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1951, pp. 104-118. https://doi.org/10.56577/FFC-2.104

in:

San Juan Basin (New Mexico and Arizona), Smith, C. T.; Silver, C.; [eds.], New Mexico Geological Society 2 nd Annual Fall Field Conference Guidebook, 163 p. https://doi.org/10.56577/FFC-2

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CRETACEOUS STRATIGRAPHY OF THE SAN JUAN BASIN

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Possibly few systems of rocks in western United States have been written about more than the Cretaceous rocks of the San Juan Basin. The publications listed at the end of this paper include many papers describing these rocks in every part of the Basin and adjoining areas with a wealth of detail not possible here. This paper will not re-describe all the stratigraphic units. The subject of this paper is the sequence of beds of differing lithology, the lateral variations in lithology of these beds and their relations to the economic deposits of coal, oil and gas that have been found and may possibly be found in the San Juan Basin. The works of previous authors are drawn upon freely for this purpose. If after reading this paper newcomers have an understanding of the thickness and position of the Cretaceous layered rocks and an understanding of the possible distribution of the contained fluids, the author's purpose will have been served.

The Cretaceous sediments of the central part of the San Juan Basin can be logically divided into two major groups: the older and lower group which includes all the sediments deposited while marine conditions endured and the upper and younger transitional group which bridged the transition from marine to wholly continental conditions of deposition. If one considers the duration of marine Cretaceous sedimentation in the central part of the basin as extending from the base of the Dakota sandstone to the top of the Pictured Cliffs sandstone, the valuable stratigraphic reference interval of the older group is established (See Figure I.) This interval contains most of the commercial deposits of oil and gas that have been found in Cretaceous rocks of the basin at this time, as well as most of the yet undiscovered deposits. This interval lies across the San Juan Basin as a sedimentary blanket of almost uniform thickness. Over much of the basin this interval is made up entirely of clastics and is constant in thickness within a few hundred feet of 4,700. However, there is a remarkable uniformity in the variation in composition of this blanket. In all but a few places the bottom and top horizons consist of sandstone a few hundred feet thick. Between these containing sandstone horizons a broad uniform variation has been established which is illustrated by Figure I. Sandstone predominates to the southwest, shale to the northeast; marine deposits make up the entire section to the northeast whereas deposits to the southwest are of intertonguing marine and continental facies.

Sears, Hunt, and Hendricks (1941, p. 102) reviewed the concept, in a paper which has become a classic, that the deposits under discussion were laid down in a broad shallow trough that extended across the area in late Cretaceous time. The general orientation of the shoreline was northwest to southeast and fluctuations in the position of this shoreline were generally in a northeast to southwest direction. Further, they elaborated the concept first stated by Lee (1915, p. 28) that both the transgressive and regressive deposits were laid down during continued sinking of the trough and that both transgressive or regressive deposits were a reflection of the rate of sinking in relation to the supply of material. Figure 2 from Sears, Hunt, and Hendricks (1941, p. 105) shows the theoretical progression. This was borne out by the "widespread occurrence of transition zones between shale and overlying regressive sandstone and by the extent of thickness and uniformity of such sandstones. With continued subsidence there would also be opportunity for the development of thick coal-bearing coastal-swamp deposits behind and encroaching upon the beach sands as the sands grew upward and seaward." (Ibid, p. 101). As regression continued flood-plain deposits encroached upon the near-shore and coastal deposits. At such time as the rate of sinking in the trough exceeded the supply of material regression ceased and the sea again transgressed the land to the southwest. The upward succession of sediments was the reverse of that during regression, coastal deposits building upward to the southwest over flood-plain deposits, which were in turn followed by near-shore sands and marine sands.

Age of the Formations.

Early workers in the Basin were perplexed by the conflicting paleontologic data relating to the age of the various lithologic units. It was not until the formations were mapped on a strictly lithologic basis disregarding age considerations that the present clear stratigraphic relationships became evident. As early as 1915 Lee (p. 36-37) pointed out that it was the custom then to assign a sandstone to the Dakota if it occurred immediately below shale known from fossil

