New Mexico Geological Society

Downloaded from: https://nmgs.nmt.edu/publications/guidebooks/42



Late Pennsylvanian phylloid-algal bioherms, Orogrande Basin, south-central New Mexico and west Texas

Donald F Toomey

1991, pp. 213-220. https://doi.org/10.56577/FFC-42.213

in:

Geology of the Sierra Blanca, Sacramento, and Capitan Ranges, New Mexico, Barker, J. M.; Kues, B. S.; Austin, G. S.; Lucas, S. G.; [eds.], New Mexico Geological Society 42nd Annual Fall Field Conference Guidebook, 361 p. https://doi.org/10.56577/FFC-42

This is one of many related papers that were included in the 1991 NMGS Fall Field Conference Guidebook.

Annual NMGS Fall Field Conference Guidebooks

Every fall since 1950, the New Mexico Geological Society (NMGS) has held an annual Fall Field Conference that explores some region of New Mexico (or surrounding states). Always well attended, these conferences provide a guidebook to participants. Besides detailed road logs, the guidebooks contain many well written, edited, and peer-reviewed geoscience papers. These books have set the national standard for geologic guidebooks and are an essential geologic reference for anyone working in or around New Mexico.

Free Downloads

NMGS has decided to make peer-reviewed papers from our Fall Field Conference guidebooks available for free download. This is in keeping with our mission of promoting interest, research, and cooperation regarding geology in New Mexico. However, guidebook sales represent a significant proportion of our operating budget. Therefore, only *research papers* are available for download. *Road logs*, *mini-papers*, and other selected content are available only in print for recent guidebooks.

Copyright Information

Publications of the New Mexico Geological Society, printed and electronic, are protected by the copyright laws of the United States. No material from the NMGS website, or printed and electronic publications, may be reprinted or redistributed without NMGS permission. Contact us for permission to reprint portions of any of our publications.

One printed copy of any materials from the NMGS website or our print and electronic publications may be made for individual use without our permission. Teachers and students may make unlimited copies for educational use. Any other use of these materials requires explicit permission.

This page is intentionally left blank to maintain order of facing pages.

LATE PENNSYLVANIAN PHYLLOID-ALGAL BIOHERMS, OROGRANDE BASIN, SOUTH-CENTRAL NEW MEXICO AND WEST TEXAS

DONALD FRANCIS TOOMEY
Consultant, 2451 Tramway Terrace Court NE, Albuquerque, New Mexico 87122

Abstract—Phylloid-algal bioherms are relatively common attributes of Late Paleozoic cyclical/repetitive sedimentation. Upper Pennsylvanian (Virgilian) rocks of the Orogrande Basin, south-central New Mexico and west Texas, contain bioherms composed of upright phylloid algae that display the relationship of facies to growth history and paleotectonics. Three outcrop locations rimming the Orogrande Basin contain excellent exposures of phylloid-algal bioherms, some of which attain a thickness of up to 34 m. Bioherms of the Panther Seep Formation in the San Andres Mountains are within an active military reservation, and information from those outcrops is limited. Exposures in the Sacramento Mountains have been studied extensively and demonstrate bioherm morphology and growth history on relatively narrow shelf margins, during intervals when regional tectonic activity on the La Luz anticline produced a distinct progression of bioherm growth stages on the western flank of the anticline, clearly showing bioherm accretion during upward-shoaling phases. Late Pennsylvanian phylloid-algal bioherms exposed in the Hueco Mountains of west Texas, along the southeastern rim of the Orogrande Basin, have a similar paleotectonic setting as the bioherms in the Sacramento Mountains. However, the biohermal interval is thicker and stratigraphically ranges through the entire Virgilian. Also, individual bioherms have rather different morphologies and associated flanking and inter-biohermal lithologies. All phylloid-algal bioherms rimming the Orogrande Basin are oriented with their long axes parallel to the trend of the depositional strike of the shelf margins.

INTRODUCTION

Evolution of organisms that comprise biohermal communities has proceeded since late Precambrian time. During this long time, various organism groups have joined together to construct organic buildups, only to die out in one location, and reappear later at a new location, with either new biotic components or with modification to pre-existing forms. Generally, appearance of a new biotic community is separated by a significant time gap from previous communities. The evolution of biohermal community structure reflects organism responses to a unique and dynamic set of physical and biological conditions imposed upon the paleoenvironment. Most important are the state of evolution of a particular biotic group, regional paleogeography and paleotectonic setting.

The evolution of organic buildups through geologic time displays a number of significant features:

1. Bioherm development has not been a continuous, straight-line evolutionary sequence; instead evolution appears to have occurred as a punctuated series of biotic experiments, some of which were unsuccessful and led nowhere.
2. The first organism-constructed algal/archaeocyathid bioherms occurred in Early Cambrian time, but were extinct by the Middle Cambrian.
3. This was followed by a significant hiatus before Early Ordovician algal/sponge bioherms arose, with an abundant and diversified bioherm biota appearing in Middle Ordovician time. This biota comprised algae, sponges, stromatoporoids, corals and bryozoans which could create substantial organic structures, thus making possible linear biohermal trends.
4. This biohermal biota evolved and matured until Late Devonian time, when collapse occurred on a planetary scale.
5. Slow resurgence in biohermal development occurred in Early Carboniferous time, and gradually accelerated in Late Carboniferous time, when a diverse variety of biotic groups came into prominence.
6. Tectonic fragmentation of the craton in Late Carboniferous time created potential basin/shelf-margin paleotectonic settings for bioherm exploitation.
7. The increased role of early carbonate cementation, coupled with favorable paleotectonic settings, set the stage for late Paleozoic, phylloid-algal biohermal development.
8. Paleozoic bioherm evolution ceased with massive Late Permian organism extinctions.

LATE PALEOZOIC BIOHERMAL BIOTIC COMPONENTS

After briefly considering the salient features of Paleozoic bioherm evolution, let us step back and focus our attention on the late Paleozoic interval. This is done to set the scene for the regional study of Late Pennsylvanian phylloid-algal bioherms rimming the Orogrande Basin, discussed below.

In Fig. 1, I have plotted those biotic components that have either singly, or in various combinations, formed bioherms during late Paleozoic time. The list is surprisingly brief and accounts for all reported late Paleozoic biohermal occurrences:

1. Phylloid algae, which occur from Late Carboniferous to Late Permian time, formed substantial shelf-margin buildups, many of which became hydrocarbon reservoirs.
2. Various problematical forms, such as the encrusting/binding *Archaeolithoporella* that ranged from Early through Late Permian time; the binding and encrusting form *Tubiphytes*, with a somewhat longer range from Late Carboniferous through Late Permian time, and even extending into the Mesozoic; and the enigmatic form *Palaeoaplysina*, with a more restricted range from Middle Late Carboniferous through Early Permian time.
3. A diverse component of calcisponges, generally occurring as framebuilders, usually bound together by *Archaeolithoporella* and/or *Tubiphytes*, and various early submarine cements. These are generally most conspicuous from Early through Late Permian time.
4. The short-lived form *Chaetetes*, a probable sponge, an evolutionary dead end.
5. Various Late Carboniferous through Permian bryozoans, showing specific adaptations and generally occurring as minor components, but becoming dominant, generally in association with stromatolitic algae, by Late Permian time.
6. Various attached brachiopods, generally in conjunction with frameworks of sponges and bryozoans, and commonly associated with much early submarine cementation.
7. At least two early cement types that were able to weld together available biotic components into a viable biohermal structure.

