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INVERTEBRATE PALEONTOLOGY OF THE BURSUM FORMATION TYPE SECTION (LATEST PENNSYLVANIAN), SOCORRO COUNTY, NEW MEXICO

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ABSTRACT.— The type section of the Bursum Formation (traditionally of earliest Permian age but latest Pennsylvanian by a recent proposed relocation of the boundary) in eastern Socorro County, NM, contains a moderately diverse megafauna (33 taxa identifiable at least to generic level) and the "algal biscuit" *Ottonosia*, all of which are described here. Although some fossils from the Bursum elsewhere in central New Mexico were studied long before the formation name was coined in 1946, this study adds numerous taxa to those previously known from the formation. Marine invertebrate assemblages occur in beds about 7, 49, 67, and 80 m above the base of the 85-m-thick Bursum type section, and each assemblage is distinctive in its taxonomic composition. The basal assemblage consists mainly of hematized bivalve shells, chiefly *Septimyalina*, representing a wave-concentrated nearshore assemblage. The next highest assemblage is dominated by moderately diverse brachiopod taxa, especially the large productoid *Reticulatia*, which lived in a shallow, open-shelf, probably offshore environment. The third assemblage contains the highest number of species, mainly brachiopods and bivalves in approximately equal abundance, and probably lived in shallow, open-shelf but nearer shore environments. The highest assemblage, near the top of the Bursum, contains bivalves and gastropods almost exclusively, with stenohaline groups absent, and may have lived in a lagoon subject to fluctuating salinity. In general, the fauna of the Bursum type section is not greatly different from underlying Virgilian faunas in New Mexico.

INTRODUCTION

The Bursum Formation was defined by Wilpolt et al. (1946) in central New Mexico as a sequence of purplish-red and green shale beds, separated by thinner beds of arkose, arkosic conglomerate, and marine limestones. The formation represents a transition between underlying, predominantly marine Pennsylvanian strata of the Atrasado and age-equivalent formations, and overlying, nonmarine red clastics of the Abo Formation (e.g., Read and Wood, 1947; Kottlowski, 1960). Since the time of its first description the Bursum has been considered as Wolfcampian (Early Permian) in age, based on the presence of fusulinaceans such as primitive species of *Schwagerina* and advanced forms of *Triticites* (e.g., zone PW-1 of Wilde, 1990). Although Wilpolt et al. (1946) designated a type section, little detailed information about it was published until Lucas et al. (2000) described the section and documented the fusulinacean record in detail. In the meantime, the Bursum Formation had been recognized elsewhere in central New Mexico (e.g., Kottlowski, 1960), and the term Bursum also began to be used as a chronostratigraphic unit (e.g., Thompson, 1954), eventually resulting in a proposal (Ross and Ross, 1994) to establish a "Bursumian" Stage between the Virgilian (Late Pennsylvanian) and Wolfcampian (Early Permian) stages (see Lucas et al., 2002; Wahlman and King, 2002, for summary and discussion).

A recent proposal to raise the Pennsylvanian-Permian boundary in the Midcontinent region (Baars et al., 1994, refined by Sanderson et al., 2001) has the effect in New Mexico of removing the Bursum interval from the basal Permian (Wolfcampian) to the uppermost Pennsylvanian (Virgilian), if the concept of "Bursumian" Stage is abandoned, as is advocated by Lucas et al. (2002). In the Midcontinent, fusulinacean assemblages similar to those of the Bursum are present in the Admire and lower Council Grove Groups, and extend to the higher Pennsylvanian-Permian boundary advocated by Sanderson et al. (2001; see also Wahlman, 1998). In the Robledo Mountains of New Mexico, fusulinaceans characteristic of the Bursum interval are present in a "Bursum-equivalent limestone unit" immediately below the basal limestone of the Hueco Group (Wahlman and King, 2002), which was considered to be of earliest Wolfcampian age. Further, the uppermost Panther Seep Formation (just below the Hueco Group) in the southern San Andres Mountains contains a fauna that appears to be slightly younger than Bursum faunas, and of early Wolfcampian rather than late Virgilian age (Kues, 2002). Thus, the significance of the stratigraphy and paleontology of the Bursum type section transcends the relatively restricted outcrop of this formation in central New Mexico. In this paper, the age of the Bursum faunas is considered latest Virgilian, in accord with recent work on the age of correlative faunas in other areas.

As noted above, the fusulinaceans of the Bursum Formation type section are now well known, but little information on the macroinvertebrate faunas of the Bursum has been reported since the formation was first recognized. Study of the Bursum type section has yielded marine invertebrates from several beds, ranging from near the base to near the top of the formation. These were briefly discussed by Kues (in Lucas et al., 2000), Kues et al. (2000), and Lucas et al. (2002, this volume), and are described in more detail and figured in this paper. All specimens discussed here are reposited in the paleontology collections of the New Mexico Museum of Natural History (NMMNH) in Albuquerque, NM.

LOCATION AND STRATIGRAPHY

The type section of the Bursum Formation is in the Hansonburg Hills, at NE1/4SE1/4 sec. 1, T6N, R4E, in eastern Socorro County (Fig. 1). The formation crops out as a NW-SE-striking band of strata that dip about 25 degrees to the NE (Lucas et al., 2000). The Bursum here is regarded as the uppermost formation of the Madera Group (Myers, 1973; Kues, 2001), and overlies what many earlier workers called the "upper arkosic limestone member" of the Madera Formation, but which is better considered the Atrasado Formation of the Madera Group (Kues, 2001). The Bursum is overlain by the Abo Formation, a nonmarine red-

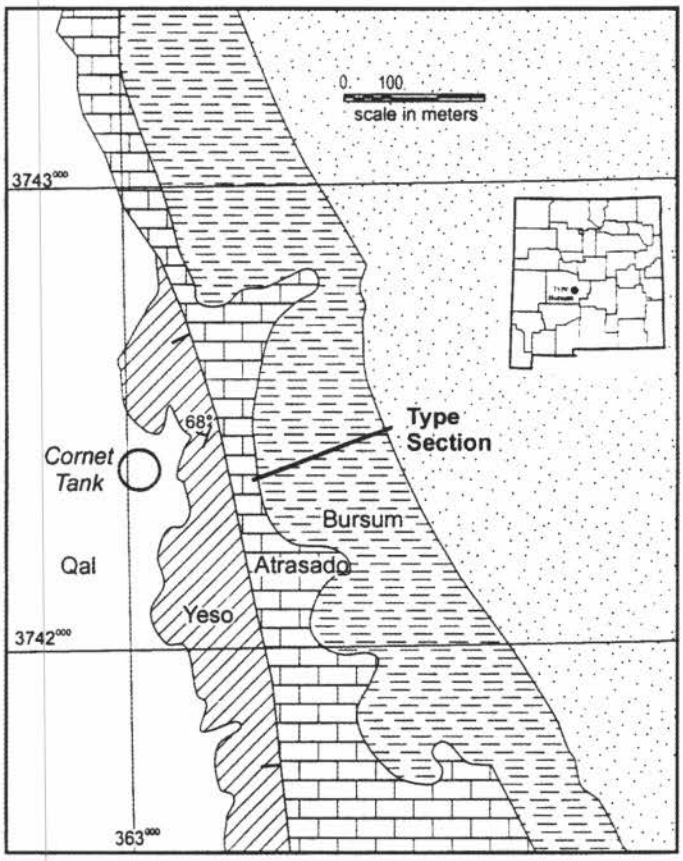

FIGURE 1. Geologic map of the area of the type section of the Bursum Formation (after Lucas et al. (2000).

bed clastic sequence, with the boundary placed at the contact between a thin red shale unit above the highest marine limestone of the uppermost Bursum, and a prominent red-brown, cross-bedded sandstone unit of the basal Abo (Lucas et al., 2000).

The type section of the Bursum (Fig. 2) is an 85-m-thick sequence composed mainly of slope forming, apparently unfossiliferous, red, grayish-red and pale brown shale and mudstone, some beds of which contain limestone nodules. Marine limestone beds are thin, gray, ledge-forming units that in total comprise about 19% of the thickness of the section (Lucas et al., 2000). Minor beds of conglomerate, sandstone, and calcarenite are also present. Lucas et al. (2000, 2002) discussed additional details of the stratigraphy.

The Bursum type section includes both marine and nonmarine depositional environments. In broad terms, the thin limestone units containing marine invertebrates and fusulinaceans were probably deposited in shallow, open-shelf to possibly lagoonal environments (see below) of relatively short duration, during times of reduced influx of fine-grained terrigenous siliciclastic sediments from nearby land areas. At this time, large volumes of clastic sediments were being eroded southward from the Uncompahgre uplift in northern New Mexico, and, to a lesser extent, westward from the Pedernal uplift, to the east of the Bursum type section (e.g., Jordan, 1975; Mack et al., 1995; Ye et al., 1996), progressively moving the shoreline southward from Virgilian to Wolfcampian time. In the area of the Bursum type section,

