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THE DAKOTA SANDSTONE AND MANCOS SHALE OF THE EASTERN SIDE OF SAN JUAN BASIN, NEW MEXICO

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ABSTRACT

In the northeastern part of the San Juan Basin, New Mexico, the Dakota sandstone of Late Cretaceous age is about 200 feet thick. It is overlain by 2,000 feet of Mancos shale divided into five members, successively upward, the Graneros shale, Greenhorn limestone, Carlile shale, Niobrara calcareous shale, and an unnamed upper member. Beds of Niobrara age in the northeastern part of the Basin rest on an unconformity, which is represented by about 400 feet of beds in the southern part of the basin including much of the Gallup sandstone. Other stratigraphic changes from southwest to northeast are described, principally those that result from the northeastward thinning and termination of tongues of littoral and offshore sandstones that form part of the Mesaverde group of the southern part of the Basin.

INTRODUCTION

In the northeastern part of the San Juan Basin, New Mexico, the lower part of the section of Cretaceous rocks includes the Dakota sandstone, about 200 feet thick; the overlying Mancos shale, about 2,000 feet thick; and three formations of the Mesaverde group that merge northeastward into an indivisible sequence of sandstone and shale. These formations are overlain by younger Cretaceous and Tertiary rocks that dip gently westward into the central part of the basin.

The present paper deals only with the stratigraphy and correlation of the Dakota sandstone and Mancos shale of the northeastern part of the Basin with equivalent beds of the southern part. It is based chiefly on mapping done by the writer and several associates in 1933 and 1936 to 1938 from the west side of the southern part of the Nacimiento Mountains northward to the Colorado—New Mexico boundary, in the vicinity of Chama, New Mexico (fig. 1). A preliminary map showing geologic structure (Dane and Bryson, 1938) and a geologic map of part of the area and a short description of the geology have appeared (Dane, 1948). From time to time during the succeeding years reconnaissance stratigraphic observations of the Cretaceous rocks in other parts of the basin have been made by the writer and associates and reported on in part (Dane, Wanek, and Reeside, 1957; Dane, Bachman, and Reeside, 1957; Dane and Bachman, 1957). These observations, although scattered and incomplete, have resulted in some modification of previous interpretations of the regional stratigraphic relations of the lower part of the section of Upper Cretaceous rocks in the San Juan Basin. One important modification is the concept of an extensive unconformity in the northern part of the Basin at the base of the rocks of the age of the **Inoceramus deformis** zone. This zone is present in the middle to upper part of the Fort Hays limestone member at the base of the Niobrara formation in the Arkansas Valley region in eastern Colorado (W. A. Cobban, oral communication, Sept. 30, 1959). The concept of this unconformity was briefly outlined in a paper by the writer that appeared in April 1960, in the Bradley volume of the American Journal of Science. The present discussion reinterprets the observations made many years ago in the northeastern part of the San Juan Basin in the light of the above mentioned reconnaissance studies in other parts of the Basin and also adds some details to the writer's previously published descriptions of the Dakota sandstone and Mancos shale. As a necessary background for the present description of stratigraphic relations on the east side of the Basin, figures 1, 2, and 3 of the previously cited paper in the American Journal of Science are reproduced in this guidebook although reference will be made principally to figure 3.

Dakota Sandstone

The Dakota sandstone includes very fine to coarse-grained, locally conglomeratic sandstone, crossbedded and parallel-bedded, and dark-gray to black carbonaceous shale and siltstone. On the eastern side of the San Juan Basin it ranges from about 120 feet to somewhat more than 200 feet in thickness. It varies markedly from place to place in lithologic character, in some places consisting chiefly of coarser grained clastic rocks, in others including half or more of fine grained carbonaceous shale and siltstone. In many places, it appears to rest on an erosional unconformity cut in the underlying Morrison formation, but no angular discordance has been observed and the unconformity is nowhere conspicuous. Because both the top of the Morrison and the base of the Dakota may consist of sandstone or conglomeratic sandstone not strikingly dissimilar in gross lithology, the contract can in some places be located only by close inspection. On such inspection, however, the formations are readily discriminated, the sandstone of the Morrison being white or having a slightly greenish cast in distinction to the normal weathered colors of the Dakota sandstone, very pale orange, tan, or brown.

The Morrison sandstone units are ordinarily coarser grained, commonly conglomeratic, and more strikingly crossbedded and lenticular. A somewhat more tangible criterion is the almost universal occurrence in the sandstone of the Dakota of carbonaceous material, either as specks distributed through the rock, as films or sheets along the bedding surfaces, as recognizable residues of stems or parts of plants, and more rarely as small blocks of mineral charcoal. Such carbonaceous plant debris is absent or exceedingly rare in the Morrison, in which, however, silified wood is not uncommon.

Most typically the Dakota of this region consists of a top hard massive ledge of fine-grained tan to brown quartzitic sandstone, 50 feet or more thick, and an underlying sequence of generally softer beds consisting of an alternation of velvety black thin-bedded shale, gray sandy shale, and light-tan bedded sandstone (fig. 7). The upper ledge of sandstone in places breaks up into an

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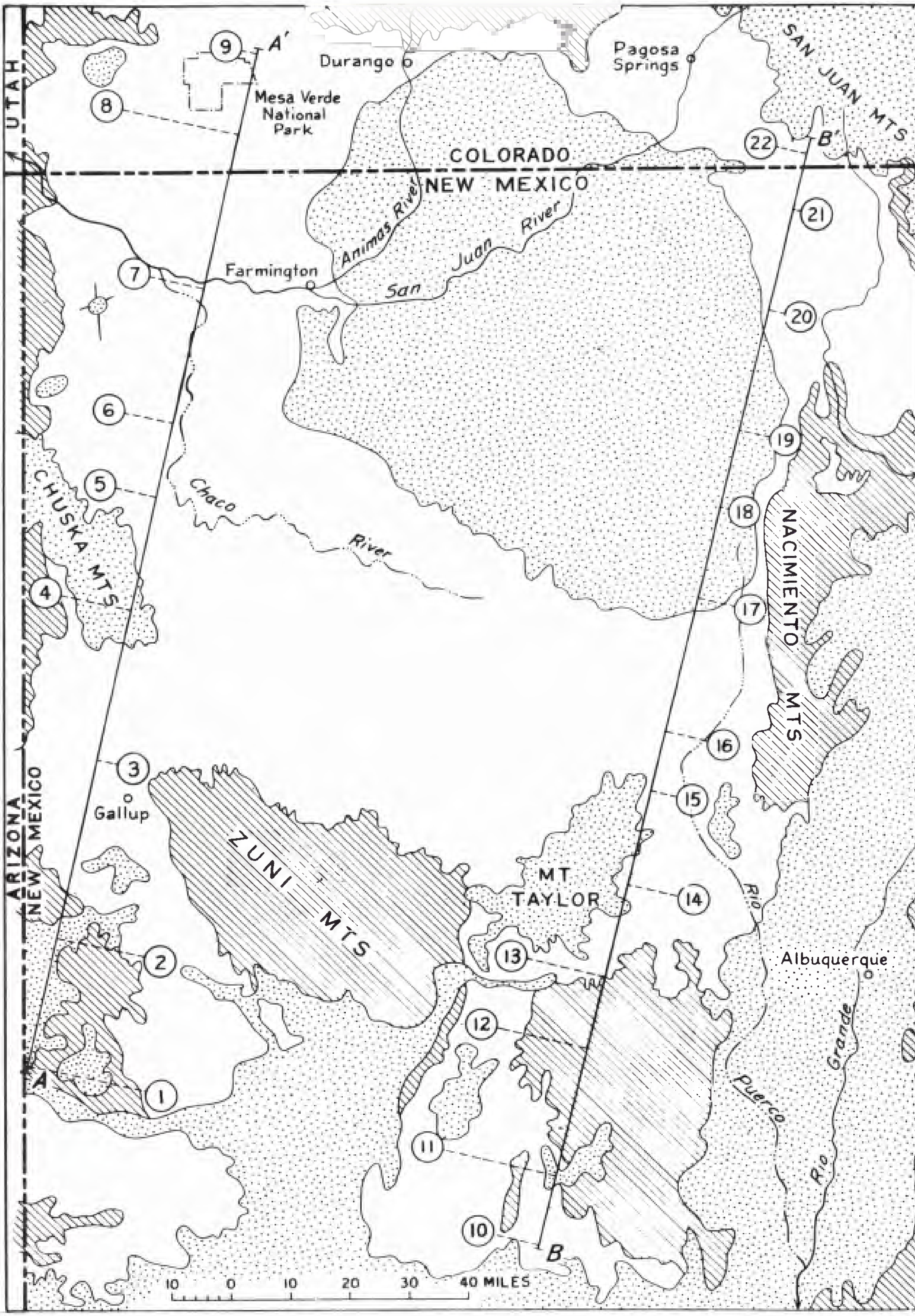

