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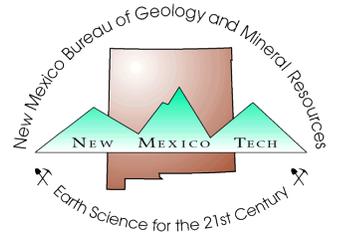
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# Marine invertebrate assemblages from the Late Pennsylvanian (Virgilian) Holder Formation, Dry Canyon, Sacramento Mountains, south-central New Mexico

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## Abstract

The Holder Formation along Dry Canyon consists of a cyclic succession of Virgilian marine siliciclastics, marine carbonates, and nonmarine siliciclastics, including a large basal algal bioherm complex, deposited on a narrow shelf just west of the shoreline of the Pederal land mass. Holder marine invertebrates have been little studied; here two quite different middle Virgilian assemblages from an 80-m-thick (262-ft-thick) section along US-82 are discussed. The first assemblage, from a 1-m-thick (3-ft-thick) dark-gray calcareous mudstone within a regressive interval approximately 50 m (164 ft) above the base of the section, is dominated by gastropods and bivalves (96% of specimens) with the gastropod *Retispira espinasa* and the bivalve *Polidevicia arata* being especially abundant. Other common gastropods are species of *Taostia*, *Colpites*, *Hypselenotoma*, and *Goniasma*, and other common bivalves are cf. *Sedgwickia* and *Myalinella*. Some mollusc species are also present in the overlying Laborcita Formation, but a few have not previously been reported from New Mexico. The absence of most stenohaline groups and low taxonomic diversity (35 species) of this

*Retispira-Polidevicia* assemblage suggest abnormal marine conditions. The taxonomic composition and relative abundances of taxa in this assemblage are unique in the Pennsylvanian of New Mexico and possibly of North America. The second assemblage, from a transgressive interval of interbedded dark-gray shale and thin limestone 15–20 m (49–66 ft) above the first assemblage, consists of 100+ species from a wide assortment of marine groups, including gastropods (40+ species), brachiopods (24 species), bivalves (18 species), scaphopods, nautiloids, ammonoids, fusulinids, sponges, rugose corals, bryozoans, crinoids, echinoids, trilobites, ostracods, and fish teeth. About 61% of the collected specimens in this assemblage are brachiopods, mostly of species that occur in other Virgilian strata in New Mexico. The common productoid *Kutorginella* aff. *K. lasalensis*, however, has not previously been reported from New Mexico. High taxonomic diversity, abundant stenohaline groups, large numbers of brachiopods and molluscs, and generally good preservation of complete specimens suggest that the fauna of this mixed marine assemblage lived in nearshore to moderately offshore, quiet, normal marine environments.

## Introduction

The Holder Formation, which crops out along the western slopes of the Sacramento Mountains, is one of the most intensively studied Pennsylvanian sedimentary units in New Mexico. The formation was named by Pray (1961) for essentially the Virgilian part of Thompson's (1942) type Fresno Group; the cyclic nature of Holder strata was recognized by Cline (1959) and has been studied and related to correlative basinal strata to the west (e.g., Wilson 1967); and its facies architecture and sequence stratigraphic record have been analyzed in detail (e.g., Rankey et al. 1999, and references therein). Large phylloid algal bioherms at the base of the Holder have likewise been intensively studied (e.g., Toomey et al. 1977; Toomey 1991), but despite the attention given to stratigraphy and bioherms little is known of the benthic marine invertebrates that inhabited the shallow marine environments preserved in the Holder. Numerous beds within the formation are fossiliferous, and in this paper two distinctive assemblages from a well-exposed roadcut along US-82 in Dry

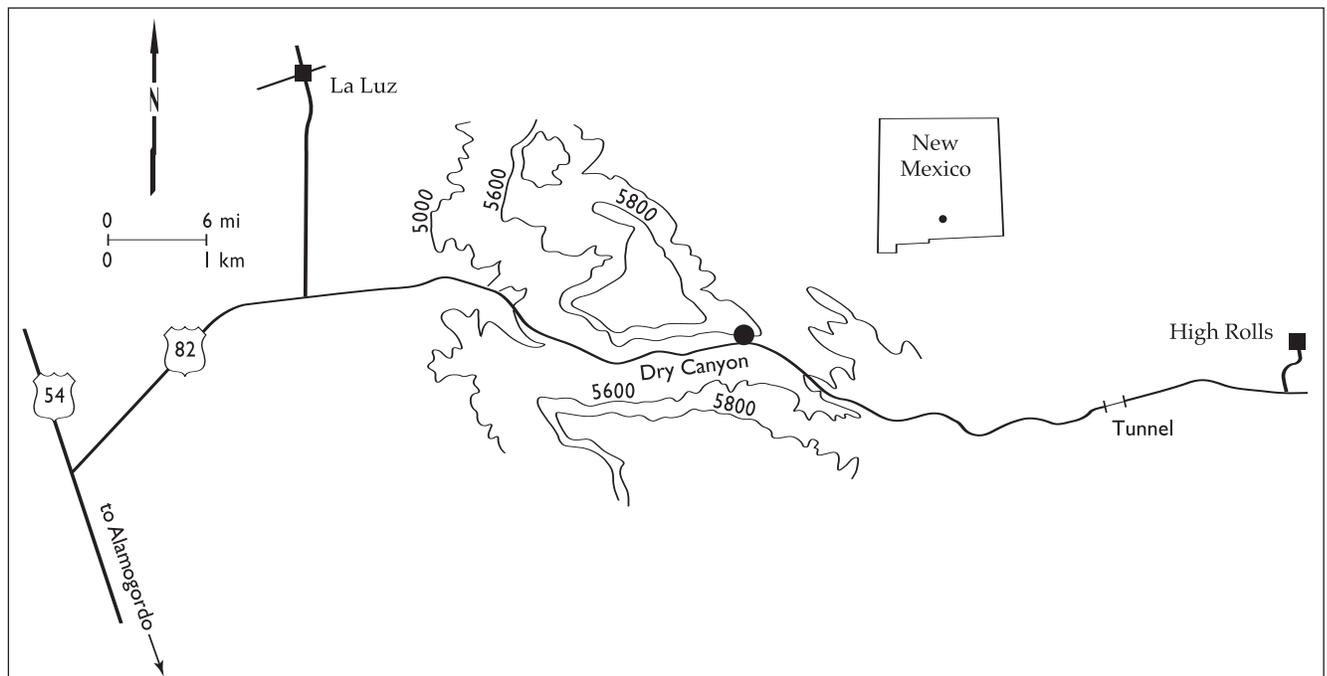
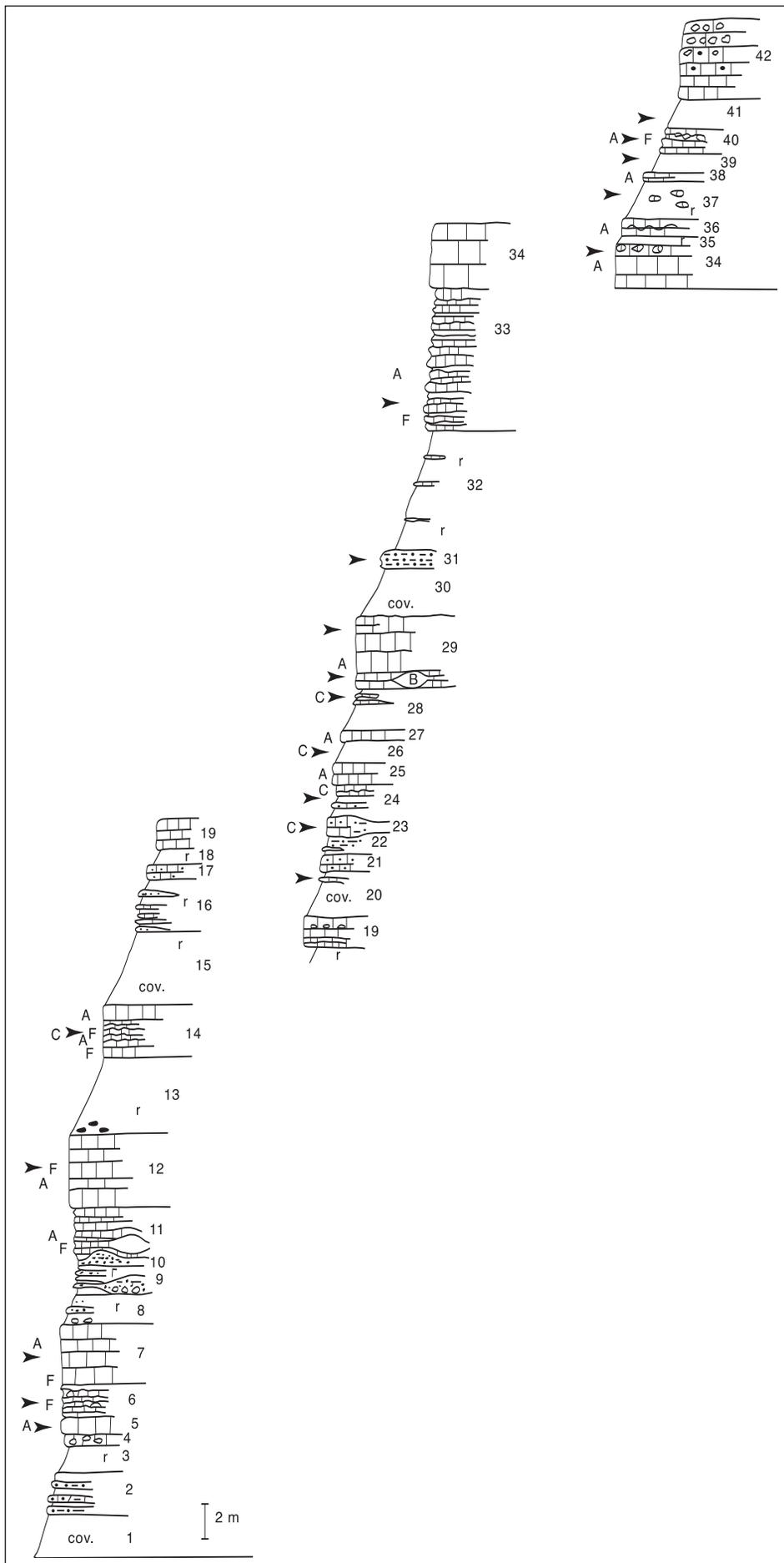


