changes in the character of the sedimentary units.

GENERALIZED GEOLOGIC SECTION AND ENVIRONMENTAL INTERPRETATIONS

Along the southern margin of the San Juan Basin, the Crevasse Canyon Formation (fig. 2) consists of the following units from bottom to top: the Dilco Coal Member, the lower unit of Dalton Sandstone Member, a lower unnamed tongue, the upper unit of Dalton Sandstone and the Bartlett Barren and Gibson Coal members. The marine Mulatto Tongue of the Mancos Shale intertongues with the Crevasse Canyon Formation, between the Dilco Coal and Dalton Sandstone members. The Crevasse Canyon Formation is underlain by the marine Point Lookout Sandstone which is split into an upper unit and the Hosta Tongue by the Satan Tongue of the Mancos Shale to

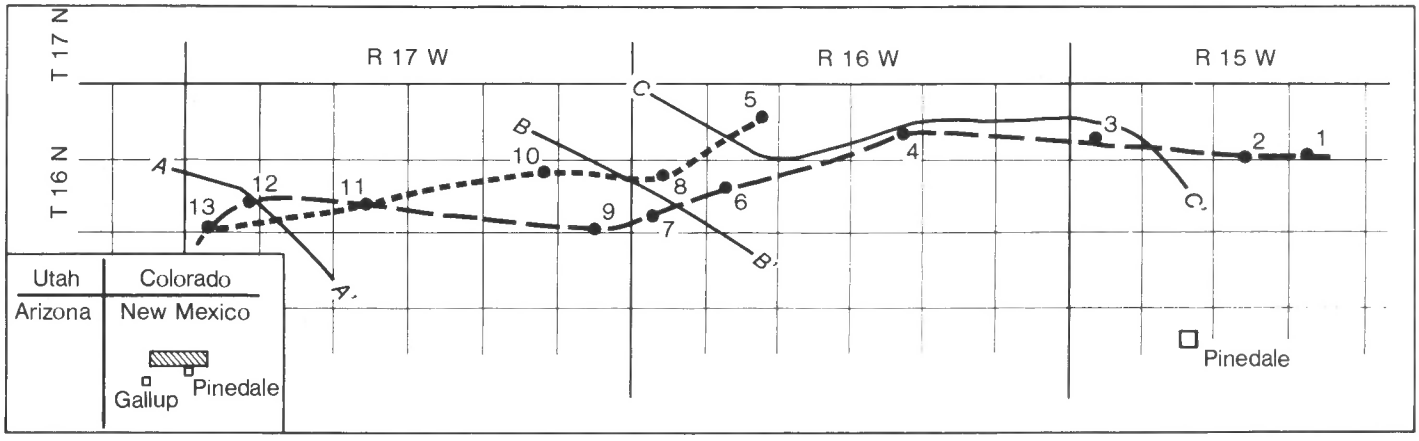


Figure 1. Index map showing: A-A', landward limit of marine upper unit of Dalton Sandstone Member; B-B', landward limit of upper unit of Mulatto Tongue; C-C', seaward limit of unnamed tongue of the Crevasse Canyon Formation. Dashed line indicates location of fence diagram for measured sections 1-4, 6, 7, 9, 11, 12 and 13. Dotted line indicates location of fence diagram for sections 5, 8, 10, 11 and 13.

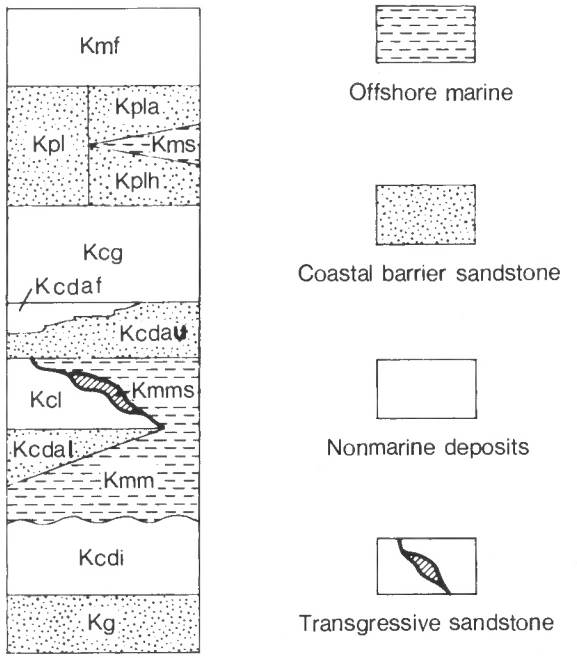


Figure 2. Idealized geologic section showing major environmental facies: (Kg) Gallup Sandstone; Mancos Shale includes: (Kmm) Mulatto Tongue, (Kmms) basal sandstone and pebble conglomerate of the Mulatto Tongue, (Kms) Satan Tongue; Crevasse Canyon Formation includes: (Kcdi) Dilco Coal Member, (Kcdal) Dalton Sandstone Member (lower unit), (Kcl) lower unnamed tongue, (Kcdau) Dalton Sandstone Member (upper unit), (Kcdaf) Dalton Sandstone Member fluvial equivalent, (Kcg) Gibson Coal and Bartlett Barren members, (Kpl) Point Lookout Sandstone; (Kplh) Hosta Tongue, (Kpla) upper unit; (Kmf) Menefee Formation.

the north and east of the study area. The Point Lookout Sandstone is in turn overlain by the nonmarine Menefee Formation. This nomenclature is in agreement with that established by Beaumont and others (1956).