Figure 1. Index map of part of northwestern New Mexico and southeastern Colorado showing locality numbers projected into lines of sections A-A' (fig. 2) and B-B' (fig. 3). Tertiary and Quaternary rocks and surficial deposits (stippled), Jurassic and older rocks (lined), and Cretaceous rocks (unpatterned). [From Dane, 1960, American Journal of Science, v. 258A, Bradley Volume, fig. 1]

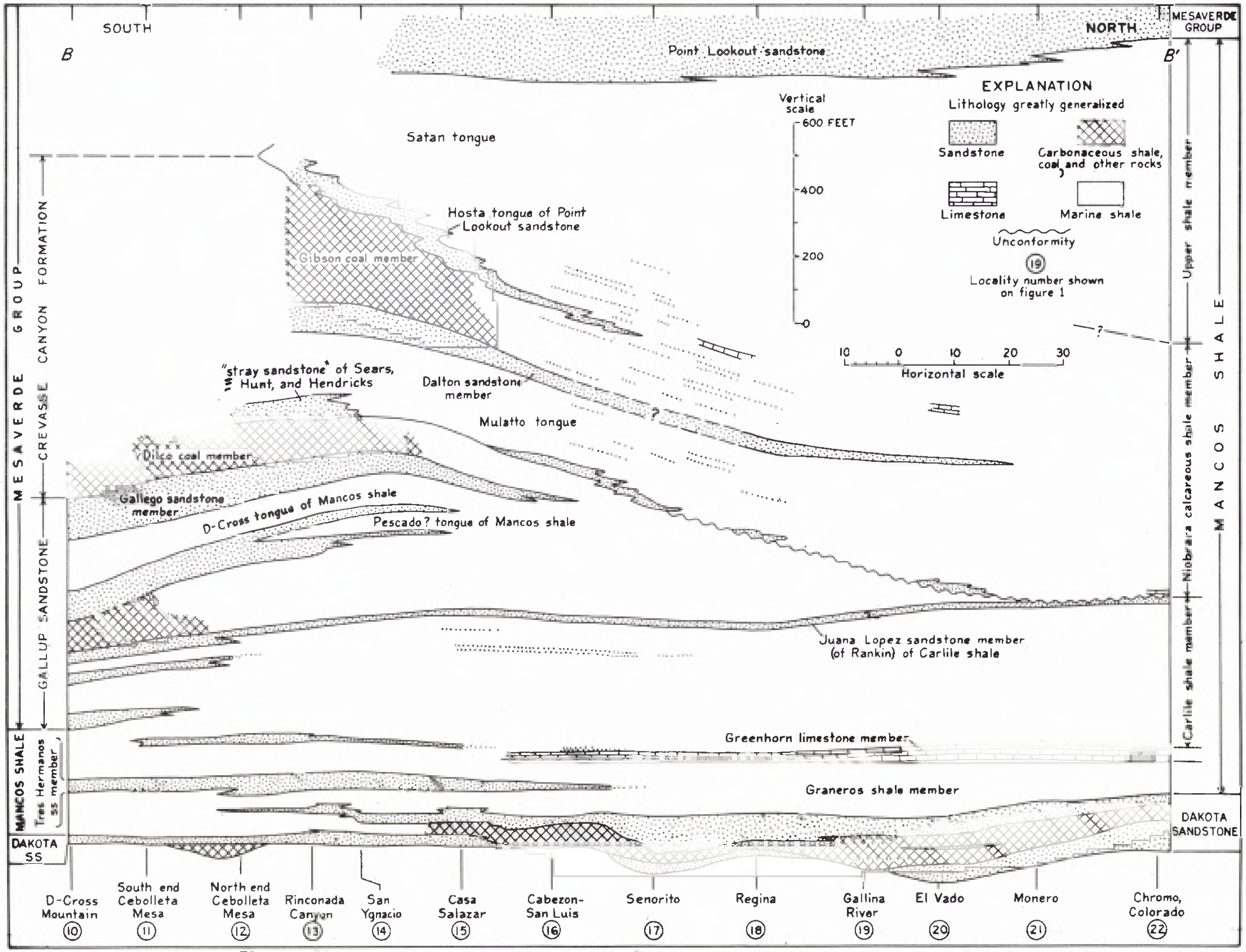

Figure 3. Diagrammatic interpretation of the intertonguing relations of the Dakota sandstone, Mancos shale, and the lower formation of the Meraverde group on the east side of the San Juan Basin from D-Cross Mountain, Socorro County, New Mexico, to Archuleta County, Colorado. [From Dane, 1960, American Journal of Science, v. 258 A, Bradley Volume, fig. 2, as incorrectly titled on p. 49 of original publication]