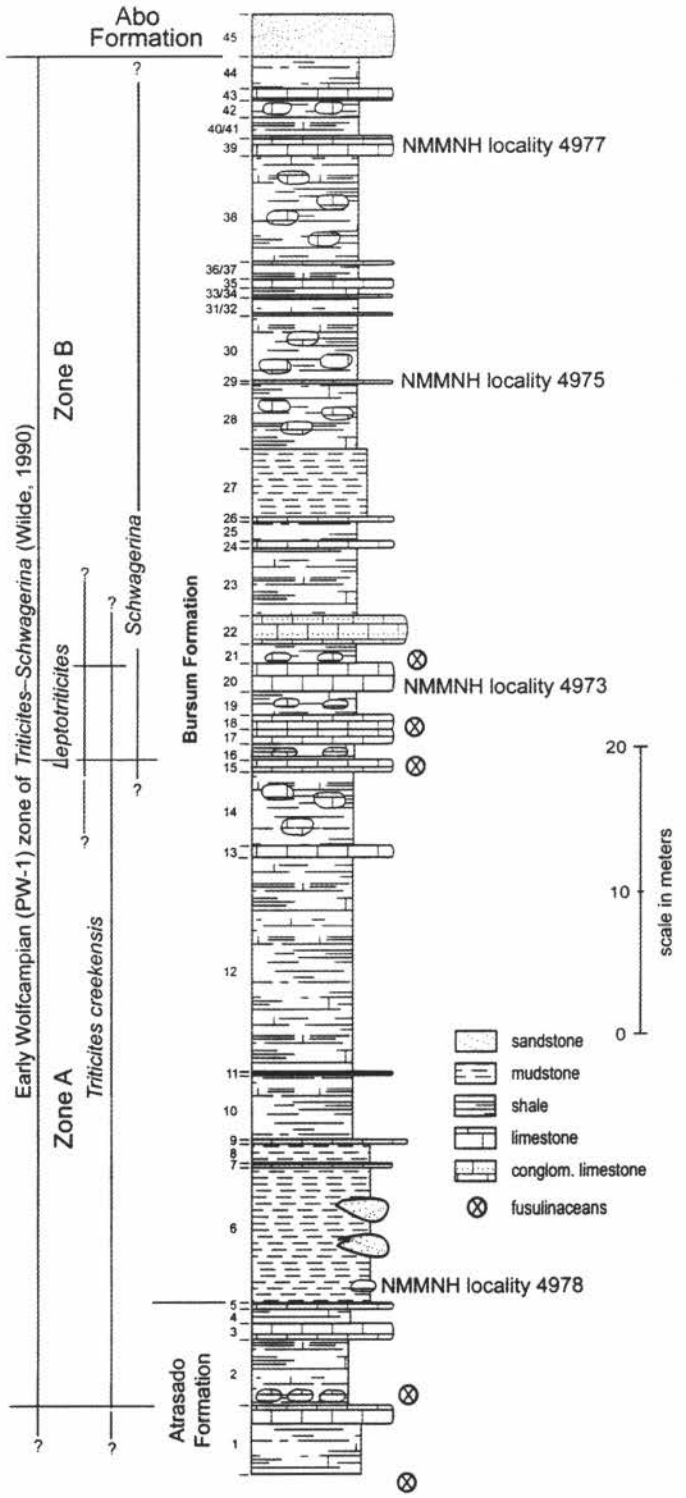

FIGURE 2. Type section of the Bursum Formation, showing beds yielding fusulinaceans and the invertebrate and algal taxa (NMMNH localities) discussed in this paper (from Lucas et al., 2002).

variations in tectonic activity and rates of erosion, coupled with migration of streams and rivers carrying sediment to the shoreline, as well as constantly changing shoreline configurations, likely resulted in local fluctuations in the volume of siliciclastic sediments being delivered by the rivers to coastal plain and adja-

cent shallow marine environments. During times of increased siliciclastic sediment input, finer-grained terrigenous sediment prograded across shallow, marine-shelf limestones, and built up to and then above sea level, where deposition occurred in tidal flat, floodplain, and similar environments. During times of reduced terrigenous sediment input, shallow marine environments could transgress into the area, producing the next thin marine limestone unit. During the time of Bursum deposition, the buildup of terrigenous, siliciclastic sediments ultimately proved to be the dominant pattern, culminating in deposition of the thick, clastic, nonmarine, red-bed sequence of the Abo Formation that overlies the Bursum.

PREVIOUS WORK

Long before the Bursum was recognized as a distinct lithostratigraphic unit, Girty (1909; see also Lee, 1909) reported numerous invertebrate taxa from marine strata then considered to represent the basal part of the Abo Sandstone at three localities in central New Mexico. At two of these localities, Abo Canyon (lot 3757a of Girty, l909) and Mesa del Yeso (lot 3751of Girty, 1909), the basal Abo fossils were without doubt derived from strata now included within the Bursum Formation. The third locality (lots 3796, 3797, and 3798 of Girty, 1909), in the northern Sandia Mountains near the former town of Tejon (7 km northeast of the present town of Placitas), probably included fossils from a thin transitional zone between upper marine units of the Pennsylvanian Wild Cow Formation (Madera Group) and the overlying nonmarine Abo Formation. These strata were studied by Lucas et al. (1999), who referred them to the uppermost part of the Wild Cow Formation; they are stratigraphically equivalent to the Bursum Formation farther south. Lee (1909, p. 19), in his stratigraphic section at this locality, provided a short list of taxa that he attributed to the Yeso Formation, but all of these taxa were cited by Girty (1909) as having been collected from the basal Abo. Curiously, in contrast to the complete lists of taxa provided for the basal Abo at Abo Canyon and Mesa del Yeso, Lee's (1909) list for the northern Sandia Mountains included only about half of the taxa reported for the basal Abo from this locality by Girty (1909), who reported no collections from the Yeso. It is difficult to explain this discrepancy; perhaps collections from the "basal Abo" and the Yeso were mixed, or there was a miscommunication between Lee and Girty concerning the provenance of these collections.

Taxa reported by Girty (1909) from strata now considered Bursum or Bursum-equivalent at these three localities are listed in Table 1, with modern names applied to some taxa as appropriate. Only a few of these taxa were figured by Girty (1909).

Very few of Girty's specimens from these localities have been restudied, and no subsequent general studies of Bursum invertebrates have been published. Newell (1942), in describing *Myalina apachesi* Marcou under the new name *Septimyalina burmai*, noted the occurrence of this species from the Abo Sandstone about 50 ft above the base of the red beds in Abo Canyon, and figured (pl. l2, fig. 6) one of Girty's (1909, pl. 9, fig. 6) specimens. Also, Newell (1942, p. 60), in his discussion of *Myalina (Orthomyalina) subquadrata* Shumard, noted that "M. L. Thompson contributed typical representatives of the species from the upper Magdalena limestone of central New Mexico, where it is associated with species of *Schwagerina*." This is almost certainly a reference to strata now called the Bursum Formation, as the fusulinacean *Schwagerina* occurs in the Bursum but not in the underlying Pennsylvanian limestones.

Miller and Youngquist (1949, p. 25, pl. 35, figs. l-3) discussed and figured, as *Mooreoceras* sp., the nautiloid specimen that Girty (1909, p. 112, pl. 12, figs. 2-2b) had described as *Orthoceras* sp., from about 50 ft above the base of red beds at the head of Abo Canyon. These authors (Miller and Youngquist, 1949, p. 40, 66) also discussed Girty's *Temnocheilus* sp. a, and referred it probably to *Stearoceras*. Among gastropods described by Girty (1909) from the "basal Abo", Winters (1963, p. 45) briefly discussed *Naticopsis deformis* and considered that two species are represented in the type lot, neither of which is recognizable. He restricted the name *N. deformis* to one of Girty's specimens (figured as pl. 11, figs. 9, 9a, from the San Andres Formation), leaving the other (Bursum) specimen (pl. 11, figs. 8, 8a) as an unnamed species of *Naticopsis*. Batten (1989) made Girty's *Phanerotrema manzanicum* the type species of a new genus, *Manzanospira* (but based on San Andres Formation specimens rather than a questionable Bursum specimen), and other workers have modernized some of the names Girty applied to gastropods (see Table 1) but without restudy of his specimens.

A few other authors (e.g., Bachman, 1968) have made passing mention of the presence of some groups of invertebrates in the Bursum, but added nothing to the work of Girty (l909). The present study is thus the first general treatment of Bursum invertebrate faunas in nearly a century, and aside from occasional taxonomic revisions of a few species provides the first new information on these faunas in more than a half century. The fauna of the Bursum type section is also important because it is from a location that Girty did not sample, and because it is relatively diverse and includes numerous taxa not previously known from the Bursum Formation. Focusing initially on the fauna of the Bursum type section also provides a convenient reference point for further studies of Bursum faunas in other areas of central New Mexico that are currently under way.

FAUNAL ASSEMBLAGES AND AGE RELATIONSHIPS

The 85-m-thick Bursum type section contains four limestone intervals yielding marine invertebrates, in addition to other units producing only fusulinaceans or which appear to be marine but lack identifiable fossils. These intervals are at the base of unit 6, units 19 and 21, unit 29, and unit 39, which are approximately 7 m, 49 m, 67 m, and 80 m, respectively, above the base of the Bursum (Fig. 2). A few additional fossils were collected as float from unit 14, but their exact provenance in the section is not known. The taxa collected from each of these beds are listed in Table 2.

The assemblage from the base of unit 6 is in a thin (5-cm-thick) limestone containing a dense coquina of hematized bivalve shells and bioclastic debris, locally with a few hematitic nodules and weathered limestone pebbles. Most of the bivalve shells are *Septimyalina burmai*, often perforated by probable sponge borings. Occasional fragments of *Aviculopecten*, *Aviculopinna*, and

TABLE 1. Invertebrate taxa reported by Girty (1909) from lower Abo Formation strata now included in the Bursum Formation or Bursum-equivalent units. Modern names are in brackets, and figures of taxa from these localities given by Girty (1909) are included. Localities are l, northern Sandia Mountains; 2, Abo Canyon; 3, Mesa del Yeso.

SPECIES	1	2	3
CNIDARIA			
*Lophophyllum?*sp. [*Lophopyllidium?* sp.]		X	
BRYOZOA			
Septopora cf. *robusta* Ulrich		X	
BRACHIOPODA			
Meekella striatocostata Cox (pl. 6, figs. 6-6b)		X	X
Productus cora d'Orbigny [*Linoproductus* sp.]	X	X	X
Productus nebrascensis (Owen) [*Juresania nebrascensis*] (pl. 7, figs. 5, 5a, 6, 6a)	X	X	X
Composita subtilita (Hall)		X	
BIVALVIA			
Edmondia gibbosa McCoy	X	X	X
Chaenomya leavenworthensis Meek and Hayden		X	X
Leda obesa (White) [*Polidevcia obesa*]		X	
Aviculipinna? *peracuta* Shumard [*Aviculopinna peracuta*]	?	X	?
A. nebraskensis Beede	?	X	
Monopteria marian White	X	X	
Pseudomontis hawni Meek and Hayden ?		X	
Myalina apachesi Marcou [*Septimyalina burmai* Newell] (pl. 9, figs. 6, 7)	X	X	X
Schizodus wheeleri Swallow ?	X	X	
Deltopecten occidentalis Shumard [*Aviculopecten occidentalis*]		X	
D. vanvleeti (Beede) [*Aviculopecten vanvleeti*]		X	
D. coreyanus (White) [*Aviculopecten*? *coreyanus*]	X	X	X
Allerisma capax Newberry [probably *Wilkingia terminale*]		X	
Allerisma terminale Hall [*Wilkingia terminale*]	X		
Pleurophorus mexicanus Girty [*Permophorus mexicanus*]	?		
P. bipartitus Girty [*Permophorus bipartitus*] (pl. 10, fig. 2)			X
P. aff. *taffi* Girty [*Permophorus* aff. *taffi*]	?	?	
P. aff. *oblongus* Meek [*Permophorus* aff. *oblongus*]		X	
P. aff. *subcostatus* Meek and Worthen [*Permophorus* aff. *subcostatus*]		X	
SCAPHOPODA			
Plagioglypta canna White [*Prodentalium canna*]	X		X
GASTROPODA			
Phanerotrema manzanicum Girty [*Manzanospira manzanicum*]	?		
Murchisonia? *terebra* White [*Goniasma terebra*]	?		
Euphemus subpapillosus (White) [*Euphemitopsis subpapillosus*]	?		
Bellerophon majusculus Walcott [*B. (Bellerophon)* sp.]	X		X
Patellostium aff. *nodocostatum* (Gurley) [*Retispira nodocostata*]	X	X	
Bucanopsis modesta Girty [*Retispira modesta*]		?	
Euomphalus sp. b	X		
Naticopsis deformis Girty [*Naticopsis* sp.] (pl. ll, figs. 8, 8a)	X	X	
Soleniscus aff. *altonensis* Worthen (pl. ll, fig. 6)		X	
NAUTILOIDEA			
Orthoceras sp. [*Mooreoceras* sp.] (pl. l2, figs. 2-2b)		X	
Temnocheilus sp. a [*Stearoceras* sp.]		?	