FIGURE 1—Location of milepost 5 Holder roadcut (black dot) in Dry Canyon, northeast of Alamogordo. Contour lines indicated in feet.



Canyon are discussed. More than 100 species of invertebrates are present within these assemblages. Here, the purpose is not to describe the species in detail, but rather to broadly discuss the taxonomic composition of the assemblages, illustrate characteristic taxa, point out unusual species, and indicate their paleoenvironments, so that the paleobiology of the Holder Formation, and relationships of Holder faunas to contemporaneous faunas elsewhere in New Mexico, may be better understood.

All specimens discussed and illustrated in this paper are catalogued in the paleontology collections of the Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque.

## Location

The fossils described here were collected from a roadcut through the middle part of the Holder Formation in Dry Canyon, along the north side of US-82, from approximately 4.8 to 5.0 mi (7.8 to 8.1 km) east of the junction of US-82 with US-54/70, just north of Alamogordo, Otero County, New Mexico (Fig. 1). The highway milepost 5 (MP-5) sign is adjacent to the east end of the roadcut. This roadcut begins approximately 1.1 mi (1.8 km) east of the entrance to Lincoln National Forest and the large bioherms in the slopes above, at the mouth of Dry Canyon. This area is shown on published aerial photographs (e.g., Cline 1959, fig. 4; Rankey et al. 1999, fig. 6), and Holder stratigraphy and facies were portrayed by Rankey et al. (1999, figs. 6,7). Cline (1959, figs. 3,5) briefly described a stratigraphic section of this roadcut, and the entire area around US-82 in Dry Canyon was mapped by Pray (1961, pl. 1).

## Stratigraphy and age

A stratigraphic section from the west to east end of the Holder roadcut was measured for this study (Fig. 2). Based on outcrop observations and the aerial photos noted above, the basal units of this 80-m-thick (262-ft-thick) section correlate to strata slightly above the top of the 23-m-thick (75-ft-thick; Toomey 1991) bioherm directly to the west and extend upward to within approximately 30 m (97 ft) of the top of the Holder. Uppermost Holder strata are present along the crest of Mill Ridge to the west and above the bioherms, but are not

FIGURE 2—Stratigraphic section of Holder Formation in milepost 5 roadcut. Standard lithologic symbols for limestone, sandstone, siltstone, and conglomerate; shale slopes are blank; cov. = covered intervals; r = red shale; A = algal remains; F = fusulinid horizons; C = large solitary rugose corals; small arrows = marine invertebrate remains. Fossil assemblages discussed in this paper are from bed 31 and beds 39–40. Section is broken in two places by small faults.

well exposed in the area of the US-82 roadcut.

In the Dry Canyon area the Holder is underlain by the Beeman Formation (Raatz and Simo 1998; exposed in a long roadcut approximately 1 km (0.6 mi) west of the Holder MP-5 roadcut) and is overlain by the Laborcita Formation (see Otte 1959), which is exposed along US-82 just east of the MP-5 roadcut. The Laborcita Formation contains a much higher proportion of nonmarine red beds than the Holder Formation. Traditional dating of the Laborcita by fusulinids (Steiner and Williams 1968) indicated an early Wolfcampian (earliest Permian) age, but recent elevation of the Virgilian-Wolfcampian boundary in the Midcontinent region (Wahlman 1998; Sanderson et al. 2001) places fusulinid assemblages correlative with those of the Laborcita in the uppermost Virgilian (latest Pennsylvanian), and that adjustment is accepted here. The Beeman-lower Holder contact, based on fusulinids, is early Virgilian in age (e.g., Raatz and Simo 1998, fig. 3, table 2). The Missourian-Virgilian boundary is approximately 80 m (262 ft) below the Beeman-Holder formational contact, based on a *Streptognathodus* condont assemblage that correlates with the Midcontinent South Bend to Iatan cyclothems (Raatz written comm. 2004). In Dry Canyon (Wahlman written comm. 2003, based on studies by G. Verville), the lower 30 m (98 ft) of the Holder contains species of the fusulinid *Triticites* present in the Midcontinent lower Shawnee Group (Snyderville-Leavenworth units) at the base and middle Shawnee Group (Lecompton) species above. The overlying 60 m (197 ft) of the Holder contains upper Shawnee Group (Deer Creek) *Triticites* and *Dunbarinella ervinensis*, and the uppermost sample contains lower Wabaunsee Group *Triticites*. *Dunbarinella ervinensis* ranges from the upper Shawnee through the lower Wabaunsee Groups in Kansas (Sanderson et al. 2001), which is from late middle to early late Virgilian age (traditional Virgilian usage). The fusulinid data and invertebrate taxa reported here indicate with a fair degree of precision that the Holder Formation ranges from late early to early late Virgilian in age. The two assemblages discussed below, both from the upper part of the MP-5 roadcut (but at least 30 m (98 ft) below the top of the Holder), thus are likely of middle Virgilian age.

The Holder Formation was deposited on a narrow shelf a few kilometers in width, between the Pederal uplift to the east and the rapidly subsiding Orogrande Basin to the west. The bioherms at the base of the Holder grew along the seaward edge of the shelf, and were influenced by development of the local, north-south-trending, La Luz anticline (Wilson 1967; Toomey 1991). The strata at the MP-5 roadcut therefore were deposited a short distance shoreward of the bioherms, although these strata

postdate cessation of bioherm growth. Rankey et al. (1999) recognized three facies associations within the Holder. Facies association A includes gray to green shale to fine-grained sandstone bearing marine fossils and representing offshore to lower shoreface deposition. Association B consists of red claystone and siltstone, locally pedogenically altered, and thin-bedded to channelform deposits of sandstone and conglomerate, representing alluvial and fluvial deposition. Association C includes various fossiliferous marine limestones. These facies were interpreted as reflecting many shallowing-upward, high-frequency sequences bounded by subaerial exposure or fluvial incision surfaces, representing sea level changes (eustatic as well as subsidence/uplift influenced) estimated to be at least 32 m (105 ft).

The MP-5 roadcut section (Fig. 2) displays all three of these facies associations and pronounced depositional cyclicity is apparent. Several 2–5-m-thick (6.5–16-ft-thick) limestone beds, typically algal, some with small bioherms and most with fusulinids, are present throughout the section. Typically these limestones are abruptly overlain by nonmarine reddish shales having limestone concretions at their bases, and the red beds may be associated with thin-bedded to thick channel deposits of greenish to gray siltstones and sandstone, some with local conglomeratic intervals. Many fossiliferous intervals, both in limestones and in marine shales, were observed in this section (Fig. 2), including several units bearing assemblages with large, solitary rugose corals. However, this paper focuses on assemblages in bed 31, approximately 50 m (164 ft) above the base of the roadcut section, and in beds 37 to 40, near the top of the section. The latter assemblage represents the most diverse normal marine assemblage in the Holder, and the bed 31 marginal marine assemblage is unique in the New Mexico Pennsylvanian.