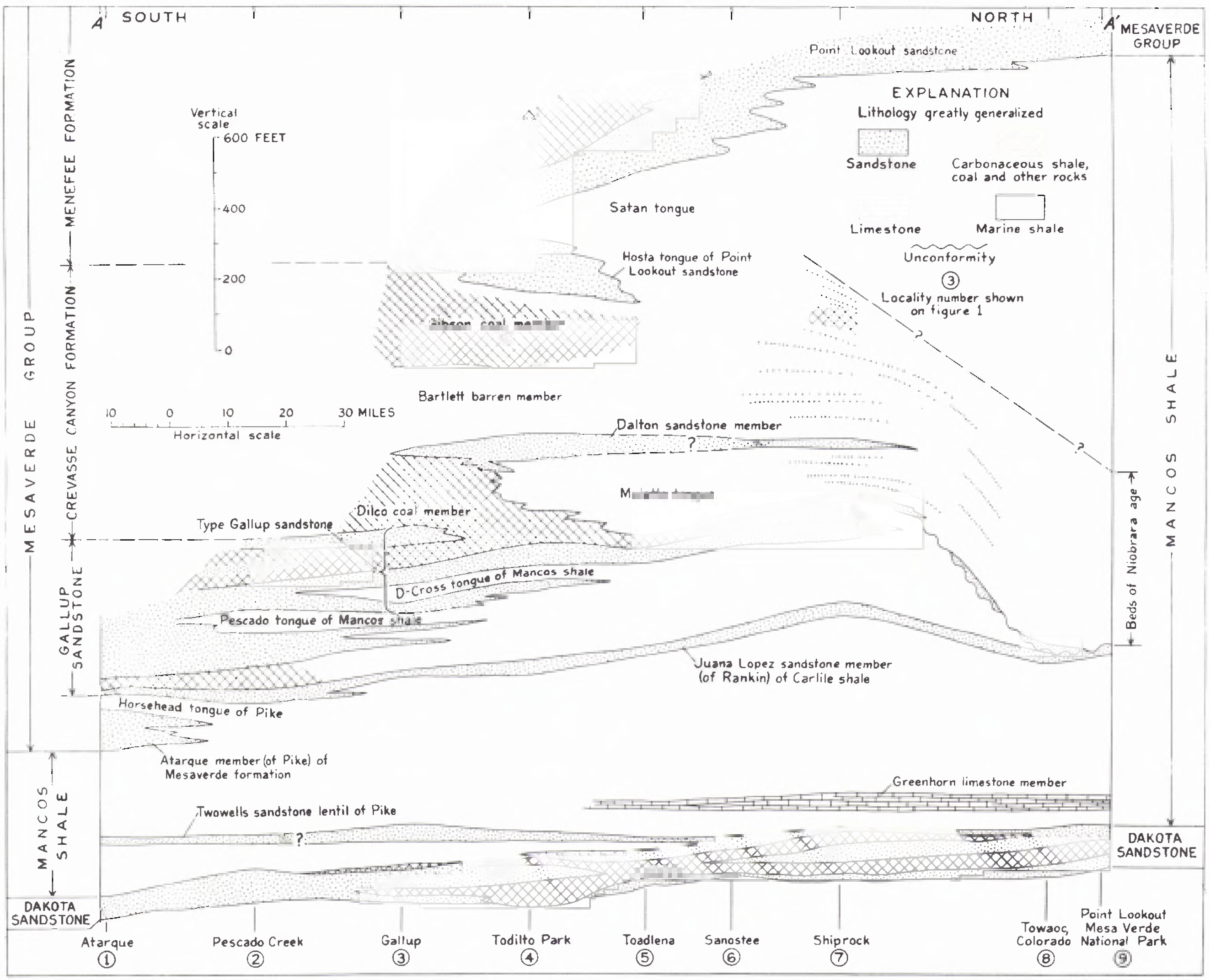

Figure 2. Diagrammatic interpretation of the intertonguing relations of the Dakota sandstone, Mancos shale, and the lower formations of the Mesaverde group on the west side of the San Juan Basin from Atarque, Valencia County, New Mexico, to Point Lookout, Mesa Verde National Park, Colorado. [From Dane, 1960, American Journal of Science, v. 258A Bradley Volume, fig. 3, as incorrectly titled on p. 51 of original publication]

Figure 7. Dakota sandstone on north bank of Rio Gallina in southwestern part of section 15, T. 24 N., R. 1 E. White patch in bank at right of center is conglomeratic sandstone of top of Morrison formation, succeeded above toward left by carbonaceous shale and tan sandstone of the Dakota sandstone.

alternation of sandstone and shale so that the topmost ledge is 20 feet or less in thickness. In places there is a tendency for closer grouping of sandstone beds in the lower part of the formation. Much of the sandstone has a siliceous cement and some beds fracture as readily through the constituent grains as around them.

Much of the Dakota bears evidence of subaqueous deposition in relatively quiet waters in its regular even bedding, the bedding surfaces being marked with thin sheets of carbonaceous debris. Current ripple marks are common, though rarely well displayed, and fucoids and miscellaneous "borings" are typical. The thick beds of thinly laminated black shale indicate deposition in still though not necessarily deep water.

The rarity of conspicuous lenses and channel fillings of sandstone in much of the Dakota suggest that in this region fluviatile deposition was not significant. The general aspect of the Dakota and its conformable position beneath the following marine sequence suggest that in this region much of it was deposited in a lagoonal environment on a previously developed surface of low relief in the initial stages of the widespread submergence under the Late Cretaceous sea.

About 80 miles south of the Colorado-New Mexico line, on the west side of the Nacimiento Mountains, about 15 miles south of Senorito (locality 17, fig. 3) the thickness and relative proportion of coarse clastic component of the Dakota begin to diminish markedly. Within a few miles the lower half to two-thirds of the unit consists chiefly of carbonaceous shale. The upper ledge diminishes also in thickness and coarseness of material southward and southwestward at a level about 80 feet below the northeasterly thinning wedge-edge of the Tres Hermanos sandstone member of the Mancos shale of the southern part of the Basin. According to the writer's interpretation, the upper ledge of the Dakota sandstone of the eastern side of the San Juan Basin is thus approximately equivalent to sandstone No. 1 of Hunt in the lower part of the Mancos shale (Hunt, p. 41-43 and fig. 1). This sandstone the writer believes to thin out and disappear altogether from the section near the south end of Cebolleta Mesa (locality 11, fig. 3). Inasmuch as the Dakota of the D-Cross Mountain (locality 10, fig. 3) and Cebolleta Mesa (localities 11 and 12, fig. 3) areas thins out northward like the Tres Hermanos sandstone member, whereas the upper and lower ledges of the Dakota of the east side of the Basin thin out southward, a dual source of clastic material from the south and west and from the north and east is implied. This implication is supported by the increase in thickness of the Dakota eastward toward the San Juan Mountains and its probable overlap onto Precambrian rocks as reported by Muehlberger and others elsewhere in this guidebook.

In so far as known to the writer, fossils closely diagnostic of age have not been found in the Dakota of the eastern San Juan Basin. A marine invertebrate fauna is, however, present in the lowermost sandstone of the Upper Cretaceous sequence near Acoma Pueblo (the Dakota sandstone of locality 12, fig. 3). This was at first reported to be of oldest Late Cretaceous age (Dane, 1959, p. 90) but is now regarded by W. A. Cobban as more probably of early Greenhorn age (letter from W. A. Cobban to C. A. Repenning, March 28, 1960). It seems likely that most of the Dakota sandstone of the eastern San Juan Basin is of Late Cretaceous age and may be entirely younger than any part of the Dakota sandstone of northeastern New Mexico and southeastern Colorado, much, if not all, of which is of Early Cretaceous age (Baldwin and Muehlberger, 1959, p. 59). The two areas may well have been separated by an erosional barrier 15 to 25 miles wide trending southward along the 106° meridian toward central New Mexico.

