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1969, pp. 80-90. https://doi.org/10.56577/FFC-20.80

in:

The Border Region, Chihuahua and the United States, Cordoba, D. A.; Wengerd, S. A.; Shomaker, J. W.; [eds.], New Mexico Geological Society 20th Annual Fall Field Conference Guidebook, 228 p. https://doi.org/10.56577/FFC-20

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MICROFACIES OF PENNSYLVANIAN AND WOLFCAMPIAN STRATA IN SOUTHWESTERN U.S.A. AND CHIHUAHUA, MEXICO

by

JAMES LEE WILSON, A. MADRID-SOLIS AND R. MALPICA-CRUZ

ABSTRACT

This preliminary communication gives facts concerning the petrographic subdivision and correlation of beds within the thick sequence of Pennsylvanian and Wolfcampian carbonate strata (Horquilla Formation) developed on the eastern and southern edges of the Florida platform in New Mexico. A second objective is to enable more precise correlation farther south in the dark siliceous facies of the Pedregosa basin. The sections studied to date lie in the Franklin, Palomas, and Big Hatchet Mountains. When the sedimentary textures and biologic components of these limestones are considered together, more accurate interpretations of depositional environments are made possible. This study has established nine key limestone types useful in such logging. For the most part these are normal marine wackestones and packstones but grain-stones of rounded bioclasts and algal plate mud mounds facies are also delineated.

Subsidence of the Florida platform in an environment of carbonate deposition resulted in accumulation of about 1600 meters of limestone which created a halo around the platform and formed a southward and westward facing shelf into the Pedregosa basin. A facies change into the basin is indicated by outcrops in the Big Hatchets, by Humble Oil and Refining Company's Alamo Hueco well, and the recently drilled PetrOleos Mexicanas well near Villa Ahumada, Chihuahua. This well encountered more than 2000 meters of basinal facies of which at least 300 meters is Wolfcampian. The best possibility for oil production within the Horquilla Formation is the platy algal-Tubiphytes lime mudstone facies. Although this is now observable only at the western edge of the Florida platform it may well occur also in the subsurface south of the platform in northern Chihuahua.

RESUMEN

Este reporte preliminar tiene object() de subdividir y correlacionar la secuencia pensilvánica de carbonatos que se encuentran en los bordes oriental y meridional de la Plataforma de Florida, con el fin de compararlos con las formaciones presentes en el subsuelo de la Cuenca Pedregosa. Las secciones estudiadas incluyen afloramientos en las Sierras Franklin, Palomas, y Big Hatchets. La interpretación textural de las calizas, consideradas como sedimentos originales, nos da idea del ambiente de depósito, particularmente cuando los componentes biológicos son tambien registrados. Nueve tipos de calizas tipo fueron utilizadas. Estas incluyen en la mayor parte "wackestone" o "packstone" de ambiente marino normal (coca de caracter micritico con fauna variada) pero tambien "grainstone" formado por bioclastos redondeados y por foraminiferos tubulares incrustantes.

Los primeros resultados nuestran que una sección de correleción orientada este-oeste, entre las sierras Franklin y Big Hatchet atravieza una secuencia gruesa de carbonatos de aguas someras depositados a partir de la Plataforma de Florida. El area alrededor de dicho elemento fué subsidente y al mismo tiempo se neve a cabo la depositación de carbonatos hasta alcanzar un espesor promedio de 1,600 metros, pudiendose esperar que se cambie de facies en dirección sur, hacia el centro de la Cuenca Pedregosa, hacia rocas más arcillosas, de color oscuro y ricas en material orgánico. El pozo perforado por Petróleos Mexicanos, cerca de Villa Ahumada, Chihuahua confirma esta idea porque ha penetrado más que 300 metros de Wolfcampiano en facies de la cuenca.

La mejor posibilidad de producción de petróleo en la Formación Horquilla, es en la facie de biohermas, de lodo calcAreo con algas laminares (platy algae) y con Tubiphytes sp. Todo esto es ahora observado solamente en la parte occidental de la Plataforma de Florida y quizá ocurra en el subsuelo, al sur de dicha Platforma.

INTRODUCTION

This is a preliminary report on carbonate facies in the Late Paleozoic Horquilla Formation and Magdalena Group of southern New Mexico and Chihuahua. The study was largely financed by Petroleos Mexicanos and is being continued by the senior author and his Rice University graduate student, Clif Jordan, aided financially by the New Mexico State Bureau of Mines and Mineral Resources. Although many persons in Mexico assisted us, the writers are pleased to acknowledge particularly aid in the field by Ing. Jorge Tovar of the Ciudad Juarez office, numerous helpful arrangements and discussions by Ing. Arsenio Navarro, Jefe de Exploración of the Ciudad Juarez office of Pemex, and the photographic assistance of Sra. Cleméncia Tellez de Alvarez of the Instituto Mexicano de Petróleo in Mexico City.

The purposes of the study are threefold: (1) to subdivide and correlate more accurately the thick Pennsylvanian carbonates around the eastern and southern edges of the Florida Platform and to compare these thick massive carbonate sections with more distant basinal sections, (2) to characterize more accurately the depositional and diagenetic environments of these strata in order to identify better the formations and facies patterns to be expected in the subsurface of the Pedregosa basin, and (3) to identify potential reservoir beds within these strata.

To date four sections have been examined, measured, described in the field, sampled at 5 meter intervals, and petrographically studied.