Crevasse Canyon Formation—Nonmarine Sequence

The Deltaic members of the Crevasse Canyon Formation, which include the Dilco Coal and Gibson Coal members and the lower unnamed tongue, are lithologically similar, with only minor variations among them. They consist of complexly interbedded siltstone; light- to dark-gray and purple shale; thin (1-2 m), fine to very fine grained, well-sorted, white to buff, highly bioturbated, laterally continuous "sheet" sandstone; lenticular, very fine grained to medium- and, locally, coarse-grained, moderately well to poorly sorted, white to tan sandstone; minor carbonaceous shale and thin (generally 35 cm), lenticular subbituminous coal beds.

The mudstone, siltstone and sandstone are locally bioturbated and contain variable amounts of carbonaceous material, plant remains, petrified wood and leaf imprints. The lenticular sandstones fine upward and contain medium-scale tabular and trough crossbeds, with troughs most commonly oriented in a northeasterly direction. These lenticular or channel sandstones generally range from 100 to 200 meters in width and 5 to 10 meters in thickness, although locally they may be as much as 30 meters thick. Point-bar accretion surfaces are rare. The lower contacts of the deltaic units are sharp, even though the units locally interfinger with the underlying regressive marine units. Units that vary from this common description include the Bartlett Barren Member, which has a paucity of coals and carbonaceous shales, and the lower unnamed tongue of the Crevasse Canyon Formation, which contains only thin coals (8-20 cm).

The paludal members of the Crevasse Canyon Formation were apparently deposited in marshes and swampy lowlands landward of the coastal barrier sandstone environment. Sandstone lenses were deposited in fluvial channels, probably in braided stream systems. Related overbank deposits are recognized in very fine grained siltstone and sandstone beds. Locally, fluvial sandstone beds, which scour and laterally replace units of the Dalton Sandstone Member may be distributary or estuarine in origin.

Mulatto Tongue of the Mancos Shale

The offshore marine mudstone, siltstone and very fine grained sandstone of the Mulatto Tongue of the Mancos Shale intertongue with the Crevasse Canyon Formation. Individual beds are very well sorted, are locally quite fossiliferous (notably pelecypods) and are bioturbated to varying degrees. The Mulatto Tongue grades from offshore siltstone, mudstone, and shale into sandier facies landward, these sandier facies in turn interfinger with the coastal-barrier sandstone beds of the Dalton Sandstone Member.

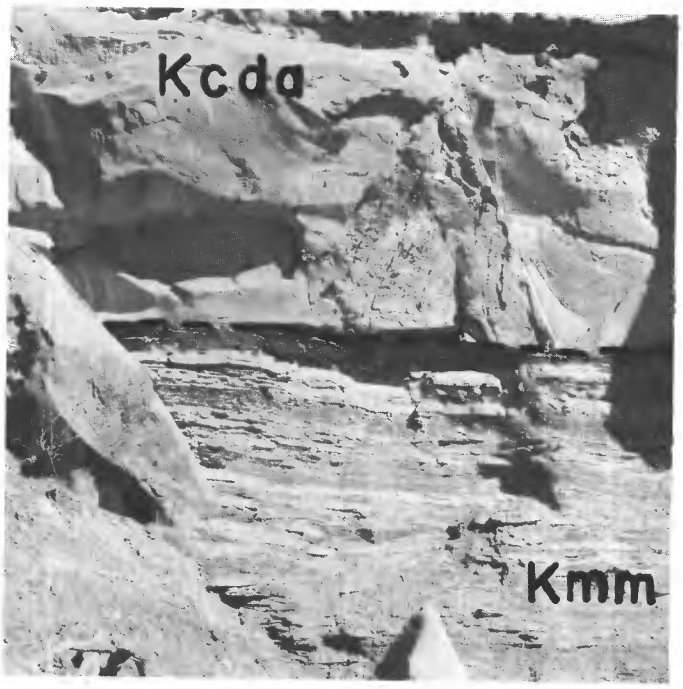
Dalton Sandstone Member of the Crevasse Canyon Formation

Both the upper and lower units of the Dalton Sandstone Member represent regressive coastal barrier sandstone, which prograded across the neritic mudstone, siltstone and sandstone of the Mulatto Tongue of the Mancos Shale. Each unit of the Dalton locally exhibits lower shoreface, upper shoreface and foreshore facies and these units are overlain by paludal deposits of the Crevasse Canyon Formation. The lateral and vertical gradation of these facies demonstrate that both the upper and lower units of the Dalton were deposited during a regressive cycle of sedimentation and are prograding in character. The facies are described below, beginning with the most marine facies and progressing landward.