MANCOS SHALE

The Dakota sandstone is succeeded by a unit consisting of rocks of marine origin of various sorts, but dominantly gray shale, the Mancos shale, approximately 2,000 feet thick. During the writer's field mapping in the middle and late thirties it was recognized that the Mancos shale of the northeastern part of the San Juan Basin contained lithologic equivalents of the Graneros shale, Greenhorn limestone, Carlile shale, and Niobrara formation as these units were distinguished in northeastern New Mexico and eastern Colorado. Inasmuch as the mapping had proceeded from the south to the north it was also recognized that these lithologic units could not be traced over the entire area being mapped, the Mancos shale of the southern part of the Basin being an undivided unit except for the local recognition of sandstone members in the lower part and the incursion of tongues of the Mesaverde formation (as it was then recognized) in the upper part. The Graneros, Greenhorn, Carlile, and Niobrara were therefore classified as members of the Mancos shale, in which an upper unnamed member overlying the Niobrara was also included.

Graneros Shale Member

The Graneros shale member is the basal member of the Mancos shale. It is recognized as far south as the overlying Greenhorn limestone can be recognized as a lithologic unit, to the vicinity of Cabezon (locality 15, fig. 3). The member crops out in small areas and bands over much of the folded and faulted northeastern part of the San Juan Basin but because it is a comparatively thin member and less resistant to erosion than the overlying and underlying beds it is normally poorly exposed and its outcrops do not in general cover large areas. The most typical patterns of outcrop are narrow belts flanking uplifted areas of Dakota sandstone or narrow bands encircling domes of the Dakota. In a few places, the Graneros crops out over areas a mile or more in width.

The Graneros consists chiefly of gray and black evenly thin-bedded shale. In the basal 6 to 10 feet in many places the shale is sandy. Locally there are thin beds of hard brown fine-grained, calcareous sandstone a few inches thick in the middle part of the member. The upper third of the member contains calcerous shale or marl and in the southwestern part of the Tierra Amarilla Grant (fig. 5) there are two harder beds of marl or shaly limestone about 30 feet below the top. Thin beds of bentonite or bentonitic clay occur at intervals but particularly near the top and base of the member. Large calcareous concretions commonly occur along the outcrop of these beds in the basal part of the member. The bentonite beds in the basal part of the formation might be traceable on detailed study. A suggested correlation of the beds at a few places where measurements were made is shown on figure 5. A bed 20 to 25 feet above the base of the formation was observed at a number of localities other than those shown. Other beds are probably present locally.

The beds of bentonite vary in thickness from place to place, probably partly because of variations in the originally deposited thickness and partly because of local squeezing of the bentonite at the outcrop due to the exceptional plasticity of bentonite when wet. There are three thin beds in the topmost 10 or 11 feet of Graneros that are believed to be essentially continuous for considerable distances. Of these the middle one is probably present for a distance of at least 30 miles along the outcrop of the Graneros.

The Graneros rests conformably on the Dakota sandstone. This is evident not only from the absence of erosional irregularity at the base where the topmost sandstone bed of the Dakota is exposed uninterruptedly, and from the concordance in attitude of the beds above and below the contact but also from the transitional sandy lithology of the base of the Graneros. The probable continuity of bentonite beds at nearly the same level above the base of the formation indicates that for a considerable area in the northern part of the area the contact falls everywhere at the same time horizon. The more conclusive correlation of the bentonite beds at the top of the formation indicates that the change to the overlying member of the Mancos shale likewise takes place at a uniform time horizon.

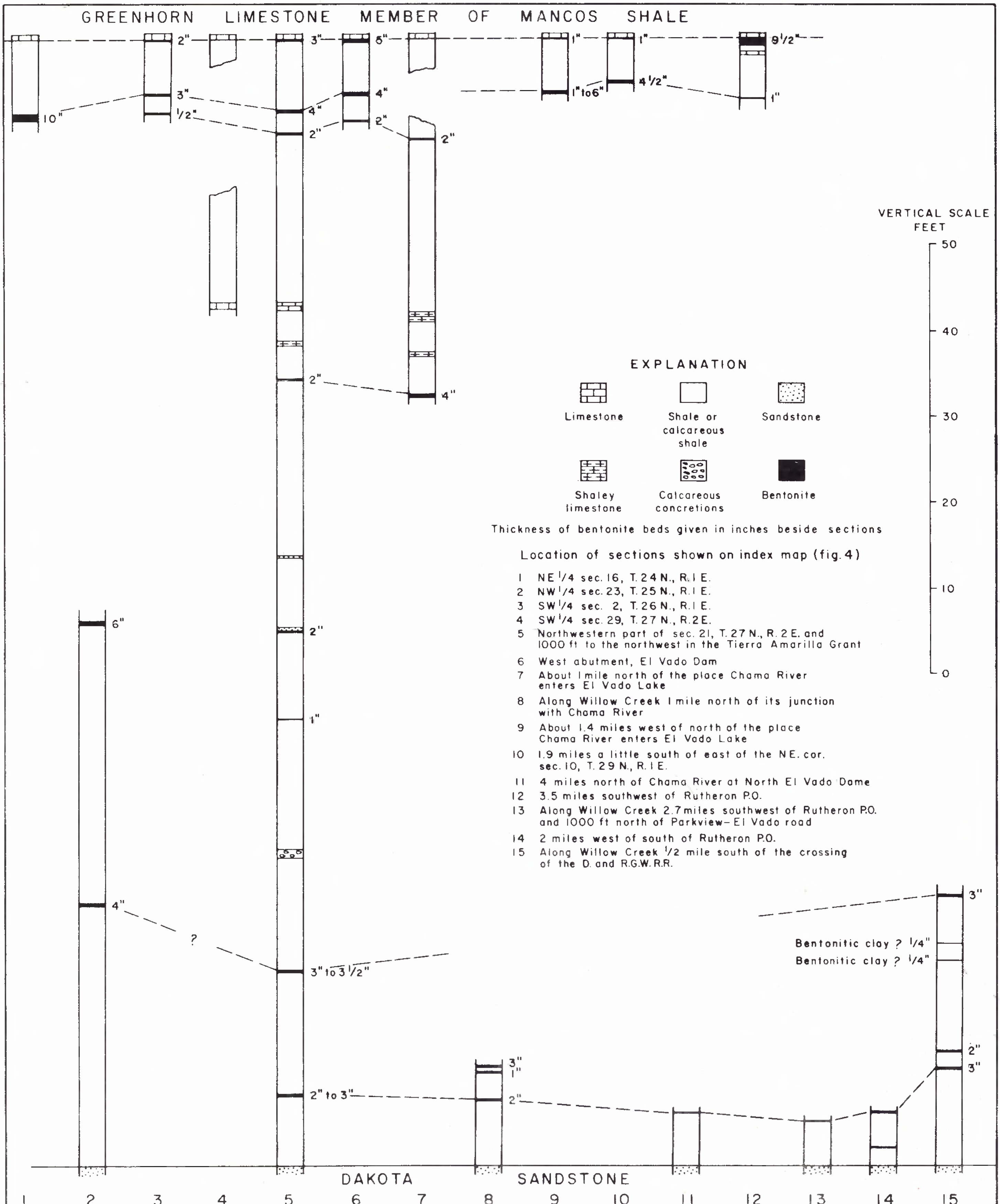

Figure 5. Graphic sections of the Graneros shale member of the Mancos shale showing the inferred correlation of beds of bentonite