1. Vinton Canyon, northwest flank of the Franklin Mountains. Total Magdalena Group and the Hueco Formation. References: Kottlowski (1960a), Nelson (1940 and 1960) and Williams (1966) . About 1500 meters.
2. Sierra Palomas, northwest corner of Chihuahua. Total Horquilla Formation, Earp and Colina Formations. References: Diaz and Navarro (1964), and Pemex stratigraphic section by Jorge Tovar. About 1400 meters.
3. Big Hatchet Mountains-Bugle Ridge and Borrego sections. Horquilla Formation. Reference Zeller (1965) . About 1000 meters. Field work incomplete.
4. Placer de Guadalupe-South central Chihuahua. Pastor and Monillas Formations in the overturned block of the Cerro Placer de Guadalupe. Reference: Bridges (1964) and Sanderson and Fickman (1964). About 500 meters.

METHOD OF STUDY

Plaquettes (thin slices of rock) were cut normal to bedding planes or lamination from each field sample. After polishing and acid etching these cut surfaces, acetate peels were made from them. The surfaces of the plaquettes were studied under oil immersion. From the Palomas section 230 thin sections were made using samples collected by Ing. Tovar. Petrographic data were recorded in a lithologic column, and sedimentary structures, brachiopod, crinoids, algal plates, encrusting foraminifera, fusulinids, and miscellaneous biota were logged. Original complete charts are on file in the Instituto Mexicano de Petróleo and in Pemex Exploration offices. The Dunham system of carbonate textural classification was used and a number appended to the abbreviation of the classes mudstone, wackestone, packstone, grainstone, or boundstone indicating the estimated percentage of grains to total volume.

Textural interpretation of these limestones as original sediments results in clarification of depositional environments particularly when dominant biological components of the strata are also recorded. The following is a list of key limestone types based on petrography and field data. These generalized interpretations have been used to designate correlative units and to delineate sedimentary cycles.

1. Normal marine wackestone or packstone (Plate 1, figure 1). Highly bioclastic micritic rock with a diverse fauna of crinoids, brachiopods, fusulinids, smaller foraminifera, ostracods, bryozoan and some algae.
2. Crinoidal packstone (Plate 1, figure 2). Coarsely bio elastic, commonly argillaceous encrinite. Silty, ferruginous stained. Grain boundaries are microstylolitic.
3. Grainstone of rounded, coated bioclastic particles (Plate 2, figure 1) . Grainstone unusually rich in dasycladacean algal particles are specially noted since such algae indicate very shallow water.
4. Oolite grainstone.
5. Packstone or grainstone almost exclusively of worn bits of tubular encrusting foraminifers; the particles may be somewhat altered. (Plate 2, figure 2) .
6. Pod-algal microbioclastic with small, rounded somewhat tubular organisms; contains scattered foraminifera and ostracods. Probably a finer textured variety of category no. 5 above.
7. Lime mudstone with almost no bioclasts or pellets (Plate 3, figure 1).

SPECIAL FAUNAL TYPES

8. Fusulinid coquina—usually packstone. (Plate 4, figure 1) .
9. Algal plate lime wackestone, commonly with a clotted or grumelous lime mudstone matrix. (Plate 3, figure 2) .
10. Tubiphytes bioclasts (Plate 4, figure 3) .
11. Komia, commonly a grainstone (Plate 4, figure 2) .
12. Chaetetes—Caninia beds, usually with a wackestone or lime mudstone matrix.

In addition to these special types of carbonate rock, quartz sandstone, shale, gypsum beds, and dolomite are particularly noted.

RESULTS OF PRELIMINARY STUDY

Many interesting facies and age relations are seen on the single cross-section presented. (Figure 1) . This trends from east to west along the international border as indicated by the large numbers on the two isopach maps (Figures 2 and 3).

1. Early *Pennsylvanian* strata *and* boundary relations *with Mississippian beds.* The lowest Pennsylvanian beds rest unconformably on the upper Mississippian Helms Formation in areas north of the Franklin Mountains and also at Vinton Canyon. We believe from fusulinid study that little or no Morrowan beds exist here. We do not know at present whether this unconformity extends into the basin. This contact is being studied separately as part of an MS thesis on the Helms Formation.

Considerable variation in thickness exists within Atokan-Derryan beds (zones of Profusulinella and *Fusulinella* below *Wedekindellina.)* Higher units of the Pennsylvanian and Wolfcampian are much more uniform in thickness. Furthermore, although most Late Paleozoic limestones that we have studied over the area represent normal marine types of sediment, the oldest Pennsylvanian beds in the Big Hatchet and Palomas section apparently do not. They contain interbedded unfossiliferous mudstones and oolite beds representing interstratified records of tidal flats and oolite tidal bars, the very shallowest water and most restricted