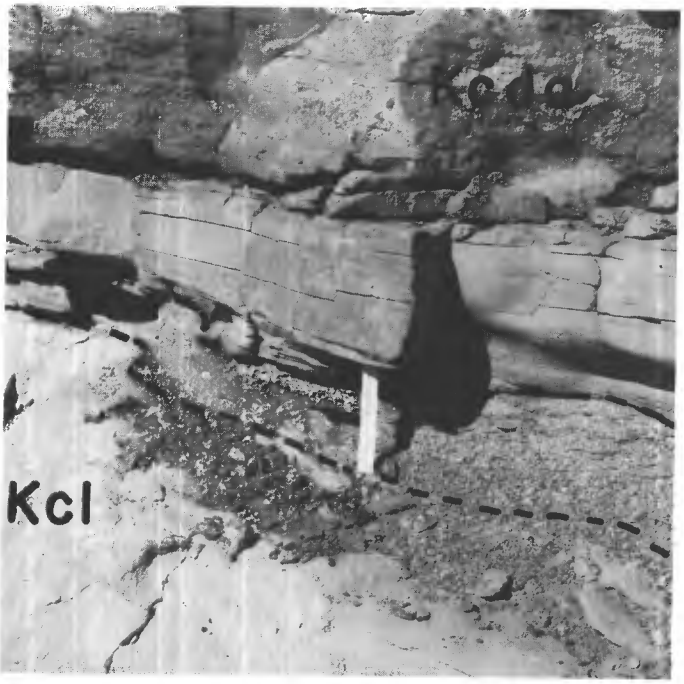
Where the Dalton units are underlain by beds of the Mulatto Tongue, their contacts are gradational and interfingered, forming transitional zones of variable thickness (3-10 m); these zones are composed of interbedded, very fine grained, well-sorted, thin sandstone, siltstone and mudstone. Grain size, as well as the abundance and thickness of sandstone beds in the Mulatto Tongue, increases upward and landward toward the coastal-barrier sandstone (fig. 3A). The contact between the Mulatto Tongue and the Dalton Member is placed arbitrarily at the base of the first sandstone bed above the zone of interfingering.

The lowermost facies of the Dalton Sandstone Member is a very fine grained well sorted, burrowed, yellowish gray to tan sandstone, which has both flat and cross-stratified bedding. Cross stratification is commonly low angle (5 to 15°) and similar to that described as hummocky cross bedding by Harms and others (1975, p. 87-89). This facies ranges from 1 to 10 meters in thickness and is present in most measured sections (fig. 3B). Beds of this facies are interpreted to have been deposited in a lower shoreface environment.

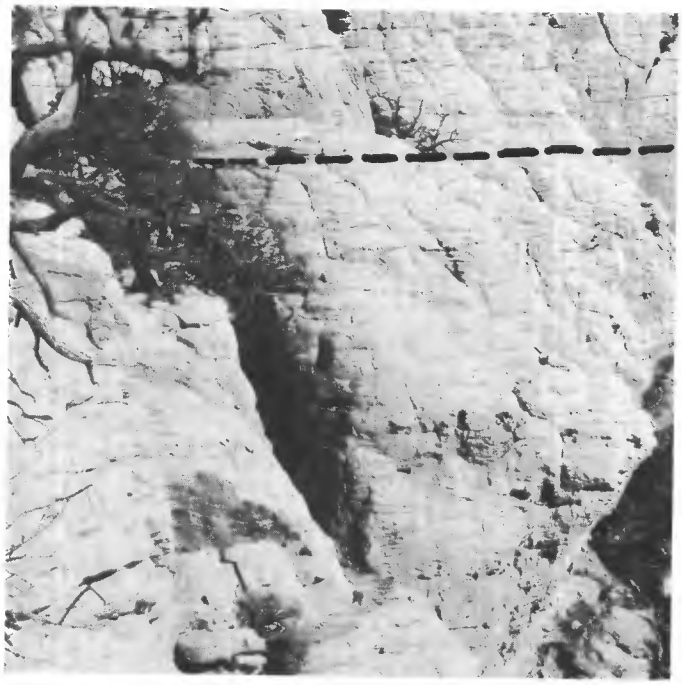
The upper shoreface facies is represented by a generally fine, to very fine grained (but medium- and coarse-grained in



3A



3B



3C



3D

Figure 3. Sandstone facies: 3A, transitional zone between the Mulatto Tongue (Kmm) and the upper unit of Dalton Sandstone Member (Kcda)—location near measured section 6; 3B, fluvial sandstone (Kcl) overlain by the transgressive pebble conglomerate (6" ruler) and by flat-bedded lower shoreface beds of the Dalton Sandstone Member (Kcda)—location near measured section 11; 3C, trough-crossbedded upper shoreface units overlain by flatbedded foreshore beds—location near measured section 7; 3D, transgressive pebble conglomerate (Kmms)—location between measured section 2 and 3.

some troughs), well sorted buff to tan, calcareous sandstone that is almost exclusively low angle, trough cross stratified with sets ranging from 10 to 60 centimeters in thickness. The lower contact with the underlying facies is almost always sharp and scoured. No marine fossils were found in this zone and burrowing is rare. This facies is the thickest of the three (10-20 m) and is the most commonly preserved (fig. 3C).

The foreshore facies, which is poorly preserved and present in only a few of the measured sections, is composed primarily of fine-grained, well-sorted, white to buff, calcareous sandstone mostly in beds 10 to 20 centimeters thick that have depositional dips of a few degrees in a seaward direction. These beds also exhibit low-angle cross stratification inclined seaward. Locally this facies is burrowed, but no fossils have been found. The contact with the underlying trough-cross-bedded facies may be sharp where the lower crossbedded unit is truncated, or gradational where crossbedded sets are destroyed by burrow mottling. Root tubes from overlying paludal sequences are common in the upper few centimeters. Weathered surfaces above the foreshore facies and on top of the upper unit of the Dalton Sandstone Member are commonly marked by petrified wood. Excellent exposures of this facies may be seen at the top of the upper unit of the Dalton at the heads of the valleys in section 33, T. 17 N., R. 16 W., N.M.P.M. It is also well exposed at the top of the lower unit of the Dalton near measured section 6 (fig. 3C).