Bed 31 (Fig. 3) is a ledge-forming, dark-gray, calcareous, silty mudstone approximately 1 m (3 ft) thick. A 2-m-thick (6.5-ft-thick) covered shale interval separates this bed from an underlying massive limestone, but bed 31 is overlain directly by a thick (7 m; 23 ft) bed of nonmarine red shale (bed 32), indicating an abrupt transition from marine to nonmarine environments. Molluscan remains in bed 31 are invariably black, their calcareous shells having been subjected to phosphatic replacement, but the relatively few brachiopod valves do not show evidence of such replacement. In general, the fossils are well preserved, many gastropod and bivalve shells being complete, although often crushed by postdepositional compaction, but shell fragments and fine bioclastic debris are also common.

Beds 37 through 40 are a 4-m-thick (13-ft-thick) interval of interbedded thin lime-

stone ledges and thicker dark-gray shale beds within a few meters of the top of the section (Fig. 4), and above a massive limestone cliff (bed 34). A thin reddish shale interval (bed 35) separates the underlying limestone from a thin (0.75 m; 2.5 ft) algal limestone ledge (bed 36). Bed 37 is a mostly covered slope of fissile dark-gray shale, reddish at its base, and bed 38 is a pair of thin, argillaceous limestone ledges separated by a shale parting, without obvious in situ fossils. Bed 39, an approximately 1-m-thick (3-ft-thick) dark-gray shale unit, and bed 40, a 1.15-m-thick (3.5-ft-thick) interval of thin ledge-forming light-gray to locally nodular limestone and dark-gray to brown-weathering calcareous shale/argillaceous limestone, are the sources of most, if not all, of the fossils in this second assemblage. Specimens collected as float from beds 37 and 38 were likely derived from beds 39 and 40. Fossils from this interval, especially from shaly lithologies, are fragile but generally complete or nearly complete, although many are weathered or covered with calcareous encrustations.

### ***Retispira-Polidevcia* assemblage**

The assemblage in bed 31 (Fig. 5; Table 1) is dominated by bivalves and gastropods in approximately equal abundance; together they comprise about 96% of the nearly 1,100 specimens collected. Brachiopods are uncommon (3%), and nearly all are fragments of a medium-sized species of *Lino-productus* (Fig. 5A). Typical stenohaline groups such as fusulinids, bryozoans, corals, crinoids, echinoids, and trilobites were not observed in this assemblage. Relatively large, fusiform coprolites (45+ mm long), presumably from fish, are present. In all, 11 species of bivalves, 18 species of gastropods, four species of brachiopods, and two species of nautiloid cephalopods are present in this assemblage, which is low in species richness compared to most Pennsylvanian normal marine assemblages, such as the bed 39–40 assemblage higher in the Holder discussed below.

Among the bivalves and gastropods, one species of each group is more than twice as abundant as the second most common species. The nuculoid *Polidevcia arata* (Girty) represents about 56% of all bivalve specimens, and the strongly ornamented bellerophonoid *Retispira espinasa* Kues accounts for 42% of the gastropod specimens obtained from bed 31. Together, these two species account for about 47% of all identifiable specimens from bed 31, an unusually high degree of dominance for two species. This assemblage is here termed the *Retispira-Polidevcia* assemblage.

The bivalves in this assemblage are mainly articulated specimens of *Polidevcia arata* (56%), with two additional taxa, cf. *Sedgwickia topekaensis* (Shumard), and *Myalinella* aff. *M. meeki* Dunbar, comprising an



FIGURE 3—View to west along roadcut, showing bed 30 to lower part of bed 33. *Retispira*–*Polidevcia* assemblage is from bed 31.

additional 36% of the bivalve specimens (Table 1). Other species are represented by only one to a few incomplete specimens. *Polidevcia arata* (Fig. 5B) is not uncommon in other New Mexico Desmoinesian to Virgilian assemblages (e.g., Kues 1984, 1996) and is widely distributed through Middle and Late Pennsylvanian strata in the United States (e.g., Driscoll 1966; Hoare et al. 1979), but rarely is it such a dominant element in the assemblages in which it occurs. Interestingly, in contrast to many Holder taxa, *P. arata* is not present in the overlying Laborcita Formation. Instead, it is replaced (in much smaller numbers and in different lithologies) by the related species *P. bellis-*

*triata* (Stevens) (see Kues 1991a), which differs slightly in valve proportions and in having finer comarginal lirae.

Second in abundance among the bivalves (25%) is a moderately large (as long as 50 mm), subrectangular, rather elongate taxon here referred to cf. *Sedgwickia topekaensis* (Figs. 5F–H). Its abundance is probably underestimated, as many small, thin, unidentifiable valve fragments in bed 31 are probably from this species. *Sedgwickia topekaensis* is a poorly known species first described by Shumard, in Shumard and Swallow (1858) and seldom reported since then. Its posteriorly extended valves display little or no gape; it



FIGURE 4—Upper part of roadcut section, just east of small fault, showing top of bed 34 to bed 42. Mixed marine assemblage is from beds 39–40 and float from underlying beds.

has high, rounded anterior beaks, and ornamentation of vague comarginal wrinkles, with radial rows of minute pustules across the valve surface. The Holder specimens agree well in these features with the few previous descriptions (e.g., Beede 1900), although they are not as elongate as the Midcontinent specimens described by Meek and Hayden (1864). The Holder specimens have some resemblance to species of *Chaenomya* as well, but that genus is characterized by increasing height posteriorly (forming a concave dorsal margin), with a widely gaping posterior margin. Similar bivalves have not previously been reported from the Pennsylvanian of New Mexico, and the abundance of this taxon in this Holder assemblage is highly unusual.

*Myalinella* aff. *M. meeki* (Figs. 5E,F) is the only myalinid bivalve in this assemblage, and is easily distinguished by its moderate size (as much as 50 mm in maximum length), broadly subtriangular shape, acuminate anterior beaks, long hingeline, straight anterior margin, angle of 40°–50° between the hingeline and anterior margin, and broadly rounded posterior margin that meets the hingeline at an obtuse angle. In most respects these specimens resemble *M. meeki* from the Midcontinent region (e.g., Newell 1942), but that variable species appears to have a shorter hingeline relative to the length of the rounded posterior margin, giving the valves a narrower overall outline. The Holder specimens also superficially resemble *Septimyalina scitula* Newell, a Midcontinent Virgilian species, but have thinner valves, a straight rather than concave anterior margin, and lack the characteristic umbonal septum of *Septimyalina*. This taxon differs considerably from the much larger, more upright valves of *Myalina* (*Orthomyalina*) *subquadrata* found higher in the Holder (see below), and from the widespread late Virgilian species *Septimyalina burmai* Newell, which has a shorter hingeline and raised, crenulated lamellae on the left valve. Myalinids of similar morphology and occurrence in low-diversity assemblages in the late Virgilian Red Tanks Formation (also called *M. aff. M. meeki*, Kues 2004) are probably conspecific. Among the other bivalves in this assemblage, fragments of the large (200+ mm long when complete), narrowly triangular valves of *Aviculopinna* (Figs. 5C,D) are conspicuous.

The gastropods of the *Retispira*–*Polidevcia* assemblage include several other characteristic species that, although not as abundant as *R. espinasa* (Figs. 5I–K), are relatively common. These are (Table 1) *Taosia crenulata* Girty, *Colpites monilifera* (White), *Hypselentoma perhumerosa* (Meek), and *Goniasma lasallensis* (Worthen). Together, these species add another 46% to the 42% of the gastropod specimens represented by *R. espinasa* and together comprise the dominant gastropod elements of this assem-