PHYLLOID ALGAE

The term phylloid is simply a descriptive morphological term that refers to the leaf-like shape of a particular group of late Paleozoic calcareous algae. The term was coined by Pray and Wray (1963) for Middle Pennsylvanian leafy algae from outcrops in San Juan Canyon, Utah. Included under the phylloid algae are green codiacean algae

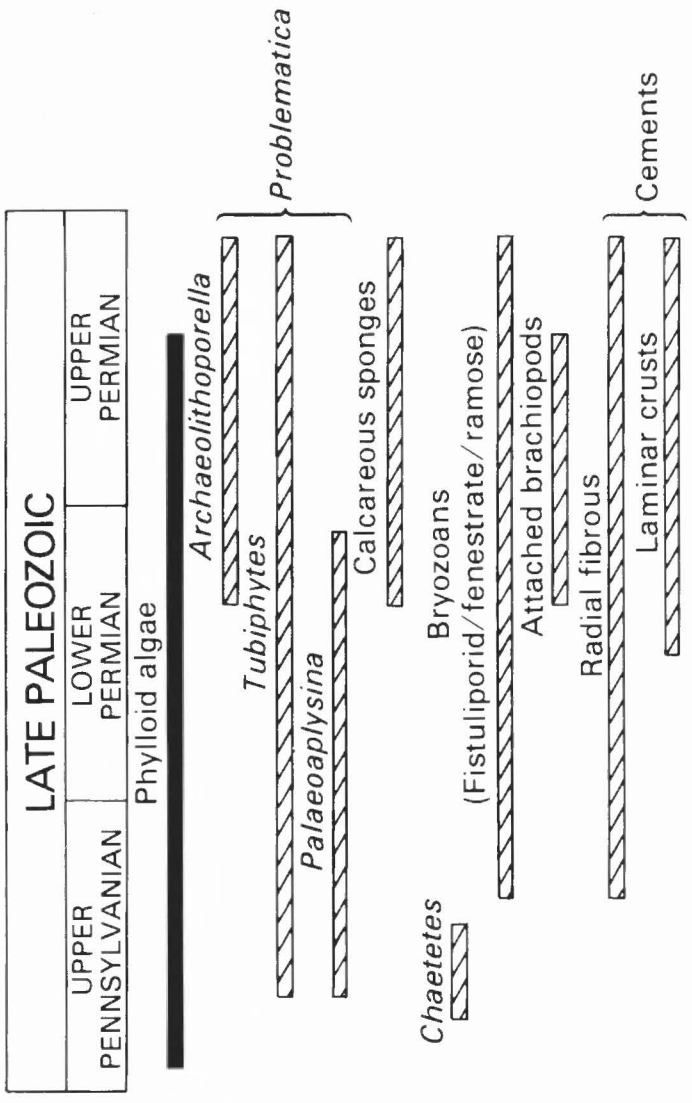


FIGURE 1. Diagnostic biohermal biotic components during Late Paleozoic time.

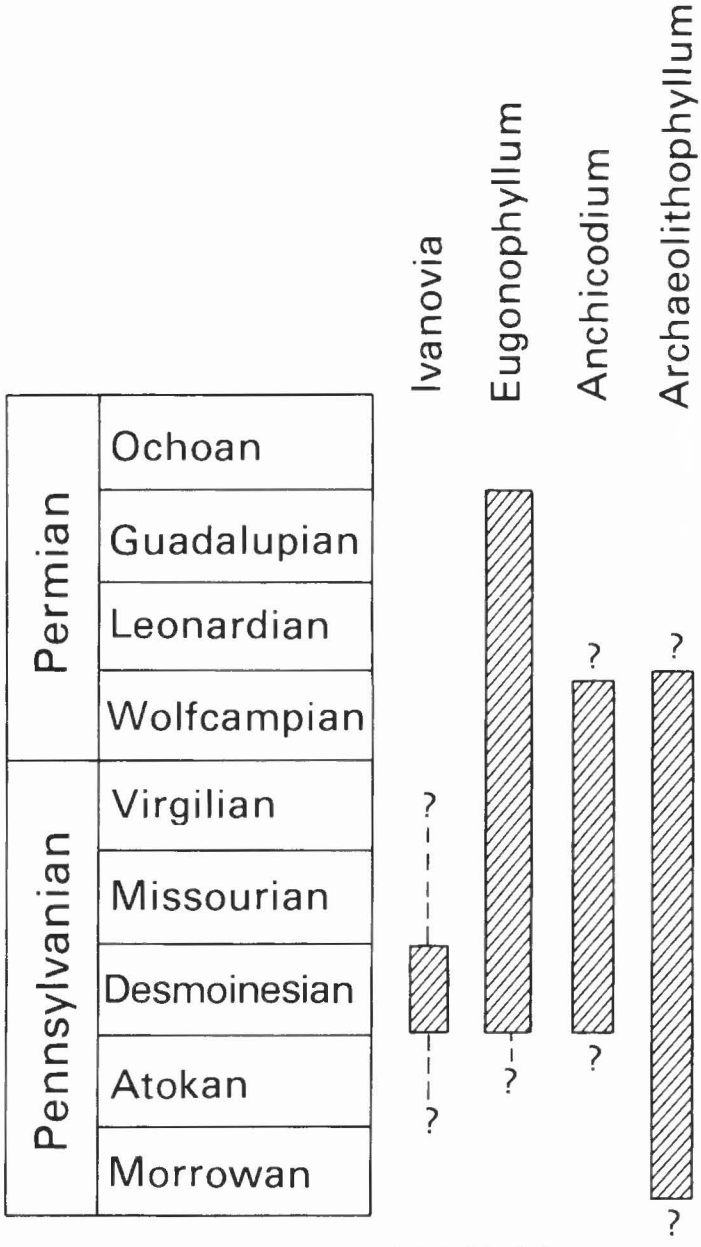


FIGURE 2. Stratigraphic ranges of the principal phylloid-algal genera, as presently known for the late Paleozoic.

referred to the genera *Ivanovia* (Khvorova, 1946), *Eugonophyllum* (Konishi and Wray, 1961), and *Anchicodium* (Johnson, 1946), and a red alga, of probable coralline algal affinity, described under the genus *Archaeolithophyllum* (Johnson, 1956). Of those phylloid algal genera only *Ivanovia* and *Eugonophyllum* are important floral components in phylloid-algal bioherms that rim the Orogrance Basin. In fact, it is debatable whether the taxon *Archaeolithophyllum* should be included within this morphological grouping. *Archaeolithophyllum* is not an upright plant, but generally occurs as laminar crusts (Wray, 1964; Toomey, 1979). In addition, *Archaeolithophyllum* is a red alga, not a green codicean alga as are the other genera. The stratigraphic ranges of these genera, as presently known, is given in Fig. 2.

The geographic distribution of phylloid algae is cosmopolitan. They occur in Late Carboniferous and Permian rocks in the Midcontinent and southwestern United States, northern Canada, China, Soviet Union, southern Europe, northern Spain and North Africa. A diagram showing the distribution of Late Paleozoic phylloid-algal limestones in the continental United States was given in Wray (1968, fig. 2).