Schizodus were also observed within the coquina layer. Isolated specimens of the bivalves *Schizodus* and *Avuiculopinna*, the gastropod *Retispira*, the brachiopods *Derbyia* and *Meekella*, rhomboporoid bryozoans, and isolated crinoid columnals also were collected from this unit. These fossils represent a wave-concentrated nearshore marine assemblage, with a minor contribution from offshore stenohaline taxa that were washed inshore.

Units 19 and 21 are thin, gray, fine-grained, argillaceous limestones separated by a thicker limestone bed that yielded no fossils. This interval is characterized especially by large productoid brachiopods (*Reticulatia*) and the fauna consists almost entirely of a moderate diversity of brachiopods (Table 2) and a few bivalves, together with fusulinaceans (*Schwagerina*). This assemblage suggests a shallow, marine, relatively offshore shelf environment. One of the brachiopods, *Neospirifer*, in particular has been interpreted as a constituent of offshore communities in the late Paleozoic (e.g., Stevens, 1971; Rollins et al., 1979; Yancey and Stevens, l981), but large productoids and *Composita* (e.g., the dictyoclostid-*Composita* community of Yancey and Stevens, 1981, in Early Permian strata of Nevada) have been interpreted to

TABLE 2. Algal and invertebrate taxa from units in the Bursum type section, and numbers of specimens observed (for units 6, 14, 21, and 29) or subjective estimate of abundance for unit 39 (A = abundant; C = common; MC = moderately common; UC = uncommon; R = rare).

SPECIES	Unit 6	Unit 14	Unit 21	Unit 29	Unit 39
ALGAE					
Ottonosia sp.				11	
BRYOZOA					
Fenestrate fragments				1	
Rhomboporoid fragments	1			6	
BRACHIOPODA					
Orbiculoidea sp.				4	
Derbyia aff. *D. strophomenoidea*			1	7	
Derbyia sp. indet.	3			22	
Meekella striatocostata			1		
Meekella sp. indet.					
Neochonetes granulifer				93	
Juresania nebrascensis		2		42	
Reticulatia americana			36		
Hystriculina wabashensis			1		
Kozlowskia? sp.			1		
Linoproductus sp.			3		
Composita subtilita			3		
Neospirifer alatus			3		
BIVALVIA					
Nuculopsis aff. *N. girtyi*				2	
Nuculavus sp.					R
Polidevcia sp.					R
Parallelodon aff. *P. kansasensis*				18	
Aviculopinna peracuta	1		1	21	
Septimyalina burmai	C			70	C
Aviculopecten sp.	3			15	MC
Pseudomonotis hawni			2	1	
Schizodus aff. *S. ulrichi*	1				
Schizodus aff. *S. alpinus*	1			5	
Schizodus sp. indet.	1				
Permophorus cf. *P. tropidophorus*					C
Permophorus sp. indet.				10	C
Wilkingia terminale		1		2	
SCAPHOPODA					
Prodentalium? sp. indet.				1	
GASTROPODA					
Retispira aff. *R. tenuilineata*	1				
Retispira sp.					MC
Amphiscapha aff. *A. subrugosa*				15	
Goniasma lasallensis				9	MC
Stegocoelia (Hypergonia)? sp. indet.					R
Apachella? sp. indet.					C
Naticopsis sp. indet.					UC
CEPHALOPODA					
Mooreoceras sp. indet.				7	R
Ammonoid, indet.				1	
ARTHROPODA					
Trilobites, indet.				5	
ECHINODERMATA					
Crinoid stem fragments	1		1	3	

range from nearshore to relatively offshore, deeper-water, open-shelf environments. The fusulinaceans in this horizon may indicate more offshore than nearshore stenohaline environments (e.g., Stevens, 1971; Yancey and Stevens, 1981). Many of the fossils of this assemblage, especially larger specimens, have been subjected to expansion of the sedimentary matrix in which they are preserved, producing numerous cracks in the shells and a separation of the resulting shell parts, the so-called "exploded" preservation.

Unit 29 is a dark gray, brown weathering, argillaceous to micritic limestone, typically coarsely crystalline and locally very bioclastic. Concentrations of shells and shell fragments are locally present, and some samples of this limestone are composed chiefly of densely packed gastropod and bivalve steinkerns. This unit contains the most diverse marine assemblage observed in the Bursum type section. It is dominated by brachiopods and bivalves approximately similar in numerical and diversity abundances. *Neochonetes*, *Juresania*, and *Derbyia* are the three most abundant brachiopods, and *Septimyalina*, *Aviculopinna*, *Parallelodon*, *Permophorus*, and *Aviculopecten* are characteristic bivalves (Table 2). *Amphiscapha* is a moderately common gastropod, and other fossil groups, including scaphopods, cephalopods, bryozoans, crinoids, trilobites, and the alga *Ottonosia* are less common con-

good representation of stenohaline groups. *Ottonosia*, present in Early Permian strata of Kansas and Oklahoma, is also part of a diverse marine biota, including many of the genera observed in unit 29 of the Bursum type section (Toomey et al., 1988). These authors inferred a shallow, marine, low-energy lagoonal environment, possibly colonized by "sea grasses", that supported a brachiopod and bivalve fauna sufficient to provide ample numbers of shells for the encrusting alga to colonize.

The uppermost fossiliferous marine unit of the Bursum type section (unit 39) is a dark brownish-gray, tan weathering, slabby micritic limestone, with dense concentrations of mollusc shells and much bioclastic debris. Locally, quartz sand grains and small wood fragments are mixed with the shells. Successive thin layers of fossil shells accumulated in low-energy conditions, as indicated by the fact that bedding planes are typically covered with weathered, disarticulated, but frequently unbroken bivalve shells and large numbers of small gastropods. Except for one fragment of a crinoid stem, typically stenohaline invertebrates, such as brachiopods, bryozoans and echinoderms are absent from this assemblage. The most abundant bivalves are *Septimyalina* and *Permophorus*, with lesser numbers of *Aviculopecten* and nuculoid taxa. At least a half dozen gastropod taxa were observed, but most are preserved as unidentifiable steinkerns or as cross sections through shells visible on the bedding planes. Many of these are of moderate size (up to about 20 mm high), rather high spired, and have inflated whorls and deeply indented sutures. Some of these are probably *Apachella*. Poorly preserved *Goniasma*, *Naticopsis*, and small to relatively large specimens of the bellerophontid *Retispira* are also present on the surfaces of limestone slabs. The depositional environment appears to have been in a quiet, nearshore marine environment, possibly within an enclosed lagoon that experienced minor salinity changes sufficient to exclude the more stenohaline invertebrate groups. This assemblage marks the final regression of marine environments from the area of the Bursum type section, before the nonmarine red clastics of the Abo Formation prograded across it.

In general, the fauna of the Bursum type section mainly includes taxa that also occur in underlying Virgilian strata of New Mexico (e.g., Kues, 1996), or are closely related to such taxa. Exceptions include the "algal biscuit" *Ottonosia* and the brachiopod *Derbyia* aff. *D. strophomenoidea*, which seem to be limited to early Wolfcampian strata. Many of the brachiopods and bivalves also occur in the Midcontinent region, where they typically range through upper Pennsylvanian and some into lower Wolfcampian strata (revised boundary). All things considered, little change in marine invertebrate faunas occurred from the time of deposition of underlying marine units (Atrasado Formation) to the time the Bursum type sequence was deposited in central New Mexico. More significant faunal differences are present between the Bursum Formation and overlying Hueco Group (e.g., Kues, 1995). Units coeval with the Bursum, such as the Laborcita Formation to the southeast, and the Red Tanks Formation to the west, although incompletely studied at present, appear to contain more diverse invertebrate faunas. This greater diversity probably reflects significant differences in the depositional environments preserved in these formations.

SYSTEMATIC PALEONTOLOGY

Identifiable invertebrate and one algal taxa from the Bursum type section are described below.

Algae

***Ottonosia* sp.**

Unit 29 contains modest numbers of irregularly shaped and variously sized algal growths (Figs. 3A, B), or "algal biscuits" named *Ottonosia* (Twenhofel, 1919). These structures are encrusting, microstromatolitic communities that also include encrusting foraminifers, which grew on and around a nucleus, usually an invertebrate shell or shell fragment (Toomey et al., 1988). The surface of these algal biscuits is composed of low, digitate, domal or knobby structures, varying from closely to rather widely spaced and ranging from about 1.5 to 5 mm in diameter. Fine-grained calcareous sediment was deposited in the depressions between the knobs, and locally was incorporated within the growing algal community, which in cross section displays sequences of very fine lamellae. Most of these growths are small and irregular in shape, but the largest specimen is lensoid in shape, roughly circular in outline and about 45 mm in maximum diameter. The most common substrate for these growths are fragments of the valves of the brachiopod *Derbyia*, and in some cases the biscuits had grown over all surfaces of their substrate, completely covering it. The sediment that filled in between the knobs contain high numbers of small, unidentified, relatively high-spired gastropods, and occasional specimens of larger shells as well.