The lateral and vertical distribution of these facies indicate that both the upper and lower units of the Dalton are prograding regressive sequences. A transition from offshore mudstone, siltstone and sandstone of the Mulatto Tongue of the Mancos Shale upwards into the coastal-barrier sandstone of the transition zone records the beginning of a regression, with a vertical sequence of lower shoreface at the base, upper shoreface, and finally foreshore at the top of the units. Overlying the Dalton units are paludal deltaic units, which complete the overall regressive sequence.

The lateral and vertical distribution of these facies are similar to those described by Peterson (1969, p. J17), Davies and others (1971, p. 553-556). Land (1972, p. 25-54), Molenaar (1973, p. 86-88), and Harms and others (1975, p. 84-91) for other coastal-barrier sandstones.

Transgressive Sandstone

Above the lower sandstone unit of the Dalton Member in the central and western portion of the study area, lies a southwesterly thickening wedge of deltaic rocks of the lower unnamed tongue of the Crevasse Canyon Formation (Kel, fig. 2). These nonmarine beds are separated from the overlying beds of the Mulatto Tongue by a thin zone (0-4 m) of very coarse, pporly sorted, highly crossbedded relatively continuous (blanket or sheet-like) pebble conglomerate and sandstone (Kmms, fig. 2). The pebbles and granules are largely quartzite and chert as much as 15 centimeters in diameter. Abraided bits of bone, shell and petrified wood are found in places. Shark teeth are common, and in one locality ophiomorpha burrows, indicating marine or marginal-marine conditions, are present. Thin marine sandstone beds overlying and locally replacing the conglomerates also have pebbles scattered along bedding surfaces in the lower meter or two of the unit. The poorly sorted sandstone and pebble conglomerate represent basal reworked deposits of the transgressive sea (fig. 3B, 3D). The transgressive cycle of deposition is further supported by the offshore-marine deposits of the overlying Mulatto Tongue of the Mancos Shale.

Dilco-Mulatto Transgression

From the outcrops north of Pinedale westward (fig. 1), the poorly exposed contact between the Dilco Coal Member and the overlying transgressive Mulatto Tongue is mainly shale on shale. Generally this contact is recognized by color change at the outcrop between the gray- and reddish-brown-weathering carbonaceous beds of the Dilco Coal Member and the overlying light yellow brown weathering neritic shale of the Mulatto Tongue. Sporadically along the contact at the base of the Mulatto, thin lenses of poorly sorted, coarse-grained sandstone containing chert and quartzite pebbles and a few shark teeth occur. The contact marks an erosional unconformity. In areas to the east, the Mulatto Shale Tongue rests on truncated beds of the Dilco Coal Member at an angle of approximately one degree (J. F. Robertson, oral commun., 1977). The deltaic Dilco beds were laid down with a slight depositional slope. The invasion of the Mulatto sea then produced a wave-cut erosion surface having a graded profile that transects the bedding in the Dilco Coal Member, and the result is a very slight angular unconformity with the overlying beds of the Mulatto Tongue. The amount of material removed by reworking during transgression of the Mancos sea is uncertain, and the amount of time represented by this break is unknown.

The Carlile-Niobrara time break of the western interior reference sequence traditionally has been placed at the same general horizon as the Dilco-Mulatto contact; however, good paleontological evidence of a time break is lacking close to the contact. On the southern and western sides of the San Juan Basin, the character of the basal Niobrara transgression and unconformity has been documented by Molenaar (1973, p. 100-106).

CORRELATIONS WITHIN THE STUDY AREA

Both the upper and lower units of the Dalton Sandstone Member represent regressive cycles of clastic sedimentation, which prograded northeastward into the Late Cretaceous sea. The essentially east-west line of outcrops within the study area is oblique to the southeast-trending shoreline of the Dalton. Two fence diagrams along lines of measured sections illustrate the sedimentological changes across the shoreline from seaward to landward—northeast to southwest (figs. 4A and 4B). See Figure 1 for the location of the measured sections.

On the east side of the study area, the offshore marine deposits of the Mulatto Tongue of the Mancos Shale lie between the Dilco Coal and Dalton Sandstone members (figs. 4A and 4B). The beds of the Mulatto Tongue were deposited in a sea which invaded from the northeast and the transgression is marked by an unconformity at the top of the Dilco Coal Member. A minor regression in the marine interval is seen where the lower unit of the Dalton Sandstone Member first appears within the Mulatto Tongue and thickens rapidly to the southwest. The overlying segment of the Mulatto records a new transgressive pulse as it rests unconformably on the lower regressive unit of the Dalton to the east, and on the paludal deposits of the lower unnamed tongue of the Crevasse Canyon Formation to the west. The onset of this transgression is marked by thy basal Mulatto deposits of a thin transgressive sandstone and pebble conglomerate.

