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PALEOZOIC SEDIMENTARY ROCKS OF SOUTHWESTERN NEW MEXICO

by
Rousseau H. Flower

Bliss sandstone

The Bliss sandstone (type section in the southern Franklin Mountains, near Ft. Bliss, where it is 250 feet thick) forms characteristic dark, often black weathering ledges which contrast strongly with the red weathering Precambrian granites beneath, and the overlying grey-brown weathering El Paso limestone. The Bliss is dominantly a sandstone, with abundant glauconite and hematite, but also with a considerable amount of dolomitic material in certain layers. The Bliss was originally considered Cambrian on the basis of **Lingulepis**, which unfortunately is a long ranging type and is not necessarily diagnostic. The discovery of Ordovician (Gasconade) fossils at the northern end of Beach Mountain in Texas raised a controversy, some insisting that the whole Bliss was Ordovician, others that the lower part was Cambrian in Texas, and that the entire unit was Cambrian in New Mexico. Until recently, the fossils known from the Bliss sandstone in New Mexico were not diagnostic types, but did suggest an age of either late Trempealeau or earliest Ordovician.

Three recent discoveries indicate three different ages. The first, of **Ptychaspis striata** and **Chariocephalus**, indicates middle Franconia age. The second, of **Briscoia** and **Prosaukia**, indicates late Franconia age. The third, the discovery of **Bellefontia** in association with linguloids, ribbed brachiopods, and the graptolite **Dictyonema**, indicates earliest Ordovician, and is possibly the correlative of zone I of Ross in the Garden City formation of Utah (Flower, 1953, p. 2055).

The Bliss represents, plainly, very slow and frequently intermittent deposition which began, from our present evidence, in the middle of the Upper Cambrian, and continued into early Ordovician time. The diagnostic fossils, all from zones of 6 inches or less in thickness, represent infrequent periods of more rapid deposition.

The Bad Axe "formation" of Wisconsin and Minnesota which consists of glauconitic and ferruginous sands, has been interpreted as representing an environment of very slow deposition. Along the edge of the basin, deposition was too slow for the preservation of fossils in general, but in the center of the basin were deposited the sands and silts which contain the most prolific succession of trilobites in North America. If the Bad Axe beds were consolidated and subjected to the weathering conditions of an arid, instead of a moist climate, they would look very much like the Bliss sandstone. The Bliss may be considered a "Bad Axe facies" laid down in the center of a basin. The marginal sediments to the west, in southern Arizona, contain a succession of Upper Cambrian faunas, beginning, as a matter of fact, in the Dresbachian which precedes the Franconian. Any marginal sediments to the north were removed by erosion and to the east were deeply covered.

