



## ***A marine invertebrate faunan from the upper part of the Panther Seep Formation (earliest Wolfcampian) near Hembrillo Pass, San Andres Mountains, south-central New Mexico***

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# A MARINE INVERTEBRATE FAUNA FROM THE UPPER PART OF THE PANTHER SEEP FORMATION (EARLIEST WOLFCAMPIAN) NEAR HEMBRILLO PASS, SAN ANDRES MOUNTAINS, SOUTH-CENTRAL NEW MEXICO

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**ABSTRACT.**—A marine invertebrate assemblage consisting of about 35 species is described from the upper 30–45 m of the Panther Seep Formation near Hembrillo Pass, in the central San Andres Mountains. The assemblage is dominated by brachiopods, which constitute >90% of the specimens, with far fewer sponge, coral, bryozoan, bivalve, gastropod, trilobite, crinoid and echinoid specimens. Of the brachiopods, four species—*Neochonetes granulifer* (24%), *Pontisia kingi* (23%), *Composita subtilita* (19%), and *Reticulatia* n. sp. (15%)—comprise about 80% of about 1100 specimens collected. Stratigraphic position, the presence of several characteristic lower Wolfcampian species, including the gastropod *Omphalotrochus*, and known and inferred relationships to regional fusulinid zones all indicate an earliest Wolfcampian (earliest Permian) age for this assemblage relative to the recently revised Pennsylvanian-Permian boundary in the Midcontinent region. This assemblage appears to be slightly younger than faunas of the Bursum and coeval units in central New Mexico, but is slightly older than faunas of the overlying lower Hueco Group in this area. The occurrence of *Omphalotrochus* in this assemblage correlates well with the first appearance of the genus in the Midcontinent region, at the very beginning of the Wolfcampian Stage. The organisms of this assemblage lived in a shallow, offshore, open-shelf, normal-marine environment with relatively little water agitation.

## INTRODUCTION

The Panther Seep Formation is a thick unit of late Pennsylvanian to earliest Permian age that was deposited in the rapidly subsiding Orogrande basin of south-central New Mexico. It was first recognized and named by Kottlowski et al. (1956) near Rhodes Canyon, in the northern San Andres Mountains, and crops out from the northern to southern parts of that range (Kottlowski et al., 1956; Schoderbek, 1994). The formation is also exposed in the Organ Mountains (Seager, 1981) and Franklin Mountains (e.g., LeMone, 1982) to the south, the Jarilla Mountains (Seager et al., 1987) and northern Hueco Mountains (e.g., Hardie, 1958; Kottlowski, 1960) to the southeast, and the Dona Ana Mountains to the southwest (Seager et al., 1976). The Panther Seep attains a maximum thickness of about 975 m in the subsurface east of Ash Canyon, San Andres Mountains, and typical outcrop thicknesses from north to south along the San Andres range are (as given by Kottlowski et al., 1956) 444 m (Rhodes Canyon), 556 m (Hembrillo Canyon), 865 m (Ash Canyon), and 794 m (Salt Canyon).

The Panther Seep consists predominantly of cyclic, mainly (74%) terrigenous strata with lesser amounts of carbonate and gypsum. Schoderbek (1994) reported eight distinctive rock types based on three measured stratigraphic sections in the San Andres range, as follows: gray to black shale (52% of total thickness, representing generally deeper basinal marine environments that were inhospitable to many organisms), coarse- (13%) and fine-grained (9%) sandstone (channel and floodplain fluvial deposition), grain-dominated limestone (18%, marginal marine tidal flats), algal limestones (3%, mostly stromatolitic to oncoidal algae representing intertidal to supratidal environments), mud-dominated limestone (2%, moderately deep marine environments), limestone breccia (1%, subaerially exposed, supratidal environment), and gypsum (2%, representing hypersaline, quiet-water conditions). Large phylloid algal bioherms, studied recently by

Soreghan and Giles (1999) and Soreghan et al. (2000), occur in the area of Hembrillo Canyon.

Fossils other than algae are sparse in the Panther Seep Formation (Bachman and Myers, 1969; Schoderbek, 1994). Most of the formation has been considered to be of Virgilian age, based upon limited fusulinacean data (Kottlowski et al., 1956), but subsequent workers have suggested that the basal hundred or so meters are of Missourian age, and that the upper beds may be early Wolfcampian. A few macroinvertebrate taxa have been noted (e.g., Kottlowski et al., 1956; Bachman and Myers, 1969) in faunal lists, but detailed knowledge of Panther Seep paleontology is lacking.

Here, a moderately diverse fauna is described from the upper part of the Panther Seep Formation near Hembrillo Pass, on the White Sands Missile Range. This is a preliminary report, as it is based on a collection made quickly during field reconnaissance from a single locality. Unfortunately, shortly after the collection was made, the range authorities closed access to the Hembrillo Canyon area, a condition that persists to the time of this writing. Further collecting from this locality will doubtless produce additional taxa, and better preserved specimens of taxa that are known only from one or a few specimens in the present collection. All specimens discussed here are deposited in the paleontology collections of the New Mexico Museum of Natural History (NMMNH), Albuquerque.

## LOCATION AND STRATIGRAPHY

The locality (Fig. 1) is about 300 m southeast of the gate at the crest of Hembrillo Pass, along a ridge that extends southeastward from the Hembrillo Canyon road, in the SW1/4SE1/4 sect. 7, T16S, R3E, Dona Ana County, New Mexico (NMMNH Locality 4992). The fauna was collected from a fossiliferous interval about a meter thick within a slope-forming, tan to gray calcareous shale unit containing thin, interbedded argillaceous limestone beds,

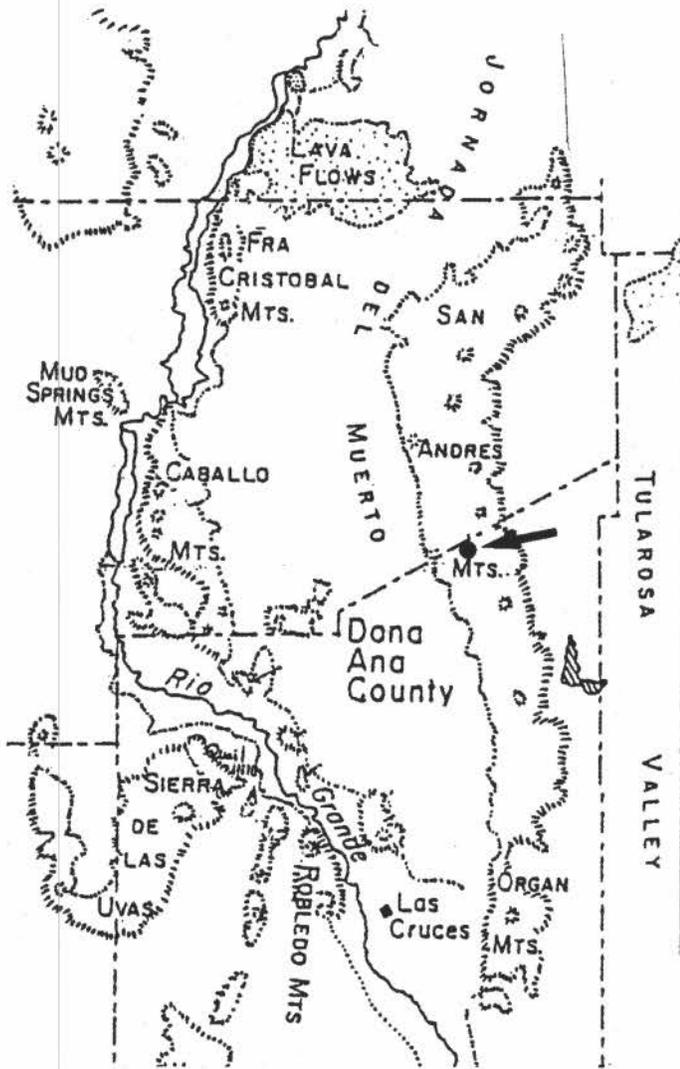


FIGURE 1. Map of central New Mexico showing location of Hembrillo Pass (dot and arrow).

about 5 m below the prominent brown sandstone that locally caps the ridge. Below the fossiliferous horizon is a dark gray limestone ledge, and below that is a thick, slope-forming sequence, mostly of shale with thin limestone and sandstone ledges. This interval was not measured but is at least 30 m thick.

Kottowski et al. (1956) measured a stratigraphic section through most of the Panther Seep along the Hembrillo Canyon road and across the crest of Hembrillo Pass. The section was offset some 730 m to the southeast (into the NE1/4 of adjacent sect. 20) to pick up the uppermost 22 m of the Panther Seep, 23 m of overlying strata that they called Bursum Formation, and the lower part of the Hueco Formation, which is marked by a basal, prominent, 5-m-thick, cliff-forming, algal limestone unit (unit H-272). The entire thickness of their Panther Seep section here is 556 m. Re-examination and measurement of the upper part of Kottowski et al.'s (1956) section with S. G. Lucas (in preparation) suggests that typical Bursum lithologies (especially red-bed clastic units) are not present here, and that the "Bursum" interval (units H-269-271) is better considered the uppermost part of the

Panther Seep. The most likely correlation of the fossiliferous interval is with unit H-266 or H-267 of Kottowski et al. (1956), or about 30 to 45 m below the (revised) Panther Seep-Hueco contact. Kottowski et al. (1956) did not note any fossils from the upper part of the Panther Seep in this section.

Traditionally, the boundary between the late Virgilian (latest Pennsylvanian) and early Wolfcampian (earliest Permian) stages was marked by the first appearance of the fusulinid genus *Schwagerina* and the presence of advanced forms of *Triticites* (e.g., zone PW-1 of Wilde, 1990). A proposal to establish the Carboniferous-Permian boundary at a higher level, based on a section in Kazakhstan, central Asia, and the resulting raising of the boundary in the Midcontinent sequence (Baars et al., 1994; see also Sanderson et al., 2001), has the effect in New Mexico of moving the Bursum Formation and approximately correlative strata such as the upper part of the Panther Seep, from the lowermost Permian to the uppermost Pennsylvanian (e.g., Lucas et al., 2000, 2002a; Wahlman and King, 2002). The Pennsylvanian-Permian (= Virgilian-Wolfcampian) boundary would then be approximately at the base of the Hueco Group in southern New Mexico (Wahlman and King, 2002).