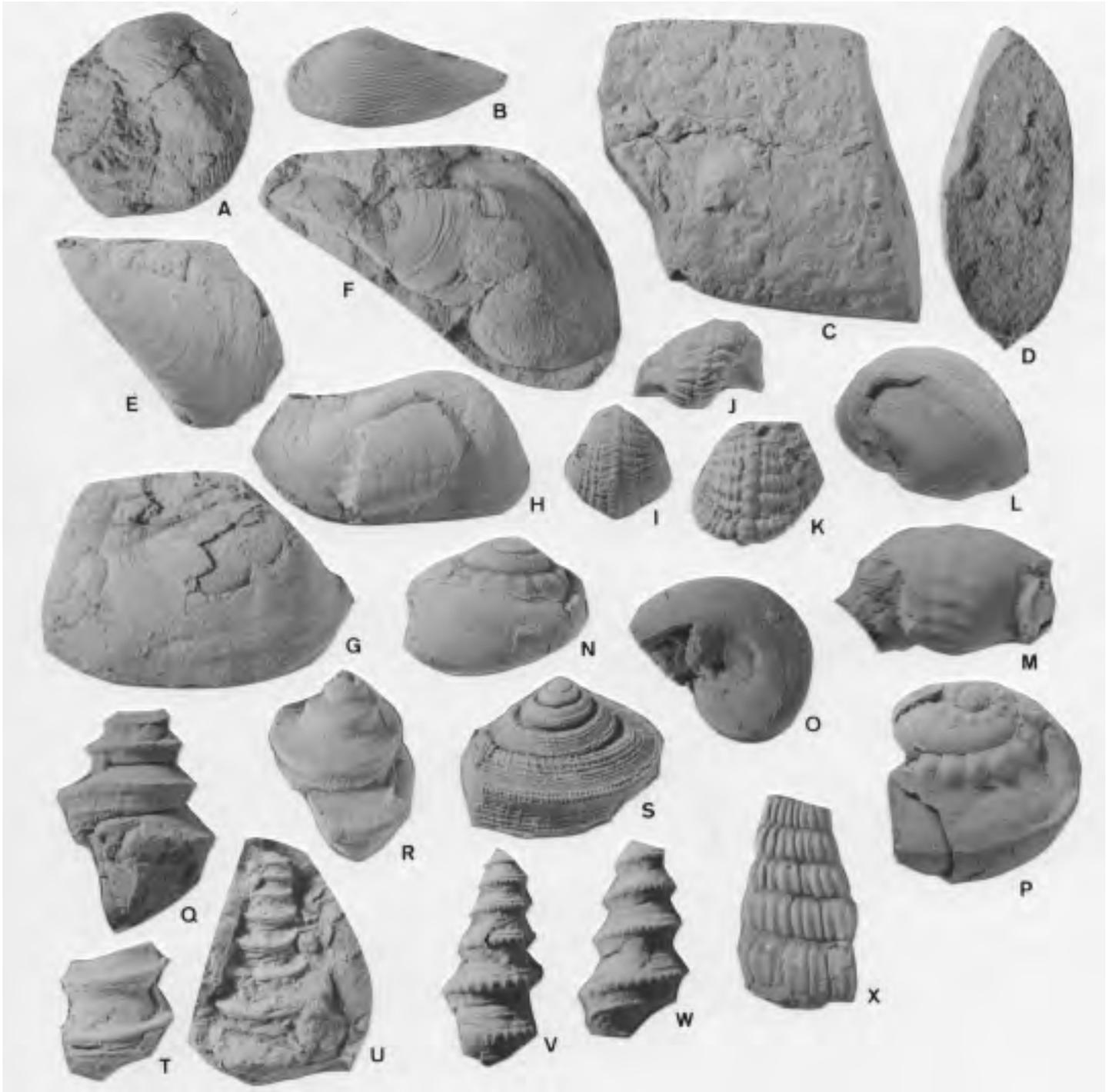


FIGURE 5—Invertebrates from bed 31, Holder Formation, at the milepost 5 roadcut on US-82, Dry Canyon. **A**, brachiopod; **B–H**, bivalves; **I–X**, gastropods. **A**, *Linoproductus* sp., incomplete pedicle valve, UNM 13,465, x 1.4. **B**, *Polidevicia arata* (Girty), left valve, UNM 13,466, x 1.5. **C, D**, *Aviculopinna* sp., side and cross sectional views of left valve fragment, UNM 13,467, x 1. **E, F**, *Myalinella* aff. *M. meeki* Dunbar; **E**, left valve, UNM 13,468, x 1.5; **F**, somewhat distorted left valve with left valve of cf. *Sedgwickia topekaensis*, UNM 13,469, x 1. **G, H**, cf. *Sedgwickia topekaensis* (Shumard); **G**, incomplete right valve, UNM 13,470, x 1.5; **H**, right valve (partially covered by shell fragment), UNM 13,471, x 1.5. **I–K**, *Retispira espinasa* Kues; **I**, top view, UNM 13,472, x 1.5; **J**, back view of distorted specimen, UNM 13,473, x 2; **K**, top front view, UNM 13,474, x 2. **L**, *Retispira tenuilineata* (Gurley), oblique top view, UNM 13,475, x 2.5. **M**, *Pharkidonotus* sp., back view of incomplete

specimen, UNM 13,476, x 1.8. **N–P**, *Colpites monilifera* (White); **N**, side view of partially exfoliated specimen, UNM 13,477, x 2.25; **O**, bottom view, UNM 13,479, x 2; **P**, oblique side view of somewhat crushed specimen, UNM 13,478, x 2. **Q, R**, *Hypselentoma perhumerosa* (Meek); **Q**, side view of large specimen, UNM 13,480, x 3.75; **R**, oblique side view, showing selenizone on outer margin of upper whorl surface, UNM 13,481, x 4. **S**, *Worthenia speciosa* (Meek and Worthen), side view, UNM 13,482, x 2.25. **T, U**, *Goniasma lasallensis* (Worthen); **T**, fragment, last two whorls of large specimen, UNM 13,484, x 2; **U**, crushed specimen in matrix, UNM 13,483, x 3. **V, W**, *Taasia crenulata* Girty, side views of incomplete specimens, UNM 13,486 and 13,487, x 4.5. **X**, *Pseudozygopleura* (*Pseudozygopleura*) sp., crushed, incomplete specimen, UNM 13,488, x 2.

TABLE 1—Number of specimens and relative abundance of taxa from the Holder Formation, bed 31, milepost 5 roadcut section.

Species	Specimens	Percent of group
<b>BRACHIOPODS</b>		
<i>Linoproductus</i> sp.	30	88
<i>Isogramma</i> sp.	2	6
<i>Hystriculina wabashensis</i>	1	3
<i>Composita subtilita</i>	1	3
Total brachiopods	34	(3.2% of assemblage)
<b>BIVALVES</b>		
<i>Polidevcia arata</i>	270	56
<i>Sedgwickia topekaensis</i>	121	25
<i>Myalinella</i> aff. <i>M. meeki</i>	52	11
<i>Permophorus</i> spp.	10	2
<i>Schizodus?</i> sp.	8	2
<i>Aviculopinna</i> sp.	7	1
<i>Nuculopsis</i> cf. <i>N. anodontoides</i>	5	1
<i>Parallelodon</i> sp.	4	<1
<i>Aviculopecten</i> sp.	3	<1
<i>Nuculavus arcuatus</i>	1	<1
<i>Leptodesma</i> ( <i>Leptodesma</i> ) sp.	1	<1
Total bivalves	482	(45.0% of assemblage)
<b>GASTROPODS</b>		
<i>Retispira espinasa</i>	230	42
<i>Taosia crenulata</i>	91	17
<i>Colpites monilifera</i>	72	13
<i>Hypselenzoma perhumerosa</i>	49	9
<i>Goniasma lasallensis</i>	41	7
<i>Pseudozygopleura</i> ( <i>Pseudozygopleura</i> ) sp.	14	3
<i>P. (P.)</i> spp. (small)	12	2
<i>Naticopsis</i> sp.	11	2
Indeterminate bellerophonoids	7	1
<i>Retispira tenuilineata</i>	6	1
<i>Bellerophon</i> ( <i>Bellerophon</i> ) cf. <i>graphicus</i>	3	<1
<i>Hypergonia</i> n. sp.	3	<1
<i>Glabrocingulum</i> ( <i>Glabrocingulum</i> ) <i>beedei</i>	3	<1
<i>Pharkidonotus</i> sp.	2	<1
<i>Euphemites</i> cf. <i>E. enodis</i>	1	<1
<i>Baylea</i> aff. <i>B. supercrenata</i>	1	<1
<i>Glabrocingulum</i> ( <i>Ananias</i> ) sp.	1	<1
<i>Worthenia speciosa</i>	1	<1
<i>Amaurotoma</i> cf. <i>A. subsinuata</i>	1	<1
Total gastropods	549	(51.3% of assemblage)
<b>CEPHALOPODS</b>		
<i>Pseudorthoceras knoxense</i>	2	
<i>Metacoceras</i> sp.	3+	
Total cephalopods	5	(0.5% of assemblage)

blage. Of these common gastropods, *R. espinasa* (Kues 2004; see also Kues 1991b, as *Retispira* n. sp.) and *Taosia crenulata* (Girty 1939; Kues 1991b; Figs. 5V,W) are species currently known only from New Mexico. Both were originally described from, and are abundant in the overlying Laborcita Formation in the northern Sacramento Mountains, and both also occur in the coeval latest Virgilian Red Tanks Formation of west-central New Mexico (Kues 2004). Specimens reported by Batten (1995, figs. 29a,b) as *Stegocoelia* (*Taosia*) *crenulata* from Morrowan strata in the Hueco Mountains, west Texas, differ from the Holder/Laborcita specimens in having four or five spiral lirae on the upper whorl surface, instead of two widely spaced lirae bordering a medial selenizone. These Morrowan specimens may be better assigned to *Stegocoelia* (*Donaldospira*) *nodosa* (Batten 1995, fig. 27). *Goniasma lasallensis* (Figs. 5T,U) is also common in the Laborcita Formation (Girty 1939; Kues 1991a) but is distributed

specimens from other areas. The two previous reports of this species from New Mexico are of specimens from the Desmoinesian near Taos (White 1881) and from Virgilian strata near the top of the Madera Group in the Jemez Springs area (Kues 1996).