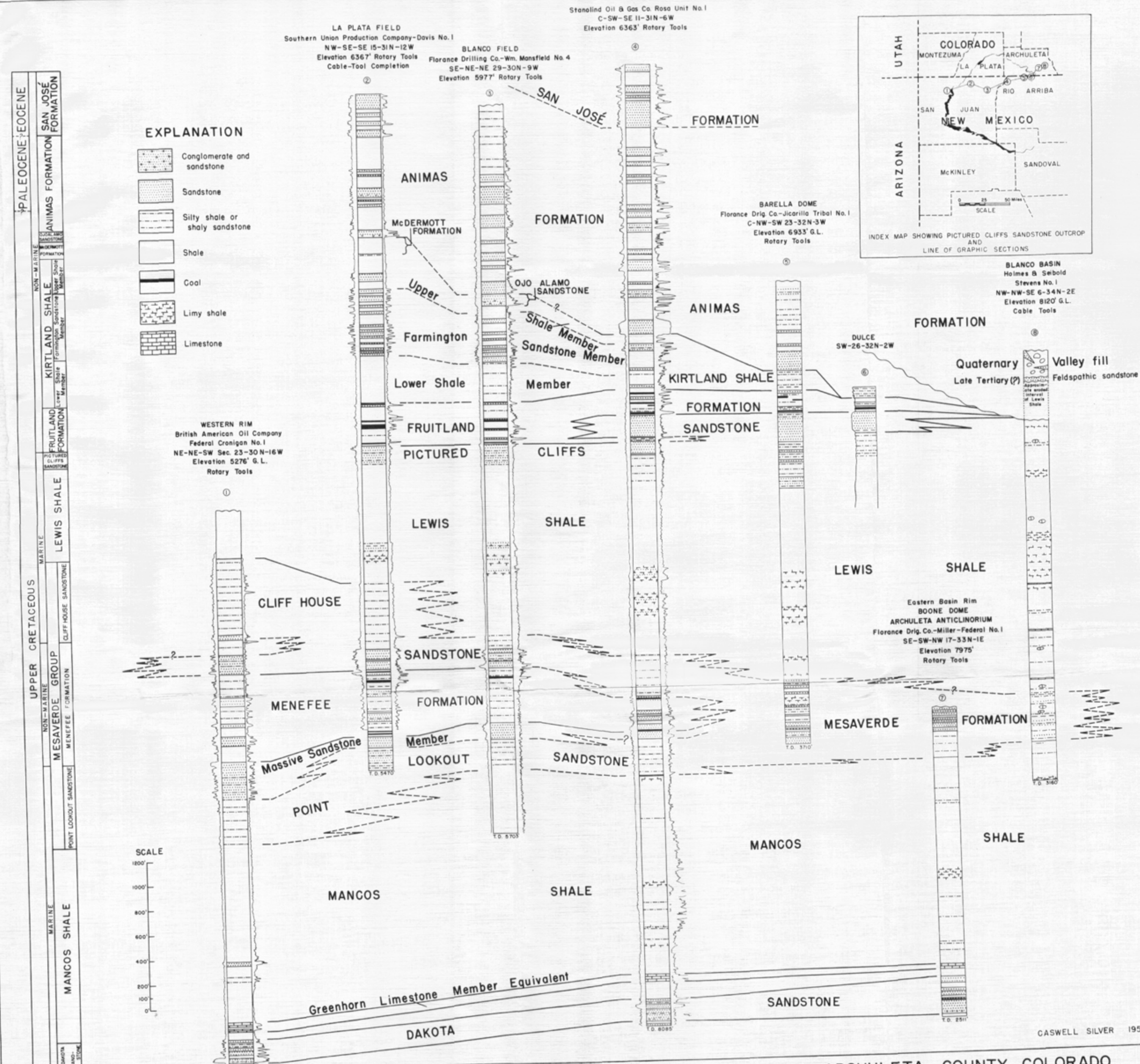

FIGURE I. STRATIGRAPHIC CORRELATION FROM SAN JUAN COUNTY, NEW MEXICO TO ARCHULETA COUNTY, COLORADO evidence to be of Benton age and that the Dakota of one locality was not the exact time equivalent of the Dakota of other localities. The transgressive nature of the Dakota shown by Lee (1915) and the transgressive and regressive Mesaverde sandstones described by Sears, Hunt, and Henricks, (1941) and Pike (1947) have established clearly the fact that these formations cut across time lines and cannot be defined solely in terms of age. Figure 3 is a time correlation chart which shows the time relation of the various units in the Basin referred to the standard time scale of the Great Plains. This figure is inherently inaccurate as the foregoing discussion has shown. The age of these formations can only be discussed in terms of a specific locality.

Lower Cretaceous Rocks (?)

Rocks of early Cretaceous age have been tentatively identified by Reeside (1944) only in the northern part of the Basin near the town of Dolores in Montezuma County, Colorado, where they have a thickness of approximately 100 feet. They consist of white, medium to fine-grained sandstone and green and gray shale. Similar rocks of like thickness appear to be locally present in northern New Mexico 150 miles to the east at the head of Arroyo Canjilon in T. 25 N., R. 4 E. Subsurface information from the few wells presently drilled to that horizon indicates that these rocks are generally present in the subsurface through the northern half of the Basin. The same rocks are not exposed in the southern part of the Basin but a thick white sandstone disconformable with the underlying Morrison formation to which it is usually assigned and distinct from the overlying Dakota sandstone may yet be correlated with possible lower Cretaceous rocks to the north. This sandstone is usually separated from the Dakota by its contrasting white color, resulting from heavy concentration of white cement, the general absence of conglomeratic material and an upper surface of ten to thirty feet of relief. Where rocks classified as Dakota contain a middle shale and coal member and a lower conglomerate member Reeside (1949) has also indicated a possible lower Cretaceous age for these units. Commercial gas has been reported from the rocks immediately below the Dakota at the Stanolind-Ignacio No. 1 B well at Ignacio, Colorado and the Doswell No. 1 Scott Federal in T. 26 N., R. 6 W. Fresh water has been reported from this horizon in the Petroleum Products Inc., No. 1 Santa Fe, in Sec. 21, T. 21 N., R. 8 W.

Dakota Sandstone.

"The Dakota sandstone," in the words of Gregory (1917, p. 72) "is highly variable in structure, texture, and composition. It is characterized more by a persistent combination of features than by the persistence of any given bed. The base is commonly but by no means universally marked by conglomerate and the top is in many places a coarse brown or gray sandstone bed but may be a group of interbedded sandstones and shales or wholly sandy shale of yellow or gray tones. Coal lenses occur prevailingly in the middle of the Dakota but are found in all positions from top to bottom. The formation is everywhere lenticular; lenses and wedges of sandstone, of conglomerate, of shale, and of coal tens of feet or a few inches thick overlap, appear, and disappear along the strike and vertically in a most capricious manner." The above general description in the opinion of this author is the best heretofor written on the Dakota sandstone of the San Juan Basin and contains within it clues to the erratic production history of this unit. Other more casual observers in the Basin have attempted to systematize the Dakota. Prevalent are such expressions as "the second Dakota," "the third Dakota." Such have no meaning except perhaps in very restricted areas yet the error has persisted. A paper by Lyons (1951) attempts to divide the Dakota into five members "on the basis of lithology and porosity." Such members it is purported can be correlated over the entire Basin. The evidence presented by Lyons for this division is not only inconclusive but as evaluated by this writer reaffirms the description of Gregory.

Gregory reports the thickness of the Dakota in Arizona to be 102 feet at Steamboat Springs, 245 feet at Todilto Park, 54 feet at a point six miles north of Lohali in the east face of Black Mesa, 210 feet six miles north of Marsh Pass at the north point of Black Mesa, and 170 feet at Carrizo Mountain. In New Mexico Renick (1931, p. 36-39) reports 189 feet in San Miguel Mine Canyon, Sec. 13, T. 19 N., R. 1 W., 263 feet in San Miguel Canyon, Sec. 35, T. 20 N., R. 1 W., 191 feet six inches in SE 1/4 Sec. 2, T. 20 N., R. 1 W. north side of Senorita Canyon. Renick reported these sections in detailed descriptions. Where these sections were measured along the east rim of the Basin at five mile intervals they appear to have a threefold division, consisting of a massive lower bed, sometimes conglomeratic, a shaly middle interval and a massive upper member. This division does not hold south of the