Algal biscuits of this type are well known from marine early Wolfcampian strata such as the Wreford and Herington Formations of Kansas and Oklahoma. Toomey et al. (1988; see for citations of earlier studies) studied large collections from the Herington and Krider limestones of the Midcontinent region and reported that *Ottonosia* is associated with a large variety of shelly invertebrates that lived on a muddy substrate in quiet, shallow marine environments. The Herington/Krider specimens colonized several different groups of invertebrates, though mainly myalinid bivalve shells, and many were bored by annelid worms and barnacles. As noted, the primary substrate of the Bursum specimens are *Derbyia* and no significant borings were observed. Possibly boring organisms were more abundant in the Midcontinent shallow, nearshore environments inhabited by myalinids than in these Bursum environments. However, like the Bursum specimens, those of the Midcontinent were preserved with many small gastropods in the low areas of their surfaces. The gastropods were probably grazing on the algae, as suggested by Toomey et al. (1988).

Bryozoans

Bryozoa are sparse and fragmentary in units 6 and 29. Most specimens are thin branches of rhomboporoids and small fragments of unidentified fenestrates.

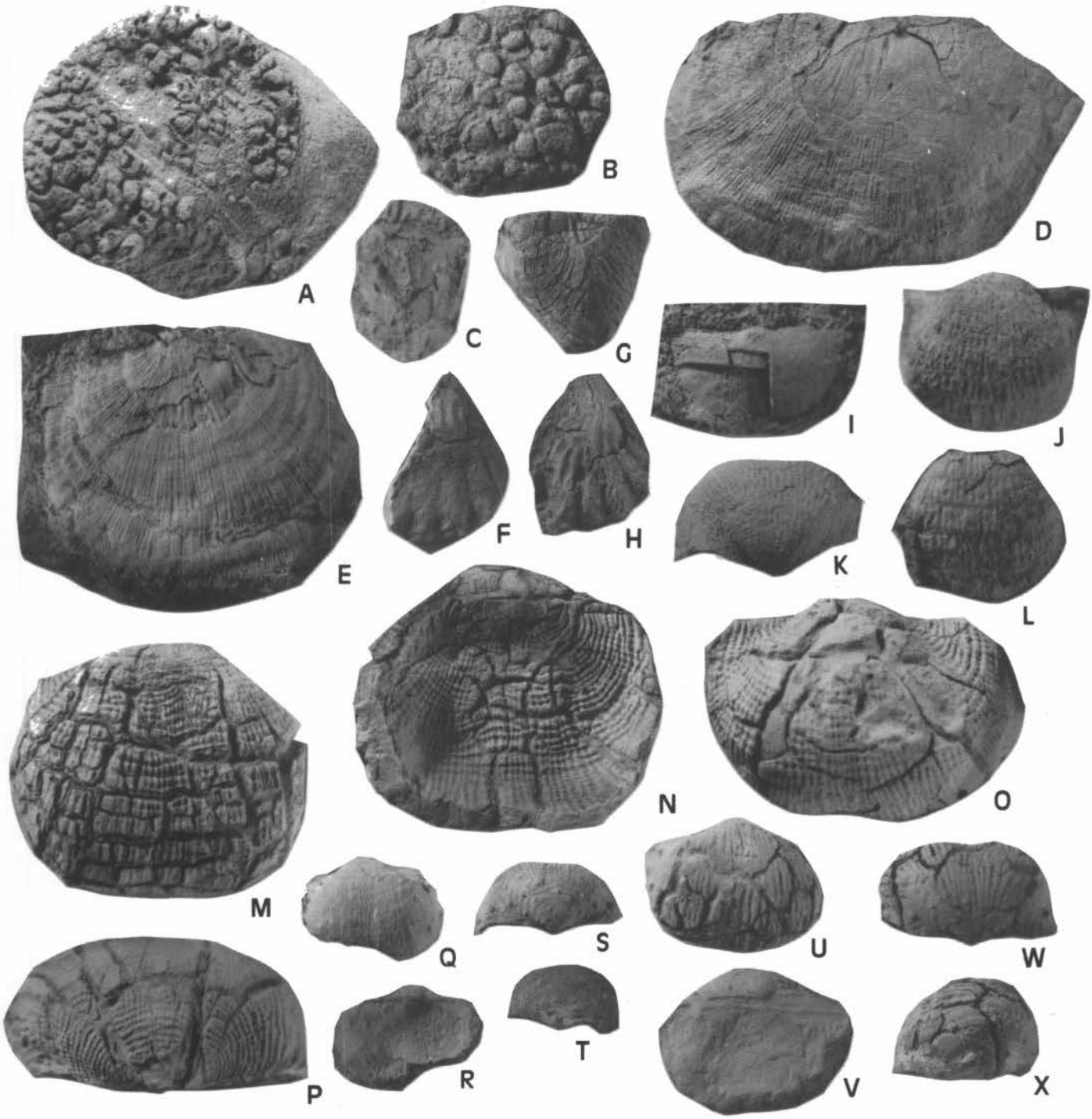

FIGURE 3. Algae (A, B) and brachiopods (C-X) from the type section of the Bursum Formation. **A, B,** *Ottonosia* sp.; A, dorsal view of surface of a large, subcircular specimen, P-35,246, unit 29, x1; B, dorsal surface of small specimen, P-35, 247, unit 29, x2. **C,** *Orbiculoidea* sp., dorsal view of a crushed, incomplete brachial valve, P-35,248, unit 29, x4.5. **D, E,** *Derbyia* aff. *D. strophomenoidea*; D, incomplete brachial valve, P-35,249, unit 29, x1; E, pedicle valve, P-35,250, unit 29, x1. **F-H,** *Meekella striatocostata*; F, G, brachial valve (x1.2) and side (x1.35) views of left half of a shell, P-35,251, unit 21; H, brachial valve, P-35,252, unit 6, x1. **I,** *Neochonetes granulifer,* incomplete pedicle valve, P-35,253, unit 29, x2. **J-L,** *Juresania nebrascensis;* J, pedicle valve surface, P-35,254, unit 29, x1; K, posterior view of pedicle valve, P-35,255, unit 29, x1; L, anterior view of pedicle valve surface, P-35,256, unit 29, x1. **M-P,** *Reticulatia americana*; M, N, posterior surface of pedicle valve and brachial valve view, P-35,257, unit 21, x1; O, posterior surface of pedicle valve, P-35,258, unit 21, x1; P, posterior view of pedicle valve, P-35,259, unit 21, x1. **Q-T,** *Hystriculina wabashensis*, pedicle valve surface, brachial valve view, posterior and side views of pedicle valve, P-35,260, unit 21, x1.5. **U-X,** *Kozlowskia*? sp., pedicle valve surface, brachial valve view, posterior and side views of pedicle valve, P-35,261, unit 21, x1.5.

Brachiopods

Orbiculoidea sp.

A few specimens of the inarticulate brachiopod *Orbiculoidea* (Fig. 3C) were collected from unit 29, but the preservation of their thin organophosphatic shells is poor within the surrounding coarsely crystalline limestone. The shells are circular in outline, small (3-4 mm in diameter) compared to most New Mexico Pennsylvanian specimens, and the brachial valves display the low, subconical form and fine concentric growth lines characteristic of the genus, but little more can be said about them. Although the genus is moderately common locally in the Pennsylvanian of New Mexico, and ranges into the Wolfcampian of the Midcontinent (Dunbar and Condra, 1932; Mudge and Yochelson, 1962), Cooper and Grant (1974) reported no specimens from the Permian of west Texas.

Derbyia aff. *D. strophomenoidea* Cooper and Grant

Remains of a large, wide *Derbyia* are present in units 21 and 29, but these are typically incomplete and distorted, and no specimens are available that would allow a full description. The largest specimen (Fig. 3D) is a nearly complete but exfoliated brachial valve that is about 65 mm wide and 39 mm long, with a transversely subrectangular shape. The valve is moderately convex, lacks a median sulcus, and attains its maximum thickness a little in back of midlength and its maximum width about at midlength. Ornamentation consists of fine radial costellae numbering about 7-8/5 mm near the center of the valve. An inferred pedicle valve of this species (Fig. 3E) is about 50 mm wide and 40 mm long, and is nearly flat. The cardinal area is not well preserved, but seems to be relatively low.

Without better specimens, precise characterization and identification is not possible. These Bursum specimens appear to closely resemble in size, valve proportions, outline, cardinal area, and ornamentation an uncommon species from the early Wolfcampian Neal Ranch Formation of west Texas described as *D. strophomenoidea* by Cooper and Grant (1974). *Derbyia carteri* Cooper and Grant, also from the Neal Ranch Formation, is similar to the Bursum specimens in general valve features but is a significantly smaller species. Aside from size, the differences between *D. strophomenoidea* and *D. carteri* seem minor. The Bursum specimens do not appear to be closely related to any of the several species of *Derbyia* described by Dunbar and Condra (1932) from the Upper Pennsylvanian and Wolfcampian of the Midcontinent region.

Small fragments of unidentified *Derbyia* valves are present in collections from units, 6, 21, and 29 of the Bursum type section.

Meekella striatocostata (Cox)

Meekella is present sparingly in units 6 and 21 of the Bursum type section. One half of a complete specimen from unit 21 (Figs. 3F, G) is 24 mm long, has strongly biconvex valves with an (apparently) high cardinal area, and had when complete about 10 relatively low, wide plicae on each valve that are well differentiated only on the anterior half of the valves. This specimen is not in any way different from typical specimens of *D. striatocostata* from Late Pennsylvanian and Early Permian strata of the Midcontinent described by Dunbar and Condra (1932). Most of the species recognized by Cooper and Grant (1974) from the Early Permian of west Texas are either considerably larger and/or have more numerous plicae than the Bursum specimens.

A second specimen of *Meekella,* from unit 6 (Fig. 3H), is specifically indeterminate but possibly represents a distorted example of *M. striatocostata*. It has a slightly sigmoidal shape, is unusually narrow, especially posteriorly, and possesses about 10 relatively high, sharp plicae.

Neochonetes granulifer (Owen)

The chonetoid *Neochonetes* (Fig. 3I) is abundant in unit 29, where it is locally present in dense, jumbled accumulations of valves. These valves, although rarely complete, are relatively small, most about 15 mm wide or less, and typically display transversely extended hingelines representing the widest part of the valve, producing relatively large width/length ratios of about 1.8 to 2.0. The pedicle valves are gently convex, lack a median sulcus, and possess several small, obliquely oriented spines along the hingeline on each side of the beak. The valve surfaces are ornamented with fine radial costellae, about 5/mm.