PLATE 1

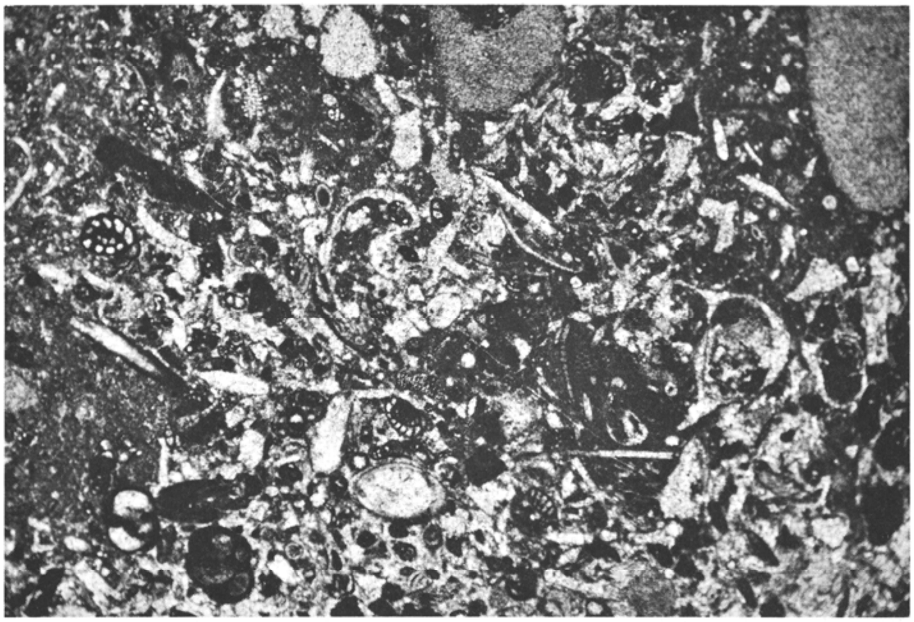

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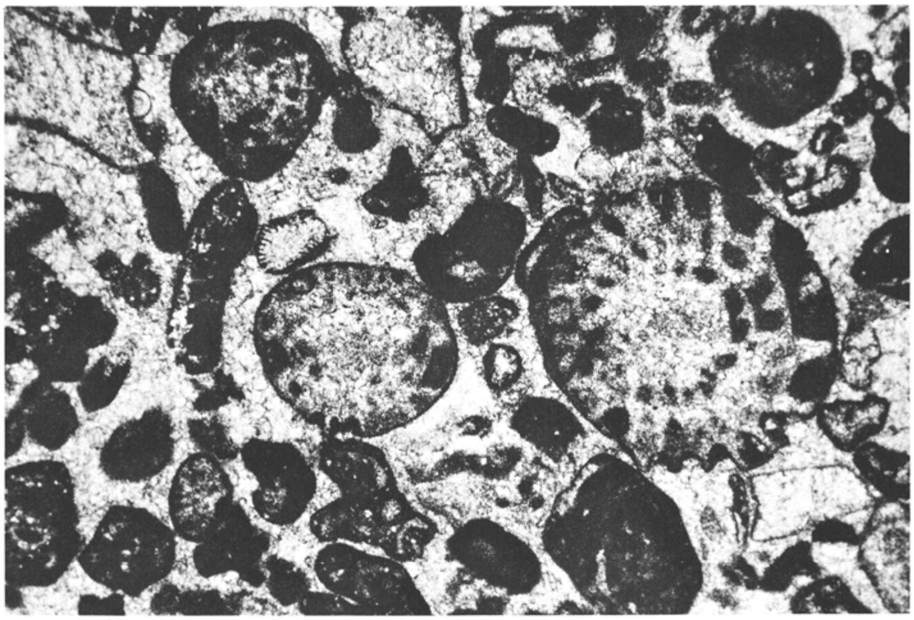
FIGURE 1.

TV-1756, X15. Bioclastic packstone deposited in a normal marine environment. The matrix is micrite with about 15 per cent sparry calcite. The fauna is varied consisting of tubular and chambered foraminifera, ostracods, brachiopod spines and shell fragments, bryozoans, and crinoid ossicles and spicules. Lower Horquilla Formation, about 500 feet above base, Derryan-Atokan age. Palomas Range, Chihuahua.

FIGURE 2.

TV-1868, X15. Normal marine packstone with a great variety of bioclasts, principally crinoid debris and brachiopods. Micrite matrix somewhat compacted by microstylolitization. Lowermost beds of Concha Formation, probably Leonardian in age. Palomas Range, Chihuahua.

PLATE 2



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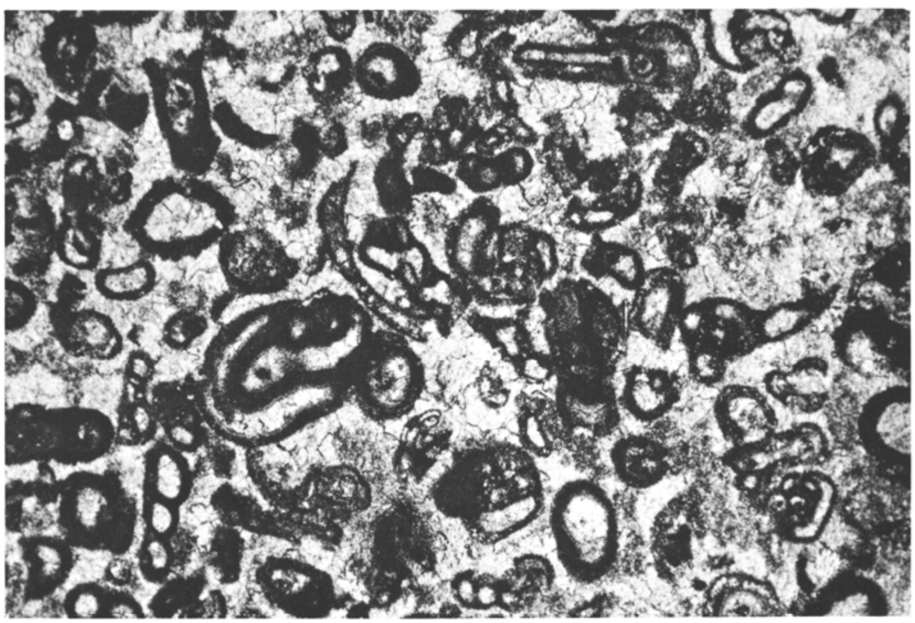

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FIGURE 1.