The upper segment of the Mulatto Tongue is overlain by the upper regressive unit of the Dalton Sandstone Member, which is in turn overlain by the paludal deltaic rocks of the Gibson Coal Member. Locally along the western end of this outcrop belt and west of the Mulatto Tongue pinch-out, the beds between the upper and lower units of the Dalton Sandstone Member are predominantly sandstone, with only minor carbonaceous shale and coal beds. Detailed examination reveals that these sandstones are fluvial-channel sandstones rather than coastal barrier sandstones (fig. 5). The upper unit of the Dalton grades landward (southwesterly) into laterally equivalent fluvial sandstones. One and a half kilometers southwest of section 13 (fig. 4A) this fluvial equivalent of the upper unit of the Dalton pinches out in the paludal beds of the Crevasse Canyon Formation. Three kilometers southwest, the lower unit of the Dalton interfingers with and is laterally replaced by fluvial sandstone, which subsequently pinches out to the south (Green and Jackson, 1976; T. J. Jackson, oral commun., 1976).

Where both units of the Dalton are replaced by fluvial sandstone, the entire Crevasse Canyon Formation becomes completely nonmarine. Likewise, with the pinch-out of the Point Lookout Sandstone in T. 17 N., R. 17 W., N.M.P.M. (Kirk and Zech, 1976b), the entire geologic section from the top of the regressive Gallup Sandstone through the Menefee Formation is characterized by continuous nonmarine deposition. Lines A-A′, B-B′, and C-C′ on Figure 1 show the limit of three sedimentary units.

THE DALTON SANDSTONE MEMBER IN OTHER PARTS OF THE BASIN

Allen and Balk (1954, p. 92) maintain that in the Tohatchi area, approximately 40 kilometers northwest of Gallup, New Mexico, both the upper and lower units of the Dalton Sandstone Member are underlain by the Dilco Coal Member. They concluded: *"Towards the southern edge of the map, the lower unit* [of the Dalton Sandstone Member] *disappears and the upper unit thins markedly."*

In contrast to this earlier study, O'Sullivan and others (1972, p. E23) maintained that, in the Tohatchi area, the Mulatto Tongue underlies the upper unit of the Dalton. They speculated that the sandstone lying between the Satan and Mulatto tongues, north of the Chuska Mountains near Toadlena, is the coalesced Hosta Tongue of the Point Lookout Sandstone and the Dalton Member. They emphasized, however, that these coalescing relationships are concealed by the Tertiary rocks of the Chuska Mountains (O'Sullivan and others, 1972, p. E34). The combined sandstone pinches out into marine shale about 5 kilometers southeast of Toadlena.

On the southeast side of the San Juan Basin, south of Cabezon and west of Bernalillo, Hunt (1936, p. 48, 49) and Sears and others (1941, p. 115 and plate 26) described the Dalton Sandstone Member as both rising stratigraphically and merging with the Hosta Tongue of the Point Lookout Sandstone. They stated that the Hosta Tongue . . . *"gradually loses its identity. By lateral gradation this sandstone and the Dalton Sandstone Member, together with the intervening coal bearing beds of the lower Gibson, become represented by a single sandstone between an expanded Mulatto and Satan tongues"* (Sears and others, 1941, p. 115). The seaward coalescing of the Dalton Sandstone Member and the Hosta Tongue of the Point Lookout Sandstone is further documented by subsurface studies in the south-central and south-eastern portions of the basin by Molenaar (1973, p. 99, fig. 11; and 1974, p. 253, 254, figs. 2 and 3).

The authors of this paper have noted a different relationship northeast of the study area. North of Dalton Pass and Crownpoint, New Mexico, the Hosta Tongue of the Point Lookout Sandstone thins dramatically and pinches out between an expanded Satan Tongue of the Mancos Shale and the Gibson Coal Member of the Crevasse Canyon Formation (Kirk and Sullivan, 1976).

CONCLUSIONS

From the geologic descriptions of the interfingering between the Crevasse Canyon Formation and the Mulatto Tongue of the Mancos Shale, as well as from the spatial arrangement of various facies within the coastal barrier sandstones, the upper and lower units of the Dalton Sandstone Member have been shown to be separate regressive coastal-barrier sequences. A marine transgression and unconformity is recorded between the Dilco Coal Member and the Mulatto Tongue of the Mancos Shale. A second marine transgression and unconformity, marked by a thin transgressive sandstone and marine shale, is recorded at the top of the lower unit of the Dalton. This transgression and unconformity rises stratigraphically in a landward direction (southwestward) across the lower unit of Dalton Sandstone Member and into the lower unnamed nonmarine tongue of the Crevasse Canyon Formation. Farther landward, the overlying Mulatto Tongue pinches out, and the upper and lower units of the regressive Dalton remains separate, and thin and pinch out by interfingering with the deltaic members of the Crevasse Canyon Formation.