Virgilian and early Wolfcampian specimens of *Neochonetes* in the Midcontinent region (e.g., Dunbar and Condra, 1932) and in New Mexico (e.g., Sutherland and Harlow, 1967; Kues, 1996) belong to the *N. granulifer* (Owen) stock. *Neochonetes granulifer* is characterized by its subquadrate shape, but in many collections a more transverse morph having an extended hingeline and acutely pointed posterolateral tips is also present. These were considered a separate variety, *N. granulifer* var. *transversalis*, by Dunbar and Condra (1932) and referred to *N. "transversalis"* by Sutherland and Harlow (1967) and Kues (1996). Most of the Bursum specimens, in their relatively small size and high width/length ratio, trend towards *N. "transversalis"*, but more quadrate valves are also present in the unit 29 collections. Mudge and Yochelson (1962) and Spencer (1970) argued convincingly for treating these intergrading morphs as elements of a single variable species, *N. granulifer*, and that concept is followed here. Accurate counts of each morph were not made because most valves are incomplete, often lacking the lateral terminations of the hingeline that are the most conspicuous indicators of overall valve shape.

Juresania nebrascensis (Owen)

Juresania nebrascensis (Figs. 3J-L) is a relatively small productoid characterized by a strongly convex pedicle valve having steeply sloping lateral flanks, small ears, and a shallow median sulcus. The pedicle valve surface displays wide, concentric growth bands, each of which bears two ranks of spines, one consisting of larger suberect spines and the other of more numerous, shorter, finer, prostrate spines. The species ranges from the Desmoinesian well into the Wolfcampian in the Midcontinent region (Dunbar and Condra, 1932; Muir-Wood and Cooper, 1960; Mudge and Yochelson, 1962).

In the limestones of unit 29, where specimens are common, they are typically exfoliated, obscuring some details of the ornamentation, but appear to fall within the rather wide range of variation accepted for the species. The pedicle valve is a little wider than long, and the largest nearly complete Bursum specimen has a length of 29 mm and an estimated width of 31 mm.

Some marine facies of the coeval Red Tanks Formation, to the west of the Bursum type section, yield large numbers of *Juresania* specimens, but these attain a significantly larger size and may represent a new species. *Juresania* does not range above the earliest Wolfcampian in west Texas (Cooper and Grant, 1975, p. 1057), and likewise it is not present in the middle part of the Hueco in the Robledo Mountains (Kues, 1995).

***Reticulatia americana* (Dunbar and Condra)**

The large productoid *Reticulatia americana* (Figs. 3M-P) is the most conspicuous element of the unit 21 fauna but has not been found elsewhere in the Bursum type section. Most of the larger specimens are cracked because of sediment expansion, and none of the specimens are complete. The largest specimens attain a width of 70 to 75 mm and the length is 80% to 90% of the width. The pedicle valve is broadly convex, with maximum width a little anterior to the hingeline, and it possesses an obscure to shallow median sulcus. The valve margin outline is subquadrate to moderately transversely subrectangular, and the ears, broken off most specimens, appear to be of moderate size. The ornamentation of the posterior one-third of the pedicle valve includes fine (8-9/5 mm), closely-spaced, radial costae, crossed by stronger, sharp, concentric rugae, forming radially elongate nodes at the intersection points, and producing a rather coarsely reticulated pattern. The concentric rugae fade abruptly, leaving the anterior two-thirds of the pedicle valve with relatively high, rounded, closely-spaced costae that number 8-9/10 mm near the front of the anterior trail. Sparse small spine bases are present across the pedicle valve surface. The brachial valve is moderately concave, most of it displaying a finely nodose, reticulate pattern, with spines being absent.

These Bursum specimens agree well in all significant characters with Midcontinent (Dunbar and Condra, 1932) and west Texas (Cooper and Grant, 1975) early Wolfcampian specimens of *R. americana*. The development of a median sulcus is variable; some of the largest Bursum specimens lack the sulcus entirely, whereas it is a very shallow depression in other specimens. Muir-Wood and Cooper (1960) claimed that *R. americana* is synonymous with *R. huecoensis* (King), but later Cooper and Grant (1975) concluded that *R. huecoensis* is a separate species, characterized by a more strongly convex pedicle valve, finer reticulation and costae, and a more transverse outline. These differences from *R. huecoensis* also apply to the Bursum specimens of *D. americana.* Cooper and Grant (1975) described a few other early Wolfcampian species from the Neal Ranch Formation of west Texas. Of these, *R. robusta* Cooper and Grant differs from *R. americana* in having a more transverse outline and coarser anterior costae. *Reticulatia* sp. 1 of Cooper and Grant (1975) differs from *R. americana* in having coarser costae and a more pronounced median sulcus; and *Reticulatia* sp. 2 of Cooper and Grant (1975) differs in having unusually low, broad costae. A form similar to the Bursum species was described as *R.* aff. *americana* by Kues (1996), from the Missourian of north-central New Mexico.

***Hystriculina wabashensis* (Norwood and Pratten)**

One incomplete specimen of the small productoid *Hystriculina wabashensis* (Figs. 3Q-T) was recovered from unit 21. Most of the anterior trail has been broken away and the shell is exfoliated. This specimen is 16.5 mm wide, and has a strongly convex pedicle valve with a slight median sulcus and steep lateral flanks. The beak is small and barely overhangs the hingeline, and the ears are relatively wide. Ornamentation consists of fine radial costae, low, more widely-spaced posterior concentric rugae, and scattered spine bases. About 10 small spines occupy the umbo, a line of four spines is present at the base of the lateral flanks near the hingeline, with the spines becoming progressively larger distally, and widely scattered spines are present across the crest and anterior trail of the pedicle valve. The brachial valve is deeply concave, closely following the contours of the pedicle valve.

Hystriculina wabashensis ranges from the Pennsylvanian into the earliest Wolfcampian in the Midcontinent region (Dunbar and Condra, 1932; Mudge and Yochelson, 1962). The Bursum specimen has somewhat more spines than is typical of the species, but such variability was noted by Dunbar and Condra (1932, p. 235). This specimen was compared with *H. armata* Dunbar and Condra, a closely related species that occurs in large numbers in the middle Virgilian of north-central New Mexico (Sutherland and Harlow, 1967; Kues, 1996). That species tends to be a little smaller and to have a little higher, more convex pedicle valve with more steeply sloping lateral flanks and a deeper median sulcus, and to bear more numerous spines that are larger relative to the size of the valve. Spines are also typically present along the hingeline of *H. armata*, whereas they are absent from that area on the Bursum specimen. Another very similar species, *H. texana* Muir-Wood and Cooper, was considered a synonym of *H. armata* by Sutherland and Harlow (1967).

***Kozlowskia*? sp.**

One incomplete small productoid specimen (Figs. 3U-X) from unit 21 is questionably assigned to *Kozlowskia*. It is about 20 mm wide (missing part of the ears) and 16 mm long. The pedicle valve is strongly convex, most sharply posteriorly, so that the area of greatest curvature is slightly anterior to the hingeline, and the wide umbo considerably overhangs the hingeline. The lateral flanks are steep, and a shallow median sulcus is present. The pedicle valve has relatively coarse, well-developed radial costae but lacks concentric rugae on the posterior part of the valve. Sparse but relatively large spines are present, especially along the base of the lateral flanks, and a cluster of four occurs medially on the anterior trail. The brachial valve is gently concave, but probably curved sharply along its margins where it met the pedicle valve. This area has been eroded, but appears to reflect the characteristic *Kozlowskia* pattern of faster pedicle valve growth and production of several anterior trails at the valve margins in order to close the gap between the two valves (Cooper and Grant, 1975).

Although this specimen bears some resemblance to *Kozlowskia* in the strong posterior convexity of the pedicle valve, few large spine bases on the anterior trail, some indication of multiple trail development, and the absence of concentric rugae, the development of strong costae is not typical of the genus. Comparison with Missourian specimens of the common late Pennsylvanian species *K. splendens* (Norwood and Pratten) from north-central New Mexico (Kues, 1996) indicates a much more prominent median sulcus and finer, somewhat obscure costae in the latter species, as

is also the case with samples of *K. splendens* from the Midcontinent (Dunbar and Condra, 1932) and Appalachian (Sturgeon and Hoare, 1968) regions. Cooper and Grant (1975) described several species of *Kozlowskia* from the Wolfcampian of west Texas, but these species typically have alate ears, finer or more obscure costae, a subcircular rather than quadrate pedicle valve body, and smaller, more delicate shells. Related small productoids, such as *Elliottella* and *Costispinifera*, have more numerous spines developed along the costae. Compared with Bursum *Hystriculina wabashensis*, *Kozlowskia*? sp. is larger, with considerably coarser costae, a more posteriorly convex pedicle valve, lacks posterior rugae, and has a much less concave brachial valve. More definite assignment of this distinctive productoid must await discovery of additional, better preserved specimens.

***Linoproductus* sp.**

Poorly preserved specimens of *Linoproductus*, having a moderately large, gently convex pedicle valve with a shallow median sulcus, are present in unit 21 of the Bursum type section. The best preserved specimen (Fig. 4A) has an incomplete width of 46 mm and when complete the length of the valve probably approached its width. The pedicle valve is missing the lateral portions of the ears and much of the anterior valve, so exact shape and proportions cannot be observed. The pedicle valve is relatively low and slopes laterally at an angle of about 45 degrees to the plane of the commissure. The areas just above the hingeline are strongly wrinkled and no evidence was observed of any spines along the posterior margin of the valve. The umbo is not inflated and projects only a short distance beyond the hingeline. Ornamentation consists of fine radiating costellae, about 7/5 mm measured on the anterior trail, and displays only a few spine bases. The brachial valve is gently concave.

The specimens available are too incompletely preserved and too few in number to gain an adequate understanding of their morphology and they are not even tentatively referred to a species. *Linoproductus prattenianus* (Norwood and Pratten), the most common species in New Mexico Virgilian strata (e.g., Kues, 1996; Lucas et al., 1999), has a more strongly convex pedicle valve, typically lacks a median sulcus, and is much more spinose.

***Composita subtilita* (Hall)**

A few, incomplete, poorly preserved specimens of *Composita* from unit 21 (Fig. 4B) range in height up to about 30 mm, and possess a relatively narrow commissural fold and sulcus. They fall within the wide range of variation developed by the common Pennsylvanian-early Wolfcampian species *C. subtilita* in the Midcontinent and in New Mexico (see Grinnell and Andrews, 1964).