TV-2128, X35. Fine-grained bioclastic grainstone; largest particles about 1 mm across, particles worn and rounded and consisting of detritus of numerous invertebrate tests such as fusulinids, echinoderms, and bryozoans. Packing of grains about normal. Blocky calcite cement. Top of typical sedimentary cycle, middle Horquilla Formation, base of upper Pennsylvania. Palomas Range, Chihuahua.

FIGURE 2.

TV-1998, X40. Bioclastic grainstone formed from calcitornellid and cornuspirid tubular encrusting foraminifera. Poor sorting and little rounding of particles. Blocky calcite cement. Lower Earp Formation. Palomas Range, Chihuahua.

PLATE 3

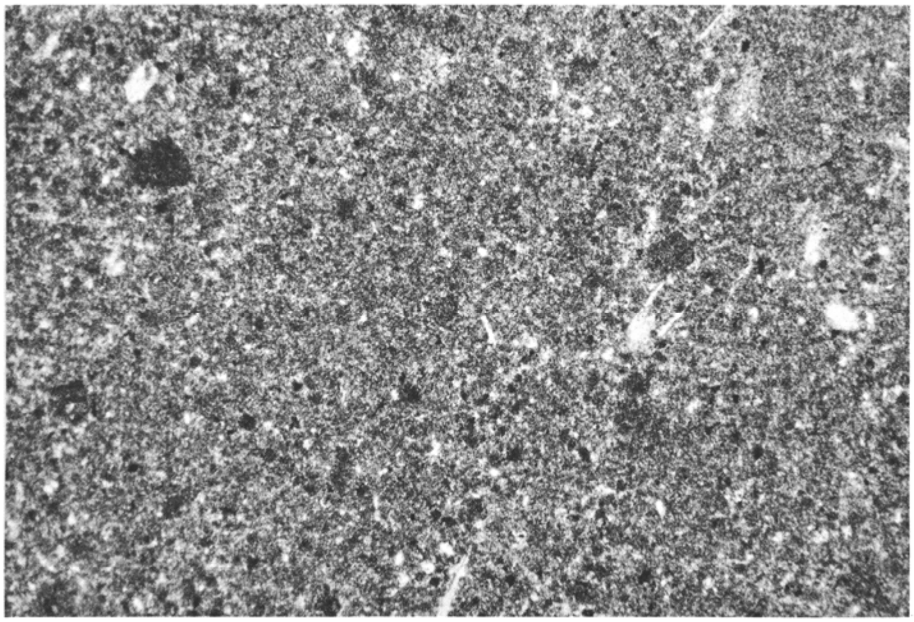

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FIGURE 1.

TV-1731, X37. Pelleted lime mudstone or wackestone, about 10 percent discrete particles some of which are blackened pelletoids and some bioclasts. Lowermost Horquilla formation, 400-500 feet above base in restricted marine sequence of Derryan-Atokan age. Palomas Range, Chihuahua.

FIGURE 2.

TV-2011, X34. Wackestone or packstone with abundant pieces of platy algae and some chambered foraminifera. Algal plates with interiors dissolved and filled-in by centripetally enlarging calcite crystals. Matrix clotted, containing some pelletoids. Upper Horquilla Formation, Wolfcampian, zone of *Pseudoschwagerina*. Palomas Range, Chihuahua.

PLATE 4

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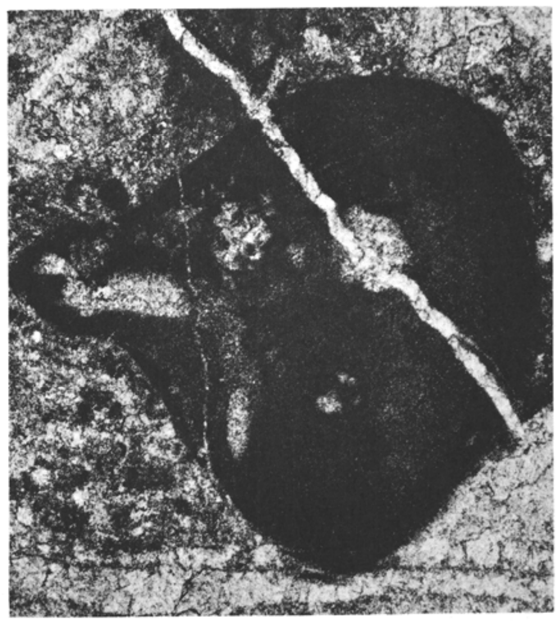
2



3

FIGURE 1.

TV-2187, X38. *Triticites* species in a wackestone with a silty microspar matrix. Upper Horquilla Formation in Palomas Range, Range, lowermost Wolfcampian.

FIGURE 2.