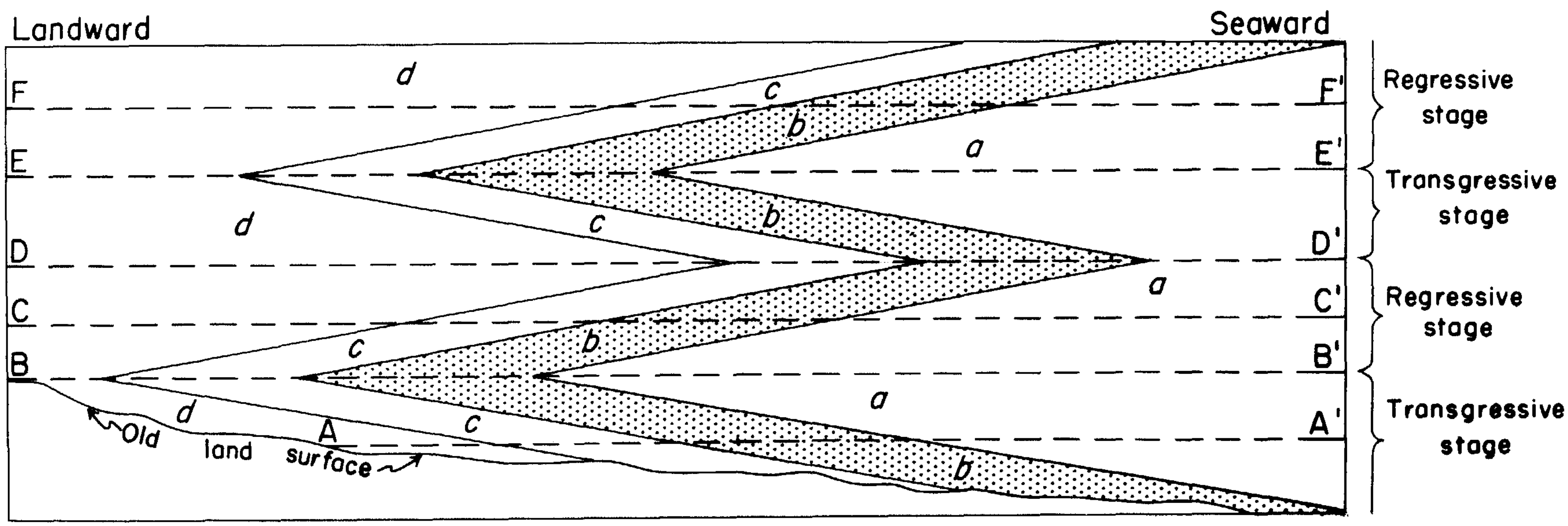

FIGURE 2. DIAGRAM SHOWING THE RELATIONS OF TRANSGRESSIVE AND REGRESSIVE DEPOSITS AND STAGES TO PLANES OF TIME EQUIVALENCE. a. MARINE MUDS; b. NEAR SHORE SANDS; c. COASTAL DEPOSITS; d. FLOOD-PLAIN DEPOSITS; A-A, B-B, etc. PLANES OF TIME EQUIVALENCE.
(AFTER SEARS, HUNT, AND HENDRICKS; 1941, p. 105)

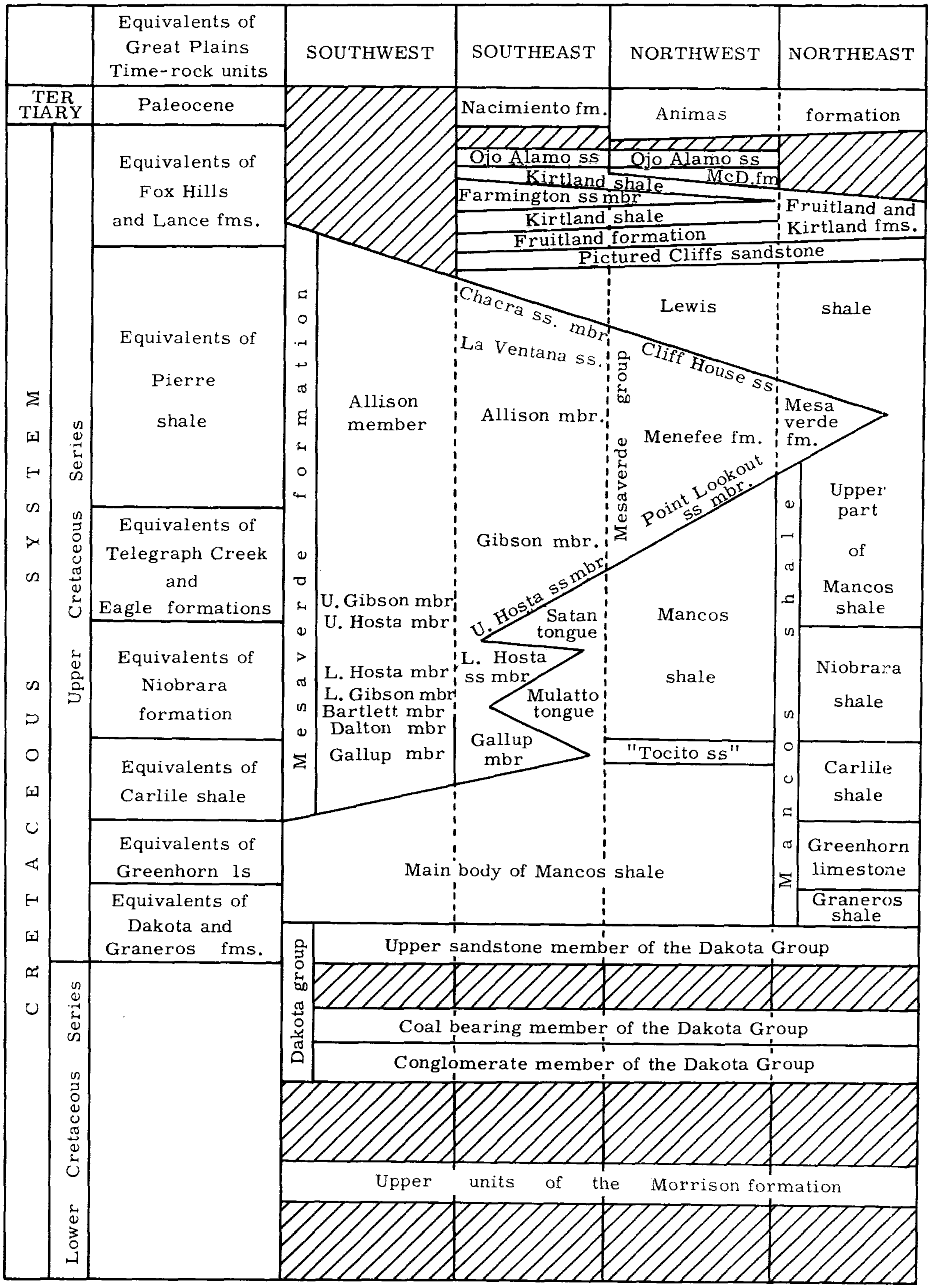

FIGURE 3. TIME-ROCK CORRELATION CHART OF SOME CRETACEOUS ROCK UNITS IN THE SAN JUAN BASIN.

Ojo del Espiritu Santo ranch in T. 16 N., R. 1 W. where the entire Dakota formation consists of massive sandstone. Dane (1948, para. 4) reports the Dakota 186 feet in Sec. 33, T. 27 N., R. 2 E. Wood et al (1948) report a thickness of 171 feet at Chromo just north of the New Mexico-Colorado line. Reeside (1949) reported 250 feet of Dakota in eastern La Plata County, Colorado, and 200 feet plus or minus in central and southern San Juan County, New Mexico. Thicknesses encountered in wells in the central part of the Basin are about the same as those reported above. Hunt (1936, p. 39) reports the Dakota along the southern edge of the basin as attaining a maximum thickness in the outcrop of 75 feet "but locally it is absent, the overlying Mancos shale resting directly upon the eroded top of the Morrison..." "East of Mount Taylor there are three prominent sandstones in the lower 350 feet of the Mancos shale, overlying the Dakota sandstone, to each of which the name Tres Hermanos sandstone' has been applied." Hunt thought it probable that the basal Dakota sandstone west of Mount Taylor is at the horizon of one of these sandstones. The name "Tres Hermanos sandstone" was first used by Herrick and Johnson (1900, p. 14) and later used by others without recording a type locality. Hunt (op. cit. p.41) used the designations "sandstone 1, 2, and 3" where locally mappable. In general the term has fallen into disuse and all of the individual units are collectively referred to as the Dakota group. (See Figure 3).