## SYSTEMATIC PALEONTOLOGY

Invertebrate taxa identified in the collection of about 1100 specimens (Table 1) are described and illustrated below. Additional taxa are known from fragments too poorly preserved to allow definite identification. Quality of preservation of these taxa ranges from reasonably complete specimens (many brachiopods), to specimens preserved mainly as steinkerns or with highly weathered shell surfaces (most gastropods and bivalves).

### Sponges

One small sponge (Fig. 2A), which grew on a valve fragment of the brachiopod *Reticulatia*, is an irregular mass about 25 mm across in maximum diameter. Weathered spicules are large (up to 2.5 mm across) and bear three or four rays. A second, large sponge about 35 mm across and 25 mm high displays a finer meshwork of smaller, three and four-rayed, weathered spicules. No attempt was made to identify these sponge specimens.

### Cnidaria

A few specimens of small, solitary, rugose corals were collected. No attempt was made to identify them, but the two taxa are described briefly and illustrated.

#### Rugosa, species 1

The most complete specimen of coral (Fig. 2B) is elongate and semicylindrical in shape, measuring 13.5 mm high, with a maximum diameter of 8 mm; details of the calice and septa were not preserved. The external surface of the corallum is ornamented with low, wide, longitudinal ribs and narrower furrows, crossed by irregular growth wrinkles, and the corallum is severely constricted at about midheight.

TABLE 1. Invertebrate taxa from the upper Panther Seep Formation, near Hembrillo Pass, San Andres Mountains, and percent of total assemblage represented by each taxon (crinoids and bryozoans excluded). Abbreviations for subjective estimates of bryozoan and crinoid abundances: MC, moderately common; UC, uncommon.

Species	Number	Percent
<b>PORIFERA</b> , indet.	2	0.2%
<b>CNIDARIA</b>		
Rugosa, species 1	2	0.2
Rugosa, species 2	1	0.1
<b>BRYOZOA</b>		
<i>Penniretepora</i> sp.	UC	—
" <i>Fenestella</i> " sp.	UC	—
<i>Septopora</i> cf. <i>S. spinulosa</i> Moore	UC	—
cf. <i>Rhombopora</i>	MC	—
unidentified encrusting form	UC	—
<b>BRACHIOPODA</b>		
<i>Petrocrania modesta</i> (White and St. John)	1	0.1
<i>Rhipidomella hessensis</i> King	1	0.1
<i>Derbyia deercreekensis</i> Dunbar and Condra	49	4.7
<i>Neochonetes granulifer</i> (Owen)	250	23.9
<i>N. semiacanthus</i> (Lintz)	12	1.1
<i>Kozłowska?</i> sp.	1	0.1
<i>Reticulatia</i> n. sp.	162	15.5
<i>Pontisia kingi</i> Cooper and Grant	235	22.5
<i>P.</i> cf. <i>P. wolfcampensis</i> Cooper and Grant	30	2.9
<i>Composita subtilita</i> (Hall)	197	18.9
<i>Cleiothyridina pecosii</i> (Marcou)	1	0.1
<i>Crurithyris planoconvexa</i> (Shumard)	1	0.1
<b>BIVALVIA</b>		
<i>Aviculopinna</i> sp.	1	0.1
<i>Septimyalina burmai</i> Newell	5	0.5
<i>Aviculopecten</i> sp.	3	0.3
<i>Acanthopecten</i> sp.	1	0.1
<i>Streblochondria</i> cf. <i>S. stantonensis</i> Newell	2	0.2
<i>Astartella varica</i> McChesney	18	1.7
<b>GASTROPODA</b>		
<i>Euphemites</i> aff. <i>E. batteni</i> Yochelson	4	0.4
<i>E.</i> sp.	1	0.1
<i>Pharkidonotus</i> sp.	6	0.6
indeterminate bellerophonids	11	1.1
<i>Amphiscapha</i> aff. <i>A. subrugosa</i> (Meek and Worthen)	9	0.9
<i>Omphalotrochus</i> aff. <i>O. obtusispira</i> (Shumard)	18	1.7
<b>TRILOBITA</b>		
<i>Ditomopyge decurtata</i> Gheyselinck	4	0.4
<i>D.</i> sp.	1	0.1
<b>ECHINODERMATA</b>		
Crinoid stem fragments	MC	—
Cidaroid echinoid interambulacral plate	1	0.1

This specimen is of unusual interest because it bears a second, more evenly conical corallum about 7 mm high that is closely appressed to its external surface, apparently having budded off the larger individual. That this was not simply a co-occurrence of two isolated specimens is indicated by the fact that the apex of the smaller individual merges smoothly with the external skeletal surface of the larger individual. In addition, undulations in the external surface of the larger specimen are matched exactly by complementary undulations in the smaller specimen, and the skeletons of both appear to be fused together along their line of contact. Such offsets of normally solitary rugosans are uncommon but have been occasionally reported among North American late Paleozoic taxa, such as *Neokoninckophyllum* (e.g., Cocke, 1970, pl. 5, fig. 6).

#### Rugosa, species 2

A second species (Fig. 2C) is represented by a small, broadly conical corallum about 7 mm high (the apical end is broken off) and 8 mm in maximum diameter. Longitudinal ribs and intervening furrows are conspicuous and have equal magnitude, and growth wrinkles and lines cross them. Septa and other internal skeletal features are not preserved on the matrix-filled and weathered upper surface.

#### Bryozoans

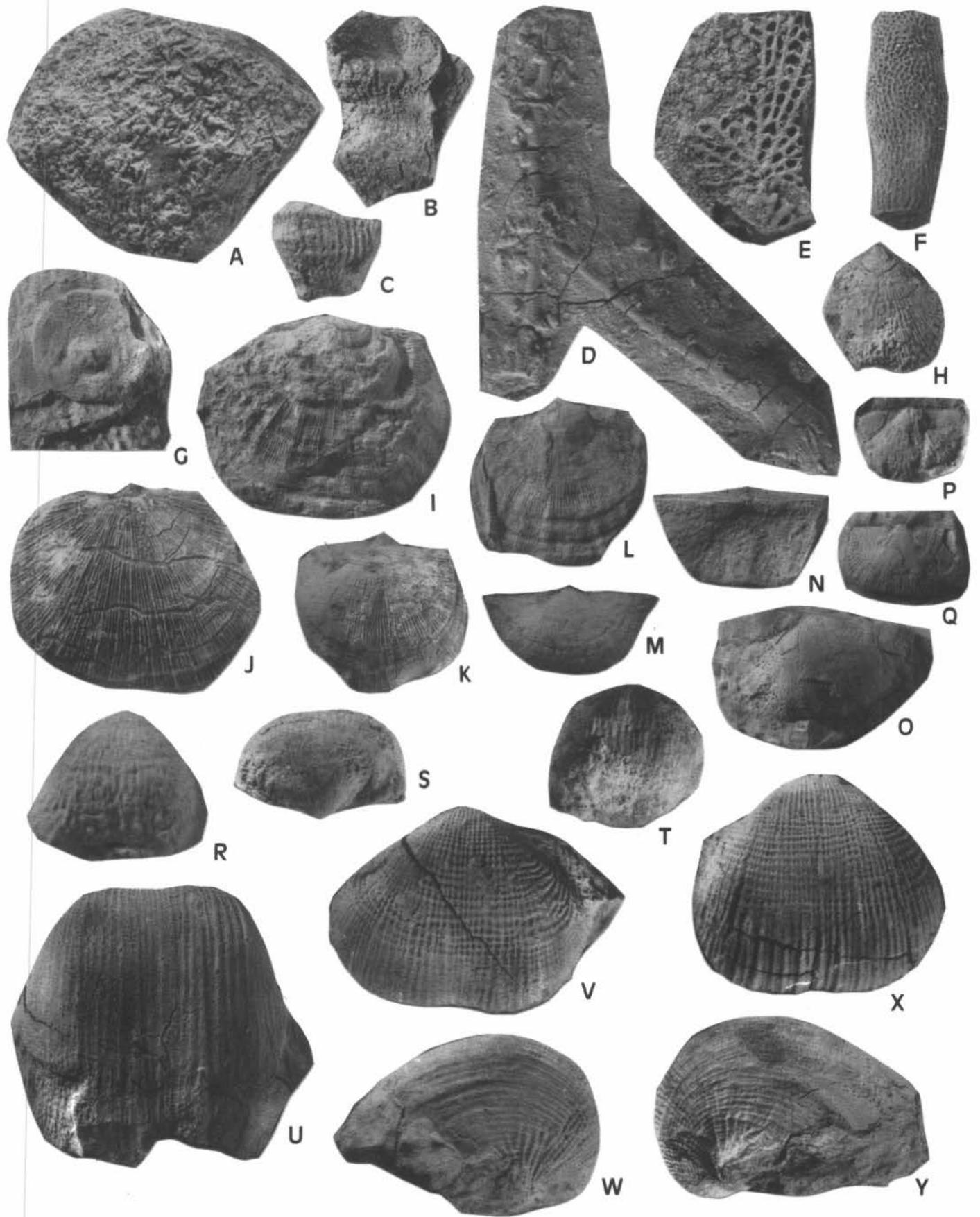
Bryozoans are moderately common in this assemblage and are represented by several genera. Thin-section studies of internal features were not done; thus, identifications are based on examination of external zoarial features and should be regarded as tentative.

Pinnate, occasionally branching fragments of the fenestrate *Penniretepora* are up to 25 mm long and 1 mm in diameter (Fig. 2D). The pinnules extend normally or slightly obliquely from the branch, are in opposition along both sides of the branch, and number six to seven per 10 mm.