TV-1940, X15. Packstone-wackestone with abundant *Komia* and *Fusulinella*. Lower Horquilla Formation, about 700 feet above base. Derryan-Atokan age. Palomas Range, Chihuahua.

FIGURE 3.

TV-2022, X40. *Tubiphytes* in packstone with clotted-pelletoidal matrix. Upper Horquilla, Wolfcampian, zone of *Pseudoschwagerina*. Palomas Range, Chihuahua.

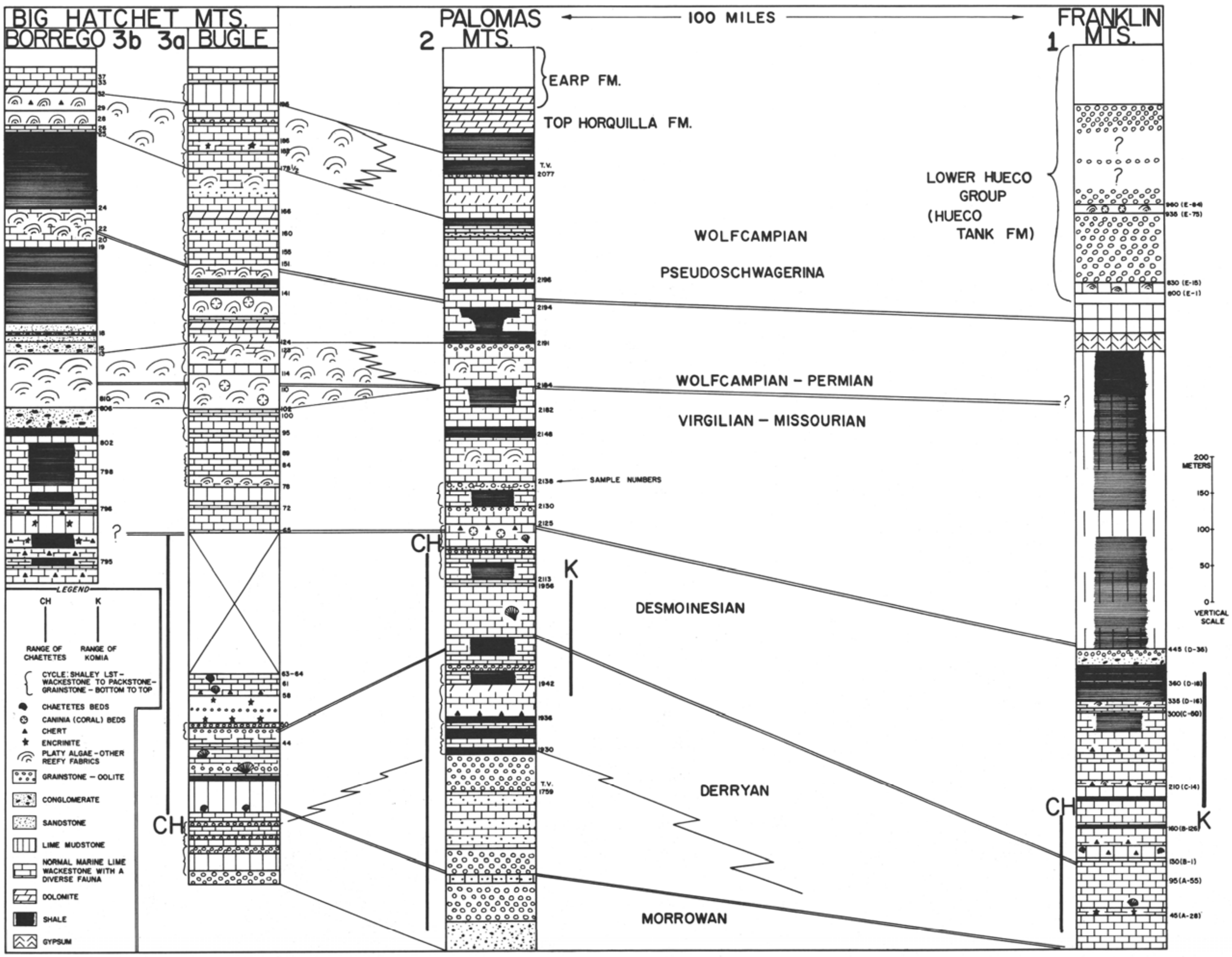


FIGURE 1.

East-west cross section of Pennsylvanian and Lower Wolfcampian strata across southern edge of Florida platform from Franklin to Big Hatchet Mountains. For locations of sections see Figures 2 and 3. Series boundaries are based on fusulinid determinations.