Several measurements of the thickness of the Graneros shale member range between 120 and 130 feet and it is 134 feet thick according to an interpretation of the log of the Perfecto Esquibel No. 1 well of the Continental Oil Company, located about 7 miles southeast of Rutheron (fig. 4). At places in the northeastern part of the area the Graneros has an apparent thickness of less than 100 feet but it is believed that at these places there may be unrecognized faults or other local anomalous relations.

Greenhorn Limestone Member

The Greenhorn limestone member conformably overlies the Graneros shale member on the eastern side of the San Juan Basin in New Mexico, and is known to be present in Colorado north of the region mapped. Although it is only from 40 to 60 feet thick fig. 6) its outcrops are relatively conspicuous because, being somewhat more resistant to erosion than the overlying and underlying members of the Mancos shale, it forms strike ridges and cuestas. In places the member appears to be thicker than it actually is because of down hill slumping of the basal limestone beds over the softer shale of the underlying Graneros member and the apparent thickness of the Graneros is reduced correspondingly. Although its relatively greater resistance to erosion makes the outcrops of the member areally more extensive than might be expected from its small thickness, it nevertheless crops out over a smaller area than the thicker overlying members of the Mancos.

The Greenhorn consists almost wholly of alternating beds of gray dense limestone and darker gray calcareous shale, there being all intermediate gradations in lithology. The beds of limestone range in thickness from a fraction of an inch to 2½ feet, the intervening shale beds being in general thicker. The beds of limestone are somewhat more resistant than the more argillaceous beds and accordingly project as small ledges from the outcrop (fig. 8). This difference in response to weathering is probably the primary field criterion for deciding whether a given bed is limestone or argillaceous shale, and accordingly the fresher the exposure the higher the percentage of the member that would be classified as limestone. In general, however, there is an approximately equal division of the member into limestone and calcareous shale except in the uppermost one-quarter to one-half of the member where shale predominates. There is also a decrease in the number and relative thickness of the limestone beds southward in the region (fig. 6). Both the limestone and associated calcareous shale of the Greenhorn weather to a white or whitish-gray color that strikingly contrasts with the overlying and underlying beds. The limestone units, although on fresh exposures appearing dense and massive, commonly develop thin platy bedding. Rather commonly they are strongly jointed perpendicular to the bedding planes. These characteristics combine to produce irregular chunky flakes and chips that commonly litter the outcrop, particularly on weathered dip slopes. Individual beds of limestone continue laterally for considerable distances and large outcrops therefore exhibit great regularity of bedding, but even in individual outcrops there is observable some lateral gradation of beds of limestone to limy shale and it is doubtful if many single beds extend so far as a mile. In the limestone beds, particularly above the middle of the member, impressions of **Inoceramus labiatus** Schlotheim are locally abundant. Other large fossils are less common.

As previously described, a group of three bentonitic clay beds occurs in the topmost part of the underlying Graneros shale member. Another group of six bentonitic clay beds was found in the basal beds of the overlying Carlile shale member in two sections measured in the southwestern part of the Tierra Amarilla Grant. The lowest two of these bentonitic beds were also found in a section measured in sec. 16, T. 24 N., R. 1 E. (fig. 6). Thinner bentonitic beds within the Greenhorn at levels that suggest that the beds are correlatable and continuous were found in two measured sections. Such thin beds in shale are not readily detected except where exposures are excellent. Thus, more detailed examination might reveal that these and perhaps other thin beds within the Greenhorn are present elsewhere and that the beds have a greater lateral extent than has been shown. In the section measured at El Vado Dam (fig. 6) the bentonitic bed nearest the base of the Greenhorn immediately overlies a bed of hard gray marl one-half inch thick having an irregular lower surface that suggests that the marl filled in trail markings on the surface of the underlying shale. At this place and in Sec. 21, T. 27 N., R. 2 E., where a 3-inch bed of limestone underlies the equivalent bentonitic bed the base of the Greenhorn strictly should be placed below this thin limestone. Elsewhere the practicable boundary lies at the top of the bentonite or, where the bentonite is missing, at the base of the limestone that would overlie it. The top of the Greenhorn in the graphic sections on figure 6 can be very well placed at the base of the lowest of the group of six bentonitic clay beds. Below this is a calcareous shale unit of greater or less thickness without hard limestone beds, but weathering to white or very light gray. Above the lowest bentonitic clay of this group, however, the shale, though calcareous, weathers to a pale-brown tint. In addition there appear locally very thin silty or sandy beds and thin lenticular hard crystalline sandy limestone beds that suggest the similar beds occurring more abundantly higher stratigraphically in the Carlile. In most places the contact at the top of the Greenhorn can be placed only approximately.

The data obtained show a definite concentration of beds of bentonitic clay near the lithologic changes from Dakota sandstone to Graneros shale, from Graneros shale to Greenhorn limestone, and again from Greenhorn limestone to Carlile shale. This relation may be wholly coincidental. It would nevertheless not be surprising if a record of more concentrated volcanic activity should correspond with diastrophic or climatic changes that would also be recorded by a change in lithology and fauna in a seaway in which sediments were being deposited.

Carlile Shale Member

The Carlile shale member as recognized in the northeastern part of the San Juan Basin from about the vicinity of El Vado (locality 20, fig. 3) north to the New Mexico-Colorado line includes two lithologic subdivisions.

The lower subdivision, probably about 200 feet thick, consists largely of very dark to black shale, containing in the basal 50 to 60 feet the group of beds of bentonitic clay shown on figure 5. Similarly, in the uppermost 70 or 80 feet of the lower subdivision, a number of detailed measured sections reveal from 4 to 11 beds of bentonitic clay ranging from a fraction of an inch to 5 inches in thickness, but these beds do not correlate as well from to place to place as those near the base of the Carlile. The most striking lithologic feature of the lower subdivision of the Carlile is the abundance of large septarian calcareous concretions in