Coal in the Dakota Sandstone

Though widely scattered in the Dakota group, coal rarely attains a thickness and continuity to be of commercial importance. Sears (1925, p. 24) reported only two places along the Defiance monocline where it was found to reach a thickness of fourteen inches. Gregory (1917) reported five feet of coal of good quality containing sulfur six miles north of Lohali, Arizona. Veatch (1911, p. 239-241) describes the coal near Pinedale, Arizona T. 11 N., R. 19 E. as occurring in the very base of the Cretaceous strata and containing from two to three feet of very good sub-bituminous coal. However, there was no distinct sandstone present resembling the Dakota of other areas. Lyons (1941) reports five feet of coal in the Dakota in the Durango area.

Fluids in the Dakota Sandstone

The fluid contents of the Dakota sandstone are as variable as its stratigraphy would indicate. It is the principal oil horizon in the Basin, at present producing in such fields as Rattlesnake, Hogback, Lindrith, Price, Doswell, Red Mesa, and Table Mesa. Commercial gas is produced from it at Barker Dome, Ute Dome, and Kutz Canyon. However, it also yields potable fresh water, sulfur water, sodic water, salt water, brackish water, thermal water. The occurrence of oil and gas in the Dakota has been up to this time about evenly divided between structural and stratigraphic traps. Some doubtful occurrences are yet to be classified. The important point about the variation in fluids is that they are irregular in different lenses in the same well bore. Salt water, sulfur water, and oil have been encountered in different lenses in the wells and it is not uncommon to find, as at the Rattlesnake field, that oil is encountered in lenses, both above and below other lenses carrying water. Several deep wells such as the Byrd-Frost-Hargraves No. 1, Sec. 4, T. 27 N., R. 10 W., Thomas C. Doswell Federal No. 1, Sec. 10, T. 26 N., R. 6 W., and the Delhi-Magnolia-Ingwersen No. 1 in Sec. 20, T. 24 N., R. 2 W. have encountered sand lenses of low permeability carrying oil and gas. The restricted nature of the production plus the apparent lack of structural closure on the surface would indicate that such accumulations are in large part due to the up-dip pinching out of individual lenses. Other fields such as Hogback, Barker Dome, and Price have found sandstones of good porosity and permeability in the same horizon. Wells which have been drilled to the Dakota sandstone in the Basin are as yet too widely scattered to permit defining areas of better porosity, but some general observations may be made subject to future modification. The Dakota sandstone appears to be a fresh water aquifer throughout the structurally shallow Zuni-Gallup reentrant of the Basin and immediately adjoining the north flank of the Zuni Uplift. So-called flushing by meteoric water in structurally deeper areas is not borne out by presently known occurrences. The lenticularity of the Dakota sandstone is such that there are unlikely to be any large specific areas where porosity can be predicted. Highly porous and permeable lenses containing oil and gas may be found in any locality.

Mancos Shale

The Mancos shale is the body of gray to dark-gray carbonaceous marine shale that overlies the basal transgressive deposits of the Dakota sandstone where they are present and elsewhere rests upon the pre-Dakota rocks. It intertongues with sandstone at successively lower intervals to the southwest and is almost wholly shale to the northeast. The greatest thickness of Mancos shale in the eastern part of the basin is in west central Rio Arriba County, New Mexico in the Delhi-Ingwersen No. 1 in Sec. 20, T. 24 N., R. 2 W., where it is 2,185 feet thick. It thins to the southwest and northeast from that point and retains approximately the same thickness to the northwest to its outcrop at Mesaverde. It is about 1800 feet thick in eastern Archuleta County, Colorado and thins to 425 feet on the Zuni reservation in the southwest. Gregory (1917, p. 74) reports 620 feet at Lolomai Point at the north end of Black Mesa, Arizona. As shown by Figure 4, it splits southwestward into three main tongues on the north flank of the Zuni Uplift. The highest tongue, the Satan tongue, thins westward and is indistinguishable from the Mesaverde in T. 17 N., R. 15 W. The middle Mulatto tongue extends as far southwest as the vicinity of Gallup where it too becomes inseparable from the Mesaverde. The lower tongue extends far to the south and west and is recognizable as far south as the Silver City area of New Mexico and as far west as the Hopi Buttes area of Arizona. It would appear entirely possible that the Mancos shale has graded completely to Mesaverde type sediments at Pinedale, Arizona.

Graneros Shale Member

Definite lithologic units other than those divided by Mesaverde tongues and locally mappable have been recognized within the Mancos shale in the Basin. The Graneros shale equivalent, a dark, almost black, evenly thin-bedded shale unit ranging from 50 to 150 feet in thickness is recognizable over much of the Basin. The name is generally applied to that part of the Mancos shale lying between the Dakota sandstone and the Greenhorn limestone equivalent. This interval is thickest to the northeast and thins to the south and west. In southern New Mexico in the vicinity of the town of Truth or Consequences there is no shale interval between the Dakota and the Greenhorn limestone and they are in contact. This would indicate that far to the south the Dakota sandstone is possibly of Graneros age. Locally even as far north as the central part of the Basin the Graneros shale interval is occupied by sandstones which are grouped with the Dakota sandstone as mentioned above. Thin beds of bentonite up to six inches thick occur in the Graneros shale in the northern half of the Basin. Production is reported from the sandy Graneros interval in the Price field in Colorado.

Greenhorn Limestone Member

The Greenhorn limestone member is applied to a lower part of the Mancos shale which is quite limy in the southwest and contains alternating beds of light-gray limestone and darker gray calcareous shale to the northeast. Many workers regard it as a fairly reliable time horizon. It is from 40 to 60 feet thick and produces a characteristic set of high resistivity curves on the electric log. Dane (1948, para. 6) reports, also in the northeast, two thin beds of shaly limestone 30 feet below the top of beds containing a Graneros fauna, which may be mistakenly included in the Greenhorn. However, most workers in the field use the closely spaced, light gray, one to two-foot thick limestone beds occurring through about a 20-foot zone as the mappable unit in the northwest portion of the Basin and label it Greenhorn without respect to age. Similar usage is applied to the characteristic resistivity curves mentioned. The Greenhorn field unit mentioned does carry a Greenhorn fauna everywhere. Shows of oil and small production of a light-brown or bright-hued green oil have been obtained from the Greenhorn limestone at widely scattered parts of the Basin in Colorado at Red Mesa and the east flank of Barker Dome in La Plata County, and at Chromo in Archuleta County. Porosity in the limestone is extremely low and the best yield reported was four barrels a day at Chromo.