*Hypselenzoma perhumerosa* was described initially by Meek (1872) from strata in eastern Nebraska near the Pennsylvanian-Permian boundary, and there have been few other reports, all of which are from the Midcontinent region. The Holder specimens have moderately high spired, turret-shaped shells of about eight whorls that attain a maximum height of approximately 19 mm. On mature whorls, the upper whorl surface slopes gently from the upper suture to a strong, carinate periphery about at mid-whorl. A fine, sometimes obscure spiral lira about midway down the upper whorl surface marks the upper border of a wide selenizone that extends across the outer half of this surface to the peripheral carina.

widely in North America, in strata from Morrowan to early Wolfcampian age.

The remaining two common gastropods in bed 31, *Colpites monilifera* (Figs. 5N-P) and *Hypselenzoma perhumerosa* (Figs. 5Q, R) are species that have only occasionally been reported in Pennsylvanian faunas of North America (e.g., Yochelson and Saunders 1967). Their appearance as conspicuous elements of this Holder assemblage is surprising. *Colpites monilifera* is easily recognized by its globose, low-spined shell, as much as approximately 17 mm wide and 16 mm high, narrow and inconspicuous selenizone along the rounded periphery, and ornamentation of a single subsutural row of strong nodes. The Holder specimens also display fine spiral lirae on the base of the body whorl, a feature not noted in descriptions of

The lower whorl surface is slightly concave and possesses one spiral lira just above the lower suture, with two or three additional smaller lirae on the base of the body whorl. The Holder specimens of *H. perhumerosa* are invariably incomplete or distorted, but agree well with Knight's (1941) detailed description of the type specimens. This species has not previously been reported from New Mexico, and its common occurrence in the *Retispira-Polidevcia* assemblage enhances the distinctiveness of this assemblage. A few other less common, but distinctive gastropods, such as *Retispira tenuilineata* (Gurley) (Fig. 5L), *Pharkidonotus* sp. (Fig. 5M), *Worthenia speciosa* (Meek and Worthen) (Fig. 5S), and an unusually large species of *Pseudozygopleura* (*Pseudozygopleura*) (Fig. 5X) are also illustrated here.

Nautiloid cephalopod remains include sparse but conspicuous fragments of the small, narrowly conical shells of *Pseudorthoceras*, and poorly preserved specimens of a large *Metacoceras*, its coiled shell having a maximum diameter of approximately 90 mm.

The taxonomic composition and relative abundances of taxa of the *Retispira-Polidevcia* assemblage of bed 31 are unique in the New Mexico Pennsylvanian and as far as I am aware, this assemblage has not previously been reported elsewhere in North America. Although composed of marine taxa, many of which are known from more typical marine faunas that are considerably richer in species, the great dominance of benthic gastropods and bivalves, the relatively low number of species, and the absence of stenohaline groups such as fusulinids, bryozoans, corals, echinoderms, trilobites, and most brachiopods, suggest that this assemblage lived in a marine environment that was abnormal in some way. Bed 31 was deposited in a regressive succession, and its abrupt transition to an overlying nonmarine red shale, with evidence of erosion at the contact, suggests a nearshore, very shallow environment that ended with a rapid, although not necessarily extreme drop in sea level. Preservation of most taxa in this assemblage is good; most gastropods are nearly complete, and most bivalves are in an articulated state, except for cf. *Sedgwickia topekaensis*, whose thin valves are both generally disarticulated and fragmented. This suggests that although these invertebrates likely lived in a nearshore, shallow marine environment above wave base, water agitation was not strong enough to damage most shells. Some transportation is indicated by the varied orientation of the shells, and local thin intervals of fine, densely concentrated bioclastic debris suggest transitory episodes of higher energy sufficient to break down and winnow larger shell fragments. Possibly this assemblage lived in a lagoon that was somewhat sheltered from normal wave activity.

TABLE 2—Number of specimens and relative abundance of taxa from the Holder Formation, beds 39–40, at the milepost 5 roadcut section. For some groups, subjective abundances rather than number of specimens are given: A, abundant; C, common; MC, moderately common; UC, uncommon; R, rare.

Species	Specimens	Percentage of group	Species	Specimens	Percentage of group
FUSULINIDS	C		<i>Acanthopecten carboniferus</i>	2	2
PORIFERA (Sponge)	1		Pectinids, indet.	2	2
SOLITARY RUGOSE CORALS	9		<i>Palaeolima retifera</i>	1	1
BRYOZOA			<i>Polidevcia arata</i>	1	1
Fenestrates	UC		<i>Parallelodon</i> sp.	1	1
Massive laminar	R		<i>Nuculaovus arcuatus</i>	1	1
Rhomboporoids	C		<i>Astartella</i> cf. <i>A. varica</i>	1	1
ARTHROPODS			<i>Astartella</i> cf. <i>A. vera</i>	1	1
Ostracods	UC		<i>Leptodesma (Leptodesma)</i> cf. <i>L. (L.) welleri</i>	1	1
<i>Ditomopyge</i> sp. (Trilobite)	5		Total bivalves	106	(5.7% of total specimens)
ECHINODERMS			GASTROPODS		
Crinoid fragments	A		<i>Euphemites</i> sp.	103	18
Echinoid fragments	R		<i>Donaldina stevensana</i>	81	14
VERTEBRATES (fish teeth)	UC		<i>Amphiscapha subrugosa</i>	59	10
BRACHIOPODS			<i>Glabrocingulum (Ananias)</i> sp. 1	45	8
<i>Crurithyris planoconvexa</i>	600+	53	<i>Retispira tenuilineata</i>	36	6
<i>Neochonetes granulifer</i>	186	16	<i>Strobeus</i> spp.	32	6
<i>Kutorginella</i> aff. <i>K. lasallensis</i>	143	13	<i>Hypergonia</i> n. sp.	28	5
<i>Composita subtilita</i>	63	6	<i>Trepostira</i> cf. <i>T. illinoisensis</i>	25	4
<i>Neospirifer</i> cf. <i>N. dumbari</i>	44	4	<i>Glabrocingulum (Glabrocingulum)</i> sp.	23	4
<i>Reticulatia americana</i>	25	2	<i>Naticopsis (Jedria) meeki</i>	18	3
<i>Punctospirifer kentuckyensis</i>	11	1	<i>Phymatopleura brazoensis</i>	15	3
<i>Hustedia mormoni</i>	10	1	<i>Cibecua?</i> sp.	15	3
<i>Hystericulina wabashensis</i>	9	1	<i>Pseudozygopleura (Pseudozygopleura)</i> sp. 3	15	3
<i>Parajuresania nebrascensis</i>	9	1	<i>Bellerophon (Bellerophon)</i> sp. indet.	11	2
<i>Cancrinella boonensis</i>	7	1	<i>Pseudozygopleura (Pseudozygopleura)</i> indet.	10	2
<i>Pulchratia</i> aff. <i>P. meeki</i>	4	<1	<i>Bellerophon (Bellerophon) graphicus</i>	7	1
<i>Derbyia</i> sp. indet.	4	<1	<i>Girtyspira minuta</i>	7	1
<i>Rhynchopora illinoisensis</i>	4	<1	<i>Araeonema novamexicana</i>	5	1
<i>Derbyia</i> cf. <i>D. deercreekensis</i>	3	<1	<i>Plocezyga</i> cf. <i>P. conica</i>	4	1
<i>Wellerella osagensis</i>	3	<1	<i>Pseudozygopleura (Pseudozygopleura)</i> sp. 1	4	1
<i>Phricodothyris perplexa</i>	3	<1	<i>Orthonema</i> sp. 2	4	1
<i>Derbyia plattsmouthensis</i>	2	<1	<i>Knightites?</i> sp.	3	1
<i>Linoproductus</i> sp.	2	<1	<i>Pharkidonotus</i> sp.	3	1
<i>Lissochonetes</i> cf. <i>L. senilis</i>	2	<1	<i>Leptoptygma</i> cf. <i>L. virgatum</i>	3	1
<i>Lissochonetes</i> cf. <i>L. plattsmouthensis</i>	1	<1	<i>Glyptotomaria (Dictyotomaria)</i> sp.	2	<1
<i>Quadrochonetes geronticus</i>	1	<1	<i>Glabrocingulum (Ananias)</i> sp. 2	2	<1
<i>Meekella striatocostata</i>	1	<1	<i>Orthonema</i> sp. 1	2	<1
<i>Neospirifer</i> cf. <i>N. alatus</i>	1	<1	<i>Eucochlis perminuta</i>	2	<1
<i>Isogramma</i> sp.	MC	—	<i>Anomphalus?</i> sp.	2	<1
Total brachiopods	1,138	(60.8% of total specimens)	<i>Plocezyga</i> cf. <i>P. turbinata</i>	2	<1
BIVALVES			The following gastropods are represented by one specimen each: <i>Colpites monilifera</i> , <i>Paragoniozona?</i> sp., <i>Worthenia</i> sp., <i>Donaldospira</i> n. sp., <i>Glabrocingulum (Ananias)</i> sp. 3, <i>Pseudozygopleura (Pseudozygopleura)</i> sp. 2, <i>Pseudozygopleura (Pseudozygopleura)</i> sp. 4, <i>?Leptozyga</i> sp., cf. <i>Microptychis williamsi</i> , <i>Platyzoa</i> sp., <i>Donaldina?</i> sp.		
<i>Myalina (Orthomyalina) subquadrata</i>	44	42	Total gastropods	579	(30.9% of total specimens)
<i>Nuculopsis</i> sp.	15	14	SCAPHOPODS		
<i>Permophorus</i> spp.	6	6	<i>Prodentalium</i> sp.	3	
<i>Edmondia</i> sp. indet.	6	6	NAUTILOID CEPHALOPODS		
<i>Edmondia</i> sp. 1	5	5	<i>Pseudorthoceras knoxense</i>	8	
<i>Nuculopsis</i> cf. <i>N. anodontoides</i>	3	3	<i>Orthocera</i> , indet.	2	
<i>Streblochondria</i> cf. <i>S. sculptilis</i>	3	3	<i>Metacocera</i> sp.	3	
<i>Pseudomonotis</i> cf. <i>P. equistriata</i>	3	3	AMMONOID CEPHALOPODS		
<i>Aviculopecten</i> cf. <i>A. moorei</i>	3	3	<i>Eoasianites</i> aff. <i>E. angulatus</i>	18	
<i>Nuculaovus</i> sp. 1	2	2			
<i>Permophorus</i> sp. 1	2	2			
<i>Leptodesma (Leptodesma)</i> sp.	2	2			