El Paso limestone

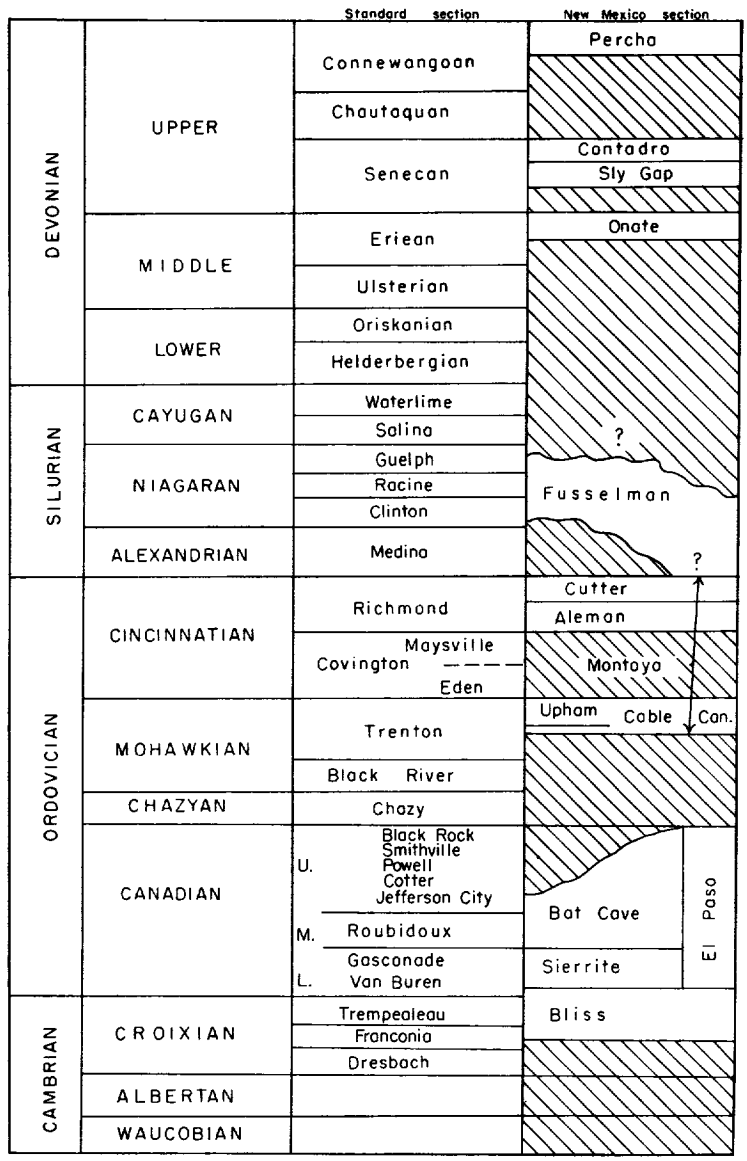
The El Paso formation consists of a group of limestones, with minor amounts of dolomite in New Mexico, with more abundant dolomite and some definitely sandy beds in the sections in western Texas. Deposition extended throughout Canadian time (often called Beekmantown except by those who have seen the type section at Beekmantown, which is miserable). At the southern end of the Franklin Mountains the lowest sediments are of Gasconade age, lower Canadian, and the highest are equivalent to the Black Rock formation of Missouri and the Odenville limestone of Alabama. In New Mexico the El Paso is generally considerably thinner than the 1590 feet measured at El Paso by Cloud and Barnes (1946), and post-Canadian erosion has removed variable amounts of the upper limestones in different places.

Kelley and Silver (1952) have treated the El Paso as a group and separated it into two formations:

Sierrite limestone – Generally thin-bedded limestones, sometimes slightly dolomitic, and extensively dolomitized in the Hatchet Mountains. Bedding planes are undulant or crinkled, and often highly styolitic. There are beds of limestone pebbles, and of small algal masses, some spherical, some tubular and branched, but massive stromatolite beds are wanting. The fauna indicates a correlation with the Gasconade, though the top of the formation may extend slightly higher than the Gasconade and its equivalents in the east. The fauna is sparse. **Clarkeoceras**, **Ophileta**, **Symphysurina**, and **Histricurus** have been collected, and a zone in the Hatchet Mountains has yielded **Kainella** and **Leiostegium**.

The Sierrite limestone ranges between 100 to 175 feet in thickness. About 100 feet of the basal dolo-

LOWER PALEOZOIC STRATIGRAPHY OF SOUTHERN NEW MEXICO



mite at El Paso is the equivalent of this formation.

Bat Cave formation – The Bat Cave contains more massive beds, and is more prominently cliff-forming than the Sierrite limestone. It is characterized by a wide variety of sedimentary types, but chiefly by thick layers of stromatolitic limestone, and, often in association with the stromatolite reefs, layers of coarse detrital limestone. Many of the beds are thin layers of lime mud, containing algal pellets and small gastropods. The Bat Cave formation contains a succession of faunas ranging in age from the Middle Canadian (Gorman and Roubidoux equivalents) to beds of Powell or possibly younger age. At El Paso the highest beds include the Smithville and Black Rock equivalents. The succession of the El Paso in New Mexico and western Texas is providing a link between the eastern sections in which the faunal succession is based primarily upon the molluscs, and the Utah sections in which the succession is based primarily upon the trilobites.