A fan-shaped, *Fenestella*-like taxon is represented by fragments of delicate zoaria with fine branches (about nine per lateral width of 5 mm) that are about 0.25 mm in diameter and bear a double row of zoecia separated by a low carina on the frontal surface. The dissepiments are smaller than the branches, lack zoecia, and define subrectangular fenestrules.

*Septopora* cf. *S. spinulosa* Moore, identified from the reverse side of one partial zoarium (Fig. 2E), has branches about 0.3 to 0.4 mm in diameter that are relatively widely spaced (4-5/5 mm lateral width) and are connected by curved or chevron-shaped dissepiments. The reverse side bears one or two circular accessory pores at the base of each dissepiment and sparse additional pores on the branches and dissepiments. The portions of the external morphology that could be observed are closely similar to *S. spinulosa*, from the Virgilian and Wolfcampian of Texas and the Midcontinent region (Moore, 1929; Simonson and Cuffey, 1980).

Fragments of the small, stick-like branches of cf. *Rhombopora* (Fig. 2F) are typically 3-4 mm in diameter. An unidentified encrusting to bilamellar bryozoan has zoaria that are 30+ mm wide and about 4 mm thick.



## Brachiopods

### *Petrocrania modesta* (White and St. John)

One specimen (Fig. 2G) of this small inarticulate brachiopod was observed adhering to the anterior trail of a large specimen of *Reticulatia* n. sp. The exposed brachial valve is roughly circular in outline, somewhat flattened, has a diameter of 8.5 mm, and displays a small conical beak offset slightly from the center of the valve. The surface is weathered, but ornamentation appears to have been limited to growth lines.

### *Rhipidomella* cf. *R. hessensis* King

One incomplete, weathered specimen is about 11 mm long, was an estimated 10 mm wide when complete, and has an articulated thickness of 4.25 mm (Fig. 2H). The brachial valve is moderately convex and the pedicle valve is thinner and nearly flat. The pedicle valve possesses a prominent, sharp, triangular, curved beak that projects beyond the hingeline; the beak of the brachial valve is smaller and does not project as far posteriorly. A large, triangular pedicle foramen is present in a well-developed cardinal area. Ornamentation consists of relatively coarse (3/mm) closely-spaced, radial costellae of somewhat variable size that are interrupted by concentric growth lines. Scattered small tubules are present on both valves.

This specimen differs from *Rhipidomella carbonaria* (Swallow), the most common American Pennsylvanian species (see Dunbar and Condra, 1932; Sturgeon and Hoare, 1968) in having a narrower, less transverse outline, in having the brachial valve considerably more inflated than the pedicle valve (rather than the valves subequal in convexity or with the pedicle valve more

convex), and in the lack of a shallow median sulcus on the brachial valve. Virgilian specimens of *R. carbonaria* from the Jemez Springs, New Mexico, area (Kues, 1996) differ conspicuously from the Panther Seep specimen in all of the features noted above. The Panther Seep specimen is most closely related to *R. hessensis* King, which occurs in several Wolfcampian units, including the Hueco Group, in west Texas. Although the valves of typical specimens of this species are more inflated than those of the Panther Seep specimen, the brachial valve is most convex, and Cooper and Grant (1976b, p. 2611) emphasized the considerable intraspecific variability of the species and included in the species specimens with valves having outline and convexity similar to the Panther Seep specimen.

### *Derbyia deer creekensis* Dunbar and Condra

Specimens of *Derbyia* (Figs. 2I-L) are common in the Panther Seep assemblage but almost always are fragmentary and distorted, so that a clear understanding of their original shape and proportions is difficult. This is a particularly vexing problem because species of *Derbyia* generally show considerable intraspecific variability. Several reasonably complete and undistorted specimens do, however, allow adequate characterization and identification.

The largest specimen (Fig. 2I) has a somewhat transverse outline, and is about 48 mm wide, 38 mm long, and 22 mm thick. Smaller specimens tend to have a less transverse, more subquadrate outline. The hingeline is relatively wide, but maximum valve width occurs at or a little behind midlength. The brachial valve is fairly convex, especially posteriorly, and displays a shallow to obscure median sulcus. The pedicle valve is flat to gently convex and bears a low cardinal area. Some pedicle valves have distinct, irregular undulations. The valves bear very fine radial costellae that increase by intercalation and are crossed by sharp, closely-spaced growth lines that impart a subnodose or serrate appearance to them. The costellae number 26-28/cm across the umbo at a distance of 10 mm from the beak, but decrease to 18-20/cm near the anterior margin.

The combination of convex brachial valve, low cardinal area, median sulcus, irregular undulations on the pedicle valve, and extremely fine costellae characterize only one Late Pennsylvanian-Wolfcampian species in North America — *Derbyia deer creekensis*, described by Dunbar and Condra (1932) from middle Virgilian strata in the Midcontinent. Cooper and Grant (1974) described seven species of *Derbyia* from the Wolfcampian of west Texas, but they typically have coarser ornamentation, higher cardinal areas, lack a median sulcus on the brachial valve, or differ in other obvious ways from the Panther Seep specimens.

### *Neochonetes granulifer* (Owen)

Specimens of the larger of the two species of *Neochonetes* in the Panther Seep assemblage (Figs. 2M-O) typically have a moderately convex pedicle valve with an obscure median sulcus, a small sharp beak, low cardinal area with a small triangular pedicle foramen, a series of six or more obliquely oriented spines along the hingeline on each side of the beak, and are ornamented by fine radial costellae, about 4-6/mm near the anterior margin. Valve outline ranges from transversely moderately subrectangu-

FIGURE 2. Sponge (A), Corals (B, C), Bryozoa (D-F), and Brachiopods (G-Y) from the upper Panther Seep Formation near Hembrillo Pass, San Andres Mountains. **A**, unidentified sponge, upper surface, showing spicules, P-35,300, x2.4. **B**, rugose coral sp. 1, side view, showing offset (budded) corallum to right, P-35,303, x2.6; **C**, rugose coral sp. 2, side view, P-35,304, x2.6. **D**, *Penniretepora* sp., reverse side of branched zoarium, P-35,301, x4. **E**, *Septopora* cf. *S. spinulosa*, reverse side of partial zoarium, P-35-302, x2.25. **F**, cf. *Rhombopora* sp., partial zoarium, P-35,305, x3. **G**, *Petrocrania modesta*, brachial valve of specimen cemented to pedicle valve of *Reticulatia* n. sp., P-35,306, x3. **H**, *Rhipidomella hessensis*, nearly complete brachial valve, P-35-307, x2.5. **I-L**, *Derbyia deer creekensis*; **I**, partly encrusted pedicle valve, showing irregular wrinkles, P-35,308, x1; **J**, brachial valve, P-35,310, x1.5; **K, L**, brachial valve and pedicle valve showing low wrinkles, of a smaller specimen, P-35,309, x1. **M-O**, *Neochonetes granulifer*; **M**, pedicle valve, P-35,311, x1.5; **N**, brachial valve, P-35,312, x1.5; **O**, partially exfoliated pedicle valve of an unusually large, convex specimen, in matrix, P-35,313, x1.5. **P, Q**, *Neochonetes semiacanthus*; **P**, weathered pedicle valve in matrix, P-35,315, x4; **Q**, weathered pedicle valve in matrix, P-35,314, x3. **R**, *Juresania nebrascensis*, external surface of part of an incomplete pedicle valve, P-35,316, x1.5. **S, T**, *Kozlowskia?* sp.; posterior and external surface views of pedicle valve, P-35,317, x2. **U-Y**, *Reticulatia* n. sp.; **U-W**, anterior and posterior surface, and side views, P-35,319, x1; **X**, posterior surface of pedicle valve, P-35,318, x1; **Y**, side view of pedicle valve, P-35,321, x1.

lar to conspicuously alate, with the lateral margins flaring outward as they meet the hingeline, so that the width is nearly twice the length. Large specimens attain a width of about 26 mm.

Like other *Neochonetes* assemblages near the Pennsylvanian-Permian boundary in New Mexico, the Panther Seep specimens represent *N. granulifer* stock. Typical specimens of *N. granulifer* from the Midcontinent are smaller and subquadrate, without flaring lateral margins; the type specimens are of early Virgilian age. In younger strata, more alate forms, called *N. granulifer* var. *transversalis* by Dunbar and Condra (1932), emerge, and somewhat alate and much larger forms (*N. granulifer* var. *meekeanus*) are common in younger Wolfcampian strata. In addition, King (1938) described *N. puebloensis*, a form he regarded as intermediate between *N. "transversalis"* and *N. "meekeanus"*, from the lower Wolfcampian Pueblo Formation of north-central Texas. In many assemblages, these morphs grade into forms with the typical features of *N. granulifer*. Because of the complete intergradation of morphologies, to some extent related to lithology (depositional environments), Mudge and Yochelson (1962), and Spencer (1970), who used multivariate analysis, argued that the various Midcontinent varieties are not taxonomic entities, and referred them all to *N. granulifer*. That assessment is adopted here.

Variation within the Panther Seep assemblage is considerable, encompassing forms that have the typical *N. granulifer* and *N. "transversalis"* morphologies. The largest specimens (e.g., Fig. 2O) exceed both these morphs in size and in the convexity of their brachial valve, and resemble *N. "puebloensis"*. Similar mixtures of *N. granulifer* and *N. "transversalis"* have been reported from the middle Virgilian of north-central New Mexico (Sutherland and Harlow, 1967; Kues, 1996), and from the latest Virgilian Bursum Formation type section (Kues, 2002). Specimens from the Bursum type section are considerably smaller, rarely attaining a width of more than 15 mm.

*Neochonetes granulifer* occurs in large numbers at the Panther Seep locality, typically in thin limestone beds in which the shells are densely concentrated.

#### ***Neochonetes semiacanthus* (Lintz)**

Among large numbers of *Neochonetes granulifer* are a few small shells (maximum width 11 mm) that are less transverse (width/length about 1.50), and differ additionally in having a narrower, more sharply defined beak and umbo area on the pedicle valve, and in sharper radial costellae. These specimens (Figs. 2P-Q) appear to be conspecific with *N. semiacanthus*, a characteristic Virgilian species of the Appalachian basin (Sturgeon and Hoare, 1968; Hoare and Sturgeon, 1984).