The absence of most stenohaline groups argues for fluctuating salinity, perhaps affected by intermittent fresh-water runoff from the nearby Pedernal land mass. Most of the common bivalves were shallow burrowers (e.g., Hoare et al. 1979), but *Myalinella* was an epifaunal filter feeder requiring at least a moderately firm substrate. The relatively high calcareous content of the shale in bed 31 and disseminated shell fragments may have lessened the fluidity of the muddy substrate on or in which these invertebrates lived. Although salinity fluctuation is the most obvious factor

that probably affected the diversity of this assemblage, it does not by itself explain its unusual taxonomic composition. It is possible that subtle features of water chemistry, dissolved oxygen content, and/or substrate quality may have played a contributing role.

### Mixed marine assemblage

Beds 39 and 40 (Table 2; Figs. 6,7) contain marine fossils far richer in species than the *Retispira-Polidevcia* assemblage of bed 31. Detailed study of these two units would

probably indicate two or more separate horizons with distinct assemblages, but as most of the collections were of eroded float material they are treated here together as a "mixed marine assemblage." This collection includes many stenohaline marine groups, including fusulinids (bed 40), sponges, small solitary rugose corals, fenestrate and other bryozoans, trilobites, ostracods, crinoid and echinoid fragments, scaphopods, ammonoid and nautiloid cephalopods, and fish teeth, in addition to 24 species of brachiopods, at least 18 species of bivalves, and more than 40

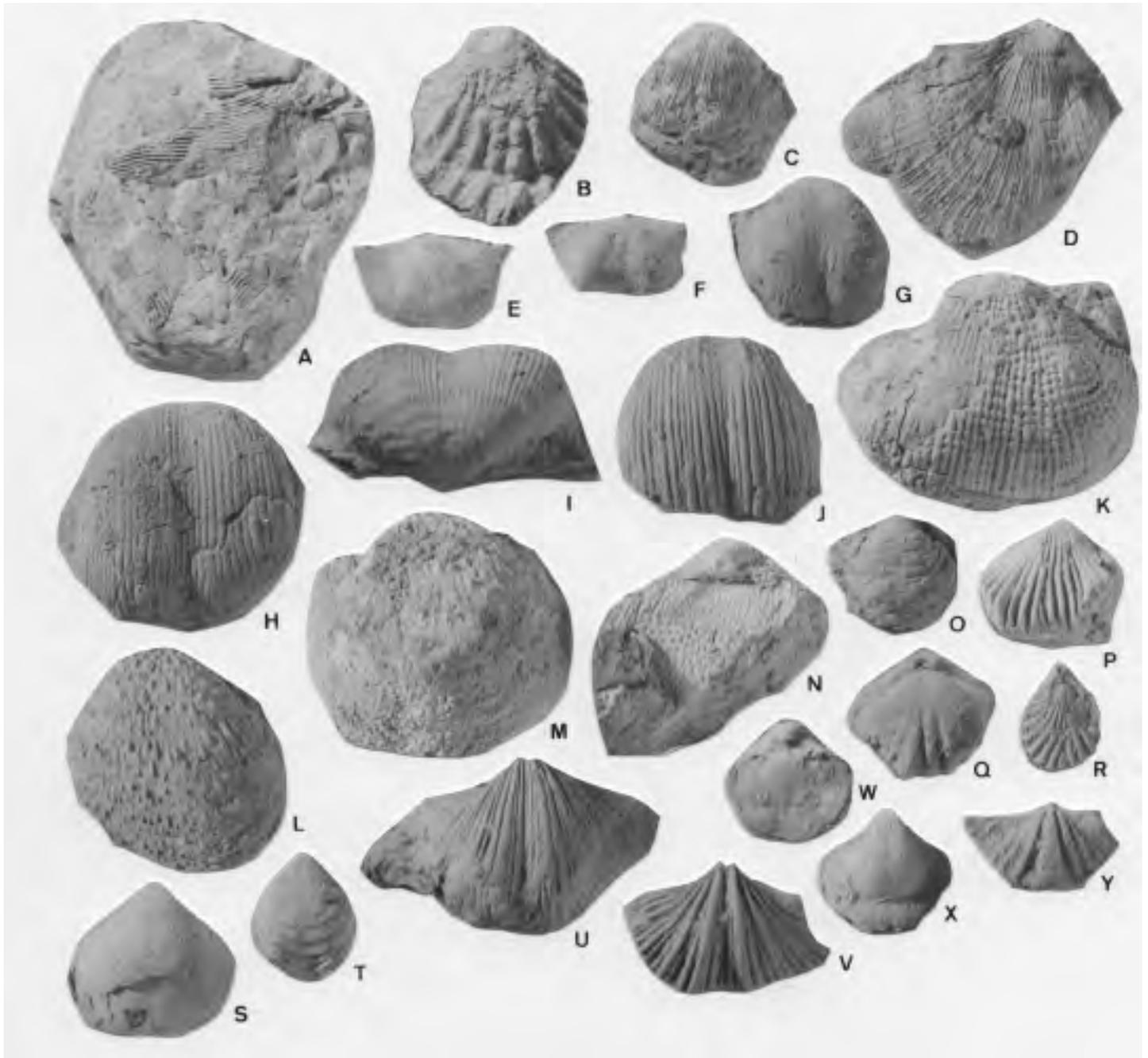


FIGURE 6—Brachiopods from beds 39 and 40, Holder Formation, at the milepost 5 roadcut on US-82, Dry Canyon. **A**, *Isogramma* sp., shell fragments, UNM 13,489, x 1.5. **B**, *Meekella striatocostata* (Cox), pedicle valve, UNM 13,490, x 1.5. **C**, *Derbyia* cf. *D. deercreekensis* Dunbar and Condra, brachial valve, UNM 13,491, x 1. **D**, *Derbyia plattsmouthensis* Dunbar and Condra, incomplete brachial valve, UNM 13,492, x 1. **E**, *Neochonetes granulifer* (Owen), pedicle valve, UNM 13,493, x 2. **F**, *Lissochonetes* cf. *L. plattsmouthensis* Dunbar and Condra, pedicle valve, UNM 13,494, x 3. **G**, *Hystriculina wabashensis* (Norwood and Pratten), pedicle valve, UNM 13,495, x 1.5. **H–J**, *Kutorginella* aff. *K. lasallensis* (Worthen); **H**, pedicle valve, UNM 13,496, x 1.5; **I**, back view of pedicle valve, UNM 13,497, x 1.5; **J**, front view of pedicle valve, UNM 13,498, x 1.5. **K**, *Reticulatia americana* (Dunbar and Condra), pedicle valve, UNM 13,499, x 1. **L**, *Parajuresania nebrascensis* (Owen), incomplete pedicle valve, UNM 13,500, x 1.5. **M**, **N**, *Pulchratia* aff.