The faunas of the Bat Cave limestones are largely undescribed. The most conspicuous elements are the siphuncles of endoceroid and piloceroid cephalopods, which are often silicified and weather red on exposures; there are abundant sponges, and a considerable variety of gastropods, brachiopods, and trilobites. The New Mexico succession in the Bat Cave interval is briefly as follows:

1. A fauna in stromatolitic and detrital limestones above the Sierrite limestone, characterized by the first (lowest) endoceroids, some primitive pliomerid trilobites, and abundant gastropods. The most common form is a small, low, broad, conical gastropod called **Rhaphistoma trochoides** Meek. This fauna is present throughout in the lowest beds and is the only fauna which persists into the Dos Cabezas region of Arizona.

2. Beds with more massive algal reefs, and with a striking fauna of large piloceroids, occasional coiled cephalopods, and abundant sponges.

3. Dark weathering limestones, dark-grey to black when fresh, with abundant pebbles, largely algal pellets, which produce a mottled weathering. In the middle are several beds of black oolitic limestone containing a characteristic fauna, largely of asaphid trilobites and low-spired gastropods.

4. Massive algal reefs with abundant sponges and otherwise a meagre fauna, but characterized by a large **Orospira**.

5. Thin-bedded blue-weathering limestones, with algal fragments and hoards of small gastropods.

6. Massive beds, usually dark and with some black oolite in stringers, containing the second piloceroid fauna.

7. Thin-bedded limestones, again with algal pellets and gastropods, but with an admixture of brachiopods and trilobites.

8. More massive beds, with a reappearance of stromatolite layers, alternating with thin-bedded limestones. Characterized by an abundance of echinoderm fragments, and a varied fauna of small brachiopods and trilobites. Various sections throughout southern New Mexico extend upward to various points in this column. All units are found in the Cooks Range. The section in the Hatchet Mountains extends up to the top of bed 6. At Mud Springs Mountain, the uppermost beds are in the middle of bed 5.

Montoya group

The Montoya group is dominantly dolomites, is as much as 250 feet thick, and on the basis of a prominent fauna of silicified brachiopods, is generally considered Richmond, latest Ordovician, in age.

Kelley and Silver (1952) divided the Montoya into four formations; the Cable Canyon sandstone, the Upham dolomite, the Aleman formation, and the Cutter formation. The Cable Canyon sandstone, at the base, ranges up to 35 feet in thickness, and contains some dolomite cement. The meagre fauna so far obtained shows nothing which has not been found in the overlying Upham formation.

The Upham dolomite is massive with a maximum thickness of 80 feet. It contains some chert in the upper portion, but the fauna is not silicified, and is therefore obscure. At El Paso the lower beds have a characteristic mottled appearance not generally found in the New Mexico sections. Most sections in New Mexico have abundant coarse sand grains in the lower part, and the basal beds contain reworked material from the underlying Cable Canyon sandstone. The fauna contains **Maclurites, Receptaculites, Halysites, Actinoceras**, and a variety of other forms. The fauna suggests a correlation with the late Trenton rather than with the Richmond.

The Aleman formation consists of thinner-bedded cherty dolomite, often white weathering and broken, and with an abundant fauna of silicified brachiopods. The lower layers contain abundant **Dalmanella, Zygospira**, and **Cornulites**, above which appears a more varied fauna with **Rafinesquina, Rhynchotrema capax**, and an abundance of orthoid and strophomenoid brachiopods. This is the fauna which has been considered Richmond.

It is an anomalous fact that west of the Mississippi River and north from central Canada to northern Greenland, late Ordovician strata occur with a mixture of Black River, Late Trenton, and Richmond types. Also, west of the Mississippi, there have been recognized beds of late Trenton age and beds of Richmond age, but never beds of the intermediate Covington (Lower Cincinnatian = Eden and Maysville) age. A time break is suggested which if it exists lies, irritatingly, in New Mexico between the Upham and Aleman formations, where no sharp contact is evident. The recent discovery of many supposedly Richmondian types in late Trenton beds in Quebec, indicates that the faunal criteria formerly used are not yet adequately known as to range. The difficulty is largely due to the fact that from Chazyan to the Richmond, Ordovician faunas are made up of complexly intertonguing faunal realms, perhaps geographic and climatic rather than ecological in the sense that this term is usually employed for

faunas confined to specific facies.