Various workers (Konishi and Wray, 1961; Toomey and Winland, 1973; Toomey, 1976; Toomey and Babcock, 1983) have speculated that both *Ivanovia* and *Eugonophyllum* were broad-leaved upright plants. The internal microstructure of both genera are schematically shown on Fig. 3. It should be noted that diagnostic internal microstructure (utricles), when preserved, exhibit bilateral symmetry. However, it does

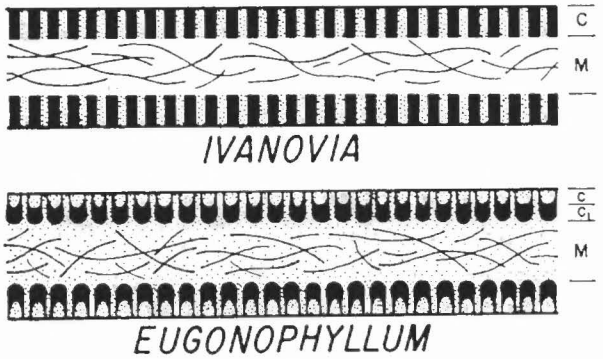


FIGURE 3. Schematic diagram showing wall microstructure as seen in transverse thin sections of the phylloid algae *Ivanovia* and *Eugonophyllum*. ×25. Utricular structures are shown in solid black; C = cortex, M = medulla, C_1 = subcortex (modified from Konishi and Wray, 1961).

appear that only the outer surface of the leaf (thallus) was carbonate encrusted. Thin-section examination almost invariably shows that the central portion (medulla) of the leaf is recrystallized to sparry calcite mosaic (Fig. 4). In many instances the entire thallus is totally recrystallized, and when fragmented, algal particles can be confused with mollusc fragments.

Rare finds of silicified specimens (Toomey, 1976) suggest that when the plants died the broad leaves dropped to the sea bottom where they accumulated in piles (Fig. 5), in a manner similar to fallen leaves littering a forest floor. It is unfortunate that only silicified fragmented leaves have been retrieved. This suggests that the plant's stems and root systems probably were not carbonate encrusted, and that they decayed immediately on death of the plant.

Phylloid algae, e.g., *Ivanovia* and *Eugonophyllum*, probably were similar to Recent leafy algae, and appear to have had relatively accelerated growth during which a new crop of plants was turned over every few weeks (Toomey, 1981). Once those broad-leaved plants had established themselves on the sea bottom they probably grew in abundance. With rapid growth rates and crop turnover the plants would eventually occupy and dominate the immediate substrate. Once this plant community had been established it would be able to exclude most "normal" marine organisms. In essence, the plants would create a unique plant-dominated and controlled marine community with relatively low biotic diversity. Only those organisms that could adapt to living conditions under this plant umbrella would be able to sustain themselves. Organisms possessing those requirements would fall into three broad categories: (1) plant-encrusting organisms such as foraminifers, worms, bryozoans, and other algae; (2) mobile grazing organisms such as snails and echinoids, together with opportunistic brachiopods with prominent pedicles that could be used to attach themselves to the plants' stems and leaves; and (3) an infaunal component comprising burrowing clams and possibly various marine worms. A schematic reconstruction of this low diversity, plant dominated and controlled marine community is given elsewhere in this guidebook.

It should be understood that a semi-rigid plant, which probably grew to a height of no more than 13 cm, could not and would not function as a rigid skeletal biohermal framework component. Accordingly, phylloid algae probably lived in water depths somewhat below appreciable wave and current action. The primary attribute of these plants in biohermal accretion was their ability to function as dense plant growths covering the sea bottom and trapping large quantities of finely suspended sediment, which normally would have been dispersed by wave and current action.

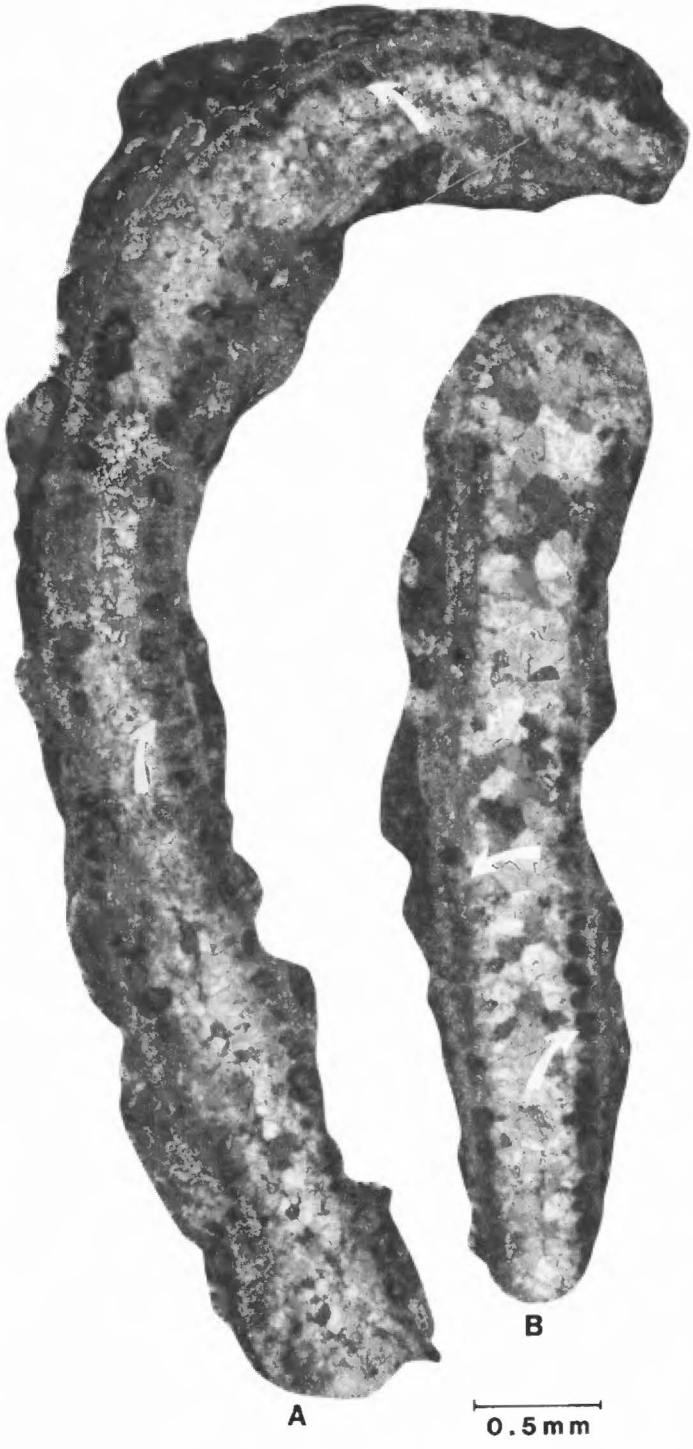


FIGURE 4. Thin-section photomicrographs of partially recrystallized phylloid-algal plates (*Eugonophyllum*), showing typical sporadic preservation of utricular microstructures (arrows) within the thalli. Specimens from the Late Pennsylvanian (Virgilian) biohermal interval exposed on "Reef" Hill, Hueco Mountains, west Texas.