*P. meeki* (Dunbar and Condra); **M**, weathered pedicle valve, UNM 13,501, x 1.25; **N**, brachial valve view of incomplete specimen, UNM 13,502, x 1.33. **O**, *Cancrinella boonensis* (Swallow), pedicle valve, UNM 13,503, x 2.75. **P**, *Rhynchopora illinoisensis* (Worthen), pedicle valve, UNM 13,504, x 2. **Q**, *Wellerella osagensis* (Swallow), brachial valve, UNM 13,505, x 2.67. **R**, *Hustedia mormoni* (Marcou), brachial valve view of a crushed specimen, UNM 13,506, x 2. **S**, **T**, *Composita subtilita* (Hall); **S**, “*C. ovata*” morph, pedicle valve, UNM 13,507, x 1; **T**, typical morph, pedicle valve, UNM 13,508, x 1.5. **U**, **V**, *Neospirifer dunbari* King; **U**, pedicle valve, UNM 13,511, x 1; **V**, pedicle valve of an immature small specimen, UNM 13,512, x 2. **W**, **X**, *Cruithyris planoconvexa* (Shumard); **W**, brachial valve view, UNM 13,509, x 3; **X**, pedicle valve, UNM 13,510, x 3. **Y**, *Punctospirifer kentuckyensis* (Shumard), brachial valve, UNM 13,513, x 1.5.

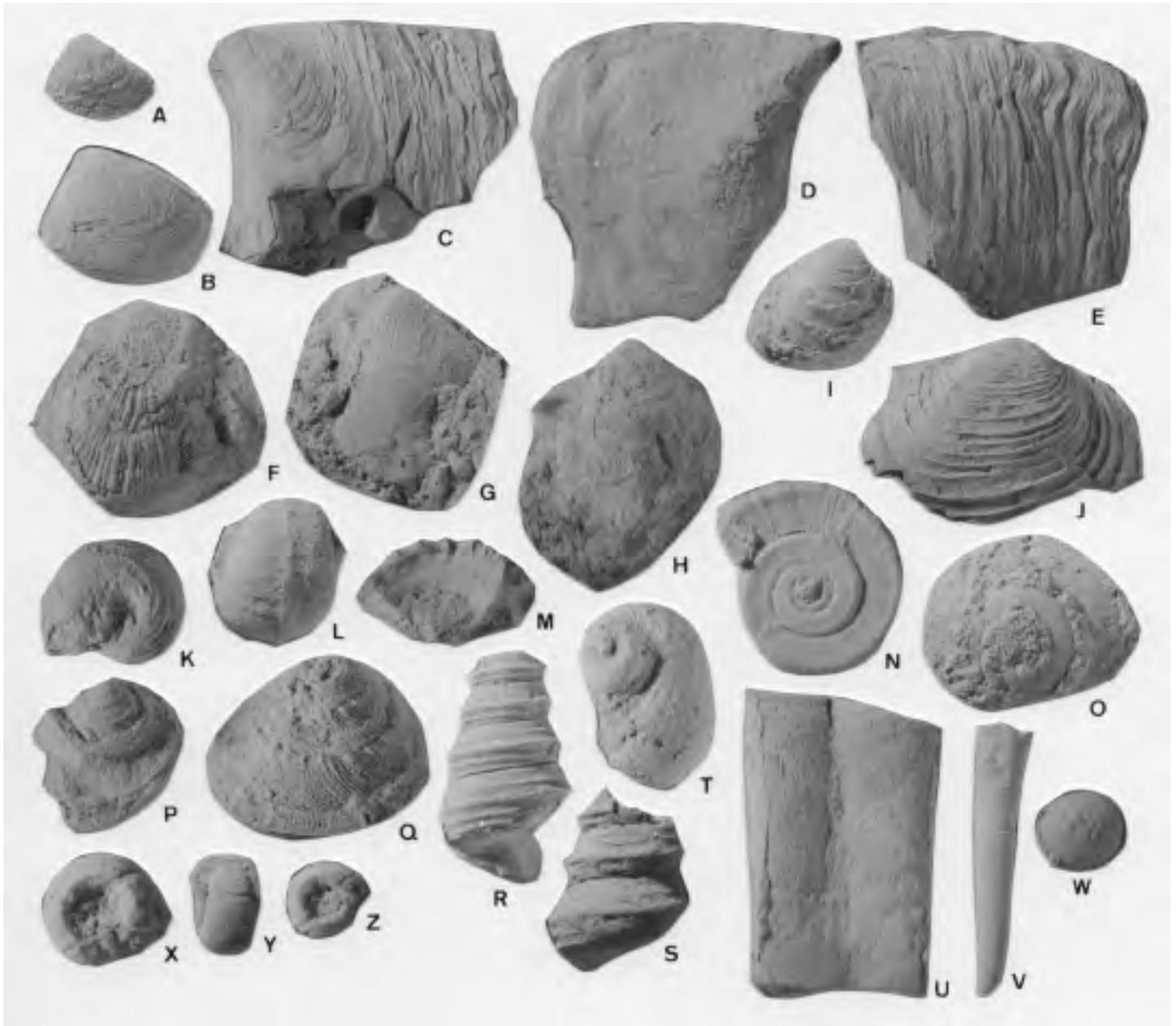


FIGURE 7—Molluscs from beds 39 and 40, Holder Formation, at the milepost 5 roadcut on US-82, Dry Canyon. A–J, bivalves; K–T, gastropods; U, scaphopod; V, W, nautiloid cephalopods; X–Z, ammonoid cephalopods. A, *Nuculavus arcuata* Kues, weathered right valve, UNM 13,514, x 5. B, *Nuculavus* sp., right valve, UNM 13,515, x 5. C–E, *Myalina* (*Orthomyalina*) *subquadrata* Shumard; C, dorsal part of left valve, UNM 13,516, x 1; D, incomplete right valve, UNM 13,517, x 1; E, fragment of large left valve, showing characteristic emargination in posterior margin near hingeline, UNM 13,518, x 1. F, *Aviculopecten* cf. *A. moorei* Newell, incomplete left valve, UNM 13,519, x 1.5. G, *Streblochondria* cf. *S. sculptilis* (Miller), incomplete left valve, UNM 13,520, x 2. H, *Pseudomonotis* cf. *P. equestrata* Beede, weathered incomplete left valve, UNM 13,521, x 1.5. I, *Astartella varica* McChesney, right valve, UNM 13,522, x 1.5. J, *Edmondia* sp., incomplete right valve, UNM 13,523, x 1. K, *Euphemites* sp., side view, UNM 13,524, x 2.5. L, *Bellerophon* (*Bellerophon*) cf. *B. (B.) graphicus* Moore, top view, UNM

13,525, x 3. M, N, *Amphiscapha subrugosa* (Meek and Worthen); M, fragment of upper surface, showing strongly rugose marginal keel, UNM 13,527, x 2.5; N, basal view, UNM 13,526, x 2. O, *Trepostira* cf. *T. illinoisensis* (Worthen), dorsal view of incomplete weathered specimen, UNM 13,528, x 2. P, *Glabrocingulum* (*Glabrocingulum*) sp., oblique side view of a partly crushed specimen, UNM 13,529, x 3. Q, *Phymatopleura brazoensis* (Shumard), oblique side view, UNM 13,530, x 4.5. R, S, *Hypergonia* n. sp.; R, side view of incomplete specimen, UNM 13,531, x 2; S, side view of last two whorls, UNM 13,532, x 2.75. T, *Naticopsis* (*Jedria*) *meeki* Knight, oblique dorsal view of weathered specimen, UNM 13,533, x 1.75. U, *Prodentalium* sp., crushed fragment, UNM 13,534, x 1.5. V, W, *Pseudorthoceras knoxense* (McChesney); V, apical end, UNM 13,535, x 2.5; W, cross section with septum and siphuncle, UNM 13,536, x 3.25. X–Z, *Eoasianites* aff. *E. angulatus* (Girty); X, side view, UNM 13,537, x 5; Y, apertural view, UNM 13,538, x 5; Z, side view of small specimen, UNM 13,539, x 5.

species of gastropods. The total number of species present exceeds 100, based on more than 2,000 specimens collected.