#### ***Juresania nebrascensis* (Owen)**

Weathered and incomplete fragments of *Juresania nebrascensis* (Fig. 2R) are moderately common in the Panther Seep assemblage. An incomplete specimen is 23.5 mm wide, and fragments of larger individuals were observed, indicating a maximum width of about 30 mm. These specimens have a shallow median sulcus on the pedicle valve, steeply sloping flanks, and are ornamented by concentric bands that each bear two transverse lines of mostly prostrate spine bases, all typical features of this long-ranging

and widespread species. It has been reported in most marine limestones of late Pennsylvanian age in New Mexico, and ranges into the early Wolfcampian in the Midcontinent (e.g., Mudge and Yochelson, 1962).

#### ***Kozlowskia?* sp.**

One small productoid (Figs. 2S, T) has a weathered, exfoliated shell that is mostly covered with calcareous deposits. From the features that are observable, especially the strong convexity of the pedicle valve over the hingeline, this specimen appears to be an unidentifiable species of *Kozlowskia*. It is 18 mm wide and 16.5 mm long. The pedicle valve is marked by a shallow median sulcus and bears moderately coarse, rounded, closely-spaced radial costae, which are possibly crossed by weak concentric rugae posteriorly, although the details of posterior ornamentation have been obscured by exfoliation and weathering. One large spine base is present on the right flank of the pedicle valve, but the occurrence of several large spine bases on the anterior trail, a distinctive feature of *Kozlowskia*, could not be verified.

#### ***Reticulatia* n. sp.**

Large specimens of *Reticulatia* (Figs. 2U-Y, 3A-D) are among the most abundant and are certainly the most conspicuous specimens at the Panther Seep locality. Most specimens collected had eroded free of the rock and many are nearly complete, typically missing only parts of the ears and anterior trail, but with exfoliated and somewhat weathered shell surfaces. The large number of specimens and reasonably good preservation allow detailed description of the morphology of this species.

The shell is large, with width exceeding length and the greatest width about at midlength. The largest nearly complete specimen is 69 mm wide and 55 mm long, and the average thickness/length ratios for undistorted individuals is about 0.60 to 0.65. The valve margin outline is subquadrate to moderately transverse. The pedicle valves are strongly convex along their length, with the area of greatest convexity at or a little anterior to midlength. In transverse view, the valve flanks slope steeply, nearly vertically in some specimens, away from the central region, and a pronounced median sulcus extends anteriorly from about 10 to 15 mm in front of the beak. The beak is small and the beak/umbo region projects only a short distance posterior to the hingeline. The ears appear to be of moderate size for the genus.

The posterior one-third of the pedicle valve surface is strongly reticulated, with radial costae and concentric rugae about equal in strength and spacing, and forming sharp, isolated nodes where they cross. Sparse spine bases develop from some nodes across the medial and lateral slopes of the reticulated area and on the ears. Rugae become more pronounced on the sides and along the base of the valve body, and the concentration of small spine bases increases in this region with no discernable pattern. The rugae become larger and more widely spaced anteriorly but dwindle abruptly, leaving most of the pedicle valve circumference with coarse (6/10 mm), rounded, radial costae. Smaller costae are in some places intercalated between larger ones, and some smaller costae end on the trail, with adjacent costae enlarging to produce the usual complement towards the anterior margin of the trail. A

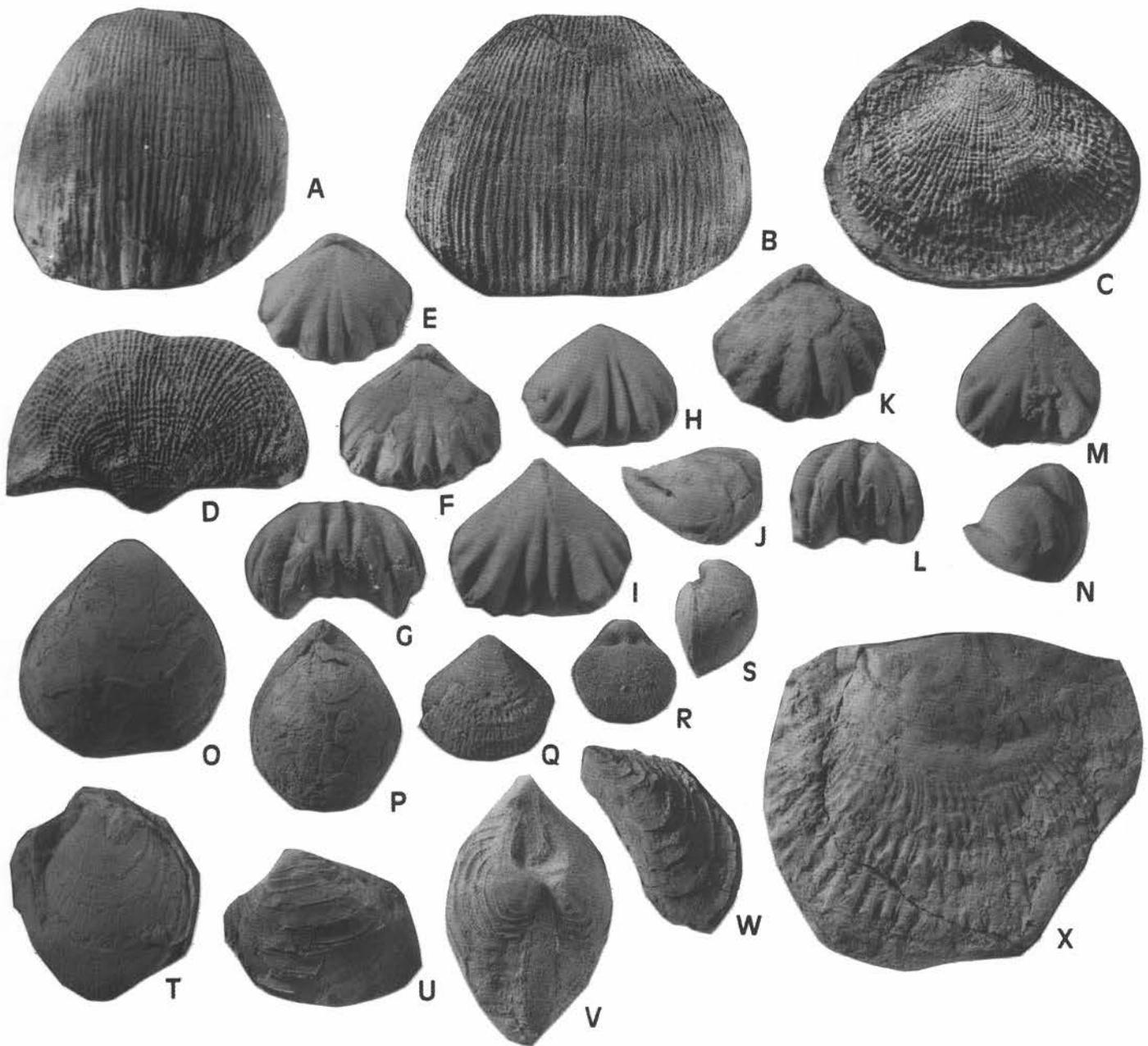


FIGURE 3. Brachiopods (A-S) and Bivalves (T-X) from the upper Panther Seep Formation near Hembrillo Pass, San Andres Mountains. **A-D**, *Reticulatia* n. sp.; A, central surface of pedicle valve, P-35,321, x1; B, anterior surface of pedicle valve, P-35,320, x1; brachial valve, P-35,322, x1; D, posterior view of pedicle valve, P-35,323, x1. **E-L**, *Pontisia kingi*; E, G, brachial valve (x2) and anterior (x2.5) views, P-35,325; F, brachial valve, P-35,326, x2.3; H, I, slightly oblique brachial view (x2) and pedicle valve (x2.3), P-35,327; J, side view, P-35,328, x2.3; K, brachial view of a specimen with two coarse plicae instead of the usual three on the fold, P-35,331, x2.4; L, anterior view of a specimen with two plicae in fold, questionably assigned to *P. kingi*, P-35,232, x2.5. **M, N**, *Pontisia* aff. *P. wolfcampensis*; M, pedicle valve, P-35,329, x2.5; N, side view, P-35,330, x2.5. **O, P**, *Composita subtilita*; O, pedicle valve of a relatively wide specimen, P-35,335, x3; P, brachial valve view, P-35,333, x1.5. **Q**, *Cleiothyridina pecosii*, pedicle valve showing external valve ornamentation, P-35,335, x3. **R, S**, *Crurithyris planoconvexa*, brachial valve (x3) and side views (x3.5), P-35,336. **T**, *Streblochondria* cf. *S. stantonensis*, incomplete left valve, P-35,339, x1. **U, V**, *Astartella varica*, left valve (x1) and dorsal view (anterior end up, x1.5), P-35,340. **W**, *Septimyalina burmai*, left valve of a small specimen, P-35,337, x1.1. **X**, *Acanthopecten* sp., incomplete left valve, P-35,338, x1.67.

few hollow spine bases are present on the costae of the median and lateral portions of the anterior trail. The brachial valve is strongly concave, with a nodose reticulated pattern of ornamentation but no spine bases.

The Panther Seep species is related to other species of *Reticulatia* from the Late Pennsylvanian and Wolfcampian of western North America, but does not appear to be conspecific with any of them. It differs from *R. americana* Dunbar and Condra (1932),

known from the Missourian to latest Virgilian of New Mexico (Kues, 1996, 2002) and the Midcontinent (Dunbar and Condra, 1932), and from the early Wolfcampian of west Texas (Cooper and Grant, 1975), in attaining a slightly smaller maximum size, developing a more pronounced median sulcus, having finer posterior reticulation but coarser anterior costae, and in its slightly more subquadrate shape with steeper valve flanks. *Reticulatia huecoensis* (King) is a smaller, more transversely subrectangular species, with finer ornamentation. *Reticulatia robusta* Cooper and Grant, from the early Wolfcampian of west Texas, is about the same size as the Panther Seep species but differs in having a more transverse outline, less well-developed median sulcus, and slightly coarser costae on the anterior trail.