Carlisle Shale Member

The Carlisle shale member can be mapped in the northern part of the Basin. As reported by Dane, it consists of two parts, a lower dark shale about 200 feet thick and an upper part containing "numerous beds of hard dark-colored platy sandy limestone or calcareous sandstone." This upper part is a distinctive zone on the outcrop through all of southern Colorado. Dane (1948, para. 10) reports a thickness for the Carlisle of 600 feet in the vicinity of El Vado from whence it thins to the north to 500 feet on the Monero Dome. The upper part often weathers a silvery gray on the outcrop and makes a distinct color band where the Mancos is well exposed. This unit is the most important producing interval of the Mancos shale. Stray sands occur in it in all parts of the Basin, becoming more common to the southwest. The "stray sandstone" of Sears, Hunt, and Hendricks (1941, p. 113) occurs in this interval. Small sand lenses in

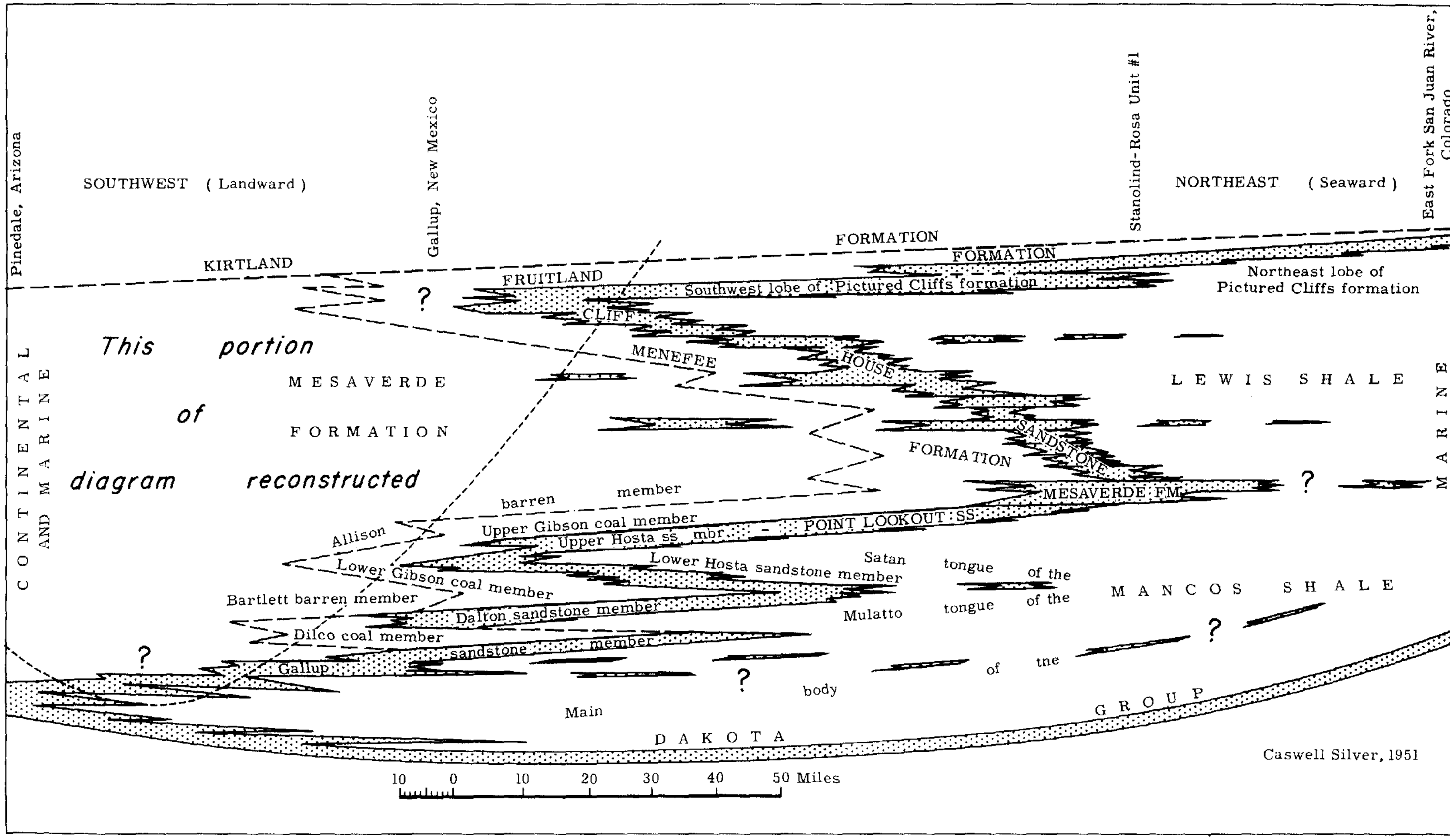

FIGURE 4. DIAGRAM SHOWING THE RELATIONSHIP OF THE MESAVERDE FORMATION TO OTHER FORMATIONS IN THE SAN JUAN BASIN, NEW MEXICO AND COLORADO.

this interval produce the shallow production at Chromo, Colorado and it is the interval containing the stray producing sand at the Thomas Doswell well in Sec. 9, T. 26 N., R. 6 W. This is also the interval split by the Gallup sandstone tongue of the Mesaverde to the southwest which further north has been called the Tocito sand stone. Pike (1947, p. 29) showed that the Gallup sandstone member, Dilco coal member, and Dalton sandstone member are essentially equivalent to the Tocito and he recommended that the latter term be dropped. However, production has been established within several sandstone bodies in this zone and the name continues to be employed in the oil industry. With the important Doswell oil discovery in this horizon in T. 26 N., R. 6 W. it appears that the term will become more firmly established than ever and that the only recourse is to give way to its usage as a zone term, recognizing that production in the "Tocito" in different fields or even in the same field is not necessarily from the same continuous sandstone lense.

Niobrara Shale Member and Upper Shale Member

The Niobrara calcareous shale member is separated with difficulty from the overlying Upper shale member of the Mancos. Dane (1948) has distinguished them in his map of part of the eastern Basin but they cannot be distinguished either in well cuttings or in the outcrop without the presence of fossils. Their usefulness as units would appear to be highly restricted if not negligible. In that area Dane (1948, para. 11) gives 250 to 350 feet for the Niobrara and 500 to 700 feet for the Upper shale member of the Mancos.

Fluids in the Mancos Shale

The Mancos shale is productive of oil and gas in several parts of the San Juan Basin. All occurrences reported have been small except for the production reported in the Price field in Colorado. In this field wells were reported to have made a potential of several hundred barrels a day in the Mancos shale above the Dakota sandstone. At Chromo, eight miles to the west of the Price field and four miles north of the New Mexico state line, more than a dozen wells are currently productive from sandy lenses in the Carlisle shale and from fractures. Wells there have had an initial potential as high as 200 barrels per day but have declined within a few days to 5-10 barrels per day. Some of these "shale" wells have made an average of five barrels a day for more than three years at depths of less than 600 feet.

Many wells scattered over the Basin and abandoned in the Mancos shale before reaching the Dakota sandstone have reported making small amounts of gas. Several of them are used as domestic sources of fuel.

Mesaverde Group

The Mesaverde group is the name applied to the regressive and transgressive wedges of sandstone which intertongue with the Mancos and Lewis shale to the southwest. The term formation is generally applied to portions of the Basin where individual mappable units are not distinguished. This applies both in the northeast where the Mesaverde is recognized as one overall sandstone wedge and in the west where sandstone, shale, and coal are extremely irregularly interbedded. Group was the original term applied by Holmes (1877, p. 244) when he named the unit from the locality at Mesa Verde and recognized three formatations. Collier (1919, p. 296) renamed the subdivisions of Holmes, the Cliff House sandstone, the Menefee formation, and the Point Lookout sandstone. The U. S. Geological Survey has followed the practice of referring to the Mesaverde as a group at the type locality and its vicinity and as a formation elsewhere. In addition, the Survey carried the name Mesaverde for coal-bearing formations in the middle part of the Upper Cretaceous series as far away as Wyoming.