The Cutter formation consists of about 160 feet of generally thin-bedded, fine-grained, light-colored dolomite, with some layers of limestone, clay shale, and lenses of chert. These beds were originally included with the Silurian Fusselman dolomite by Darton, but they have yielded a fauna which is clearly late Ordovician, and probably late Richmond. The fauna contains some brachiopods apparently similar to those of the underlying Aleman formation. In addition, it contains abundant but poorly preserved pelecypods (**Whitella?** and **Ctenodonta?**), gastropods, and cephalopods. There are favositid corals and **Beatricea**. The fauna, as yet inadequately known, suggests a possible correlation with the Whitewater-Elkhorn portion of the Richmond. In some sections the contact with the Aleman is sharp, while that with the Fusselman cannot be determined accurately. In other sections the reverse has been found.

Fusselman dolomite

The Silurian is represented in New Mexico by the Fusselman dolomite, a massive grey dolomite, which attains a thickness of as much as 1000 feet in some places. Dolomitization is advanced, producing local brecciation, and the dolomite often weathers with mottled surfaces which, in some instances at least, are shadows of almost completely destroyed fossils. The known fossils are those which were replaced by silica prior to dolomitization. The faunas are spotty geographically, and the associations vary considerably from place to place. The most abundant forms are several species and probably several genera of pentameroid brachiopods, the large atremate, **Monomerella**, and corals including **Heliolites**, **Favosites**, and **Halysites**.

With its great thickness, it is quite possible that the Fusselman dolomite represents a considerable part of Middle Silurian time, but the isolated faunules are not adequate as a basis for precise correlation, and no accurate zonation is possible. Bowsher has regarded a fauna from the Sacramento Mountains as possibly Alexandrian in age.

Devonian

The Devonian of New Mexico consists dominantly of shales, with relatively thin-bedded siltstones, sandstones, and limestones. As a unit, it is readily differentiated from the resistant dolomites below, and from the ledge-forming limestones of the Mississippian above. Various formations have been recognized, and it is known that together they embrace a time interval ranging from late Middle Devonian to the very latest Devonian. The formations are briefly summarized as follows (Stevenson, 1945).

Canutillo formation – Recognized only in the Franklin Mountains. See El Paso section for a brief discussion.

Onate formation – 87 feet thick with the type section in the San Andres Mountains; consists of shale, siltstone, and some fine-grained grey-brown weathering sandstones. The fauna is regarded as late Middle Devonian. The most characteristic forms are a **Leiorhynchus** and **Sulcoretopora anomalotruncata**, and a bryozoan with broad, flat, dichotomously branching colonies.

Sly Gap formation – 114 feet thick; type section in San Andres Mountains. The formation consists of thin-bedded shales, limestones, and siltstones, tan to light yellow weathering; in general it is lighter weathering and has less massive beds than the Onate formation. The fauna, allied to that of the Hackberry of Iowa, indicates an early Upper Devonian age.

Contadero formation – 66 feet thick, type section in central San Andres Mountains. Carbonaceous shales and thin-bedded limestones, with a basal grey limestone. Except for an undescribed **Ambocoelia** common in the basal beds, the known fauna is not different from that of the underlying Sly Gap. Lithology, however, is strikingly different.

Percha shale – 178 feet of shale, divided into two portions. The lower Ready Pay member consists of about 130 feet of calcareous shale, containing calcareous and often fossiliferous nodules. The Box member consists of black fissile shale, but contains some layers of limestone. The calcareous content increases westward and near Silver City one limestone may attain a thickness of 16 feet. The known brachiopod fauna is largely confined to the lower Ready Pay member. It is allied to the fauna of the Ouray limestone of Colorado and that of the Martin limestone of Arizona.

The distribution of the Devonian formations varies widely. In the Franklin Mountains only the Canutillo formation is recognized. The Onate, Sly Gap, and Canutillo formations are best developed in the Sacra-

mento and San Andres Mountains. At Hermosa the Onate was found overlaid by the Percha shale. At Percha Creek, and in the regions west and south, only the Percha shale has been recognized. At some places its base contains a layer which has yielded fragmentary fish plates and teeth.