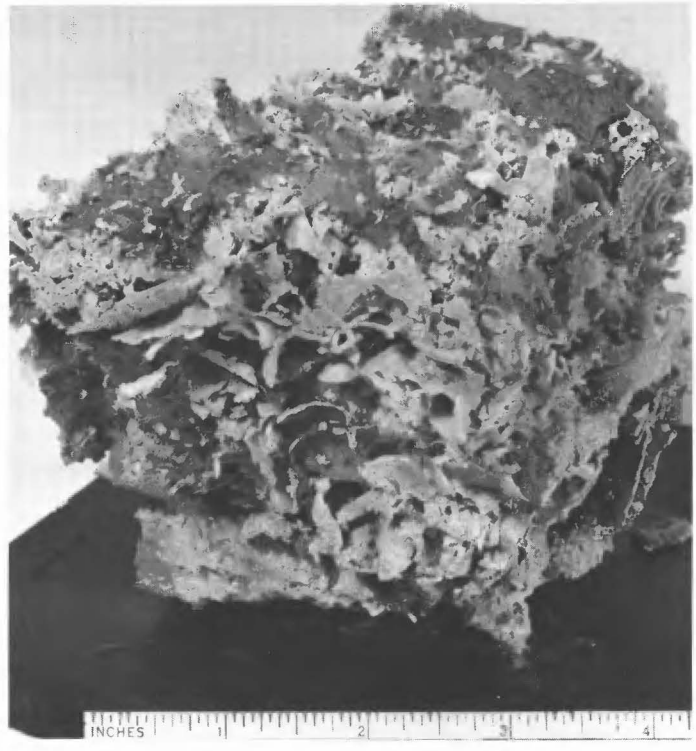


FIGURE 5. Partially acid-etched block of Lower Permian silicified phylloid-algal, biostromal limestone from Vinton Canyon, northern Franklin Mountains of west Texas. Note that the silicified algal plates are stacked like a pile of dead leaves, that acid-leached dark spaces are shelter cavities, and the overall muddy composition of the rock.

Late Paleozoic phylloid-algal growth appears to have occurred primarily in relatively shallow tropical seas, in locations conducive to early submarine cementation. This added diagenetic effect would aid in creating a more rigid biohermal structure than could be expected solely from relatively small, sessile, flexible plants. Petrological examination of phylloid-algal biohermal rock indicates that the phylloid-algal component is less than 25%, with the remaining 75% comprising lime mud, minor scattered skeletal debris, sparry calcite mosaic-filling voids and/or algal shelter cavities, and isolated fans of radial, fibrous, submarine cements.

OROGRANDE BASIN

The Late Paleozoic Orogrande Basin of south-central New Mexico and west Texas was defined by Pray (1958), and definitively outlined by Kottlowski (1960). A generalized map showing the paleogeographic setting of the basin during Late Pennsylvanian (Virgilian) time is given in Fig. 6. This map delineates the position of the positive land areas, basinal deposits including evaporites, marine shelf deposits, transitional deposits, and the locations of reported Virgilian phylloid-algal bioherms.

Basin tectonic evolution during late Paleozoic time

Detailed field mapping and study of Pennsylvanian sediments cropping out in the Sacramento Mountains (Pray, 1961) provides the best starting point in describing basin tectonics. Pennsylvanian sediments in the Sacramento Mountains are approximately 900 m (3000 ft) thick, and range in age from Early (Morrowan) through Late Pennsylvanian (Virgilian). These sediments represent a period of essentially continuous

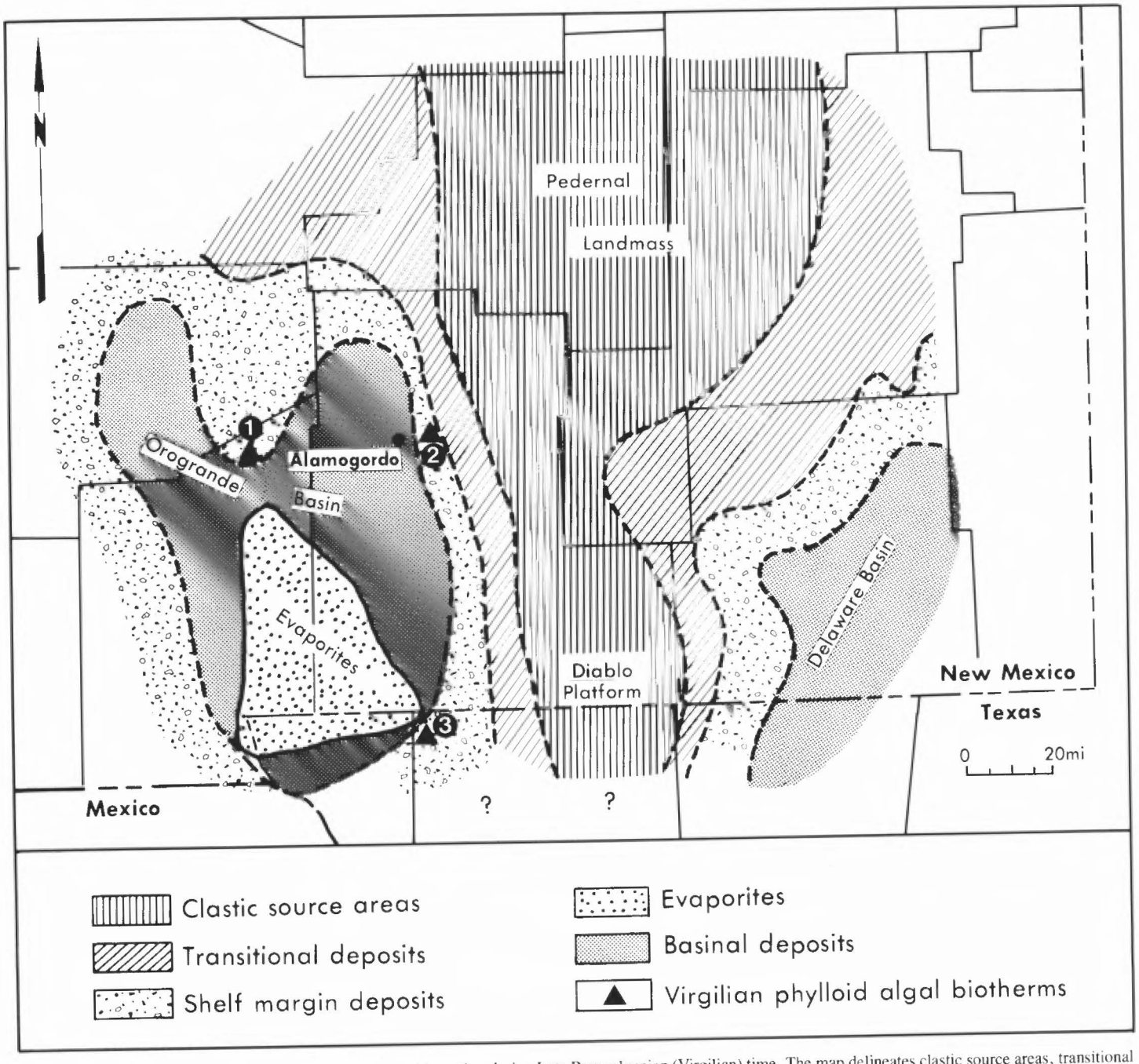


FIGURE 6. Index map showing the regional paleogeographic setting during Late Pennsylvanian (Virgilian) time. The map delineates clastic source areas, transitional deposits, shelf-margin deposits, basins, evaporites, and the locations of reported Virgilian phylloid-algal bioherms rimming the Orogrande Basin. 1) San Andres Mountains (Panther Seep Formation); 2) Sacramento Mountains (Holder Formation); and 3) Hueco Mountains (upper division of Magdalena Group).

deposition. The clastics and carbonates comprising the sequence are involved in lateral facies changes that have made difficult the recognition of any lithostratigraphic unit across the entire area. The deposits also reflect increasing tectonic instability which led to the formation of basins, shelf margins, and source areas of more localized extent than had previously occurred in early Paleozoic time. During Pennsylvanian time the Sacramento Mountains area was situated between a positive area to the east (Pedernal landmass), and a relatively negative area to the west (Orogrande Basin) (Wilson, 1967, 1972). The degree of tectonic differentiation varied from slight at the beginning of the period to major by the end of the Pennsylvanian.