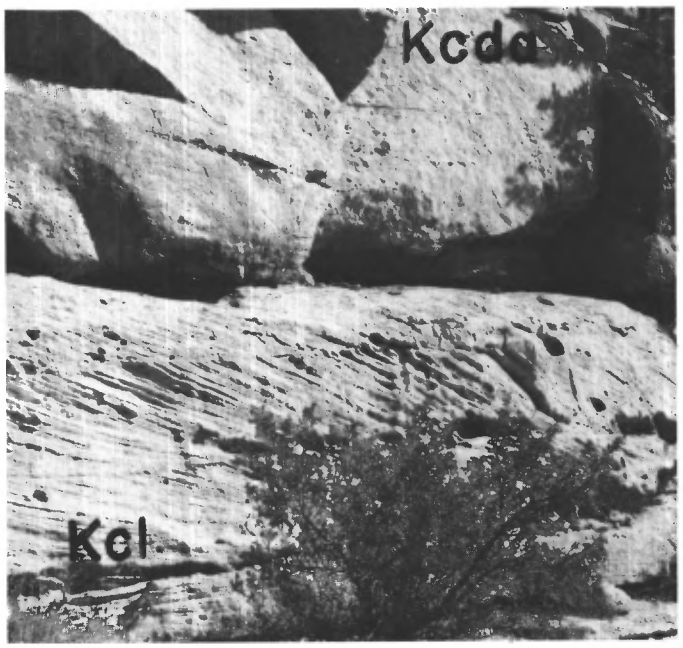


Figure 5. Fluvial sandstone of the lower unnamed tongue of the Crevasse Canyon Formation (Kcl) overlain by a very thin transgressive pebble conglomerate (in weathered notch) which in turn is overlain by a poorly sorted, flat bedded interval of the Dalton Sandstone Member (Kcda) which is lower shoreface.

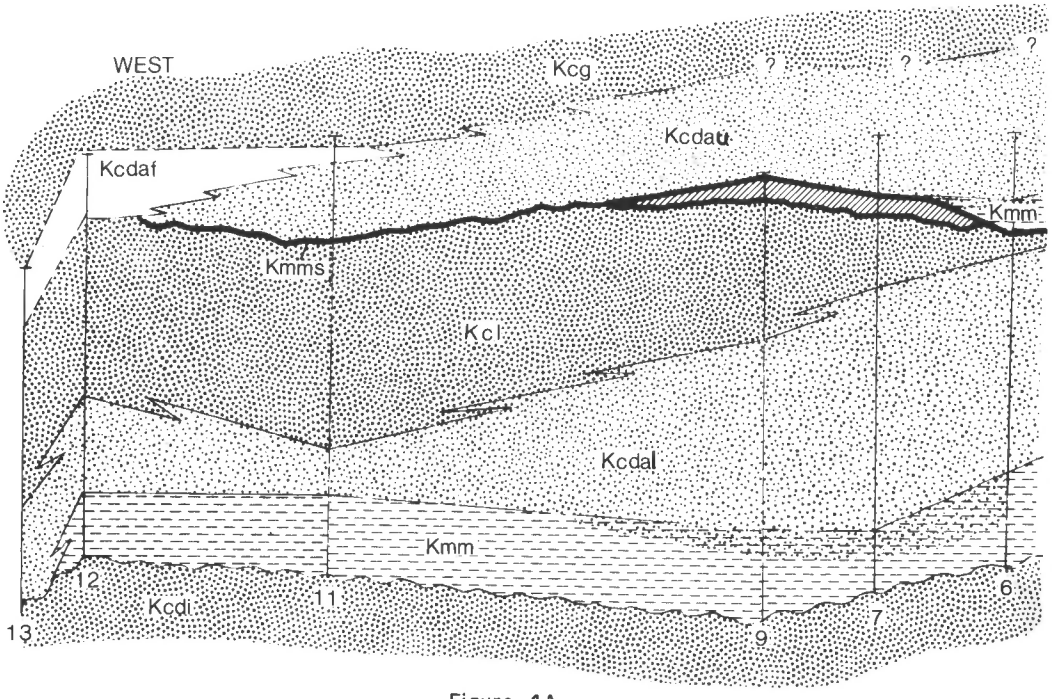


Figure 4A.