The Devonian of New Mexico appears to consist of three distinct periods of deposition, one of Middle Devonian (Onate) age, the second, including the Sly Gap and Canutillo, of early Upper Devonian, and the third, the Percha shale, of very late Upper Devonian. There has been some discussion as to whether the Percha shale is latest Devonian or earliest Mississippian. The late Devonian age is indicated in particular by the occurrence in New Mexico of a clymenid ammonite, one of the three occurrences in North America, the others being the upper Devonian of New York and the Three Forks shale of Montana. Clymenids have served as a basis of elaborate zonation of the Upper Devonian in Europe and North Africa, and are unknown in the Mississippian.

Mississippian

Caballero formation – Strata of Kinderhook age, confined to the Sacramento, San Andres, and Lake Valley regions. It is highly variable in thickness and lithology. In the Sacramento Mountains it is 60 feet thick and is composed of nodular limestones in shale. In the Lake Valley region it is thin, and consists largely of thin, silty limestones at the base, with some thin-bedded nodular limestone above. It is absent near Hillsboro and regions west.

Lake Valley formation – This has been divided into a number of members by Laudon and Bowsher (1949), of varying lithologies and faunas.

Andrecito member – Highly variable in lithology and fauna. In the Lake Valley and Percha Creek sections there are about 15 feet of thin, silty fossiliferous limestones. The maximum reported thickness of 75 feet is found in the San Andres Mountains. Locally, thin silty beds are replete with the trail called **Taonurus**.

Alamogordo member – Typically, the Alamogordo consists of massive black limestones, weathering grey, with abundant large chert nodules; 12 feet thick at Percha Creek. In the Sacramento Mountains, the large bioherms, composed largely of crinoidal fragments, have their base in the Alamogordo member.

Nunn member – Named from the Nunn ranch, near Lake Valley. This consists of soft, non-resistant, blue-grey marls and limestones. It contains an abundant fauna of brachiopods, bryozoa and other forms, and is the main source of the Lake Valley crinoids. Maximum thickness is 100 feet; 50 feet at Percha Creek.

Tierra Blanca member – Grey to brown, thin-bedded lime-sands, made up largely of crinoid and bryozoan fragments. It grades downward into the Nunn member without any clear break. The upper portion becomes cherty. A total of 40 feet measured at Percha Creek. Type section is along the Tierra Blanca Creek between Lake Valley and Hillsboro. This is the highest Mississippian which will be seen in the trip.

The Sacramento and San Andres mountains contain in addition two other members, the Arcente member 230 feet thick at maximum, of calcareous siltstone interbedded with soft grey shale, and the Dona Ana member, 175 feet at maximum of medium-to massive-bedded, grey to black, cherty, crinoidal limestone.

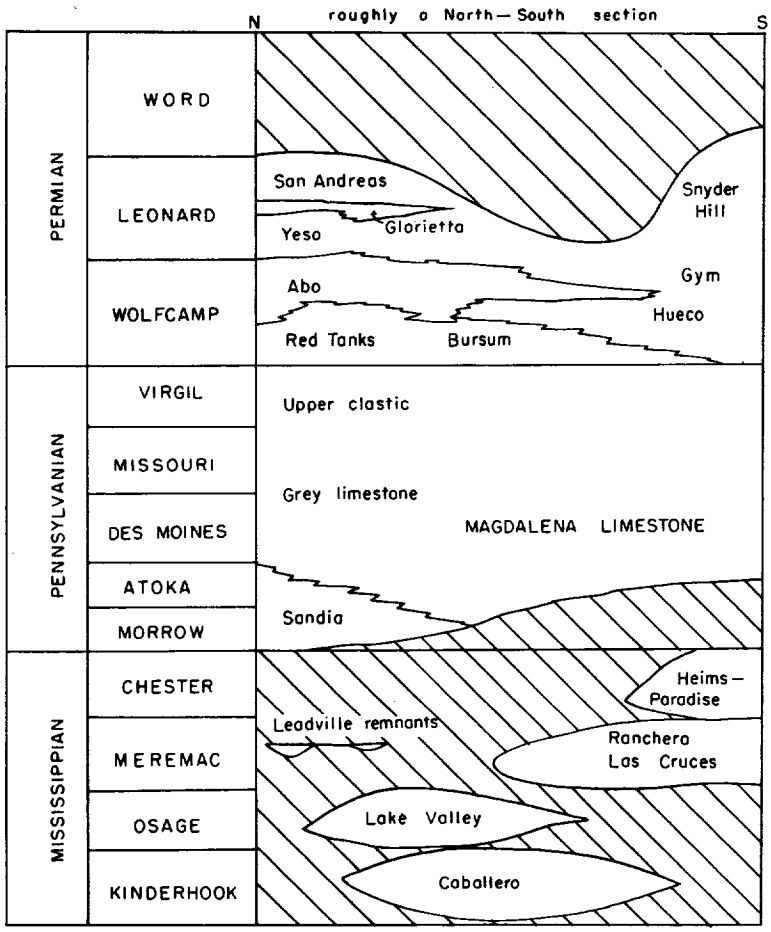
Uppermost Mississippian beds at Percha Creek and near Silver City have been identified by Laudon and Bowsher as the Kelly limestone. These are massive, slightly crinoidal limestones containing white chert, and attaining 60 feet in thickness at North Percha Creek. The identity of these beds with the type Kelly limestone requires substantiation, and the age of the type Kelly is still uncertain.