Pray (1961) defined the Pennsylvanian formations in the Sacramento Mountains and named them (from oldest to youngest) Gobbler, Beeman, and Holder Formations. Most of the Gobbler Formation, up to about 500 m thick, represents Morrowan into Missourian time, and appears to have been deposited on a broad marine shelf that was subjected to local invasions of detrital sediments derived from the positive areas to the east and northeast. The basal sandstones and conglomerates of this formation were deposited on a channeled erosional surface. Overlying the basal sequence are two distinct facies, the Bug Scuffle Limestone, and an unnamed detrital facies. These two facies are coeval, interfinger layer by layer, and comprise about 300 m of sediments. The Bug Scuffle appears to have been laid down on a broad marine shelf west of the present escarpment area. The detrital facies developed shoreward (east) in response to tectonic activity in the highlands.

By Missourian time a clearer tectonic differentiation existed in the area. Evidence for this includes facies changes from shallow-water platform and shelf-margin sediments on the east to a more basinal area to the west. Within this tectonic framework, the Beeman Formation (up to 150 m thick) was deposited. Two major facies in the Beeman are developed on either side of a hinge line striking north-south through the central portion of the present escarpment. A basinal facies is found west of the hinge line, whereas to the east the basinal facies grades within 5 km to massive pure limestones interbedded with gray and red marls and limestone conglomerates. Those facies within the Beeman Formation reflect increasing tectonic activity in the area, with the emergence of the eastern area and the development of both transitional and terrestrial strata within the section.

By Late Pennsylvanian time (Virgilian), the presence in this area of a shallow marine to terrestrial shelf margin on the east, with repetitive or cyclic sediments, and a basin to the west with thick terrigenous sediments, becomes abundantly clear. Here, up to 250 m of the Virgilian Holder Formation was deposited, comprising limestones, sandstones, shales and conglomerates. Approximately 18 to 21 m above the base of the formation is a distinct unit of massive phylloid-algal bioherms as much as 23 m thick. Above the bioherms, cyclic or repetitive deposits, including phylloid-algal biostromal layers, characterize much of the Holder Formation. Interbedded terrestrial units increase both upward in the section, and eastward in Dry Canyon. Wilson (1967) described Holder cyclical deposition relative to the Orogrande Basin, and noted that while the carbonate shelf margin was being built, the basin was reciprocally filled with clastic sediments at times of lower sea level. Later, Wilson (1972) also described the effect of local structure (La Luz anticline) on the development of lower Holder phylloid-algal bioherm accretion.

The San Andres Mountains, located 110 km west of the Sacramento Mountains escarpment, delineate the western edge of the Orogrande Basin. Kottlowski et al. (1956) described approximately 900 m of Late Pennsylvanian sediments in the San Andres Mountains, and proposed the name Panther Seep Formation for this sequence. The formation comprises repetitive or cyclic deltaic-to-brackish-water clastics and limestones, with thick lenses of massive phylloid-algal biohermal and biostromal limestones. Gypsum beds are present near the top of the formation. Many of the sandstone beds are crossbedded and contain ripple marks, whereas the shales contain plant fragments and petrified wood. Local desiccation cracks are also present, and oolites and algal stromatolites are found in some limestones. These sediments were evidently deposited in a basin more characterized by rather rapid subsidence than one marked by significant water depth. It appears that much of the Panther Seep Formation was deposited within shallow marine to brackish waters in an area of continued sinking beneath a constant supply of clastics that were flushed westward from the Pedernal landmass.

The Hueco Mountains of west Texas are located approximately 130 km southeast of Alamogordo, New Mexico, and delineate the southeastern rim of the Orogrande Basin. This range was mapped and described by King et al. (1945). The exposed Pennsylvanian section is 400 m thick, was assigned to the Magdalena Group, and is subdivided into three divisions. The lower division is of Early to Middle Pennsylvanian (Morrowan and Atokan) age, and is approximately 150 m thick. The rocks consist of gray, massively bedded, cherty, crinoidal and coral limestones. In addition, prominent ooid banks and small bioherms composed of *Archaeolithophyllum* are also present. The middle division is of Middle Pennsylvanian (Desmoinesian) age and comprises approximately 90 m of relatively thin limestones interbedded with skeletal marls and shales. The upper division is of Middle to Late Pennsylvanian (Desmoinesian, Missourian and Virgilian) age, and is approximately 150 m thick. The rocks include thin-bedded fine clastics, thin-bedded shallow-water limestones including spiculites, and a series of prominent limestone conglomerates. Within the Virgilian portion of the sequence, massive, light-colored phylloid-algal bioherms and biostromal units are well exposed.

The tectonic setting for the Hueco Mountains is quite similar to that of the Sacramento Mountains. The Hueco Mountains area is east of the Orogrande Basin near the Pedernal landmass and Diablo platform positive areas (see Fig. 6). East of these positive areas were narrow shelf margins containing transitional clastics that grade westward into shallow-water clastics and carbonates. Lateral facies changes occur across the shelf margin. Within 5 to 11 km the rocks change laterally from red coarse and fine clastics with minor nodular limestones, to repetitive/cyclical clastic/carbonate sequences, to massive phylloid-algal bioherms, and finally to channel sandstones, dark shales and thin dark limestones of the basin.

As noted in the discussion of the San Andres Mountains, sea level fluctuations of more than one hundred meters occurred within the Orogrande Basin, but at various times the basin appears to have been almost drained. During low stands of sea level the basin held relatively shallow, muddy, euxinic waters. At other times, thin intertidal carbonates with desiccation features were deposited, and in the southern Orogrande Basin active gypsum-producing ponds existed.

It appears that during low sea-level stands the narrow shelf margins were intermittently exposed but never severely eroded. Nonetheless, with continued uplift and ongoing erosion on the positive elements, clastics bypassed the shelves in well-defined channels on their way to deposition within the Orogrande Basin as feldspathic sandstones. As transgression on the shelves progressed, appreciable thicknesses of shales and siltstones were deposited, and sandstones back-filled and plugged up previously cut stream channels on the shelves. Conversely, the narrow shelf margin was most prone to drowning during high sea-level stands. Deposition of thin, upward-shoaling carbonates prevailed on the shelf margin. Here, massive phylloid-algal bioherms developed with relief as much as 26 m. As the bioherms accreted, little or no basinal sedimentation was occurring.

PHYLLOID-ALGAL BIOHERMS RIMMING THE OROGRANDE BASIN

The Virgilian phylloid-algal bioherms rimming the Orogrande Basin appear to be oriented with their long axes parallel to the trend of the depositional strike of the shelf margins, a significant feature reported by Wilson (1975). Their rather common, somewhat tabular overall morphology is thought to be related to sea level standstill on the shelf margins, during which time phylloid-algal growth rapidly spread laterally. Local tectonic pulses on the nearby land masses would mainly control whether sufficient time was available for lateral bioherm accretion. Rapid shifts in sea level would tend to modify tabular-shaped bioherm accretion, a feature evident along the southeastern rim of the

basin. There, outcrops of Virgilian phylloid-algal bioherms exhibit both tabular and more mound-like morphologies, which probably were related to and influenced by a more active tectonic component.

A summary (Table 1) of biohermal intervals exposed around the Orogrande Basin includes stratigraphy, thickness, associated lithologies, and types and relative ages of the bioherms.