Brachiopods are well represented taxonomically and represent about one-half of the total number of specimens collected, but only a few species are common. The five most abundant species are *Crurithyris planoconvexa* (53%; Figs. 6W,X), *Neochonetes granulifer* (16%; Fig. 6E), *Kutorginella* aff. *K. lasallensis* (13%; Figs. 6H–J), *Composita subtilita* (6%; Figs. 6S,T), and *Neospirifer* cf. *N. dunbari* (4%; Figs. 6U,V). Together these species comprise 91% of all of the brachiopod specimens (excluding small fragments of *Isogramma* sp., Fig. 6A). The apparent dominance of this assemblage by *C. planoconvexa* is somewhat deceptive, as it is a very small species (most specimens are less than 6 mm long), and individuals tend to be concentrated in large numbers in thin shale horizons of bed 39. Similar high abundances of *Crurithyris* in thin shale units have been reported in other Late Pennsylvanian units elsewhere (e.g., Mudge and Yochelson 1962; Hickey and Younker 1981), where this genus has been interpreted as a eurytopic opportunistic taxon, responding to transitory fluctuations in an unstable marine environment.

Four of the five most abundant brachiopod species (and many of the less common Holder species as well) are typical constituents of other Virgilian faunas in New Mexico (e.g., Kues 1996, 2004), but *Kutorginella* aff. *K. lasallensis* has not been reported previously from New Mexico. The Holder specimens attain a maximum valve width of approximately 35 mm and are characterized by a strongly convex pedicle valve, especially posteriorly, so that the beak and umbo extend considerably beyond the hingeline. This valve also bears a pronounced, narrow median sulcus, and ornamentation consists of regular, even, closely spaced radial costellae (5–6 costellae/5 mm), many small spines across most parts of the valve and some larger spines on the anterior trail, and low, concentric rugae across the visceral disc. The Holder specimens are possibly conspecific with *K. lasallensis* (Worthen), which is common in the Virgilian of the Midcontinent region (e.g., Dunbar and Condra 1932; Mudge and Yochelson 1962), but appear to attain a larger size, have slightly coarser radial costellae, and have less conspicuous rugae than the Midcontinent representatives of that species. The west Texas upper Gaptank/Neal Ranch species *K. uddeni* Cooper and Grant (1975) is also similar but is smaller, has a less pronounced median sulcus, and has a more anterior point of maximum pedicle valve convexity compared with the Holder species. The abundance of *K. aff. K. lasallensis* in these Holder beds, and its apparent absence in all other Virgilian strata in New Mexico, for which the faunas are reasonably well known, is curious. This distribution per-

haps reflects adaptation to some subtle environmental condition not present elsewhere in the state, or a southern pattern of biogeographic dispersal through Texas and southern (but not northern) New Mexico from the Midcontinent area during the Late Pennsylvanian.

Several other productoids are present in this assemblage, but they are much less common than *Kutorginella* aff. *K. lasallensis*. These include the much larger *Reticulatia americana* (Dunbar and Condra 1932; Fig. 6K), the tiny *Cancrinella boonensis* (Swallow) (Fig. 6O), *Hystriculina wabashensis* (Norwood and Pratten) (Fig. 6G), and the spinose species *Parajuresania nebrascensis* (Owen) (Fig. 6L) and *Pulchratia* aff. *P. meeki* (Dunbar and Condra) (Figs. 6M,N). All but the last of these species are common constituents of Virgilian faunas in New Mexico. Most of the other brachiopod species in this assemblage are illustrated in Figure 6.

Bivalves, although taxonomically fairly diverse, are far less abundant than either brachiopods or gastropods, and account for less than 6% of the total brachiopod and mollusc specimens in the assemblage. Valve fragments of the large myalinid *Myalina* (*Orthomyalina*) *subquadrata* Shumard (Figs. 7C–E) represent nearly one-half of the total bivalve specimens collected. Although their exact stratigraphic horizon was not located, these valves probably originated from a thin horizon in the upper part of bed 39. Thin but dense *Orthomyalina* beds are present in Virgilian units in New Mexico (e.g., Kues 1996, 2004), in the Midcontinent region (e.g., Newell 1942; Olszewski and Patzkowsky 2001), and in north-central Texas (e.g., Lobza et al. 1993). They attained high population densities on muddy substrates in quiet, nearshore, shallow-marine environments and typically were among the first epifaunal invertebrates to enter an area during the beginning of a marine transgression. Small to tiny nuculoids (Figs. 7A,B), *Edmondia* (Fig. 7J), and several pectinid genera (Figs. 7F–H) comprise most of the remainder of the bivalve taxa in this assemblage. The two most abundant bivalves in the *Retispira–Polidevcia* assemblage, *P. arata* and cf. *Sedgwickia topekaensis*, are present in beds 39 and 40 but are rare.

Gastropods are abundant and rich in species in this mixed marine assemblage, but many of the specimens and taxa were obtained from a bulk sediment sample screen-washed for microgastropods. More than one-half of the total of nearly 600 gastropod specimens examined for this study, and about 40% of the 40+ species (Table 2) were restricted to this sample. The Holder gastropods are being studied separately and will be described elsewhere; here the discussion and figures of gastropods are of the more common and characteristic larger species.

In general, because of their relatively small to microscopic sizes, gastropods are

not nearly as conspicuous on the outcrop as brachiopods. Furthermore, no one species is particularly abundant. The bellerophonoid *Euphemites* sp. (Fig. 7K), the microgastropod *Donaldina stevensana* (Meek and Worthen), and the flat, discoid species *Amphiscapha subrugosa* (Meek and Worthen) (Figs. 7M,N) are the only taxa comprising 10% or more of the total gastropod specimens (Table 2). Several other bellerophonoids, including *Bellerophon* (*Bellerophon*) cf. *B. (B.) graphicus* Moore (Fig. 7L), are present, which, together with *Euphemites* sp., account for a total of 28% of the gastropod specimens. As is typical of Pennsylvanian faunas rich in gastropods, pseudozygopleurids are represented by numerous taxa, but each is uncommon and together they account for only about 7% of the total gastropod specimens. “Pleurotomarioid” taxa, such as *Trepsira* cf. *T. illinoisensis* (Worthen) (Fig. 7O), *Phymatopleura brazoensis* (Shumard) (Fig. 7Q), and especially *Glabrocingulum* (*Glabrocingulum*) sp. (Fig. 7P) and *G. (Ananias)* spp. comprise about 20% of the gastropods collected. Interestingly, the high-spined, selenizone-bearing goniasmid taxa *Goniasma* and *Taosia* that are relatively common in the *Retispira–Polidevcia* assemblage were not observed in beds 39 and 40, although a related form, *Hypergonia* n. sp. (Figs. 7R,S), that is rare in bed 31 is more abundant in the bed 39–40 collections. Moderately large but poorly preserved taxa such as *Naticopsis* (*Jedria*) *meeki* Knight (Fig. 7T) and at least two species of *Strobeus* are moderately common in the bed 39–40 assemblage.

Other molluscs are rare to uncommon. A few fragments of the large scaphopod *Prodentalium* (Fig. 7U) were collected, as well as the nautiloids *Pseudorthoceras knoxense* (McChesney) (Figs. 7V,W) and *Metacoceras*. Specimens of a small (maximum diameter approximately 5 mm) ammonoid are also present in this assemblage. This species, *Eoasianites* aff. *E. angulatus* (Girty) (Figs. 7X–Z), is characterized by a large umbilicus bordered by a sharp carina, transverse grooves across the broadly convex venter, and lacks ornamentation. These specimens do not appear to be conspecific with any of the species described by Miller (1932) from the Laborcita Formation at the Tularosa clay pit locality. Furnish and Glenister (1971, p. 310) noted that most of the small ammonoids from the clay pit are immature shells referable to *Eoasianites*, that they show great variability, and that so “many names have been proposed for such specimens that no meaningful specific assignments can be made.” My collections from that locality do include a few that approach the Holder specimens in morphology, although they are generally significantly larger.

As noted above, the large number of species representing most major Pennsylvanian invertebrate groups collected from beds 39 and 40 probably represent at least

two distinct assemblages that cannot yet be separately characterized. Taken together, this “mixed marine assemblage” reflects a transgressive episode that brought nearshore and opportunistic marine taxa into this area in an environment of dark-gray muds (bed 39) shed from the nearby Pedernal uplift. Siliciclastic input then waned briefly, and marine carbonate environments became temporarily reestablished during the time of deposition of bed 40 thin limestones. These limestones likely represent more offshore conditions of stable salinity, conducive to colonization by a wide variety of stenohaline invertebrates.

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