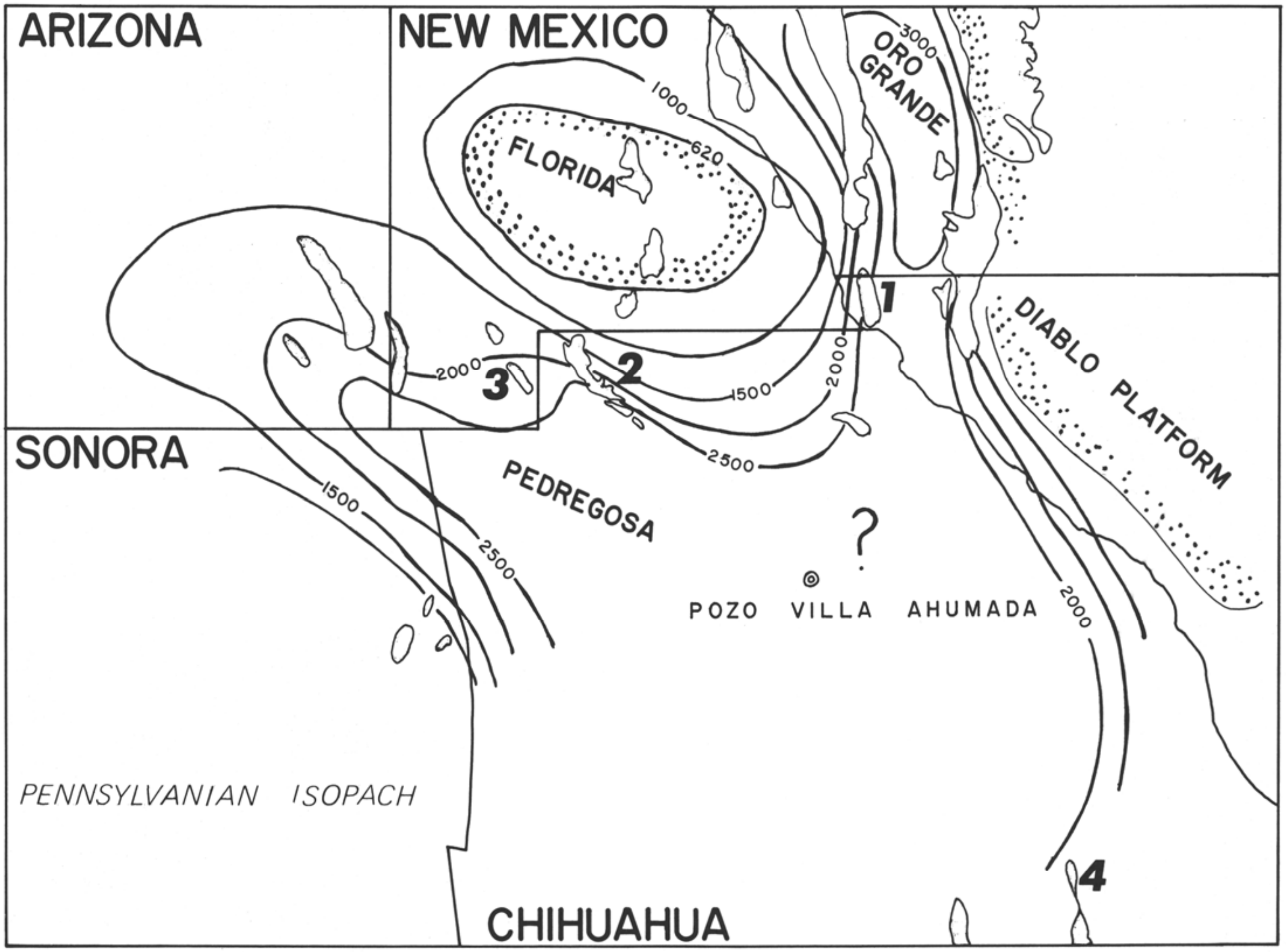


FIGURE 2.

Interpretative isopach map of Pennsylvanian strata in and around Pedregosa and Oro Grande basins of Chihuahua and New Mexico. Paleotectonic high areas are stippled. Circle by ? in center is location of Petróleos Mexicanos Pozo Villa Ahumada No. 1.

marine sediments seen in our stratigraphic columns. These sediments are products of the initial transgression of Pennsylvanian seas. They are not seen at the base of Pennsylvanian strata in the Vinton Canyon and Placer de Guadalupe localities, perhaps because strata this old were not deposited outside of the Pedregosa basin.

2. Paleotectonic controls on sedimentation. Of particular interest is the cyclic sedimentation well displayed throughout the Pennsylvanian and Wolfcampian sections. These cycles are best seen in the more shelfward sections around the Florida platform. Probably within the 1000 meters now studied in some detail at least 35 of these are present. Typical cyclic development consists of a lower shaly or silty limestone grading upward to thin or medium-bedded dark cherty limestone with many fusulinids. Petrographically the lower units consist of normal marine bioclastic wackestone or packstone. The upper unit is of more massive limestone and contains commonly bioclastic or oolitic grainstone. The top of the massive unit in places contains a peculiar lithoclastic limestone which may be caused by a drying-out of the surface or alteration of its lime mud associated with subaerial or near subaerial exposure. Commonly the next occurring shaly unit abruptly overlies this surface at the top of the massive unit. By analogy with other Pennsylvanian cycles studied by the senior author in New Mexico, each cycle probably represents relatively rapid transgression (or at least consists of a thin transgressive deposit) and a gradual passage through normal marine conditions and clearing water to a shoal environment which in places came above tidal levels.