Middle and Upper Mississippian beds – The southern end of the Sacramento Mountains and the Franklin Mountains contains the Middle Mississippian Las Cruces and Rancheria formations, discussed briefly in the El Paso section. Above is the Upper Mississippian Helms formation, a unit of Chester age.

The Mississippian sequence of the Hatchet Mountains is anomalous, but contains an upper unit of definitely Chester age, closely allied faunally and lithologically to the calcareous Paradise formation of Arizona, rather than to the dominantly shaly Helms formation of the Franklin Mountains.

Mississippian rocks have generally been regarded as confined to southern New Mexico. The discovery by A. K. Armstrong of a Meremac fauna, closely allied to that of the Leadville limestone of Colorado, in isolated limestone remnants formerly mapped as the lower grey limestone of the Pennsylvanian Sandia

UPPER PALEOZOIC STRATIGRAPHY OF SOUTHERN NEW MEXICO



formation, shows that as far south as Albuquerque there are remnants of Middle Mississippian, which elsewhere was removed by erosion.

Pennsylvanian

The Pennsylvanian of southern New Mexico consists of a great thickness of limestones. They are not easily divisible into stratigraphic units on the basis of lithology or megafossils, and as a result, there is no general agreement as to how to treat this part of the section. Thompson (1942) proposed a revision based almost completely on the succession of fusulines, but while his work was of the greatest significance in indicating correlation with the mid-continent divisions, it requires a knowledge of fusulines not possessed by the average field geologist. The general reaction, the wisdom of which is doubtful, has been to ignore his formation names completely, and to employ others.

In north central New Mexico, the Pennsylvanian is readily divisible into the upper Madera limestone and the underlying clastic Sandia formation. However, when this unit is traced southward, the clastics in the base of the Pennsylvanian disappear, and the entire sequence is mapped as "Magdalena", though including the lateral equivalents of the Sandia beds.

A good practical solution has been obtained by the use in mapping of lithological units. From Albuquerque to Socorro above the Sandia formation are recognized a lower grey limestone, and an upper clastic limestone. Still higher, is the Bursum, which is of shaly limestones with fusulines indicating Wolfcamp age. In the Lucero uplift above the Sandia, are recognized the Grey Mesa member, Atrasado member, and Red Tanks member. The Red Tanks is very possibly the Bursum equivalent, but differs from it lithologically and faunally. At Las Cruces, the Pennsylvanian is divisible into a lower, relatively thin-bedded unit 240 feet thick, and an upper, more massive limestone unit 425 feet thick. Above that is 190 feet of limestones attributed to the Bursum formation.

In the Franklin Mountains the La Tuna, Berino, and Bishops Cap members are recognized, but the upper part of the Pennsylvanian is not exposed in the section studied by Nelson (1940).