Cooper and Grant (1975) also described, on the basis of a few fragmentary specimens, two other taxa from early Wolfcampian strata, designated *R. sp. 1* and *R. sp. 2*. The Panther Seep specimens appear to be conspecific with *R. sp. 1*, from the Neal Ranch Formation of west Texas. *Reticulatia sp. 2*, as described and illustrated (Cooper and Grant, 1975, pl. 392, figs. 7-10) differs mainly in having unusually wide, low (3/10 mm) costae on the anterior trail. Curiously, Cooper and Grant (1975, pl. 378, figs. 18-20) assigned another specimen, from the Gaptank Formation to *R. sp. 2*, but that specimen has much narrower anterior costae and cannot be the same taxon as the specimens illustrated on pl. 392. The specimen of "*R. sp. 2*" illustrated on pl. 378 differs in no significant way from the Panther Seep species, which appears to be new. Thus, the Panther Seep species, which is rare in the early Wolfcampian of west Texas, is very abundant in the upper part of the Panther Seep Formation in the central San Andres Mountains of New Mexico.

#### ***Pontisia kingi* Cooper and Grant**

The dominant plicate rhynchonellide in the Panther Seep assemblage is *Pontisia kingi* (Figs. 3E-L). Its shell is relatively large for the genus, attaining a maximum width of about 14 mm, and is transversely subtriangular in outline. The mean width/length ratio (N=17) is 1.18, and the mean thickness/length ratio is 0.76. The pedicle valve is flat to gently convex for most of its length, whereas the brachial valve is moderately inflated anteriorly. The brachial valve bears a fold consisting of three strong plicae that is elevated slightly or not at all above the lateral valve areas, which display two or three smaller plicae on each side. The plicae begin at about midlength along the valve. The pedicle valve bears a medial sulcus that contains two strong plicae; a second pair of strong plicae line the margins of the sulcus, and the lateral flanks typically display two additional plicae on each side. The pedicle beak is sharp, curved, and extends past the hingeline, and a small oval pedicle foramen is present. A few specimens differ in having only two plicae in the fold and one in the sulcus (e.g., Figs. 3K, L).

Although Cooper and Grant (1976a) described numerous, homeomorphic genera of *Wellerella*-like brachiopods, and noted that internal features are required to identify them, most of the taxa most similar to the Panther Seep specimens are not known from strata older than late Wolfcampian or Leonardian. The genus *Pontisia*, however, is common and diverse in early Wolfcampian

strata of west Texas, and it is therefore likely that the Panther Seep specimens are *Pontisia*, even though their internal structures have not been observed. Most of the Wolfcampian species of *Pontisia* described by Cooper and Grant are much smaller than the Panther Seep specimens, and differ in other features (mainly valve shape and ornamentation) as well. The size and external morphology of the Panther Seep specimens agrees well with only one of these species, *P. kingi*, which occurs in the lower Wolfcampian Gaptank, Neal Ranch and Lenox Hills formations of west Texas.

These specimens also resemble *Wellerella osagensis* (Swallow), which occurs in the Virgilian to early Wolfcampian of the Midcontinent region (e.g., Dunbar and Condra, 1932). Although the intraspecific variation within that species has not been studied, the Panther Seep specimens differ in having more transverse shells (higher width/length ratios), in having a less elevated fold, and in having a curved pedicle beak — all features that Cooper and Grant (1976a, p. 2022) utilized to distinguish *P. kingi* from *W. osagensis* externally. *Pontisia kingi* is one of the most abundant invertebrate species in the Panther Seep assemblage.

#### ***Pontisia cf. P. wolfcampensis* Cooper and Grant**

A second species of *Pontisia* differs from *P. kingi* in having a narrower, thicker shell, a higher fold, a more inflated brachial valve, more steeply sloping flanks, and in attaining a smaller maximum size (Figs. 3M, N). The largest specimen is 9.9 mm wide and length and width are subequal (mean width/length = 1.06; N = 9); the articulated valve thickness nearly equals valve length (mean thickness/length = 0.90). The fold includes three strong plicae and rises conspicuously above the lateral valve surface, which bear two or three smaller plicae on each side. The sulcus contains two wide plicae and is bordered by two others, with two smaller plicae on each lateral flank. The anterior margin of the valves is severely truncated.

The strong inflation anteriorly of the brachial valve, in particular, indicate that these specimens are not extreme forms of the much more numerous *P. kingi*, because the valve inflation is a gerontic feature that develops late in growth as the anterior commissure abruptly begins to grow ventrally rather than anteriorly. This character is not expressed nearly as strongly on the larger specimens of *P. kingi*. These specimens are related to *P. wolfcampensis* and *P. parva*, both described from the lower Wolfcampian Neal Ranch Formation of west Texas (Cooper and Grant, 1976a), and which differ in such subtle ways that they may be the same species. Both species tend to develop grooves in the anterior portion of the plicae, a feature not observed on the Panther Seep specimens.

#### ***Composita subtilita* (Hall)**

*Composita subtilita* (Figs. 3O, P) is abundant at the Panther Seep locality and most specimens are reasonably well preserved, although weathered and in some cases crushed. Since the work of Grinnell and Andrews (1964) on Missourian to Wolfcampian assemblages from the Midcontinent region, it has been recognized that *C. subtilita* includes several intergrading morphs, each of which had received a typological species name previously.

The Panther Seep specimens show considerable variability. Typically they have a relatively short, wide, pedicle beak and a

moderately deep anterior sulcus. Width/length ratios, from 16 undistorted specimens more than 20 mm long, varied from 0.77 to 1.02 (mean = 0.88), and thickness/length ratios varied from 0.52 to 0.68 (mean = 0.61). Most specimens are “*C. subtilita*” and “*C. ovata*” forms, with a small number of “*C. elongata*”. Sutherland and Harlow (1967) studied large assemblages of *C. subtilita* from middle Virgilian strata in north-central New Mexico. These had a mean width/length ratio of 0.90 (range = 0.73-1.09), and a mean thickness/length ratio of 0.61 (range not given), proportions and variability that are very similar to that of the Panther Seep assemblage. The latter differs in attaining a maximum size of about 25 mm long, compared to the somewhat larger size (maximum length = 34+ mm) reported by Sutherland and Harlow (1967), but easily fall into the range of variability accepted for *C. subtilita*. Cooper and Grant (1976a) described several Wolfcampian species of *Composita* from west Texas, some of which might fall within the range of variability of late Pennsylvanian-Wolfcampian populations of *C. subtilita*.

#### *Cleiothyridina pecosii* (Marcou)

The single specimen of *Cleiothyridina pecosii* (Fig. 3Q) is small (length = 6.8 mm; width = 7.3 mm; thickness = 4.1 mm), and has a suboval, slightly transverse outline with a relatively sharp projecting pedicle beak and a small, circular pedicle foramen. An obscure medial sulcus in the pedicle valve barely deflects the anterior commissure. A portion of the external shell adhering to the otherwise exfoliated pedicle valve reveals widely-spaced, sublamellate growth bands, each of which is covered by closely-spaced, prostrate, radial spines (3/mm near the central anterior margin) that extend the entire width of each band and terminate in a slight thickening at the anterior band margin. The exfoliated shell beneath displays closely-spaced growth lines but little indication of the surficial spines.

This species has commonly been called *Cleiothyridina orbicularis* (McChesney) by many earlier workers (e.g., Dunbar and Condra, 1932; Sturgeon and Hoare, 1968), but Sutherland and Harlow (1973) pointed out that the name *C. pecosii* (Marcou), described initially from Virgilian strata near the town of Pecos, New Mexico, has priority. Most descriptions of this species are based on specimens lacking the full complement of surficial spines. *Cleiothyridina rectimarginata* (Cooper and Grant, 1976a), from early Wolfcampian strata of west Texas, is similar in size to the Panther Seep specimen but its length typically exceeds the width, the two valves are more inflated (greater thickness/length ratios), and the spines are finer and mostly limited to later growth, compared to *C. pecosii*.

#### *Crurithyris planoconvexa* (Shumard)

This small species (Figs. 3R, S) is characterized by its strongly inflated pedicle valve, large projecting incurved pedicle beak, and large pedicle foramen in a high cardinal area. The brachial valve is much less convex. The single Panther Seep specimen is 5.7 mm wide, 5.5 mm long, and 4.0 mm in thickness, and agrees in all features with the long-ranging, Pennsylvanian to earliest Permian species, as described by Dunbar and Condra (1932) from the Midcontinent region. Mid-Virgilian specimens from the

Jemez Springs area, north-central New Mexico (Sutherland and Harlow, 1967) are a little larger and a little less thick (thickness/length ratio = 0.61) compared with the Panther Seep specimen, but the width/length ratios are similar, as are other valve features. A related Midcontinent species, *Crurithyris expansa* Dunbar and Condra, differs in attaining a much larger size (up to 12 mm wide), and in having a more transverse shape and smaller beak.

### Bivalves

#### *Aviculopinna* sp.

One poorly preserved fragment of a large *Aviculopinna* is about 55 mm long and 35 mm in width at the larger end. The cross section through the articulated valves is nearly circular. When complete, the shell probably exceeded 20 cm in length. This specimen may be *A. peracuta*, the most common species of the genus in the Pennsylvanian-Early Permian of New Mexico, but its incompleteness and poor preservation preclude specific assignment.

#### *Septimyalina burmai* Newell

A few specimens of this common and distinctive species were collected from the Panther Seep locality. Fragments suggest a maximum length of about 50 mm along the anteroventral margin, but the most complete specimen (Fig. 3W) is relatively small. *Septimyalina burmai* occurs in middle Virgilian to early Wolfcampian strata in New Mexico (e.g., Kues, 1995, 1996, 2002).