San Andres Mountains

This very long (140 km) north-south-trending mountain range lies wholly within the restricted area of the White Sands Proving Grounds and associated installations. Accordingly, access into this area has been, and continues to be, very limited. During the early 1950s, New Mexico Bureau of Mines and Mineral Resources personnel were allowed extended access to complete a geological survey of the mountain range (Kottlowski et al., 1956). Their report is the definitive work on the area. It indicates that more than 2100 m of Paleozoic sediments are exposed in the range, overlain by slightly more than 200 m of Mesozoic sediments.

Of special interest is the Pennsylvanian interval, which overlies Mississippian beds with pronounced erosional unconformity. The thickest Pennsylvanian section is exposed near Hembrillo Canyon, where it is slightly more than 900 m thick. Fusulinid studies indicate that the entire Pennsylvanian (Morrowan-Virgilian) sequence is represented in the range. Rocks of Virgilian age are lithologically quite different from sequences of similar age elsewhere in New Mexico. The Virgilian Panther Seep Formation, approximately 730 m thick, comprises dark silty shales, dark carbonaceous shales, dark argillaceous limestones, silty calcarenites, lenses of massive biostromal limestones and calcareous sandstones. Two thick gypsum beds occur in the upper part of the formation near Ash Canyon, whereas massive phylloid-algal bioherms occur near Rhodes and Hembrillo Canyons, in the lower part of the formation.

The phylloid-algal bioherms cap small peaks that rise above shaly slopes, and are exposed for 4 km along strike. Five bioherms are exposed in a lower horizon and five in an upper horizon. One exposure that extends vertically as a solid mass from the lower to upper horizon is almost 140 m thick. The bioherms range in thickness from 15 to 34 m (Kottlowski et al., 1956). Phylloid-algal masses, local coquinoid lenses of fusulinids, brachiopods, and crinoid columnals, and flanking lenses of pebble conglomerates are all present. Biohermal limestones dip off into, and thin out between, dark shales, sandstones, and dark muddy limestones more typical of the bulk of the Panther Seep Formation. Limestone pebble conglomerates also occur in patches on the tops of bioherms, and as relatively persistent beds between adjacent bioherms. Other than these conglomerates, which are in immediate juxtaposition with the bioherms, not much bioherm-derived debris occurs in the surrounding, laterally equivalent, typical Panther Seep beds. Fusulinid foraminifers occurring within the biohermal interval suggest an early Virgilian age. Obviously, more detailed work is needed, especially petrologic studies of the bioherms and flanking beds, so that the depositional history can be deciphered.

Sacramento Mountains

As noted above, much detailed work has been done on the early Virgilian Holder Formation phylloid-algal bioherms of the Sacramento Mountains, especially in the Dry Canyon area. Following the initial work by Plumley and Graves (1953) and Wray (1962), James Lee Wilson (1967, 1969, 1975, 1977) mapped in detail and studied the sediments comprising the Holder phylloid-algal bioherm interval. This was augmented by a detailed study of one specific phylloid-algal bioherm by Toomey et al. (1977). All of those data, and additional information on bioherm flanking beds, were summarized by Toomey and Babcock (1983).

The phylloid-algal bioherms so well exposed in Dry Canyon and described at Stop 2 of the Day 1 road log (this guidebook) are part of a more extensive complex whose overall morphology can be seen by projecting those east-west canyon outcrops, specifically Indian Wells and Beeman Canyons, in a northwest-southeast direction. This bioherm complex appears to be a Y-shaped body that extends for approximately 4.9 km with a width of about 1.2 km. Thickness of the bioherm in Dry Canyon is about 23 m, with the best exposures of flank beds occurring on the western side of this exposure. Examination of this exposure, and additional ones in other canyons, show that all bioherms possess a distinctive "core." At the base of the Dry Canyon massive phylloid-algal bioherm approximately 3 m of what seems to be a core of vuggy rock is exposed. This is misleading, for when this rock is broken open it is found to be very fossiliferous. The fossils, almost entirely brach-

TABLE 1. Synopsis of Late Pennsylvanian (Virgilian) phylloid-algal biohermal intervals rimming the Orogrande Basin, including stratigraphy, thicknesses, associated lithologies, types of bioherms and their relative ages.

		SAN ANDRES MOUNTAINS (Kottlowski et al., 1956)	SACRAMENTO MOUNTAINS (Pray, 1961)	HUECO MOUNTAINS (King et al., 1945; Pol, 1985)
LATE PENNSYLVANIAN	VIRGILIAN	PANTHER SEEP FORMATION	HOLDER FORMATION	MAGDALENA GROUP (UPPER DIVISION)
		Thickness: Up to 2400 ft.	Thickness: 850 ft.	Thickness: 500 ft (interval ranges from Desmoinesian through Virgilian).
		Lithologies: Silty shales, dark argillaceous limestones, silty skeletal limestones, with gypsum beds in upper part of formation.	Lithologies: Skeletal limestones, shales, sandstones, and conglomerates.	Lithologies: Pre-biohermal sequence comprises thin-bedded fine clastics, thin-bedded shallow-water limestones, spiculites, and coarse limestone conglomerates.
		Bioherms: Massive phylloid algal bioherms from 50-110 ft thick occur in lower part of formation, associated with skeletal coquinas and lenses of limestone pebble conglomerate.	Bioherms: Massive phylloid algal bioherms up to 75 ft thick occur as a distinct interval 60-70 ft above base of formation.	Bioherms: Massive phylloid algal bioherms up to 85 ft thick occur in the uppermost 160 ft of the upper division, and are associated with much inter-biohermal deposits.
		Age: Fusulinids within the biointerval suggest an early Virgilian age.	Age: Triticitid fusulinids within bioherms indicate an early Virgilian age.	Age: Triticitid fusulinids within the biohermal interval range in age from early to latest Virgilian.

iopods (*Composita*), have been extensively leached and are in a micritic matrix. This "core" interval can be regarded as the shelly hardground foundation on which the bioherm was initiated. The "core" rock probably represents quiet subtidal waters where abundant, gregarious brachiopod populations clustered.

Above the "core," in the bioherm proper, the shelly interval gives way as phylloid algae (*Eugonophyllum*) become more and more abundant. At this point the biohermal rock can be classified as an algal-plate packstone/bafflestone, with only a relatively sparse brachiopod component. As rapid phylloid-algal growth continued, and the algae functioned more and more effectively as sediment-trapping baffles, the bioherm built upward into increasingly shallow waters. At some point the optimum depth range for phylloid algae was passed. That probably occurred in water depths on the order of 6 m or less. Increasingly shoal waters offered other opportunitistic organisms a favorable niche to exploit. In this case, algal/foraminiferal boundstones, containing much dasyclad algae, became dominant.

With further shoaling, the bioherm was capped with grainstones composed of tubular foraminifera and ostracodes, organisms that probably lived on and amongst a luxuriant "sea weed" community. Alternately, the capping beds may consist of thin oolitic grainstones, thus marking the termination of active bioherm accretion. At this stage, the bioherm was probably subaerially exposed as indicated by red weathering zones, and *in situ* clast brecciation on the crest of the bioherm. Overlying sediment cycles generally begin with relatively thin, basal siltstones and sandstones. The biohermal growth sequence is diagrammatically shown in the Day 1 road log (this guidebook).

Flanking beds of the Holder phylloid-algal bioherm in Dry Canyon are best exposed on the west (ocean-facing) side of the bioherm. The flank beds are of very limited lateral extent, thin-bedded and steeply dipping (up to 35°). They contain abundant shallow marine biotic components, including dasyclad algae (*Macroporella*), various encrusting forams, fusulinids, worm tubes, myalinid pelecypods and ostracodes. These organisms probably lived on or close to the bioherm crest, and at death were swept off the bioherm into surrounding downslope waters.