The cross section (Figure 1) trending east-west crosses a thick ramp of shallow water carbonates built out (southward) from the Florida platform, a positive element defined by Kottlowski (1958). This area seems to have formed a

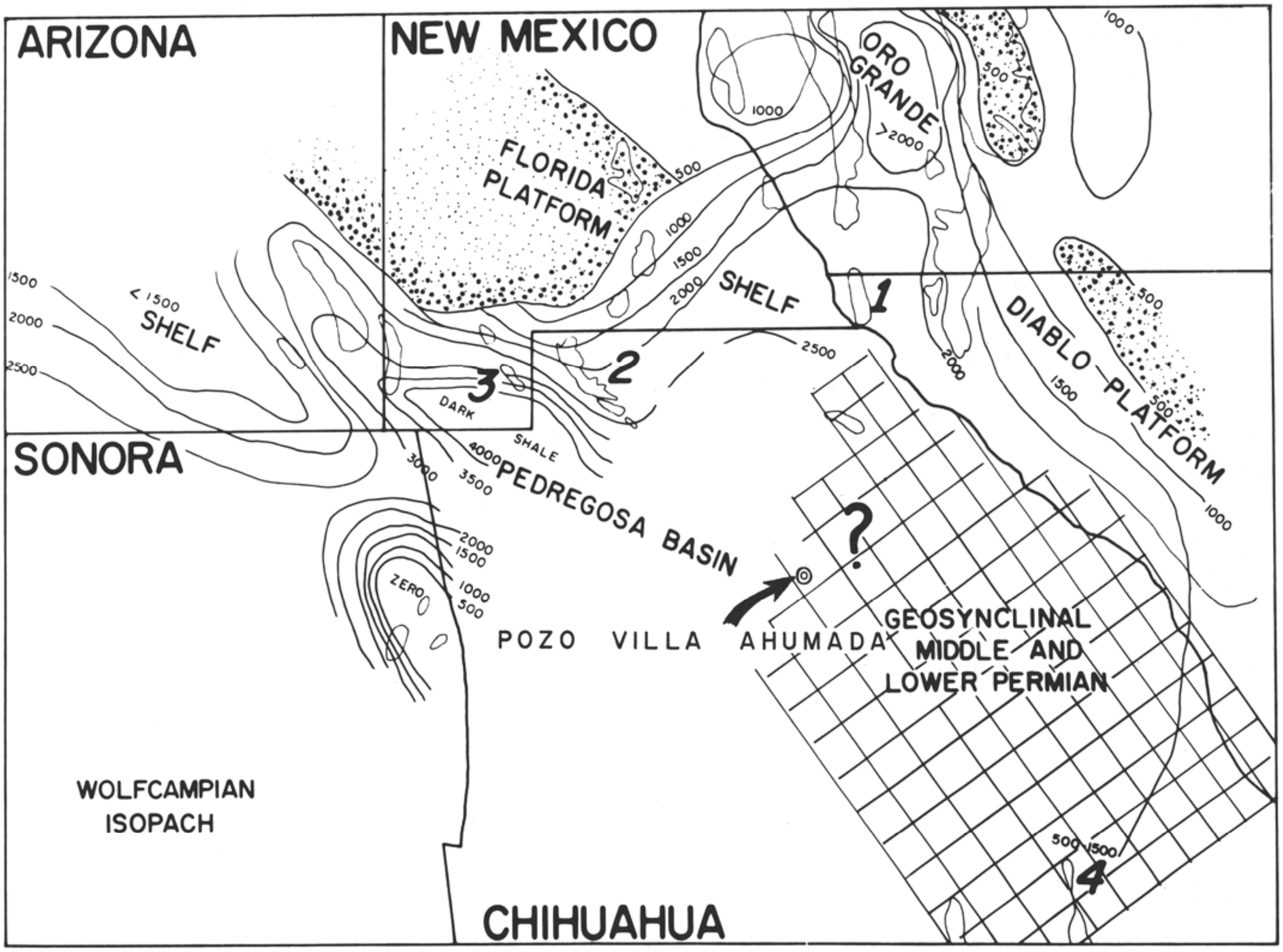


FIGURE 3.

Interpretative isopach map of total Wolfcampian strata in and around Pedregosa and Orogrande basins of Chihuahua and New Mexico. Paleotectonic high areas are stippled.

nucleus around whose subsiding shoulders as much as 3000 feet of pure limestone accumulated, carbonate sedimentation having kept pace with subsidence on the edges of the Pedregosa basin. These limestones are predominately wackestones or packstones with a diverse normal marine fauna indicating water deep enough for normal circulation. Middle Pennsylvanian beds particularly contain widespread biostromes of the corals Chaetetes and Caninia further indicative of shelf deposition.

Virgilian and Wolfcampian strata show more varied and more rapidly changing facies than older Pennsylvanian beds. In the Franklin Mountains, Vinton Canyon section, the upper Pennsylvanian consists of dark shale, calcisilt, and gypsum, and represents the interior deposits of the Orogrande basin (Kottlowski, 1960b) . Here the lowermost Hueco Formation consists of Bahama-bank type sediments with a large amount of grainstone and represents apparently a shelf or backreef facies formed in highly agitated, very shallow marine water. Westward in Chihuahua equivalent strata at Palomas contain more shale beds and less algal plates than do nearby beds of the Big Hatchet Mountains. The lack of shale and presence of prominent algal plate mounds in the Big Hatchets indicate a carbonate shelf margin, a fact first noted by Zeller (1965). Our petrographic studies generally confirm the concept that the area of the Palomas Range was located farther shelfward than the Big Hatchet area. If this be true, and if our isopachs correctly locate the basin center, more reefs should exist south and east of Sierra de Palomas.