The Mesaverde of the Basin can be conveniently divided into two parts for discussion; (1) the original group of Holmes and its extension north and east, and (2) all the regressive and transgressive sandstone units that tongue to the Mancos shale below the original group of Holmes. The base of the Mesaverde may theoretically fall as low as the top of the Dakota sandstone or the pre-Dakota erosion surface in localities far to the south and west. Inasmuch as the Mesaverde is erosionally truncated to the south and west on the flanks of the Zuni and Defiance Uplifts, the discussion which immediately follows will be confined to the five members into which part (2) has been subdivided in the southern part of the Basin.

The Gallup Sandstone Member

Stray (i.e., unnamed) sandstones intertongue with the lower part of the Mancos shale between its base and the base of the Mesaverde but the first persistent regressive sandstone which has been mapped over a large area is called the Gallup sandstone. In the Gallup-Zuni basin the Gallup sandstone consists of three persistent, massive sandstones and interbedded shale and coal 180 to 250 feet thick. The lower one of these sands splits to the east and northeast, being recognized west of Mount Taylor as two sandstone tongues in the upper part of the main body of the Mancos shale. The upper two sandstones of the Gallup converge to the east and northeast, pinching out the intervening coal and shale and gradually replace the overlying Dilco coal member. Where it appears on the surface in northwestern San Juan County it is known as the "Tocito" sandstone. As is the case with most regressive sandstones in the area, the base is often transitional to Mancos shale.

Dilco Member

This member is 240-300 feet thick in the Gallup-Zuni Basin and is gradually replaced northeastward by sandstone and shale. It contains many of the valuable coal beds in the western part of the Basin and gets its name from the village of Dilco (Direct Line Coal Company). It is unique in the San Juan Basin in that over a large area it is directly overlain by the Mulatto tongue of the Mancos shale. Together with the Gallup sandstone it is the only regressive unit in the Basin which does not have a continuous littoral sandstone intervening between it and the overlying marine shale and therefore it is similar to the sedimentary sequence of the Book Cliffs of Utah. In this respect it is the only regressive sequence of the Mesaverde known to the author which does not combine with a transgressive sandstone to form a wedge of dual nature, as discussed by Spieker (1949, p. 66). This could result from a more rapid shoreward shift of strandline or sudden rise in sea level.

Dalton Sandstone Member

The Dalton sandstone member in its extreme southwestern position is the missing littoral sandstone enclosing the Mulatto tongue of the Mancos shale (see Figure 3). It does not extend into the Gallup-Zuni basin. It splits into two tongues northeastward, the lower tongue intervening between the Mulatto tongue of the Mancos shale and the Dilco coal member for a few miles before lensing out. The upper sandstone tongue of the main body of the Dalton is the regressive sandstone lying above the Mulatto tongue of the Mancos shale. Where the Dalton sandstone is not split by shale in T. 16 N., R. 16 W. it is 180 feet thick but eastward it splits into an upper unit above the Mulatto tongue 96 feet thick and a lower unit included between two tongues of shale 72 feet thick. (Sears, et al, 1941).

Bartlett Barren Member

In working with the Mesaverde formation of western and southwestern parts of the Basin, Sears (1925, p. 16-17) apparently found it difficult to separate the flood-plain deposits from the coastal deposits although he clearly felt such a distinction existed. In mapping, it is apparent that the sediments immediately overlying the off-shore and beach deposits contain more numerous and thicker coal beds than the contiguous flood-plain deposits and that they do not exhibit the scour and fill relationships to as marked a degree. Since the intertonguing prevents any sharp separation, Sears arbitrarily divided the two on the basis of the number and thickness of the contained coal beds. Those sediments containing commercial coal beds over fourteen inches thick were mapped as coal members and the contiguous sediments generally containing coal beds of lesser thickness were termed the barren members.

The Bartlett barren member contains beds lithologically similar to the beds of the Dilco coal member. In the Gallup-Zuni Basin this interval is 330 to 400 feet thick and is separated by Sears (1925, p. 17) from the Dilco coal member. Actually as discussed above the separation is purely arbitrary; the Bartlett member is made up of the flood-plain deposits which increasingly dominate the Mesaverde to the southwest. In all probability this unit converges to the southwest with the Allison barren member as the overlying Gibson coal member wedges to a thin edge.

Gibson Coal Member

In the Gallup-Zuni area the Gibson coal member consists of 150-175 feet of clay, irregular sandstone and coal which thicken northeast until at the north end of the Nutria monocline in T. 17 N., R. 17 W. it is 350 feet thick. Just northeastward from this location it splits into two tongues enclosing the Hosta sandstone member of the Mesaverde. The lower tongue is the coaliferous coastal lagoon and swamp deposit between the converging wedge of the underlying regressive Dalton sandstone member and the overlying transgressive lower Hosta sandstone member. The upper tongue is the coastal swamp deposit lying above the upper Hosta sandstone member. In its further extension east and north it is the lower part of the Menefee formation in the area where the Upper Hosta sandstone bears the designation of the Point Lookout sandstone.

Allison Barren Member

The Allison barren member makes up the upper part of the Mesaverde in the southwestern part of the Basin. It wedges to the north and east where it forms together with the Gibson coal member the Menefee formation of the central part of the Basin. It thickens rapidly to the southwest near Gallup where its top is eroded. In Sec. 32, T. 16 N., R. 18 W. a thickness of 800 feet is reported by Sears (1925, p. 18) from drill-hole information.

Lower Hosta Sandstone

The lower Hosta sandstone is the lower bed of a thick sandstone 200 feet in thickness which lies between the lower and upper Gibson coal members along the southern boundary of the Navajo Indian reservation in T. 17 N., ranges 11 to 15 W. The Satan tongue of the Mancos shale splits this sandstone into an upper and lower unit. The Lower Hosta sandstone converges with the Upper Hosta sandstone in approximately Sec. 2, T. 17 N., R. 15 W. where the Satan tongue wedges to a thin edge. It is the transgressive sandstone underlying the Satan tongue and in turn is underlain by the Lower Gibson coal member. The lower Hosta sandstone is about 100 feet thick through most of its extent but grades to sandy shale to the east in T. 16 N., R. 1 W. on the Ojo del Espiritu Santo Grant.

Point Lookout Sandstone and
Upper Hosta Sandstone Member

In introducing the subject of the Mesaverde sediments of the Basin, a two fold division of the entire sequence was proposed, followed by a discussion of part 2 in terms of the individual units. A discussion of part 1 follows.