Phylloid-algal bioherms appear to have been affected by local structure on or close to the shelf margins, in addition to the regional structure. The detailed surface mapping of Holder sediments and bioherms by Wilson (1972) has shown that the bioherms indeed have a preferred position within vertical, upward-shoaling cycles, and this is nicely demonstrated during the growth history of the Dry Canyon bioherms. Significantly, Wilson (1972, 1975) also demonstrated that the Holder bioherms, and their associated cyclic/repetitive sediments, comprise a distinct progression of growth stages off the western flank of the local, actively growing, La Luz anticline. This is important because it indicates the influence of local anticlinal structure on phylloid-algal bioherm growth, and the direction of submarine slope during early Virgilian time. The subsequent, detailed study of Yucca bioherm by Toomey et al. (1977) tends to substantiate those findings.

An additional important point is that the Holder bioherms, so well exposed in the east-west-trending canyons of the Sacramento Mountains, are essentially diachronous. Overall bioherm morphology at any specific growth interval does not resemble the final outcrop exposures we see today. In essence, Wilson's mapping has shown conclusively that the biohermal complex is older to the southeast, and becomes progressively younger in a northwestern direction.

Hueco Mountains

Late Pennsylvanian bioherms have been known from the Hueco Mountains since King et al. (1945) mapped the "Reef" Hill locality. Subsequent studies by Seewald (1968), Toomey and Babcock (1983) and Pol (1985) demonstrated that those bioherms are composed of phylloid algae, and are Virgilian in age. The paleogeographic setting, with phylloid-algal bioherms rimming the southeastern portion of the Orogrande Basin, is similar to that seen in the Sacramento Mountains. However, there are notable differences in bioherm ages, morphology, associated sediments, and local tectonics which impart a unique character to this biohermal sequence.

The bioherm exposures on "Reef" Hill (an erosional remnant with about 90 m of relief; see Fig. 7) are of limited lateral extent but include approximately 50 m of biohermal rocks within the uppermost portion of King et al.'s (1945) upper division of the Magdalena Group. These exposures range in age from probable Missourian through Virgilian. The lower portion of the outcrop is about 30 m thick and is generally poorly exposed due to much slumping from above. Sediments include shales, sandstones, thin carbonates, and at least five intervals of limestone conglomerates. Above this, approximately 50 m of limestone characterized by phylloid-algal massive bioherms and biostromal units are exposed. The biohermal interval is unconformably overlain by the Lower Permian Pow Wow Conglomerate.

Deposition of the clastics within the lower portion of the outcrop is intimately related to uplift on the Pedernal-Diablo positive areas east of the depositional area (see Fig. 6). Tectonic activity in the highlands appears to have been spasmodic. This activity, coupled with ongoing erosion, and subsequent river and stream entrenchment and erosion, brought large amounts of clastics into the immediate area. Those clastics were deposited as sequential events in the building of deltaic lobes that fanned out into the Orogrande Basin. These clastics were reworked along the narrow shelf margins, where various shallow marine environments developed. Rivers and streams incised the narrow shelf margins a number of times, and in the process incorporated ripped-up and reworked sedimentary clasts into distinctive limestone conglomerates.

An abrupt change in lithology and biota occurs at the contact between the underlying, predominantly clastic sequence and the overlying limestone interval. This change appears to be related to a halt in clastic influx from the positive areas to the east, and a continued upward shoaling of the immediate depositional area. A rugose coral horizon with common *Eugonophyllum* is a distinctive stratigraphic marker bed. Above this is a sequence of skeletal limestones with phylloid and dasyclad algae. The uppermost portion of this interval changes abruptly, becoming thin-bedded and lacking algae. This horizon represents a significant transgression in which the shallow shelf margin was drowned in relatively deeper waters. Laterally, and within this deeper water phase, and extending upward to the base of the principal phylloid-algal bioherm interval, are a series of small patches of silicified brachiopod shells, associated with discrete, though somewhat larger patches of silicified colonies of the tabulate coral *Syringopora*. These silicified shelly patches appear to have served as hardground foundations for subsequent phylloid-algal bioherm accretion, a feature reminiscent of the Holder Formation bioherms in Dry Canyon.

Bioherm growth, once initiated, appears to have occupied only certain areas of the sea bottom, and most bioherms appear to have grown upward into increasingly shallower waters. This phenomenon occurred a number of times, probably coincident with alternating sea level fluctuations. Some bioherms grew into very shallow water, and some were subaerially exposed. Evidence that the bioherms grew upward into shoal waters is indicated by the biota present in bedded interbiohermal rocks. In those beds dasyclad algae, broken phylloid algae (*Eugonophyllum* and *Ivanovia*), and triticitid fusulinids occur in abundance. This biota, especially the dasyclad algae and fusulinids, originally lived within grasses on the tops of the bioherms, and on death, were swept off the bioherms and intermixed with reworked phylloid-algal plates. Although some bioherms attained a height of up to 26 m (Pol, 1985), and are massive and somewhat pinnacle-shaped (see Fig. 7), others are smaller and have a more mound-like morphology. The bioherm-accretion process appears to have been repeated a number of times during the deposition of the biohermal interval and probably is related to abrupt fluctuations in sea level in response to tectonic activity on the highlands to the east. Bioherm growth ceased in this area with increased tectonic activity, and a major angular unconformity separates terminal bioherm growth (latest Virgilian) from the overlying Early Permian (Wolfcampian) Pow Wow Conglomerate.

REFERENCES

Johnson, J. H., 1946, Lime-secreting algae from the Pennsylvanian and Permian of Kansas: Geological Society of America Bulletin, v. 57, p. 1087–1120.