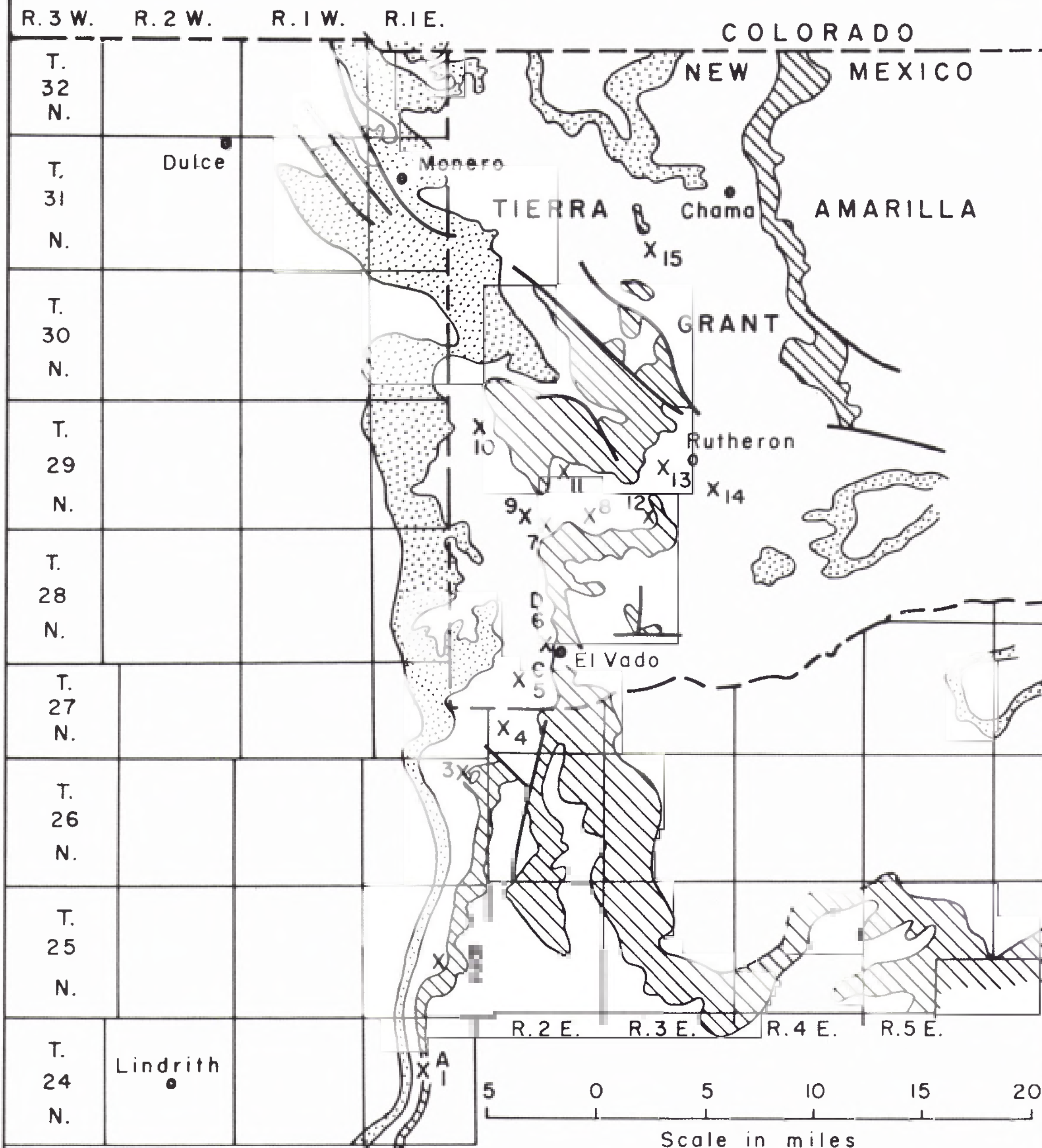

FIGURE 4. Index map showing location of graphic sections of Graneros shale member (1 to 15) and of Greenhorn limestone member (A to D) of Mancos shale shown on figures 5 and 6. Approximate distribution of outcrops of Mesaverde group (stippled), of Dakota sandstone (lined), of other rocks including Mancos shale (unpatterned). Faults shown in part.

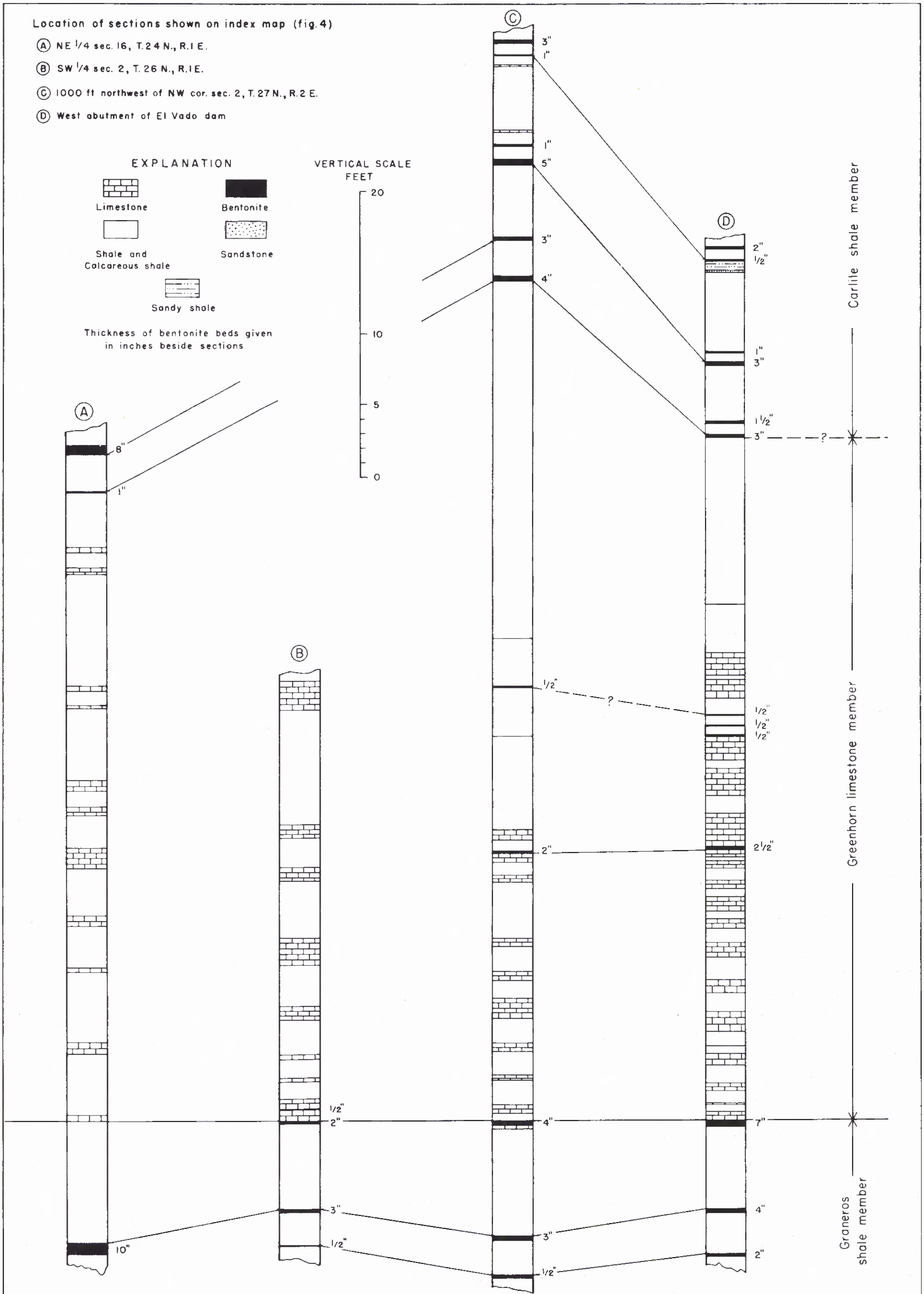

Figure 6. Graphic sections of the Greenhorn limestone member of the Mancos shale and underlying and overlying beds on eastern side of San Juan Basin, New Mexico