***Neospirifer alatus* Dunbar and Condra**

Large specimens of *Neospirifer alatus* occur sparingly in unit 21, although none are complete. The best preserved specimen (Fig. 4C) is 61 mm wide at the hingeline, which is the widest part of the shell, and has a moderately transverse, although not alate, outline. The fold and sulcus are rather wide but not strongly developed. The costae are conspicuously fasciculate and are strong and numerous on both the flanks of the valve, where they number about 30 on each side, and on the fold and sulcus, where they number about 20.

These specimens do not differ significantly from typical representatives of *N. alatus* (= *N. latus* of Dunbar and Condra, 1932; = *N. latus latus* of Spencer, 1967; see Sutherland and Harlow, 1973). The species was described originally from the Missourian of the Midcontinent (Dunbar and Condra, 1932), and Spencer (1967) reported its presence to the top of the Virgilian in Kansas. The typical late Virgilian-early Wolfcampian *Neospirifer* species in the Midcontinent is *N. kansasensis* (Swallow), which generally does not become as large as *N. alatus* and is further distinguished by its finer costae (40-45 on each flank) and considerably narrower, more sharply defined fold and sulcus. *Neospirifer pattersoni*, an endemic Virgilian species described from north-central New Mexico by Sutherland and Harlow (1967), is smaller, less transverse in shape, and has fewer lateral and fold/sulcus costae. None of the lower Wolfcampian species described by Cooper and Grant (1976) appear to be closely related to the Bursum species.

Bivalves

***Nuculopsis* aff. *N. girtyi* Schenck**

Two specimens of small nuculoid bivalves having strongly inflated valves were recovered from unit 29. The best-preserved specimen (Figs. 4D, E) has length = 13.2 mm, height = 8.3 mm, and articulated width = 10.1 mm. The umbos are greatly swollen and terminate in small, strongly incurved, opisthogyrate beaks situated near the posterior end of the valve. A round, shallow escutcheon is present below the beaks, and a shallow lunule extends along the anterior hingeline. The posterior margin is sharply convex, as is the anterior margin, both appearing somewhat pointed. The ventral margin is broadly and evenly convex, and ornamentation is limited to weak growth lines.

This species most closely resembles *Nuculopsis girtyi*, but has more inflated umbos, a more prominent lunule and escutcheon, and more sharply rounded anterior and posterior margins, as shown by comparison with specimens of *N. girtyi* from Desmoinesian (Kues, l984a) and Missourian-Virgilian (Kues, 1996) strata of New Mexico. These Bursum specimens differ from all of the nuculoids reported from the coeval Laborcita Formation (Kues, l991b), and appear to represent an unnamed species.

***Nuculavus* sp.**

The cross-sectional outline of a small nuculoid bivalve (Fig. 4F) was observed on the surface of a limestone slab from unit 39. The valve is subtriangular in outline, with nearly central beaks, and is 4.8 mm long and 5.2 mm high. It is similar in size and outline to specimens identified by Kues (l991b) as *Nuculavus levatiformis* (Walcott), from the Laborcita Formation of south-central New Mexico. A few isolated taxodont hingelines, possibly from this species or the previous one, were also observed among the bioclastic debris of unit 39.

***Polidevcia* sp.**

A cross section of a valve on the surface of a limestone slab from unit 39 (Fig. 4G) has the characteristic shape of *Polydev-*

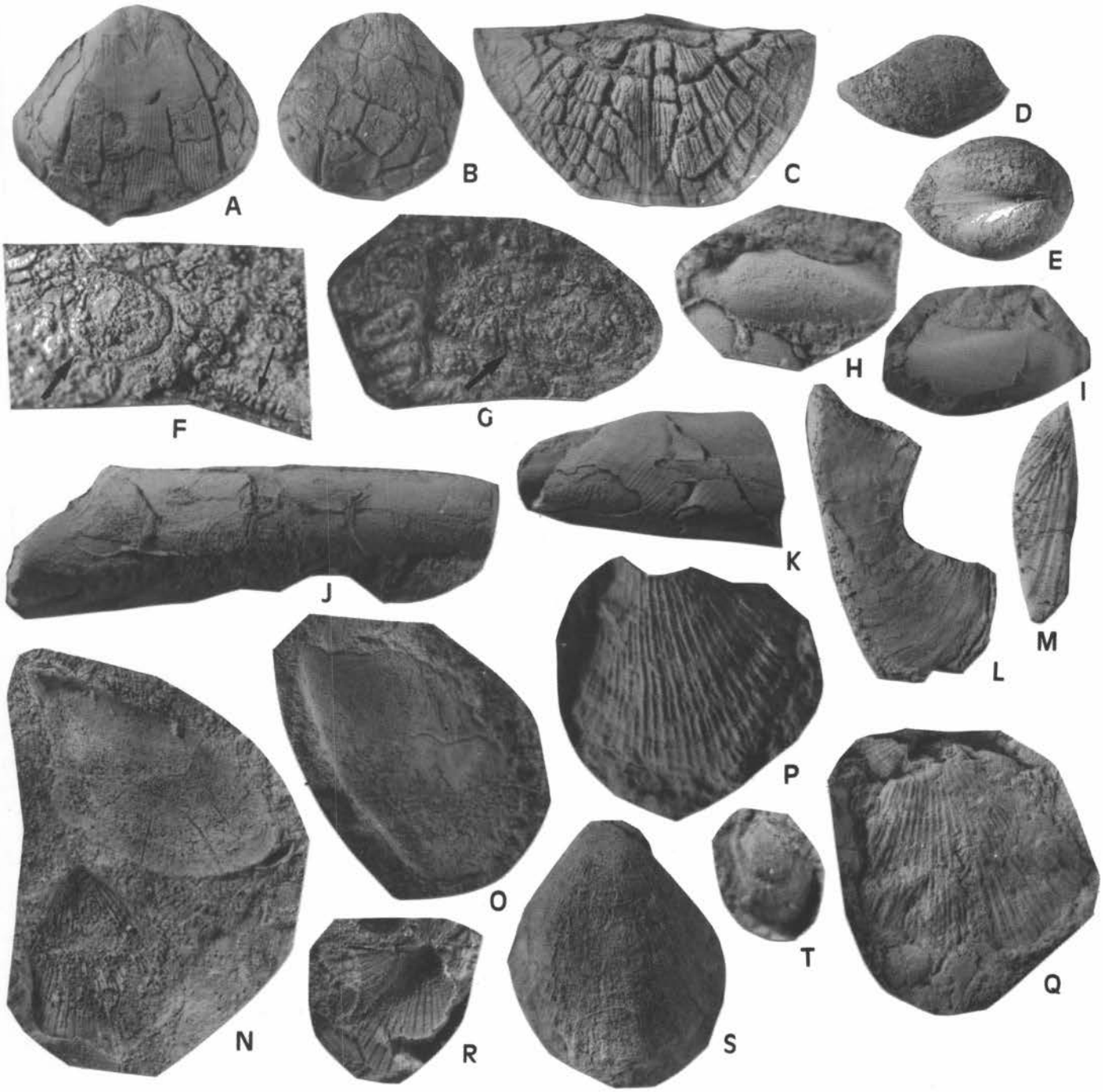

FIGURE 4. Brachiopods (A-C), and bivalves (D-T) from the type section of the Bursum Formation. **A,** *Linoproductus* sp., pedicle valve surface, P-35,262, unit 21, x1. **B,** *Composita subtilita*, pedicle valve, P-35,263, unit 21, x1.2. **C,** *Neospirifer alatus*, brachial valve, P-35,264, unit 2l, x1. **D, E,** *Nuculopsis* aff. *N. girtyi*, left valve and dorsal view, P-35,299, unit 29, x2.25. **F,** *Nuculavus* sp., cross section through valve (left arrow), P-35,265, unit 39, x3.5; note also isolated taxodont hingeline (right arrow) of unidentified nuculoid bivalve. **G,** *Polidevcia* sp., cross section through valve (arrow at ventral margin), P-35,266, unit 39, x2; note also steinkern of unidentified gastropod to left. **H, I,** *Parallelodon* aff. *P. kansasensis*; H, left valve steinkern, P-35,267, unit 29, x3; I, right valve steinkern, P-35,268, unit 29, x2.6. **J, K,** *Aviculopinna peracuta*; J, portion of right valve, P-35,269, unit 29, x1; K, portion of left valve showing ornamentation, P-35,270, unit 29, x1.1. **L-O,** *Septimyalina burmai*; L, incomplete isolated left valve, P-35,271, unit 29, x1.1; M, view of anterior margin, right valve, P-35,272, unit 29, x1. N, interior of right valve (upper), P-35,273, and interior of weathered left valve of *Aviculopecten* sp., unit 39, x1.8; O, external view of left valve, P-35,274, unit 39, x1.67. **P-R,** *Aviculopecten* spp., P, incomplete large left valve, P-35,275, unit 29, x1.67; Q, incomplete large left valve, P-35,276, unit 39, x2; R, interior view, incomplete small right valve, P-35,277, unit 29, x2.5. **S, T,** *Pseudomonotis hawni*; S, weathered left valve, P-35,278, unit 21, x1; T, juvenile left valve, P-35,279, unit 29, x4.

cia — a broadly convex anterior region, high beaks, and a low, extended posterior part of the valve that is acutely rounded at the posterior margin. Its length is 17 mm. No better preserved *Polidevcia* valves were observed in the Bursum type section, but the genus was reported from Bursum strata by Girty (1909), as *Leda*, and is not uncommon in the Laborcita Formation (Kues, 1991b), as well as in middle and upper Pennsylvanian strata in New Mexico.

***Parallelodon* aff. *P. kansasensis* Sayre**

Numerous steinkerns of a small, elongate bivalve related to *Parallelodon kansasensis* (Figs. 4H, I) are present in the limestone of unit 29. A typical specimen (Fig. 4H) is 11.5 mm long and 4.25 mm high, but fragments indicate some individuals attained a length of approximately 20 mm. This taxon is characterized by small prosogyrate beaks that rise well above the hingeline and are situated about one-quarter of the distance from the anterior to posterior margin. The anterodorsal margin is straight to slightly concave and curves sharply into a fairly acute anterior margin. The posterior umbonal ridge is well defined and descends at a low angle to meet the rather sharply rounded posterior margin. The posterodorsal region is depressed between the hingeline and the umbonal ridge, and extends a considerable distance before bending at an obtuse angle downward to meet the posterior margin. The ventral margin is gently convex. Few traces of shell material adhere to the steinkerns, but what is present indicates that the posterodorsal region has sharp, rather lamellate, comarginal growth increments, and the valve surface probably was ornamented with sharp, comarginal lirae with faint radiating lirae crossing them.