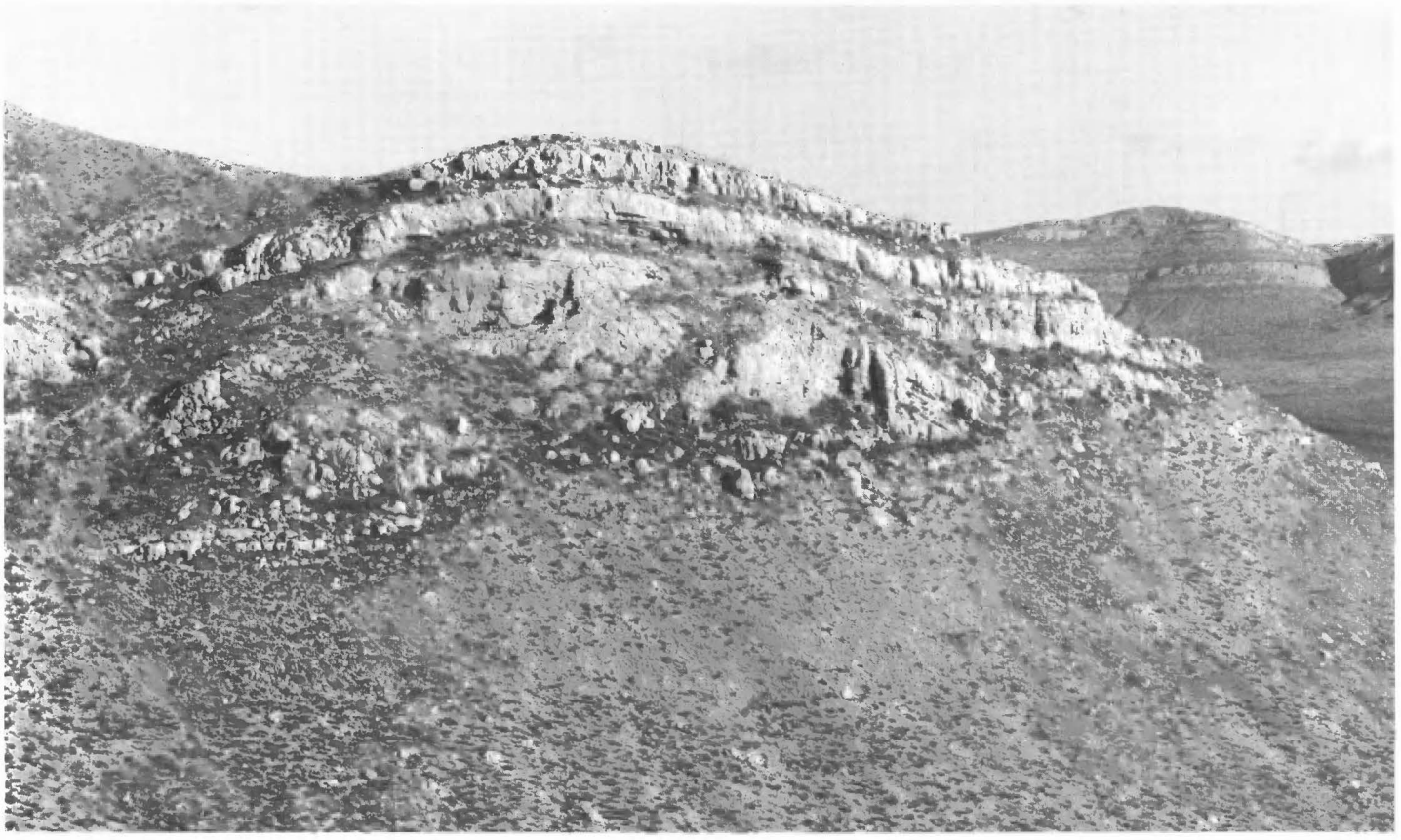


FIGURE 7. Aerial photograph of the phylloid-algal biohermal complex exposed on "Reef" Hill, Hueco Mountains, west Texas. Note the massive, mound-like morphology of the large, conspicuous bioherm overlain by relatively thick, massive, phylloid-algal biostromal units.

Johnson, J. H., 1956, *Archaeolithophyllum*, a new genus of Paleozoic coralline algae: Journal of Paleontology, v. 30, p. 53–55.

Khvorova, I. V., 1946, On a new genus of algae from the Middle Carboniferous deposits of the Moscow Basin: Academy of Sciences, U.S.S.R., CR, Doklady, v. 53, p. 737–739.

King, P. B., King, R. E. and Knight, J. B., 1945, Geology of the Hueco Mountains, El Paso and Hudspeth Counties, Texas: U.S. Geological Survey, Oil and Gas Investigations, Preliminary Map No. 36, 2 sheets.

Konishi, K. and Wray, J. L., 1962, *Eugonophyllum*, a new Pennsylvanian and Permian algal genus: Journal of Paleontology, v. 35, p. 659–666.

Kottlowski, F. E., 1960, Depositional features of the Pennsylvanian of south-central New Mexico: Roswell Geological Society, Fall Field Conference Guidebook, p. 96–130.

Kottlowski, F. E., Flower, R. H., Thompson, M. L. and Foster, R. W., 1956, Stratigraphic studies of the San Andres Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 1, 132 p.

Pol, J. C., 1985, Sedimentation of an Upper Pennsylvanian (Virgilian) phylloid algal mound complex, Hueco Mountains, El Paso County, West Texas; *in* Toomey, D. F. and Nitecki, M. H., eds., Paleoalgology: contemporary research and applications: Heidelberg, Springer-Verlag, p. 188–207.

Plumley, W. J. and Graves, R. W., Jr., 1953, Virgilian reefs of the Sacramento Mountains, New Mexico: Journal of Geology, v. 61, p. 1–16.

Pray, L. C., 1958, Pennsylvanian sedimentation of the Sacramento Mountains area, New Mexico: 3rd Annual Meeting, Permian Basin Section, Society of Economic Paleontologists and Mineralogists, Abstracts with Programs, p. 7.

Pray, L. C. and Wray, J. L., 1963, Porous algal facies (Pennsylvanian) Honaker Trail, San Juan Canyon, Utah: Four Corners Geological Society, 4th Field Conference, p. 204–234.

Seewald, K. O., 1968, Pennsylvanian and Lower Permian stratigraphy, Hueco Mountains, Texas: Guidebook—Delaware Basin exploration, West Texas Geological Society, Publication No. 68-55, p. 45–49.

Toomey, D. F., 1976, Paleosynecology of a Permian plant dominated marine community: Neues Jahrbuch für Palaontologie, Abhandlung, v. 152, p. 1–18.

Toomey, D. F., 1979, Role of archaeolithophyllid algae within a Late Carboniferous algal-sponge community, southwestern United States: Bulletin Central Research, Exploration and Production, Elf-Aquitaine, v. 3, p. 843–853.

Toomey, D. F., 1981, Organic buildup constructional capability in Lower Ordovician and late Paleozoic mounds; *in* Grey, J., ed., Communities of the past: Stroudsburg, Hutchinson Ross Publishing Company, p. 35–68.

Toomey, D. F. and Winland, H. D., 1973, Rock and biotic facies associated with a Middle Pennsylvanian (Desmoinesian) algal buildup, Nena Lucia Field, Nolan County, Texas: American Association of Petroleum Geologists Bulletin, v. 57, p. 1053–1074.

Toomey, D. F., Wilson, J. L. and Rezak, R., 1977, Evolution of Yucca Mound complex, Late Pennsylvanian phylloid algal-buildup, Sacramento Moutnains, New Mexico: American Association of Petroleum Geologists Bulletin, v. 61, p. 2115–2133.

Toomey, D. F. and Babcock, J. A., 1983, Precambrian and Paleozoic algal carbonates, West Texas–southern New Mexico: Colorado School of Mines, Professional Contributions No. 11, 345 p.

Wilson, J. L., 1967, Cyclic and reciprocal sedimentation in Virgilian strata of southern New Mexico: Geological Society of America Bulletin, v. 78, p. 805–818.

Wilson, J. L., 1972, Influence of local structure in sedimentary cycles of Beeman and Holder Formations, Sacramento Mountains, Otero County, New Mexico; *in* Elam, J. C. and Chuber, S., eds., Cyclic sedimentation in the Permian Basin, a symposium: West Texas Geological Society, p. 100–114.

Wilson, J. L., 1975, Carbonate facies in geologic history: New York, Springer-Verlag, 471 p.

Wray, J. L., 1962, Pennsylvanian algal banks, Sacramento Mountains, New Mexico; *in* Malone, D. J., ed., Geoeconomics of the Pennsylvanian marine banks in southeast Kansas: Kansas Geological Society, Guidebook 27, p. 129–133.

Wray, J. L., 1964, *Archaeolithophyllum*, an abundant calcareous alga in limestones of the Lansing Group (Pennsylvanian), southeastern Kansas: Kansas Geological Survey, Bulletin 170, pt. 1, p. 1–13.

Wray, J. L., 1968, Late Paleozoic phylloid algal limestones in the United States: 23rd International Geological Congress (Prague), Proceedings, v. 8, p. 113–119.