To many in the oil industry of the Basin the Mesaverde is the Point Lookout sandstone, Menefee formation, and Cliff House sandstone of the northern part of the Basin. This is a natural result of subsurface development in areas close to where these units have been well defined on the surface. Correlation of these units with similar units termed Upper Hosta sandstone member, Allison-Gibson member and Chacra sandstone member became evident when Pike (1943, p. 37) established the fact that the Upper Hosta sandstone of the southern part of the Basin was traceable into the Point Lookout sandstone as one continuous unit. Zapp (1949, para. 9) distinguished an upper massive sandstone member of the Point Lookout sandstone on the surface in the Durango area. Silver (1950, p. 110) showed that the upper part of this regressive sandstone consisted of a massive bed of medium-grained sandstone 100 to 300 feet thick, extensive in the subsurface and continuous to the northeast to the vicinity of the Stanolind-Rosa Unit No. 1 well in Sec. 11, T. 31 N., R. 6 W. where it thinned and became indistinguishable from the thin sandstones in the lower part of the Mesaverde formation.

Menefee Formation and the Allison-Gibson Member

With the establishment of the equivalence of the Point Lookout sandstone and the Upper Hosta sandstone member as one continuous regressive sandstone horizon, it was logical to recognize that the overlying coastal swamp deposits were also continuous. Silver (1950, p. 110) pointed out that such deposits were an over-all wedge to the northeast within the converging regressive Point Lookout and Cliff House sandstones and that these deposits finally merge into the over-all sandy Mesaverde formation (see figure 1).

At the type locality at Mesa Verde the Menefee consists of 400 feet of coal, shale, and sandstone and it thickens southward to the Gallup area where it is subdivided into the members already described. Pike (1947, p. 49) reports the Menefee as 812 feet in Sec. 17, T. 29 N., R. 16 W. a point approximately 35 miles south of the type locality and 90 miles north of the Gallup area. In the latter area the top of equivalent sediments is erosionally truncated and Sears (1925, p. 16) reports an incomplete thickness of approximately 1600 feet. While the Menefee deposits are in large part continental in origin they are not entirely so and it must be emphasized that even far to the west in Black Mesa some units containing marine fossils are present. It would appear that during transgressions of the sea far to the west local inundations flooded well back upon the coastal plains deposits and left a marine invertebrate fossil record intercalated in otherwise continental type deposits. The continental deposits are characterized by thick lenses of sandstone, coal and shale in intricate scour-and-fill relationship as contrasted to the more regular bedding of the coastal deposits.

Cliff House Sandstone and the Chacra Sandstone Member.

The Cliff House sandstone of the north and the Chacra sandstone and La Ventana sandstone of the south are deposits of the transgressive transition zone between the marine Lewis shale and the largely nonmarine Menefee formation. These transgressive deposits differ from the regressive sandstones in that they are not continuous sand bodies but rather a continuous zone of sand lenses which tongue deeply to both the Lewis shale and the Menefee formation. Lensing of sands in this transition zone is well known in both the surface and subsurface. Lenses of sandstone appear to be gradational at any horizon northeastward into marine shale of the Lewis formation and gradational southwestward into the highly variable shale and sandstone of the Menefee formation. Because of their restricted extent the lenses of this transgressive transition zone apparently do not rise stratigraphically. The zone rises stratigraphically but not the individual lenses. They differ markedly from the Point Lookout sandstone in that such lenses form separate local units imbricated upward to the southwest -- such as the La Ventana sandstone and the Chacra sandstone, whereas the regressive sandstones rise stratigraphically as continuous blanket sandstones whose lower margins intertongue with shale.

Coal in the Mesaverde

The coal beds of the Mesaverde are the principal coal deposits of the San Juan River region. Coal is found throughout the Mesaverde but the thickest and most continuous beds have been found principally in the coastal swamp deposits immediately above regressive marine sandstones and immediately below transgressive marine sandstones with which they are often in direct contact. In the subsurface of the central part of the Basin the larger coal beds which yield a distinctive resistivity "kick" on the electric log are found close to the top and the base of the Menefee formation. Because of the differing stratigraphic relationship between the regressive and transgressive sandstones the more continuous coal beds lie above regressive sandstones.

Fluids in the Mesaverde

The Mesaverde contains within it the sedimentary deposits formed near the demarcation between marine and non-marine environments and it is only natural to anticipate fluids reflecting both. Fresh water, brackish water, salt water, gas, and oil have been encountered in well bores in this zone. Silver (1950, p. 109) emphasized that the Mesaverde group is an over-all wedge of porosity and permeability between the converging Lewis and Mancos shale formations (Fig. 4) and that large accumulations of gas are present in the northeast end of some sandstone lenses. The low permeabilities encountered in the gas reservoirs plus the lack of free oil in these horizons where well bores have encountered the gas and water contact would indicate that there will not be an oil ring around the gas within the Point Lookout sandstone to the west. Information to the south and east is insufficient to support a similar conclusion there; it is possible that the petroliferous accumulation in the Point Lookout sandstone did not extend to the present outcrop in that direction. Local lenses within the Menefee zone have encountered sandstones containing oil. A core containing four feet of fully saturated oil sand was "pulled" from the Menefee of the Stanoline-Elliot No. 1 B in Sec. 14, T. 29 N., R. 9 W. Shows of oil and production of a few barrels of oil a day are indicated in wells drilled in the Mesaverde in T. 18 N., R. 3 W., Red Mountain and Seven Lakes and scattered areas in the southwest part of the Basin. Because of their discontinuous nature it can be anticipated that the sandstone lenses not yet exposed by erosion that occur within the transgressive sandstone zones will contain oil and gas accumulations. Where such subsurface lenses have the extent of 5 x 10 miles and larger, similar to La Ventana sandstone on the surface, large accumulations are possible.

The lower Mesaverde is part of the wedge belt of porosity pinching out to the northeast. Silver (1951) pointed out that its occurrence in the subsurface is mostly over the south half of the Basin, an area in which few wells have been drilled. The occurrence of salt water and oil shows in the few wells drilled to this horizon is highly encouraging. Buried, sealed sandstone lenses in the subsurface, such as the "stray sandstone" of Sears, Hunt and Hendricks (1941, p. 113) and the La Ventana sandstone are to be anticipated.

The Lewis Shale

The Lewis shale, a thick body of sandy gray marine shale lying between the Mesaverde and the Pictured Cliffs sandstone is a wedge-shaped body that thins to the southwest and thickens to the northeast. The thickness of the Lewis shale from north to south on the west side of the Basin is 1700 feet at the type locality in Colorado, 1,100 feet at Navajo Springs, 475 feet on the San Juan River and 76 feet at Coal Creek (Reeside, 1924, p. 17). It is thickest north of Pagosa Springs in Archuleta County, Colorado where it is 2,580 feet. Sandy zones are common in the Lewis shale and one of them has produced gas and distillate in the Union Oil and Mining Company No. 2 Pine well in Sec. 8, T. 29 N., R. 9 W.

Pictured Cliffs Sandstone

In the 1950 Guidebook (Silver, p. 112) appears the following description: "In addition to being an important producing horizon, the Pictured Cliffs is the most persistent and valuable subsurface stratigraphic datum in the Basin. Many workers have noted its close resemblance in lithology and general appearance to the Point Lookout sandstone (Zapp, Sheet 1). It is the uppermost wholly marine lithologic unit in the basin and it records the final withdrawal of the Cretaceous sea in the area. Where it is found it is medium to fine grained and at any stratigraphic horizon it is gradational northeastward into Lewis shale. It ranges from 50 to 400 feet in thickness and crops out on the north, west and south sides of the basin. It is notably absent on the east side. Its top over large areas is recognized as virtually a stratigraphic plane and it is used as such in Figure 1."