Detailed study has not yet been done on the partially exposed Borrego section thrust eastward along the west side of the Big Hatchets. This section includes both reef masses and interstratified basinal beds. Those petrographic samples we have collected from Borrego show clearly that the basinal facies contains detrital lithoclastic limestones and limestone conglomerates derived from the reef masses and embedded in dark shale and sandstones between the three thick reef intervals. The major reef masses can be correlated easily from the Bugle Ridge section (shelf margin and back reef) to the westerly and partly basinal section of Borrego.

This indicates that the thrusting from the west is probably not very great in the Big Hachet Mountains.

The thick pure carbonate section bordering the Pedregosa basin on the north may be expected to change facies toward the south into the center of the Pedregosa basin as indicated by Robert Zeller's Borrego section (1965) and the Alamo Hueco well drilled by Humble Oil and Refining Company west of the Big Hatchets in 1958. The recently drilled well of Petróleos Mexicanos west of Villa Ahumada, Chihuahua, supports this assumption. Under Mesozoic strata and a 750 foot dolomite unit of probable Middle Permian age this well encountered at least 1000 feet of black siliceous limestone, shale, and siltstone of Wolfcampian age. In all, the well penetrated some 5000 feet of such basinal strata, a substantial part of which may also be Wolfcampian. It appears that in late Pennsylvanian and early Permian time a considerable amount of fine elastic sediments accumulated in the rapidly subsiding Pedregosa basin. The earlier Pennsylvanian tectonic history is not yet known.

Thanks to an important section studied recently by Petróleos Mexicanos' Ing. Jorge Tovar at Sierra Bavispe along the Sonora-Chihuahua border, it is possible to delineate a probable western side of the Pedregosa basin. Fusulinids in these strata show a relatively thin (about 700 feet) but more or less complete section of Pennsylvanian beds with little or no Wolfcampian beneath thick Middle Permian strata.

Although control in northwestern Mexico is as yet very limited, a pronounced northwesterly trend appears on our isopachs with rapid changes of facies and thickness. This tectonic trend in northern Chihuahua is at least as old as late Pennsylvanian time and is in accord with the trend of the ancient Diablo Platform.

3. Studies of *special* organisms. Petrographic studies have also brought to light some interesting facts about ecologic and biostratigraphic distribution of organisms. For example, the carbonate mud mounds, which by analogy with other Pennsylvanian producing areas, offer the best chance of reservoir development in the Horquilla Formation, contain several characteristic organisms useful in identifying this facies in drilling; some of these may be persistently associated with reservoir rock. Algal plates, probably *Ivanovia* or Eugonophyllum, form masses of packstone in the Upper Pennsylvanian and Wolfcampian bioherms. Algal plates, in many cases Archeolithophyllum, are also commonly seen in Middle or Lower Pennsylvanian beds. This type of platy algae seemingly does not form mounds in the New Mexico and Chihuahua areas. The plates are shorter and less crinkled than are those in the higher beds studied. Another good marker for the bioherms or reef buildups of Wolfcampian age is the organism Tubiphytes (Nigraporella of Rigby). These small encrustations are seen commonly in the bioherms, probably as accessory members of the biota and not as major frame-builders although later study may prove that they serve in this role also. They are particularly common in Lower Permian strata in the Big Hatchets and at Sierra de Monillas, Mina Plomosas, Chihuahua. A coral assemblage consisting mainly of Chaetetes and the large horn coral *Caninia* characterizes massive beds in the Derryan and Desmoinesian in all sections studied. Chaetetes is known to form bioherms of moderate size in the Paradox Formation of Utah but only massive biostromes of such organisms have been seen in Chihuahua and New Mexico. Of interest and use in biostratigraphy is the distribution of the small twig-like stromatoporoid Komia which appears to be largely of Desmoinesian age rather than Desmoinesian and Derryan as reported in the Great Basin of the United States. Most occurrences of Komia in central and west Texas are also in Middle Pennsylvanian strata.

RESERVOIR FACIES

Regional interpretation of reservoir facies is related to present stratigraphic-petrographic knowledge but at present our petrographic data do not cover a sufficiently wide area to permit construction of meaningful maps of carbonate lithofacies. The best possibility for reservoir development within the Horquilla Formation is the lime mud mound facies with algal plates and Tubiphytes. This can now be observed only at the west side of the Florida platform. Perhaps it occurs in the subsurface south of the platform. In the Oro Grande basin such facies occur in various places around the perimeter of the basin. Such carbonate buildups, although basically of dense micrite, are rich in organisms. Where they have been exposed, albeit briefly, to subaerial conditions or to diagencsis by meteoric waters, the mud has slumped and brecciated and the organic content is fractured and leached. Rocks of this type are known to be excellent reservoirs in the northern parts of the Delaware and Midland basins of New Mexico and West Texas, on the eastern shelf of the Midland basin, and in the Paradox basin of Utah. The presence of dolomite at the stratigraphic position of these carbonate buildups at Palomas and the Big Hatchets is of importance because this improves chances for porosity and permeability development. Oolitic lime sand present in the older Pennsylvanian beds is not considered very important as a potential reservoir because in Paleozoic strata such original sediment is commonly cemented and no field indications of such porosity were observed.

Probably the most favorable reservoir beds seen while in the field are those dolomites above the Horquilla in the Earp, Epitaph, and Concha formations. These strata have not yet been studied petrographically except at Sierra de Palomas. However, the association of these beds with argillaceous units and the organic-rich, black Colina limestone plus the abundant oil reserves in strata of Lower and Middle Permian age in West Texas and New Mexico are encouraging.

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