Pennsylvanian—Permian boundary

In northern New Mexico a logical base for the Permian is provided by the base of the red Abo sandstone. However, beneath it lies the Bursum formation which, by faunal indication, is equivalent to the Hueco limestone of Wolfcamp age, generally accepted as lower Permian. It is perhaps futile to worry about a systematic break between the Pennsylvanian and Permian, for this is a part of the world where Pennsylvanian-Permian deposition was essentially continuous. As a result, an apparent paradox results. In New Mexico the (Pennsylvanian) Magdalena limestone is considered as extending up to the top of the last marine bed. In east-central Arizona, marine beds above the first red beds are considered as part of the Permian. This anomaly does not imply as serious controversy as to the age as would at first appear. As Needham (G.C. not C.C.) puts it: "When we want to think, we scratch our heads; when the Chinese wants to think, he scratches his foot. Who is there among us who can say which produces the better result?"

Permian

The Permian of central New Mexico consists of the shaly Bursum formation, the red sandstones, largely continental, of the Abo formation, the gypsiferous Yeso formation, and the massive San Andres limestone. The Abo is considered Wolfcamp in age, the Yeso and San Andres together as equivalent to the Leonard. But the formational boundaries are not clear time lines. The Bursum has been found to interfinger with the lower Abo in the Sacramento Mountains. Read has reported a flora from the upper Abo indicative that in some places, at least, the Abo deposition continued on into Leonard time. Lateral gradation of part of the Glorieta sandstone into beds of Yeso lithology has been demonstrated.

The problem becomes more complex in southern New Mexico, where Bursum and Abo beds grade laterally into lower Permian limestones, and become the Hueco limestones in Texas. The little known Gym limestone of southern New Mexico is apparently of lower Permian age, and its fauna indicates that it is the equivalent, at least in part, of the Hueco limestone. In the Hatchet Mountains a thick Permian section is found, clearly extending farther up in the section than any beds known in the south-central region, and more closely allied to the higher Permian beds of Arizona, than to anything in the southeast region of New Mexico.

THE HISTORY OF PETROLEUM EXPLORATION IN SOUTHWESTERN NEW MEXICO

by
William M. Sandeen*

Introduction

The southwestern one quarter of New Mexico includes Catron, Dona Ana, Grant, Hidalgo, Luna, Sierra, and Socorro counties.

This region may be divided into three separate physiographic divisions. The Mogollon Plateau comprises the northwestern portion of the region. The Basin and Range province includes the southern portion of the area, the eastern portion of which is the southern Rio Grande Valley. This area between the Black Range and the Sacramento Mountains, extends into portions of Lincoln and Otero counties.

The Mogollon Plateau is almost exclusively covered by Tertiary intrusives and extrusives. The Basin and Range section consists of a series of tilted fault-block mountains separated from one another by the flat-floored desert valleys called bolsons.

The pre-Mississippian sedimentary beds thin depositionally and erosionally northward to the Mogollon Plateau on the west and to the approximate location of San Antonio (Socorro County) on the east. Epeirogenic downwarping took place to the south during lower Paleozoic time. Mississippian sediments appear to overlap onto the margins of the erosional surface but were subsequently eroded in central New Mexico. This late Mississippian-early Pennsylvanian erosion was followed by the invasion of widespread Pennsylvanian seas. The Wolfcamp, basal Permian, seems to follow the sedimentation pattern originated in Pennsylvanian time, with the Abo representing a regressive facies. A prolonged period of erosion followed the deposition of the San Andres formation.

The Permian-Cretaceous unconformity is overlain in some regions by thick conglomerates. Cretaceous seas appear to have advanced over an irregularly developed land-mass of which local islands remained during at least a portion of Mesaverde time.

History of petroleum exploration

The search for oil and gas in southwestern New Mexico began more than thirty years ago. Although more than a hundred wells have been drilled in this region, the Laing No. 1 Sanchez, Socorro County, approximately eight miles southwest of Scholle, is the only one that encountered significant shows of oil or gas. This test, which was completed in January of 1952, recovered 200 MCFGPD from the Pennsylvanian at a depth of 836 feet. The offset to this test, the No. 2 Sanchez, reportedly shut down due to financial difficulties.

Although shows of oil and gas have been reported in the twenty-seven wells listed in the accompanying table, there is a reasonable doubt as to the validity of many of the shows.

Approximately 35% of the wells drilled in the area were started in the twenties. The year 1926 was a

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