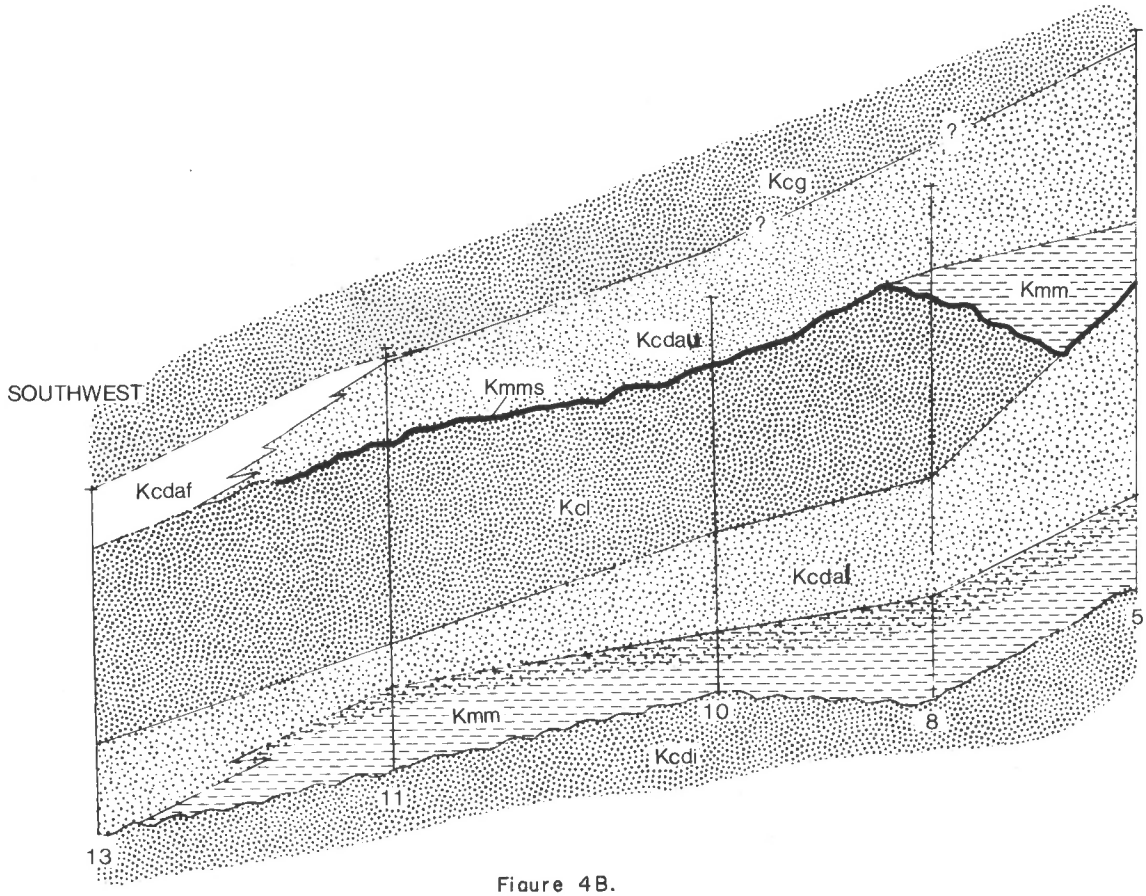


Figure 4B.

Figure 4. Fence diagrams showing correlations within the study area: 4A, east-west fe

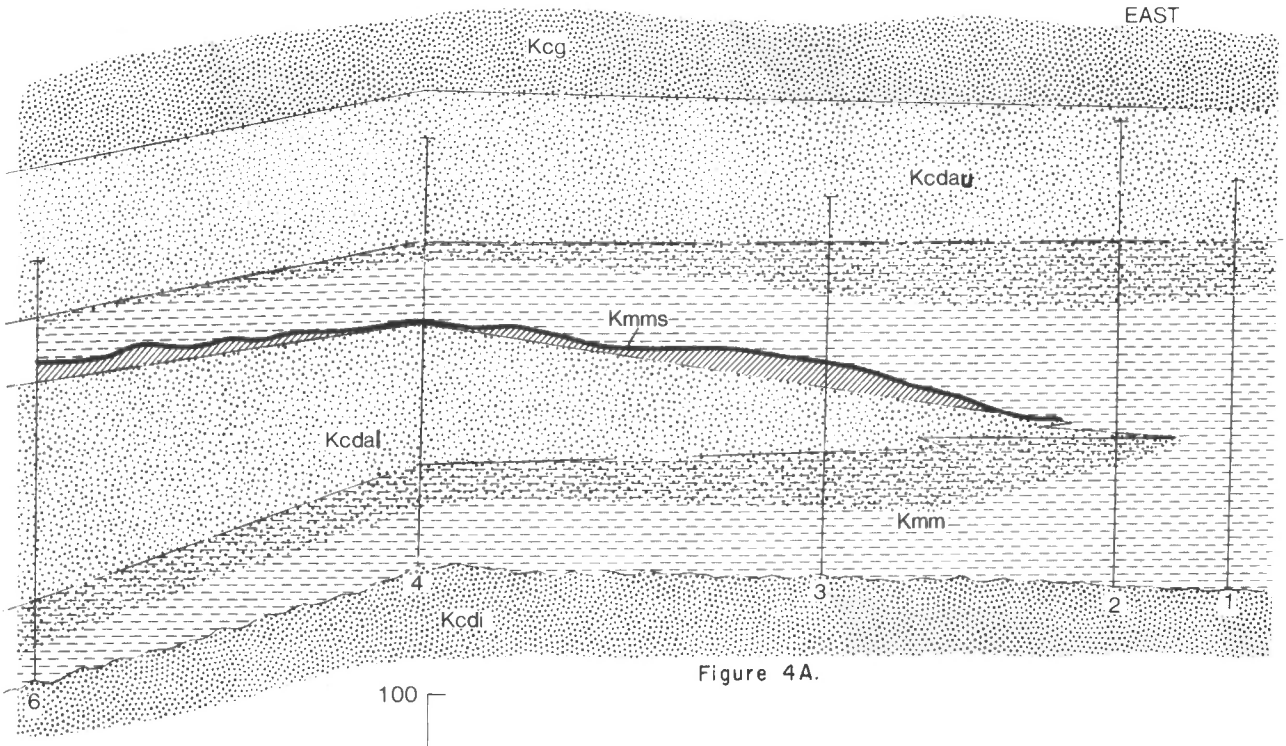
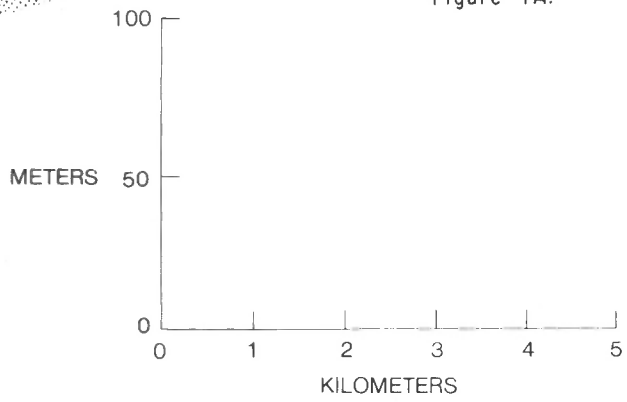


Figure 4A.