The Bursum specimens closely resemble *Parallelodon kansasensis*, described by Sayre (1930) from the Missourian of Kansas. That species differs in having a shorter, less produced anterior margin. A similar species, described by Bird (1968) from the Missourian part of the Gaptank Formation of west Texas, has a produced and relatively sharp anterior margin like the Bursum specimens, and similar ornamentation, but differs in having a less well developed posterodorsal region.

***Aviculopinna peracuta* (Shumard)**

The long, slender, gently tapering triangular shells of *Aviculopinna peracuta* are among the most distinctive fossils in the Bursum type section, occurring as fragments commonly in unit 29 and sparsely in unit 6. No complete specimens were collected, but the longest fragment (Fig. 4J) is about 85 mm long, with dorsal and ventral margins of the valves diverging at an angle of about 10 degrees. A shorter fragment (70 mm long) represents a later part of the shell, as the height and width of the cross section are about 35 mm and 25 mm, respectively. In cross sectional view, the articulated valves bulge laterally, but taper dorsally and ventrally to form compressed flanges along the length of the valves, both specific characters of the species. Unweathered valve surfaces are rarely preserved, but a few shell fragments display undulatory, relatively widely-spaced, fine transverse lirae along their length (Fig. 4K).

***Septimyalina burmai* Newell**

Septimyalina burmai (Figs. 4L-O) is common in units 6, 29, and 39, with isolated valves, mostly fragmentary, weathering free from the limestones of unit 29. This myalinid species is characterized by its strongly convex anterior umbonal ridge, obliquely prosocline valves, moderate size, and strongly lamellate valve surfaces. A nearly complete specimen, a left valve (Fig. 4L) is about 50 mm long along its anterior margin, and this is a typical size for specimens from the three horizons in which it is present.

Girty (1909) reported similar specimens, as *Myalina apachesi* Marcou, from all three of his lower Abo localities (Table 2). *Myalina apachesi* was initially described from strata near Pecos, New Mexico, now known to be of Virgilian age (Sutherland and Harlow, 1973, p. 2, 3). Newell (1942, p. 67) regarded *Myalina apachesi* Marcou as unrecognizable. He named a new species, *Septimyalina burmai*, for the common taxon present around the Pennsylvanian-Permian boundary in the Midcontinent region and elsewhere. Northrop (in Kelley and Northrop, 1975, p. 47) disagreed, advocating reviving Marcou's name, at least for Virgilian specimens. *Myalina apachesi* and *S. burmai* may be conspecific and occur both in Virgilian (e.g., Kues, 1996) and Wolfcampian (e.g., Kues, 1995) strata in New Mexico, including the Red Tanks Formation. Because Newell's name has been widely used, and Marcou's type specimens are apparently lost and his original description of *M. apachesi* was inadequate by modern standards, *S. burmai* is used here.

***Aviculopecten* sp.**

Aviculopecten is moderately common in units 6, 29, and 39 of the Bursum type section, but the specimens are invariably fragmentary and often are exfoliated or weathered, precluding identification to the species level. Two species appear to be present. The larger (Figs. 4P, Q) attains a height of about 30 mm, and the left valve is ornamented with rather widely-spaced radial costae of two ranks, the secondary costae intercalated early in growth between the slightly larger primary costae. Incipient nodes are present locally on a few primary costae, but no spines were observed. The second species (Fig. 4R) is smaller, and has two ranks of costae on the valve body and 10 or more fine radiating costellae on the posterior auricle. Some juvenile valves with widely spaced costae are also present.

***Pseudomonotis hawni* (Meek and Hayden)**

One large left valve of *Pseudomonotis hawni* (Fig. 4S) from unit 21 is identified, despite missing the auricles and being severely weathered. The valve body is roughly tear-drop shaped, rather convex, and is 43 mm high, with a length of 36 mm. Ornamentation consists of about 10 widely separated primary radiating costae having sparse nodes along their length, with three or four finer, slightly undulatory costellae between each pair of primary costae. Little of the original shell material remains, but it is sufficient to indicate the nature of the ornamentation, which, together with the size and shape of the valve, agree well with *P. hawni*. Girty (1909) and Newell (1937) reported this species from strata in New Mexico that are now considered the Bursum Formation, and it is common in the Early Permian of the Midcontinent region.

One tiny steinkern from unit 29 (Fig. 4T) represents a juvenile left valve of *Pseudomonotis*. It has a maximum length of 3.0 mm,

is 4.2 mm high, and is strongly inflated, especially in the umbonal region, which tapers dorsally to a small beak. The valve is nearly acline, with a slightly produced anterior auricle and a gently sloping posterodorsal margin that curves sharply into the posterior margin. Newell (1937) figured similar juvenile valves of several species of *Pseudomonotis*, and although the Bursum specimen is not itself diagnostic to species, I infer that it is a juvenile of *P. hawni*.

***Schizodus* aff. *S. ulrichi* Worthen**

Schizodus aff. *S. ulrichi* is a relatively elongate taxon (length/width = 1.25) with high, sharp, strongly prosogyrate beaks situated about 30% of the distance from the anterior to posterior margin. The best-preserved specimen (Fig. 5A), from unit 6, is articulated and preserves much of the shell. It is 27.9 mm long, 22.4 mm high, and 16.6 mm wide. The valves are strongly inflated at the umbos. The anterior margin is short and curves with broad convexity from the base of the umbo to the ventral margin, which is strongly convex. The posterior region of the valve is produced and terminates in an acutely convex posterior margin. The posterodorsal area is compressed, and the hingeline is slightly elevated to form a gently convex dorsal ridge. The posterior umbonal ridge is broadly rounded, gently arcuate from the umbo to the posterior margin, and bears a single small radial lira, across which the growth lines are sharply deflected anteriorly. Valve ornamentation includes very fine (5-6/2 mm) comarginal lirae that are best expressed and may be restricted to the anterior portion of the valve, becoming obscure posteriorly.

This species is similar to *Schizodus ulrichi*, a long ranging Pennsylvanian to Wolfcampian species (see Newell and Boyd, 1975), in numerous features: size, valve length/height ratio, general valve proportions including the acutely convex, produced posterior margin, nature of the beaks, and poor development of a distinct posterodorsal commissural ridge. Despite these similarities, the curvature of the posterior umbonal ridge, somewhat greater inflation of the umbos, and presence of fine comarginal lirae anteriorly suggest that this Bursum taxon is not *S. ulrichi*. *Schizodus texanus* Clifton is a similar Wolfcampian to Guadalupian species that displays anterior ornamentation like that of the Bursum specimen, but possesses a more produced posterior margin, orthogyrate rather than prosogyrate beaks, a straight posterior umbonal ridge, and a less convex ventral margin. A specimen of *Schizodus* sp. from the Laborcita Formation, Sacramento Mountains (Kues, 1991b, fig. 2.32) is also similar, but has a higher, more regular posterodorsal commissural ridge and orthogyrate beaks.

Girty (1909) reported steinkerns questionably referred to *S. wheeleri* Swallow from numerous locations in the lower Abo, Yeso, and San Andres formations of New Mexico. The single specimen he figured (pl. 10, fig. 6) from the Yeso Formation generally resembles the Bursum specimen described here, but has a slightly more produced anterior margin and a more prominent posterodorsal ridge. Newell and Boyd (1975, p. 122) regarded *S. wheeleri* as an unrecognizable species.

New Mexico Wolfcampian examples of *Schizodus* include at least two and perhaps more species, but rarely are specimens present in sufficient numbers and preserved well enough to adequately characterize and distinguish them.

***Schizodus* aff. *S. alpinus* (Hall)**

A second species of *Schizodus* from unit 6 differs from the more elongate specimen described above in its higher, more rounded valve outline, nearly centrally located beaks, and strongly truncated posterior margin. The best-preserved specimen (Fig. 5B) is 21.0 mm long, 20.4 mm high (length/width = 1.03), and has an articulated width of 11.9 mm. The beaks are slightly prosogyrate and are situated about 40% of the distance between the anterior and posterior margins. The anterior margin is broadly and gently convex and curves smoothly into the moderately convex ventral margin. The posterior part of the valve is truncated and displays a slightly pointed posterior margin. The sloping posterodorsal margin is elevated slightly into a low, evenly arched commissural ridge, and the posterior umbonal ridge slopes steeply and straightly from the umbo to the posteroventral margin. Most growth lines are fine and regular, with widely spaced, slightly larger and more uneven lines periodically.

The short, high shell is distinctive, and most closely approaches *Schizodus alpinus* in size, valve profile, and beak features, although typical specimens of that species are a little more elongate than the Bursum specimen (see Newell and Boyd, 1975). A large number of steinkerns probably conspecific with *S. alpinus* are in collections from the Red Tanks Formation of the Lucero uplift, but few have as low a length-height ratio as this Bursum specimen. The poorly known Pennsylvanian species *S. subcircularis* (Herrick) is similar in size and shape but has a more broadly convex posterior margin.

***Permophorus* cf. *P. tropidophorus* (Meek)**

Permophorus cf. *P. tropidophorus* (Figs. 5C-F) is abundant in unit 39, where it occurs as complete, isolated valves, often with the internal surface exposed or in cross-sectional view, on the surface of limestone slabs. Few specimens display the external valve surface (Figs. 5C, D), though characters such as the subrectangular valve shape, low anterior beaks with valve height increasing posteriorly, and moderately strong posterior umbonal ridge sloping to meet a spatulate posterior margin suggest that the Bursum specimens are conspecific with or closely related to *P. tropidophorus*. Similar specimens were reported by Kues (1991b) from the Laborcita Formation.

Another species of *Permophorus* (Fig. 5G), more elongate and with a more anterior beak than *P.* cf. *P. tropidophorus*, is also present in unit 39, but is rare and too poorly preserved to characterize further.