#### *Aviculopecten* sp.

*Aviculopecten* is uncommon in the upper Panther Seep and is represented only by a few small valve fragments insufficient for identification to the species level. The fragments suggest a relatively large species, possibly as much as 35 mm long.

#### *Acanthopecten* sp.

A weathered fragment (Fig. 3X) of a relatively large left valve (length = 35 mm; height about 40 mm) is referable to *Acanthopecten*. The dorsal part of the valve, including the auricles, is missing, and the valve body is gently curved, as is indicated by the arcuate radial ribs, and these ribs are somewhat irregular in width, both features that differ from the typically nearly acline valves and sharp, straight ribs of *Acanthopecten*. However, like *Acanthopecten*, the ribs possess periodic vaulted, lamellate projections, which divide them into several intervals radially, and these projections are aligned in comarginal rows across adjacent ribs. There are three or four of these intervals on the ribs of the valve body, but they are locally muted. The specimen is too incomplete and weathered to be fully described, but it does not appear to be conspecific with the three species of *Acanthopecten* (*A. carboniferus* [Stevens], *A. meeki* Newell, and *A. coloradoensis* [Newberry]) commonly encountered in the Pennsylvanian and Early Permian of the western United States.

#### *Streblochondria* cf. *S. stantonensis* Newell

A moderately large (height about 30 mm) left valve (Fig. 3T) and its counterpart has the general shape and ornamentation of *Streblochondria stantonensis*, described by Newell (1937) from the

Missourian of Kansas. Unfortunately, the dorsal part of the valve, including the beak and auricles, is not preserved. The valve is ornamented with low radial costellae, about 7/5 mm occurring near the central anterior margin, which are crossed by closely-spaced, sublamellate very fine growth lines. *Streblochondria sculptilis* (Miller), a similar Late Pennsylvanian species, is distinguished by finer radial costellae and comarginal lirae of about equal size that produce a finely cancellate pattern of ornamentation.

#### *Astartella varica* McChesney

Articulated specimens of this distinctive species (Figs. 3U, V) are moderately common in the upper Panther Seep Formation at Hembrillo Pass. The valves are severely weathered, so that the shell is thin and locally completely weathered from the surface of the underlying steinkerns, and some specimens have been moderately distorted. The best-preserved and largest specimen is 30.7 mm long, 23.8 mm high at the beaks, and has an articulated width of 18.3 mm. The valves are subrectangular in outline, with the high, sharp, slightly prosogyrate beaks situated about one third of the distance from the anterior to posterior end. The anterodorsal margin is slightly concave, encompasses a relatively deep, circular lunule, and curves sharply, at nearly a right angle, into the anterior margin. The longer posterodorsal margin is straight, slopes gently away from the beaks, and includes a well-developed, narrow, fusiform escutcheon. The posterior margin is broadly convex to somewhat truncated, and the ventral margin is gently convex. The ornamentation, characteristic of the species, consists of prominent, narrow, widely-separated, wall-like comarginal ribs that become more widely spaced with growth and number about 13 on the largest specimen. They cross the posterior umbonal ridge with no diminution and are deflected anteriorly towards the hingeline.

The Panther Seep specimens were compared with large collections of *Astartella varica* from the Desmoinesian Flechado Formation of north-central New Mexico (Kues, 1984). The former specimens are typically a little wider, have slightly higher, sharper beaks, and a slightly more sharply rounded posterior umbonal ridge, than the Desmoinesian specimens, but clearly are within the range of variation of the species. The presence of *Astartella varica* in the upper Panther Seep is unusual, as it has not been encountered elsewhere in Late Pennsylvanian-Early Permian strata of New Mexico. However, the species is present in the Gaptank Formation of west Texas (Bird, 1968), and is known as high as the early Virgilian (Ames Limestone) in the Appalachian basin (Hoare et al., 1979).

### Gastropods

Gastropods are not common in the Panther Seep assemblage, and most specimens, except *Amphiscapha*, are severely weathered, generally producing steinkerns with recrystallized shell material adhering to more or less of their surfaces. The taxa described below are those that could be identified at least to generic level, but other taxa, unidentifiable based on present collections, are also present.

#### *Euphemites* aff. *E. batteni* Yochelson

Specimens of the bellerophontid *Euphemites* are mainly preserved as steinkerns with weathered shell residue adhering to them. Most specimens have a moderately compressed whorl that does not expand much anteriorly, and bear 18 to 20 sharp, narrow, widely-spaced inductural lirae. The largest, best-preserved specimen (Figs. 4A, B) is 32.5 mm long, 25 mm wide, and 26 mm high. These specimens are similar to *E. batteni* in shape and proportions, and in the relatively few, fine spiral lirae, but attains a significantly larger size than that species, which occurs in Guadalupian strata of the Southwest (Yochelson, 1960). Also, the Panther Seep specimens appear to have a relatively wide, deep umbilicus, whereas it is shallow on *E. batteni*. Poor preservation precludes detailed identification of the Panther Seep specimens, but they may be conspecific with equally poorly preserved specimens identified as *E. sp. 1* (Kues, 1995) from the Hueco Group of the Robledo Mountains, New Mexico.

#### *Euphemites* sp.

A second species of *Euphemites* is present in the Panther Seep assemblage but is too poorly preserved to describe it. The shell is small (about 8 mm long) and rather globose in shape, and bears well-developed, closely-spaced inductural lirae. The single specimen is a coarsely recrystallized, weathered and severely distorted shell.

#### *Pharkidonotus* sp.

Several bellerophontid steinkerns retain barely enough shell material to indicate that they belong to *Pharkidonotus* (Figs. 4C, D). These are of typical size for the genus, the largest being about 25 mm long, and the shell expanded significantly with growth, producing a wide, flaring aperture. The external surface of the shell is characterized by a narrow median ridge that bears low nodes along its length, with arcuate transverse undulations extending laterally across the shell surface from the nodes. Subsidiary nodes are developed on the undulations near where the dorsum descends to the flanks of the shell, producing a pair of lateral spiral node rows in addition to that of the median ridge. No trace of the selenizone, which occupied the crest of the median ridge, nor any evidence of fine spiral or collabral ornamentation was observed on the shells.

These specimens are similar in size and general features to *Pharkidonotus percarinatus* (Conrad), the common, widespread Pennsylvanian North American species, but differ from most representatives of that species in possessing lateral node rows. Some Pennsylvanian assemblages, however, include a variant that has been called *P. tricarinatus* (Shumard). The Panther Seep specimens are too poorly preserved for further comparison with *P. percarinatus*.

#### *Amphiscapha* aff. *A. subrugosa* (Meek and Worthen)

Small specimens of the discoidal gastropod *Amphiscapha* (Fig. 4G) are represented by several individuals with their ventral surface exposed in slabs of limestone. The ventral surface is very gently concave around the shallow umbilical region, and the ventral-lateral margin possesses a somewhat crenulated swollen

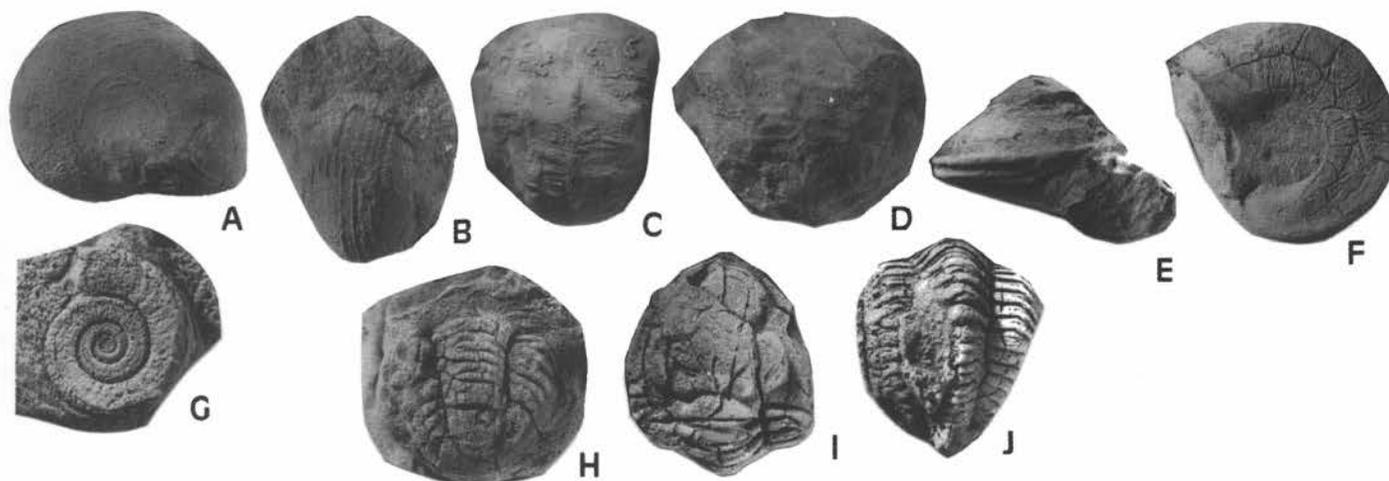


FIGURE 4. Gastropods (A-G) and Trilobites (H-J) from the upper Panther Seep Formation near Hembrillo Pass, San Andres Mountains. **A, B**, *Euphemites* aff. *E. batteni*, side and apertural views, P-35,341, x1. **C, D**, *Pharkidonotus* sp.; C, dorsal view of a steinkern with some shell adhering, P-35,342, x1.5; D, dorsal view of steinkern in matrix, P-35,343, x1.5. **E, F**, *Omphalotrochus* aff. *O. obtusispira*, apertural and ventral views of a relatively small specimen, P-35,344, x1. **G**, *Amphiscapha* aff. *A. subrugosa*, ventral view, P-35,345, x2. **H**, *Ditomopyge decurtata*, weathered pygidium, P-35,346, x3. **I, J**, *Ditomopyge* sp., cephalon and anterior thoracic segments (I) and posterior thoracic segments and pygidium (J) of an enrolled specimen, P-35,347, x2.

bourrelet. The outer shell surface appears to be flat to slightly convex, and nearly vertical, but no dorsal surfaces are exposed for inspection. These specimens appear to be the taxon referred to as *A. aff. A. subrugosa* by Kues (1991), from the Laborcita Formation of south-central New Mexico, which is probably an unnamed species. This species also occurs in the coeval Red Tanks and Bursum Formations (e.g., Kues, 2002) of central New Mexico.