Figure 8. Greenhorn limestone member of Mancos shale on Willow Creek one mile north of its junction with Chama River (near locality 8, fig. 4).

a zone beginning perhaps 100 feet above the base of the member. These concretions range up to a maximum diameter of about 5 feet. The septa are commonly of brown, translucent coarsely crystalline calcium carbonate having a resinous luster. The septa of the concretions become thinner toward the exterior of the concretions but commonly emerge to the surface. Where the septa are well developed the central mass of the concretions may consist entirely of crystalline carbonate. Cone-in-cone structure is quite common and well developed in the surface layers of the concretions.

The upper subdivision of the Carlile shale member also consists chiefly of dark to black shale weathering light brownish gray, but contains throughout numerous beds of hard, dary colored, platy, sandy limestone or calcareous sandstone, many of which are richly fossiliferous, containing several species of molluscs and fish scales, teeth and bone fragments, and bits of carbonized wood. These sandstone beds range from less than an inch to one or two feet in thickness.

Where the dips are low, the lower part of the Carlile shale member normally crops out in shallow valleys or gentle slopes below low escarpments formed by the more resistant beds of the basal sandy limestone beds of the upper subdivision of the Carlile. The beds of the upper subdivision as a whole, however, are not especially resistant to erosion and form generally broad valleys and low rolling hills, not uncommonly flat topped.

The upper subdivision of the Carlile shale member contains a Carlile fauna like that found in the Codell sand stone member of the Carlile shale in the Arkansas Valley (Dane, Pierce, and Reeside, 1937, p. 220). From collections made during the thirties on the eastern side of the San Juan Basin, the late J. B. Reeside, Jr., identified **Inoceramus labiatus, Inoceramus fragilis, Ostrea lugubris, Baculites gracilis, Scaphites warreni, Prionocyclus wyomingensis,** and **Prionocyclus macombi.** Within this region the fauna of the lower subdivision of the Carlile was not adequately collected and more information is needed on the stratigraphic limits of the several Carlile faunal zones now recognized (Cobban and Reeside, 1952).

Estimates from measured dips and altitudes east of Monero (locality 21, fig. 3) indicate a thickness of 440 feet for the Carlile member. In the area between Mount Taylor and the southern part of the Nacimiento Mountains (localities 15 to 17, fig. 3) beds of Carlile age are considerably thicker, but these beds must be considered in the nomenclatural terms that have been applied to rocks of the southern part of the Basin. In this area a fine-grained hard brown calcareous sandstone bed or sequence of beds intercalated with sandy shale ranging in thickness from a few feet to about 15 feet lies about 450 feet above the base of the Carlile. This sandstone bed contains the **Prionocyclus wyomingensis** fauna of middle Carlile age (Cobban and Reeside, 1952, p. 1018) and corresponds in position, lithologic character, and age with the Juana Lopez sandstone member of Rankin as described at the type locality (Rankin, 1944) and later described by Stearns (1953) in the Galisteo-Tonque area. The Juana Lopez sandstone member of Rankin of the eastern part of the Mount Taylor area localities 15 to 17) is believed by the writer to be continuous with, and equivalent in age to the sandstone near or at the top of the Carlile in the Chama area (localities 20 and 21, fig. 3). About 100 feet below the Juana Lopez of Rankin is a thin sandstone that in several places has yielded **Collignoniceras hyatti,** the index fossil of an older Carlile faunal zone (Cobban and Reeside, 1952, p. 1018) than that characterized by **P. wyomingensis.** Above the Juana Lopez lies a sequence of shale and sandy shale about 450 feet thick in large part of Carlile age, but containing in the upper part some beds probably of earliest Niobrara age (Dane, 1960), p. 52). In the southern part of the San Juan Basin this sequence above the Juana Lopez is invaded by northeastwardly thinning tongues of the Gallup sandstone of the Mesaverde group that are separated by tongues of Mancos shale. The tongues of the Gallup sandstone terminate northeastward before reaching the front of the Nacimiento Mountains (Hunt, p. 47). Exposures of the equivalent, generally shaly sequence are poor and discontinuous northward along the foothills of the mountains (localities 16 to 18, fig 3) and also along the strike valley between the Dakota sandstone and the sandstone of the Mesaverde group (localities 18 to 20, fig. 3), and they have not been carefully reexamined by the writer since his field work of the thirties. Regional relations suggest that the unit is truncated northward by an unconformity at the base of beds containing the **Inoceramus deformis** fauna of early Niobrara age and that equivalents of this unit of Carlile and earliest Niobrara age are missing in the northeastern part of the San Juan Basin. Similar uncomformable relations are more clearly evident in the northwestern part of the San Juan Basin (localities 7 to 9, fig. 2).

Beds of Niobrara age in southern San Juan Basin.—In the southern part of the San Juan Basin, specifically in the Mount Taylor coal field, the Gallup sandstone is successively overlain by the Dilco coal member of the Crevasse Canyon formation, the stray sandstone of Sears, Hunt, and Hendricks (1941, p. 113), the Mulatto tongue of the Mancos shale, the Dalton sandstone and Gibson coal members of the Crevasse Canyon formation, the Hosta tongue of the Point Lookout sandstone, and the Satan tongue of the Mancos shale (localities 13 and 14, fig. 2). These units, except for the upper part of the Satan tongue, are all of Niobrara age (Hunt, p. 45) although the Niobrara age of the Dilco is inferred as such only because the seaward feather edge (presumably the youngest part) of the underlying Gallego sandstone member of the Gallup sandstone is apparently of earliest Niobrara age (Dane, 1960, p. 52). Northeastward from the eastern part of the Mount Taylor coal field, the Gallup sandstone tongues out, the overlying Dilco coal

member grades into marine shale, and the younger beds of Niobrara age grade into a nondescript poorly exposed sequence of thin-bedded silty sandstone and intervening sandy shale in which there are no strongly marked readily traceable sandstone units. This sequence is intermittently exposed in the belt of steeply dipping and overturned rocks at the western foot of the Nacimiento Mountains (locality 17, fig. 5) but is for the most part concealed by thick and extensive deposits of pediment gravels from the mountains. From a locality northeast of Regina (locality 18, fig 3) northward a conspicuous sandstone bed forms a nearly continuous cuesta ridge (fig. 9) in the shale valley between the ridges formed by the Dakota
and Point Lookout sandstones. This bed, which lies at approximately the stratigraphic level of the Dalton sandstone member, typically consists of numerous thin layers of hard slabby yellowish-gray and brownish-gray calcareous sandstone and intervening layers of softer muddy sand. Many of the harder beds are irregularly ripple marked or have worm trails or scratch marks on their surfaces. The sandstone zone merges downward gradually into decreasingly sandy shale beds and into gray to black shale. Upward, however, it is succeeded sharply in places by a cemented coquina of smooth oyster shells and fragments of thick **Inoceramus shells**. The sandstone unit thins northward, and terminates between El Vado and the area east of Monero (localities 20 and 21, fig. 2). In the southern part of its outcrop it is, in the upper part, generally coarse grained or a fine grit. Locally it is pebbly grit with pebbles one-quarter of an inch or larger. Although the sandstone at this level is correlated (with a question) with the Dalton sandstone member, detailed surface and subsurface studies may well show that it requires a separate name.