EXPLANATION

Nonmarine deposits

Coastal-barrier sandstone

Transitional zone (Mulatto Tongue-Dalton Sandstone Member)

Offshore marine siltstone

Transgressive sandstone and pebble conglomerate

Fluvial-estuarine? sandstone

northeast-southwest fence. Symbols are explained on Figure 2. Traces of cross sections are shown on Figure 1.

REFERENCES

Allen, J. E., and Balk, R., 1954, Mineral resources of the Fort Defiance and Tohatchi quadrangles, Arizona and New Mexico: New Mexico Bur. Mines and Mineral Resources Bull. 36, 192 p.

Beaumont, E. C., Dane, C. H., and Sears, J. D., 1956, Revised nomenclature of Mesaverde Group in San Juan Basin, New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 9, p. 2149-2162.

Davies, D. K., Ethridge, F. G., and Berg, R. R., 1971, Recognition of barrier environments: Am. Assoc. Petroleum Geologist Bull., v. 55, no. 4, p. 550-565.

Green, M. W., and Jackson, T. J., 1976, Preliminary geologic and structure contour maps of the Gallup East quadrangle, McKinley County, New Mexico: U.S. Geol. Survey Open-File Report 76-453, 2 pl.

Harms, J. C., Southard, J. B., Spearing, DR., and Walker, R. G., 1975, Depositional environments as interpreted from primary sedimentary structures and stratification sequences: Lecture Notes for Shore Course No. 2, S.E.P.M., Dallas, Texas, April 5, 1975, 161 p.

Hunt, C. B., 1936, The Mount Taylor Coal Field, Part 2, of Geology and fuel resources of the southern part of the San Juan Basin, New Mexico: U.S. Geol. Survey Bull. 860-B, p. 31-80.

Kirk, A. R., and Sullivan, M. W., 1976, Preliminary geologic map of the Dalton Pass quadrangle, McKinley County, New Mexico: U.S. Geol. Survey Open-File Report 76-184, 1 pl.

Kirk, A. R. and Zech, R. S., 1976a, Preliminary geologic and structure contour maps of the Oak Spring quadrangle, McKinley County, New Mexico: U.S. Geol. Survey Open-File Report 76-347, 2 pl.

Kirk, A. R. and Zech, R. S., 1976b, Preliminary geologic and structure contour maps of the Hard Ground Flats quadrangle, McKinley County, New Mexico: U.S. Geol. Survey Open-File Report 76-859, 2 pl.

Land, C. B., Jr., 1972, Stratigraphy of Fox Hills Sandstone and associated formations, Rock Springs uplift and Wamsutter Arch area, Sweetwater County, Wyoming—A shoreline-estuary sandstone model for the Late Cretaceous: Colorado School of Mines Quart., v. 67, no. 2, 69 p.

Molenaar, C. M., 1973, Sedimentary facies and correlation of the Gallup Sandstone and associated formations, northwestern New Mexico, *in* Fassett, J. E., ed., Cretaceous and Tertiary rocks of the southern Colorado Plateau: Four Corners Geol. Soc., p. 85-110.

——— 1974, Correlation of the Gallup Sandstone and associated formations, Upper Cretaceous, Eastern San Juan and Acoma Basins, New Mexico, *in* Siemers, C. T., ed., *in* 25th Ann. Field Conf., Ghost Ranch, Central-Northern New Mexico, 1974: p. 251-258.

O'Sullivan, R. B., Repenning, C. A., Beaumont, E. C., and Page, H. G., 1972, Stratigraphy of the Cretaceous rocks and the Tertiary Ojo Alamo Sandstone Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah: U.S. Geol. Survey Prof. Paper 521-E, 65 p.

Peterson, Fred, 1969, Four new members of the Upper Cretaceous Straight Cliffs Formation in the southeastern Kaiparowits region, Kane County, Utah: U.S. Geol. Survey Bull. 1274-J, 28 p.

Pike, W. S., 1947, Intertonguing marine and nonmarine Upper Cretaceous deposits of New Mexico, Arizona, and southwestern Colorado: Geol. Soc. America Mem. 25, 103 p.

Robertson, J. R., 1975, Preliminary geologic map of the Hosta Butte quadrangle McKinley County, New Mexico: U.S. Geol. Survey Open-File Report 75-302, 1 pl.

Robertson, J. R., 1976, Preliminary geologic map of the Casemero Lake quadrangle, McKinley County, New Mexico: U.S. Geol. Survey Open-File Report 76-681, 1 pl.

Sears, J. D., 1934, The coal field from Gallup eastwards towards Mount Taylor with a measured section of pre-Dakota (?) rocks near Navajo Church, Part 1, of Geology and fuel resources of the southern San Juan Basin, New Mexico: U.S. Geol. Survey Bull. 860-A, p. 1-29.

Sears, J. D., Hunt, C. B., and Hendricks, T. A., 1941, Transgressive and regressive Cretaceous deposits in southern San Juan Basin, New Mexico: U.S. Geol. Survey Prof. Paper 193-F, p. 101-121.

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