#### *Omphalotrochus* aff. *O. obtusispira* (Shumard)

Isolated, weathered, typically incomplete shells of *Omphalotrochus* are the most common gastropod in the Panther Seep assemblage. The best preserved specimen (Figs. 4E, F) is 31.5 mm in maximum width, and 20.5 mm high (with the earliest two or three whorls missing), but small fragments indicate a much larger size was attained. These rather low-spired shells are distinguished by the wide umbilicus, deeply impressed sutures, and the nature of the whorl surfaces and ornamentation. The upper whorl surface begins with a narrow shelf just below the upper suture, which displays an obscure spiral cord along its outer margin. Below this, the upper whorl surface is gently convex to nearly flat, and slopes outward at about a 45 degree angle to the periphery, which is low on the whorl. The periphery is a bold, rounded spiral cord or carina, with a faint narrow depression above it. Below the carina, the outer whorl surface is low, and flat to moderately concave, and the intersection of the outer surface and the basal surface is raised slightly into a low carina. The base of the shell is nearly flat. The lower carina is typically covered by the succeeding whorl, leaving all but the body whorl with the upper carina exposed just above the lower suture. Growth lines, visible on a few specimens, are characteristic of the genus: strongly opisthocyrt from the upper suture across the upper whorl surface, then swinging back in another, aperture-forward, convex arc across the upper carina and outer whorl face, then across the base

in another broad, opisthocyrt curve. The earlier whorls (and the whorls of small specimens) are higher and a bit more inflated than the later whorls, producing higher-spired small individuals, and the upper carina is often more conspicuous on the earlier whorls.

The Panther Seep specimens agree well in most shell features with *Omphalotrochus obtusispira*, described in great detail by Girty (1937) and Yochelson (1956). The main difference is in the more strongly developed peripheral carina and the basal-lateral cord, of the Panther Seep specimens. Although Yochelson (1956) emphasized the significant intraspecific variability within *O. obtusispira*, none of the specimens he discussed display such prominent peripheral cords, which on some specimens appear as a double carina of almost equal strength. To some extent this is an ontogenetic feature, as a strong upper peripheral carina just above the lower suture is present on the earlier whorls of some specimens of *O. obtusispira* illustrated by Girty (1937) and Yochelson (1956).

*Omphalotrochus* is common in the Hueco Group of New Mexico and west Texas (Yochelson, 1956), but interestingly, has not been reported in strata of the Bursum, Laborcita and Red Tanks Formations that are approximately coeval with the upper Panther Seep. The genus has been regarded (e.g., Yochelson, 1956, p. 202) as a reliable indicator of basal Permian strata, and it has not been reported from the Pennsylvanian in North America. The implications of this stratigraphic distribution are discussed in more detail below.

#### Trilobites

##### *Ditomopyge decurtata* Gheyselinck

Four specimens, including two isolated pygidia (Fig. 4H), fragments of the thoracic region, and a small, complete but distorted enrolled specimen that is partially covered with matrix, are assigned to *Ditomopyge decurtata*, a widespread Virgilian-Wolf-

campian species. The cephalon of the enrolled specimen is about 6.5 mm long but most of its surface is covered by matrix. The thoracic region consists of nine segments and is about 7 mm long, and the pygidium (with 12 axial rings and seven pleural ribs) is about 5.5 mm long. Allowing for expansion of the thorax in the enrolled condition, the total unenrolled length of this specimen was about 18 mm. What little can be seen of the cephalon, and the characteristics of the pygidium are consistent with *D. decurtata*, and the pygidium is closely similar to the two isolated pygidia in the collection. These pygidia are both small (6.5 and 4.5 mm long), parabolic in shape, wider anteriorly than long (length/width = 0.7 to 0.8), have a relatively wide border around the margins, and each possesses 14 axial rings and eight pleural ribs. The axial lobe is moderately high and evenly convex to slightly flattened across the crest, and each of the rings possesses a transverse line of about eight tiny, sharp nodes. The pleural ribs are relatively wide, slightly elevated, and broadly rounded in cross-sectional view. These pygidia agree well in all characters, including the rounded rather than trapezoidal transverse cross section, with that of *D. decurtata* (see especially Brezinski et al., 1989; Brezinski, 1992), which is known from Wolfcampian strata of west Texas.

#### *Ditomopyge* sp.

The fifth trilobite in the Panther Seep collection is an unusually large enrolled specimen (Figs. 4I, J) that is partially exfoliated and weathered. The cephalon is 10.5 mm long, the thorax (nine segments) is about 11.5 mm, and the pygidium about 9 mm in length, measured along the midline, suggesting a total (unenrolled) length of perhaps 30 mm. On the cephalon, the glabella is relatively wide between the large, reniform eyes, and expands to a moderate degree anteriorly. Posteriorly is a wide, rather ill-defined median preoccipital lobe, and the lateral preoccipital lobes are subcircular to slightly suboval in shape, of moderate size, and are well defined by marginal furrows. The occipital lobe is broad, slightly arcuate, and tapers slightly laterally from the midline. The cephalon border is well developed, relatively wide, and extends past the anterior edge of the glabella.

The pygidium is parabolic in shape, with a somewhat acute posterior margin, and its length is about 0.8 of its maximum anterior width. It displays 13-14 axial rings, and eight, possibly nine, pleural ribs. The axial lobe is elevated strongly, and is evenly convex across the crest. Small nodes along the crest of each axial ring appear to have been present, although obscured by weathering. The pleural ribs are wide, slightly elevated, and bend moderately laterally in descending to the marginal borders.

This specimen appears to possess the cephalon and pygidium characters of *Ditomopyge* but is considerably larger than the specimens of *D. decurtata* discussed above, and indeed, of specimens of this species described from other areas. Interestingly, although the pygidium is larger, the number of axial rings is about the same as on *D. decurtata*, and there is possibly one more pleural rib.

Brezinski (1992), in describing the Permian trilobites of west Texas, noted two faunas, one Wolfcampian (*Ditomopyge-Triproetus* fauna) and one Leonardian-Guadalupean (*Delaria-Anisopyge* fauna) in age. The Wolfcampian fauna is a continuation of taxa and trends of the Pennsylvanian (stage 3 of Brezinski, 1999),

whereas the Leonardian-Guadalupean fauna (stage 4) consists of new genera. The Panther Seep specimen described here differs in obvious ways from minor elements of the earlier fauna (e.g., *Pseudophillipsia*, *Cheiropyge*), and differs from the more abundant genus *Triproetus* in the non-pyriform shale of the glabella, in having smaller, more circular lateral preoccipital lobes, and in having a more pronounced median preoccipital lobe. Some species of *Anisopyge* from the younger fauna attain the approximate size of this specimen (e.g., Brezinski, 1992), but the glabella of that genus has two or three lateral furrows and lobes posteriorly and the pygidium has many more axial rings, among other differences. Pending further study, this specimen is assigned tentatively to *Ditomopyge*.

### Echinoderms

Crinoid stem segments are fairly common, vary widely in size, and probably represent three or more taxa. One incomplete specimen of a typical cidaroid echinoid interambulacral plate is also present in the collection. Little can be said about these highly fragmentary echinoderms.

### FAUNAL SUMMARY AND PALEOENVIRONMENTS

This assemblage from the upper Panther Seep Formation near Hembrillo Pass is moderately diverse (Table 1), but is strongly dominated by brachiopods, which comprise more than 90% of the specimens collected (excluding crinoids and bryozoans, which preserve as small fragments that do not closely correlate to number of individual organisms). Other stenohaline groups (sponges, corals, bryozoans, trilobites, echinoderms) are also present but are much less abundant than brachiopods. Modest numbers of gastropods (4.7%) and bivalves (2.9%) include a few species of each group present in low numerical abundance. The brachiopods *Neochonetes granulifer*, *Pontisia kingi*, *Composita subtilita*, and *Reticulatia* n. sp. together account for approximately 80% of all specimens collected.

Because of the short time spent collecting at this locality, the sample is undoubtedly biased towards larger specimens, and those that had eroded free from the sediments and were lying on the surface of the outcrop, easily observed and collected. Smaller and more fragile taxa were not well sampled and are underrepresented in the collections. A longer-term, more sustained collecting effort, including sampling for tiny specimens, would doubtless produce many more taxa. As an example, at a locality in the lower Hueco Group a few hundred meters from the Panther Seep locality, a small (1-2 kg) sediment sample yielded thousands of specimens of tiny gastropods, bivalves, ostracods, and echinoderm ossicles (Kues, in preparation), representing at least 25 species. Thus, more complete and accurate knowledge of the taxonomic composition and species abundance in the Panther Seep assemblage depends upon additional sampling.

The strong dominance of stenohaline, benthic taxa, especially brachiopods, suggests that these organisms lived in a shallow, open-shelf, offshore environment. Calcium carbonate precipitated readily in this environment but input of fine, siliciclastic grains into

the area was also significant. Most specimens were not strongly fragmented and many are essentially unbroken. This includes, for example, the thin valves of *Neochonetes*, some of which are preserved retaining their delicate spines along the hingeline. Water agitation was therefore moderate, sufficient to gently transport specimens from their living positions on the seafloor and to concentrate them locally, but not to break most of them up. During the Pennsylvanian and Early Permian, southern New Mexico was situated along the west coast of Pangea, in a tropical climate, 10 degrees or less north of the equator (Ziegler et al., 1996).