Silver (1950, p. 112) shows the separation of the Pictured Cliffs sandstone into an upper and lower stratigraphic unit (Figure 1). The lower or southwestern lobe of the Pictured Cliffs is an important gas horizon in the Basin. Gas is widely distributed in the Pictured Cliffs sandstone over more than 1,500,000 acres and appears to have accumulated in the northeast end of the southwestern lobe at a time when this unit was inclined to the west. Water is apparently encroaching from the outcrop in some areas at the present time and the area of gas will apparently be limited only by the extent of water invasion. No free oil has as yet been found in the Pictured Cliffs sandstone and none is indicated for the southwestern lobe. However, there is no apparent reason why accumulations could not be present in the northeast lobe where structural conditions are favorable.

Fruitland and Kirtland Formations

The Fruitland formation is the name applied to the 200–300 feet of coal-bearing coastal swamp and flood-plain deposits which accumulated behind and above the near-shore sands of the Pictured Cliffs sandstone as it retreated to the northeast. After the retreat of the Cretaceous seas from the area, a late Cretaceous basin of deposition, which has been called the Kirtland Basin (Silver, 1950, p. 112), developed in the western half of the present San Juan Basin. In it accumulated the Kirtland formation, with its three-fold lithologic divisions. The Kirtland formation is a wedge-shaped mass of sediment which thins from a maximum of 1700 feet on the Colorado-New Mexico line in T. 14 W. to a thin edge in central Rio Arriba County. The three members also thin in the same direction, the lower shale member from 550 feet to zero, the middle Farmington sandstone member from 480 to zero feet, the upper shale member from 675 feet to zero.

Coal in the Fruitland Formation

The Fruitland formation is one of the important coal horizons in the northern and central parts of the Basin. Most of the coal beds occur in the lower half of the formation. In the subsurface of the central part of the Basin coal beds immediately above the Pictured Cliffs sandstone are important stratigraphic markers. Coal in this horizon is usually five to 14 feet thick but in the Hauck No. 1 in Sec. 1, T. 29 N., R. 10 W. more than 80 feet of coal beds separated by thin shale breaks was reported. This is very similar to the 80 feet of coal reported for the "Carbonero Bed" near Durango (Zapp, 1949).

Fluids in the Fruitland and Kirtland Formations

Commercial gas has been produced from the Fruitland formation and commercial oil and gas from the Farmington sandstone member of the Kirtland formation. The Fruitland producrion consists of two types. Segregated sand lenses in the Blanco area have shown gas in what appears to be a stratigraphic trap. Wells have also tested gas in the beds which are called "Fruitland" in the Ignacio area, Colorado. The latter occurrence appears to be a structural accumulation in a locally transgressive tongue of the Pictured Cliffs formation. Since the Pictured Cliffs sandstone occurs twice in the well bores separated by a regressive tongue of coal-bearing beds similar to the log of the Rosa Unit No. 1 well (Figure 1), the term "Fruitland" is erroneously applied to the upper gas horizon. Elsewhere in the Basin salt water occurs in lenses of the Fruitland formation and brackish water in the coal horizons.

The Farmington sandstone member is largely a concentration of sand lenses in the middle portion of the Kirtland formation. Individual lenses have produced salt water, oil and gas. Commercial gas was produced from this zone near Aztec and Bloomfield and small commercial oil wells with an initial production of 25 barrels a day are reported from the Oswell field by Bates (1942, p. 115). Production of 57°gravity oil is reported from different levels in offset wells. A well in the Blanco field tested 40 barrels a day from a sandstone lens in this zone but was perforated into water. Small commercial oil production from this zone was also reported in the Israel well in the Fulcher Basin area. The largest field as yet developed in the Farmington sandstone was the Bloomfield pool which had a total of thirty producing wells out of some 60 drilled. Bates (op. cit., p. 96) concluded that the accumulation is due to shale-sealed lenses as neither surface or subsurface data indicate any structural closure.

McDermott Formation

The McDermott Formation lies in the western half of the Basin as a thin wedge on top of the Kirtland shale. Its greatest thickness is 300 feet and it thins to the south and east and becomes indistinguishable from the Kirtland shale in the subsurface in the central part of the Basin. In its northern extent it consists of lenticular sandstones, shales, and conglomerates containing much andesitic debris and usually it is in part of purple color. It grades to purple streaked shale away from its thickest occurrence along the Colorado-New Mexico boundary in R. 11 W. It appears locally unconformable to the beds above and below.

Ojo Alamo Sandstone

The Ojo Alamo sandstone is an approximately 200-foot thick conglomeratic sandstone containing occasional lenses of shale. It appears to be restricted to the western and southern portions of the Basin where it overlies the McDermott formation or rests directly upon the Kirtland shale. Several unconformities have been noted above, below and within the Ojo Alamo sandstone but these have been interpreted by Dane (1946, para. 7) as not being significant either as time lapses or as intervals of erosion. Others have held (Silver, 1950 p. 112) that such unconformities become more important as time breaks in areas away from the Kirtland Basin.

Animas and Nacimiento Formations

The Animas formation consists of some 2,000 feet of greenish and tan andesitic sandstones and shales lying in the northern half of the Basin. Its lower part contains the latest Cretaceous deposits in the Basin and its upper part is gradational into the Nacimiento formation of the southern part of the Basin which contains beds of Puercan and Torrejonian age. A difference of opinion exists as to the relation between the the Animas formation and the underlying Cretaceous formations. Dane (1946, para. 7) and Wood et al (1948, para. 21) have held that the Animas intertongues in the northeast part of the Basin with beds as old as the Lewis shale. Others (Reeside 1924, p. 48-49) and Silver (1950, p. 121) hold that a hiatus exists at the base of the Animas. While deposition of sediments may have been more or less continuous in the Kirtland Basin during latest Cretaceous time, these beds lap upon the east flank of the Kirtland Basin and later reworking into lower beds of the Animas has obscured the hiatus which could have followed the deposition of the Kirtland shale. The relationship of the Animas formation, as given by Dane, is one of progressive overlap to the south in which successively higher and younger beds appear at its base. Such a relationship is not in conflict unless accompanied by intertonguing.

Coal occurs in scattered seams in the beds above the Fruitland formation, but none appears to be thick enough or to have continuity sufficient to be of commercial importance. Scattered shows of gas have been reported from shallow wells in the Animas but prospects for commercial production do not appear favorable. Potable fresh water and sulfurous "black water" poisonous to stock occur in both wells and springs in the Animas beds in the central part of the Basin.

Conclusion

The stratigraphy reviewed in this paper has necessarily emphasized the discontinuous lithology of the various units. Variations of permeability have been demonstrated in these units in the so-called gas areas (Silver, 1950). The known fields and numerous shows of oil and gas indicate that these units are petroliferous. It is the author's belief that a large part of the original fluids developed in the Cretaceous strata are still confined to the Basin by the aforesaid lenticularity. Aside from structural accumulations stratigraphic traps containing minor and major accumulations are very probable.

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