Figure 9. — Cuesta of sandstone of Niobrara age at about the horizon of the Dalton sandstone member of the Crevasse Canyon formation on north bank of Canoncito de los Lleguas, SE¼ section 21, T. 25 N., R. 1E.

Niobrara calcareous shale member in northeastern part of San Juan Basin. — The Niobrara calcareous shale member of the Mancos shale, as recognized in the northeastern part of the San Juan Basin approximately from El Vado (locality 20, fig. 2) northward and eastward includes a considerable variety of beds. The lower part includes 250 to 350 feet of beds that consist chiefly of gray brittle calcareous shale and gray shaly limestone. In the upper part, of about the same thickness, softer less calcareous shales predominate. From El Vado Lake northward the lower part of the member forms a nearly continuous ridge of low hills, gray to blue-white in color where the bedrock is exposed. At a locality north of the western head of El Vado Lake (locality 20, fig. 2) a sequence of beds, totalling about 5 feet thick, of hard gray calcareous medium-grained sandstone contains abundant grains of bright-green glauconite. The beds of glauconitic sandstone, ranging from 6 inches to 1 foot in thickness, alternate with softer shaly beds, particularly in the upper part. The glauconitic sandstone contains **Inoceramus deformis** but rests on about 35 feet of shale, probably of Carlile age, that overlies the thin hard brown calcareous fossiliferous sandstone beds characteristic of those present in the upper part of the Carlile shale member.

In the area east of Monero (locality 21, fig. 2) however, the basal beds of the Niobrara consist of soft thin-bedded shale containing **Inceramus deformis** and about 30 feet thick. These beds are succeeded by beds that are very similar lithologically, but contain the very large flat **Inceramus (grandis** of authors) thickly coated with **Ostrea congesta.**

Figure 10. — Jointed limestone bed in upper part of Niobrara calcereous shale member of Mancos shale in SE¼ section 27, T. 27 N., R. 1 E.

Although the upper part of the Niobrara is in general less calcareous than the lower part, there are thin hard beds of gray limestone at several places above the horizon of th Dalton sandstone member (fig. 10). The uppermost beds of the Niobrara are not much unlike
the overlying beds of the upper member of the Mancos shale. The contact is of a kind that can be discriminated only by close examination and not then everywhere with assurance. It should therefore be noted that recognition of a stratigraphic unit as a member does not require that it be mappable, but only that it have a recognizable overall distinguishable lithologic character.

Upper member of the Mancos shale. — The upper member of the Mancos shale crops out beneath the escarpment made by the sandstone of the Mesaverde group. It consists almost altogether of gray and dark shale and sandy shale and thin beds of sandstone. At most places there are near the base one or more zones of large roundish concretions of dense gray limestone, weathering yellow gray, and having a horizontal diameter of as much as 3 feet. Sandstone beds become thicker and more abundant upward in the member and in the uppermost part predominate over the interbedded shale in the transitional zone into the Mesaverde. The member has been estimated at different places to be 500 to 700 feet thick. Inasmuch as the upper contact is transitional and the lower contact not everywhere closely determinable, this range in estimates of thickness is not surprising.

The member contains throughout, in calcareous concretions, a molluscan fauna that was considered by the late John B. Reeside, Jr., to be of the age of that found in the Telegraph Creek formation and the overlying Eagle sandstone of Montana. The fauna of the Telegraph Creek formation was not separately recognized on the eastern side of th San Juan Basin and although it may be represented by beds that were here included in the upper part of the Niobrara, it seemed best to Dr. Reeside to regard the fauna of the upper member of the Mancos shale as a composite one including equivalents of both the Telegraph Creek and Eagle faunas.

LITERATURE CITED

Baldwin, Brewster, and Muehlberger, W. R., 1959, Geologic studies of Union County, New Mexico: New Mexico Bureau Mines and Mineral Resources Bull. 63, p. 1-171.

Cobban, W. A., and Reeside, J. B., Jr., 1952, Correlation of the Cretaceous formations of the Western Interior of the United States: Geol. Soc. America Bull., v. 63, no. 10, p. 1011-1043.

Dane, C. H., 1948, Geologic map of part of eastern San Juan Basin, Rio Arriba County, New Mexico: U. S. Geol. Survey Oil and Gas Inves. Prelim. Map 78.

.................., 1959, Historical background of the type locality of the Tres Hermanos sandstone member of the Mancos shale in New Mexico Geol. Soc. Guidebook 10th Ann. Field Conf., West-central New Mexico, 1959: p. 85-91.

.................., 1960, The boundary between rocks of Carlile and Niobrara age in San Juan Basin, New Mexico and Colorado: Am. Jour. Sci., Bradley Volume, v. 258A, p. 46-56.

Dane, C. H., and Bachman, G. O., 1957, The Dakota sandstone and Mancos shale in the Gallup area, in Four Corners Geol. Soc. Guidebook 2nd Field Conf., Geology of southwestern San Juan Basin, 1957: p. 95-98.

Dane, C. H., Bachman, G. O., and Reeside, J. B., Jr., 1957, The Gallup sandstone, its age and stratigraphic relationships south and east of the type locality, in Four Corners Geol. Soc. Guidebook 2nd Field Conf., Geology of southwestern San Juan Basin, 1957: p. 99-113.

Dane, C. H., and Bryson, R. P., 1938, Preliminary map showing geologic structure of part of Rio Arriba County, New Mexico: U. S. Geol. Survey Prelim. Map.

Dane, C. H., Pierce, W. G., and Reeside, J. B., Jr., 1937, The stratigraphy of the Upper Cretaceous rocks north of the Arkansas River in eastern Colorado: U. S. Geol. Survey Prof. Paper 186-K, p. 207-232.

Dane, C. H., Wanek, A. A., and Reeside, J. B., Jr., 1957, Reinterpretation of section of Cretaceous rocks in Alamosa Creek Valley area, Catron and Socorro Counties, New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 41, no. 2, p. 181-196.

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

Rankin, C. H., 1944, Stratigraphy of the Colorado group, Upper Cretaceous in northern New Mexico: New Mexico Bur. Mines and Mineral Resources Bull. 20, p. 1-26.

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.

Stearns, C. E., 1953, Upper Cretaceous rocks of Gallisteo-Tonque area, north-central New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 37, no. 5, p. 961-974.