#### AGE

The upper part of the Panther Seep Formation has usually been assigned a late Virgilian or early Wolfcampian age (see above). Recent elevation of the Pennsylvanian-Permian boundary would imply that most, if not all, of the upper part of the Panther Seep is probably Virgilian. In the following discussion, the new Pennsylvanian-Permian boundary, as defined by Sanderson et al. (2001), is used, and the interval between the traditional boundary and the new boundary is considered latest Virgilian. This interval includes the Bursum and coeval formations in New Mexico (e.g., Lucas et al., 2000, 2002a), and the Admire and lower Council Grove Groups in the Midcontinent region (e.g., Wahlman and King, 2002). A "Bursumian" stage name for this interval, as proposed by Ross and Ross (1994) is not accepted here (see Lucas et al., 2002a). Regionally the upper Panther Seep directly underlies the basal part of the Hueco Group, which is known on the basis of good fusulinacean evidence to be early Wolfcampian (e.g., Thompson, 1954; Williams, 1963; Wahlman and King, 2002). In the Hembrillo Canyon section, Kottlowski et al. (1956) reported the early Wolfcampian fusulinacean *Schwagerina andresensis* Thompson in the basal Hueco unit, not far above the Panther Seep assemblage discussed in this paper, which suggests an earliest Wolfcampian or latest Virgilian age for the assemblage. Soreghan and Giles (1999, p. 900) cited mid- to late Virgilian fusulinacean taxa associated with phylloid algal bioherms in the upper part of the Panther Seep near Hembrillo Canyon, and suggested that the bioherm mound core interval extended into earliest Wolfcampian time. The upper Panther Seep in the San Andres Mountains is approximately correlative with the latest Virgilian Bursum Formation to the north (e.g., Bachman and Harbour, 1970; Lucas and Kues, 2001). However, no fusulinaceans are present in the upper Panther Seep at the Hembrillo Pass section; the highest fusulinacean reported by Kottlowski et al. (1956), here was *Triticites* sp. from a level about 320 m below the base of the Hueco, near the middle of the Panther Seep. Fusulinaceans are similarly lacking in the upper Panther Seep to the north (Rhodes Canyon) and to the south (Ash Canyon) (Kottlowski et al., 1956).

The macroinvertebrate taxa reported here are broadly indicative of a latest Virgilian to earliest Wolfcampian age, but most strongly suggest an earliest Wolfcampian age. Several of the brachiopods (*Rhipidomella* cf. *R. hessensis*, *Pontisia kingi*, *Pontisia* aff. *P. wolfcampensis*, *Reticulatia* n. sp.) are taxa that occur only in the early Wolfcampian of west Texas, and the remainder mostly have ranges that extend through the latest Virgilian or into the ear-

liest Wolfcampian in the Midcontinent region and in New Mexico. Among the bivalves, *Septimyalina burmai* ranges through much of the Wolfcampian in the Midcontinent region (e.g., Newell, 1942; Mudge and Yochelson, 1962), and is known from the Virgilian (Kues, 1996) through Wolfcampian (Kues, 1995) in New Mexico. The gastropod *Amphiscapha* aff. *A. subrugosa* is a probable new species that occurs in large numbers in the latest Virgilian Laborcita, Red Tanks, and Bursum Formations in New Mexico.

A particularly important indicator of Wolfcampian age is the gastropod *Omphalotrochus*. Yochelson (1954; 1956, p. 202) reported the genus widely in the Wolfcampian of the Southwest, and suggested that its range zone marks basal Permian time, although it occurs in slightly older (Gzhelian, uppermost Carboniferous) strata in Russia (Mazaev, 1994). *Omphalotrochus* is common in the Hueco Group in New Mexico (e.g., Kues, 1995; Lucas et al., 2002b), but has not been reported from underlying units (Red Tanks, Bursum, Laborcita; e.g., Otte, 1959; Kues, 1991, 2002) in the state or from Virgilian strata anywhere in North America.

The absence of *Omphalotrochus* in the latest Virgilian units mentioned above could be explained by an absence of suitable ecological conditions in the environments represented by those formations. This is unlikely, as these units include a variety of depositional environments, some of which contain many of the same brachiopod and mollusc taxa present in the Panther Seep assemblage. Alternatively, the age of the Panther Seep assemblage near Hembrillo Pass may be slightly younger than the age of the uppermost marine limestone in the Bursum and correlative units. The implication would be that *Omphalotrochus* migrated into New Mexico after deposition of these units (or at least the datable parts of these units) had stopped, but before Panther Seep deposition had ceased.

Evidence for this idea comes from an examination of fusulinacean ranges, in particular the first appearances of the basal Hueco species *Schwagerina andresensis*, and of *S. grandensis* Thompson, which occurs in the Bursum Formation (e.g., Thompson, 1954; Kottlowski and Stewart, 1970; Bachman and Myers, 1969), including the middle of the Bursum type section (Lucas et al., 2000). At Hembrillo Canyon, as noted above, *S. andresensis* first appears in the basal (lower 4-5 m) limestone of the Hueco Group. It also occurs in the basal Hueco throughout the San Andres range (Thompson, 1954; Kottlowski et al., 1956; Bachman and Myers, 1969) and elsewhere, so that the species was described as characteristic of the lower part of the lower Hueco throughout southern New Mexico (Wahlman and King, 2002).

The stratigraphic separation between the first appearances of *S. andresensis* and the slightly older *S. grandensis* is known with certainty only in the Robledo Mountains, where both species occur in a sequence of shelf carbonates. Thompson (1954, fig. 8) portrayed the stratigraphic separation there as about 32 m, whereas Wahlman and King (2002, fig. 3) narrowed the separation to about 19 m, with the first appearance of *S. andresensis* marking the basal part of the Hueco and the first appearance of *S. grandensis* the upper part of an underlying Bursum-equivalent limestone. It is possible that the range zone of *S. grandensis* extends into the Hueco, as Bachman and Myers (1969) reported a taxon they called *S. aff. S. grandensis* from near the base of

the Hueco in the southern San Andres Mountains. However, the identity of this taxon has yet to be well documented and verified.

The separation of the first appearances of these two species should be greater in the Orogrande basin upper Panther Seep/basal Hueco sequence, because the rate of sedimentary deposition was much lower on the Robledo shelf than in the Orogrande basin during this time. Only about 73 m of Virgilian strata are present in the Robledo Mountains (Kottlowski and Seager, 1998), compared with an estimated 350–400 m of Virgilian (most of Panther Seep Formation) near Hembrillo Canyon, and even greater thickness towards the southern end of the San Andres range. This disparity continued into early Wolfcampian time, as Orogrande basin subsidence persisted (King and Harder, 1985); Ye et al. (1996, p. 1416) noted that thick basinal sediments continue from the Virgilian into the early Wolfcampian in the Orogrande basin. If, as is suggested by these figures, the sedimentation rate of the Panther Seep in the Orogrande basin (San Andres Mountains) was five or more times the rate on the Robledo carbonate platform, the predicted stratigraphic separation between the horizons marking the first appearances of *S. grandensis* and *S. andresensis* in the central to southern San Andres Mountains might be five or more times the 19-m separation in the Robledo Mountains. If this assumption is approximately correct, the horizon of the first appearance of *S. grandensis* in the Hembrillo Canyon area would be approximately 90 m below the Panther Seep-Hueco contact. Evidence proving this suggestion would require the discovery of that species in the upper Panther Seep, which is probably unlikely given the apparent lack of fusulinaceans in the upper Panther Seep in the central and southern San Andres Mountains.

The conclusion that results from this line of reasoning is that the age of the Panther Seep assemblage described here, from 30 to 45 m below the base of the Hueco Group, likely is slightly older than the first appearance of *S. andresensis* and somewhat younger than the faunas of the Bursum, which contain *S. grandensis*. This age appears to approximate the time at which the gastropod *Omphalotrochus* first entered New Mexico, and explains why the genus is not present in the Bursum and correlative formations. It also is consistent with the stronger influence of Hueco/Neal Ranch-age taxa in the upper Panther Seep assemblage than in the slightly older faunas of the Bursum and correlative formations.

*Omphalotrochus* is also known from the Midcontinent Wolfcampian succession, occurring (in ascending order) from the Bennett Shale and Howe Limestone members of the Red Eagle Limestone to the Neva Limestone Member of the Grenola Limestone, and in the Florena Shale Member of the Beattie Limestone (Mudge and Yochelson, 1962, table 6). All of these occurrences postdate the Midcontinent interval (Admire and lower Council Grove Groups) that correlates with the Bursum Formation (Thompson, 1954; Wahlman and King, 2002), and which is the interval proposed as a “Bursumian Stage” (see Lucas et al., 2000, 2002a; Wahlman and King, 2002, for full discussion), an idea that is rejected here. In the Midcontinent sequence, the uppermost “Bursumian” fusulinaceans occur in the Glenrock Limestone Member of the Red Eagle Limestone, just below the first appearance of *Omphalotrochus* in the overlying Bennett Shale Member (Wahlman, personal commun., 2002). Thus, the Midcontinent first appearance of *Omphalotro-*

*chus* is consistent with its first appearance in New Mexico in beginning slightly later than the time of Bursum deposition.

The revised position of the Midcontinent Pennsylvanian-Permian boundary was placed at the contact between the Glenrock Limestone and Bennett Shale Members of the Red Eagle Limestone by Sanderson et al. (2001). *Omphalotrochus* first appears in the Bennett Shale Member, at or possibly slightly above the boundary. Thus, this first appearance marks, within present stratigraphic resolution, the beginning of the Permian (Wolfcampian) in the Midcontinent region. Assuming that the first appearance of *Omphalotrochus* in the upper Panther Seep Formation of south-central New Mexico was simultaneous with its first appearance in the Midcontinent region, which is reasonable given the relatively close geographic proximity of the two areas and absence of significant paleogeographic barriers separating them, then the age of the Panther Seep assemblage described here is likewise earliest Wolfcampian. Because sedimentation was occurring much faster at this time in central New Mexico than in the Midcontinent, the probable position of the Pennsylvanian-Permian boundary in the upper Panther Seep is likely somewhere between 30–45 and 90 m below the Panther Seep-Hueco contact. Because it is a large gastropod, the first appearance of *Omphalotrochus* may be the most conspicuous biostratigraphic marker on the outcrop for this boundary.

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