***Wilkingia terminale* (Hall)**

Wilkingia terminale is represented in the Bursum type section by a few incomplete steinkerns. The largest specimen (Fig. 5I), from unit 14 float material, lacks the beaks and anterior areas of the valves, yet still measures 82 mm long. In addition to its large size, this distinctive bivalve is characterized by its elongate shape, compressed, broadly rounded posterior margin, anterior beaks with inflated umbos, and ornamentation of strong, low, comarginal folds, crossed by radial rows of fine papillae. This species is widespread and moderately common in New Mexico Pennsylvanian strata and ranges well into the Wolfcampian, occurring elsewhere in the Bursum Formation (Girty, 1909), in

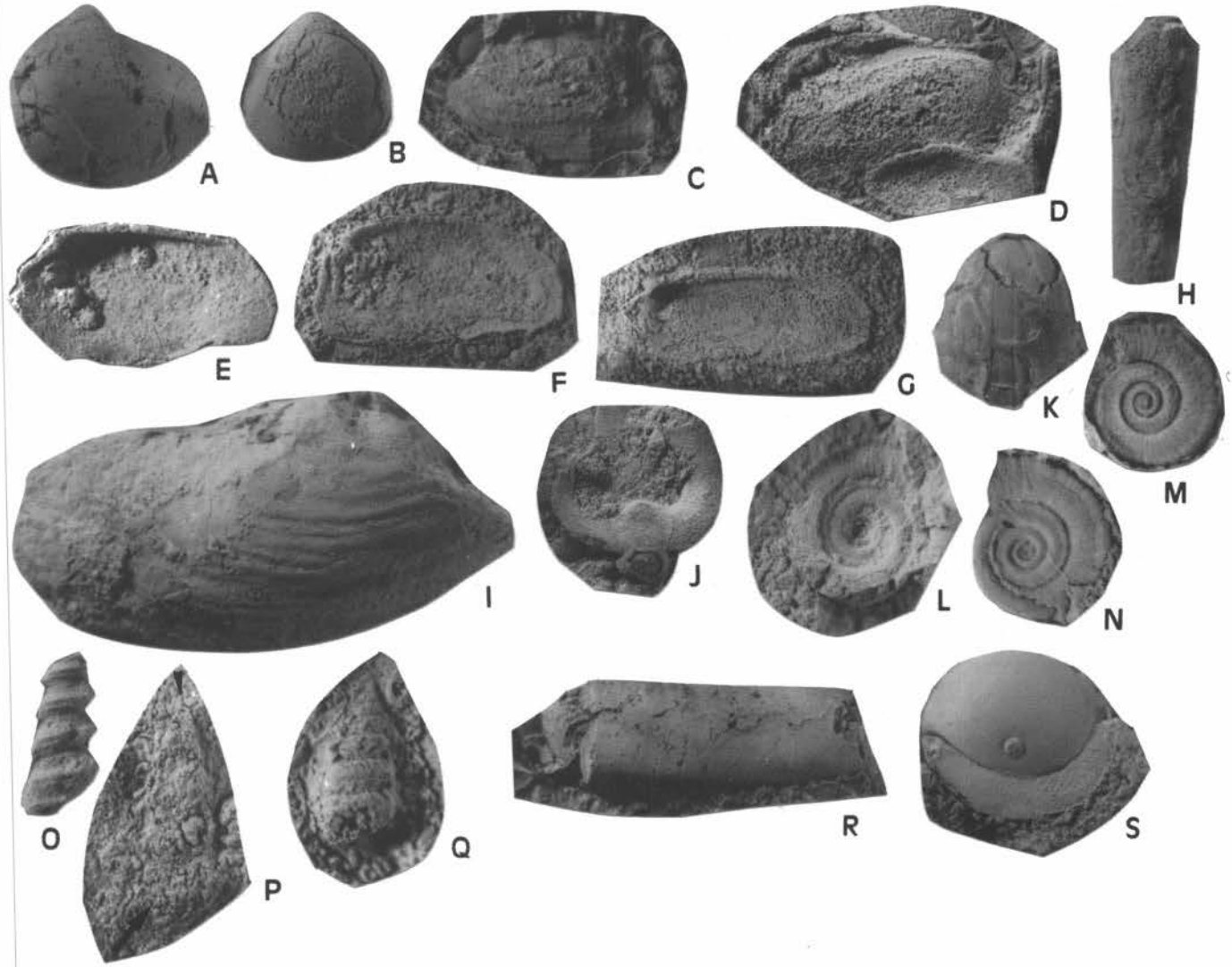

FIGURE 5. Bivalves (A-G, I), scaphopod (H), gastropods (J-Q), and nautiloid cephalopods (R, S) from the type section of the Bursum Formation. **A,** *Schizodus* aff. *S. ulrichi*, left valve, P-35,280, unit 6, x1.1. **B,** *Schizodus* aff. *S. alpinus*, right valve, P-35,28l, unit 6, x1. **C-F,** *Permophorus* cf. *P. tropidophorus*; C, external view of left valve, P-35, 282, unit 39, x2; D, external view of right valve, P-35,283, unit 39, x2; E, internal view of a weathered, incomplete right valve, P-35,284, unit 39, x2; F, internal view of a weathered right valve, P-35,285, unit 39, x2.25. **G,** *Permophorus* sp., internal view of a weathered right valve, P-35,286, unit 39, x2.35. **H,** *Prodentalium*? sp., fragment of shell, P-35,288, unit 29, x1.5. **I,** *Wilkingia terminale*, incomplete right valve steinkern missing beaks and anterior end, P-35,287, unit 14, x1. **J,** *Retispira* sp., apertural view, showing widely flaring lips, P-35,290, unit 39, x1. **K,** *Retispira* aff. *R. tenuilineata*, anterior dorsal view, P-35,289, unit 6, x2.25. **L-N,** *Amphiscapha* aff. *A. subrugosa;* L, dorsal view, P-35,291, unit 29, x2.75; M, ventral view, P-35,293, unit 29, x2; N, ventral view, P-35,292, unit 29, x2.75. **O, P,** *Goniasma lasallensis*; O, incomplete isolated specimen, P-35,294, unit 29, x4; P, cross section through large specimen in limestone (small arrow at top indicates tip of apex; large arrow at bottom is on body whorl), P-35,295, unit 39, x3. **Q,** *Apachella*? sp., abapertural view, weathered specimen, P-35,296, unit 39, x5.75. **R, S,** *Mooreoceras* sp.; R, side view of incomplete phragmocone, P-35,297, unit 29, x1.2; S, view of septum with siphuncle, P-35,298, unit 29, x1.75.

the Laborcita Formation (Kues, 1991b), in the Red Tanks Formation (Kues, 1984b), and in the Robledo Mountains Formation of the Hueco Group (Kues, 1995).

Scaphopods

Prodentalium? sp.

One highly weathered scaphopod shell fragment (Fig. 5H) from unit 29 is 26 mm long, slightly compressed laterally, and has a diameter of 9 mm and 7 mm at its larger and smaller ends. The shell is relatively thick in cross section, up to 1.5 mm around the larger end. Weathering has obliterated the surficial ornamentation. Girty (1909) reported *Plagioglypta canna*, presently assigned to *Prodentalium,* from Bursum-equivalent units in central New Mexico (Table 1).

Gastropods

Most gastropods, with the exception of those described below, are preserved as steinkerns with internal molds, or with shells

so coarsely recrystallized that original surficial features are not preserved. Small, moderately high-spired gastropods having inflated whorls and deeply indented sutures occur in large numbers in units 29 and 39. Unfortunately, most are unidentifiable, but some, based on hints of external ornamentation, may be *Apachella* (Fig. 5Q). Several weathered specimens of *Naticopsis* were observed on limestone slabs of unit 39.

***Retispira* aff. *R.* tenuilineata (Gurley)**

One incomplete specimen (Fig. 5K) of a small, crushed bellerophontid gastropod from unit 6 resembles *Retispira tenuilineata*, a common species in New Mexico Virgilian (e.g., Kues, 1996) and early Wolfcampian (Kues, 1991a) strata. The fragment is of the dorsal surface of the body whorl, is 11.5 mm long, and retains well-preserved ornamentation. The relatively wide selenizone is flush with the shell surface, contains about 13 very fine, sharp, spiral lirae, and is bordered on each side by a low ridge onto which the fine lirae extend. The lateral portions of the shell surface are likewise ornamented with fine, closely and evenly spaced spiral lirae (about 6/mm near the anterior margin) that are slightly coarser than the lirae within the selenizone. No transverse ornamentation or growth lines are apparent on the specimen.

Comparison of the Bursum specimen with large collections of *R. tenuilineata* from the coeval Laborcita Formation of south-central New Mexico indicates that the Bursum taxon has finer spiral lirae and lacks the fine transverse ornamentation present in *R. tenuilineata.* *Retispira modesta*, described by Girty (1909) from the San Andres Formation and questionably from Bursum-equivalent strata, and redescribed by Yochelson (1960), is a broader species, with a narrower selenizone, much coarser spiral lirae, and conspicuous collabral lirae. More specimens of the Bursum taxon are needed in order to determine intraspecific variability and to definitely identify it.

***Retispira* sp.**

Small to moderately large, complete specimens of a bellerophontid gastropod that is probably a species of *Retispira* different from *R.* aff. *R. tenuilineata* are moderately common in unit 39 (Fig. 5J). All specimens observed, however, are on the surfaces of limestone slabs and oriented with their aperture exposed and the rest of the shell buried, so that the nature of the external surface of the body whorl and selenizone is unknown. The aperture of this species is transversely reniform, and the apertural lips, which are complete around the aperture of some specimens, flare widely, as is typical of some Lower Permian species of *Retispira* from the New Mexico-Texas area (see Yochelson, 1960). Height and width across the apertural lips of a large specimen are subequal at about 25 mm, and a thickened inductural knob is present in the plane of the aperture on the earliest exposed part of the body whorl, a feature also characteristic of *Retispira*.

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

Small discoidal gastropods readily assigned to *Amphiscapha* (Figs. 5L-N) are moderately common in limestones of unit 29. The shells are relatively small for the genus (maximum diameter about 13 mm), low, and consist of about five whorls. The dorsal surface descends gradually to the central initial whorl, with the profile of the upper whorl surfaces gently sigmoidal between deeply incised sutures. The lower shell surface is nearly flat to very gently concave, and the lower whorl surfaces are gently convex. A prominent, high, somewhat crenulated ridge occupies the outer margin of the dorsal surface. Whorl sides are flat to gently convex, and a small bourrelet extends outward at the corner of the whorl side and the lower shell surface.

The Bursum specimens are conspecific with specimens from the Laborcita and Red Tanks Formations, described as *A.* aff. *A. subrugosa* by Kues (1991a). They differ from *A. muricata* Knight in being smaller, having a moderately crenulated rather than sharp dorsal ridge, and in possessing a less conspicuous basal bourrelet. *Amphiscapha proxima* Yochelson, the species most often encountered in the Hueco Group of New Mexico (Yochelson, 1960; Kues, 1995), typically is a little smaller and has a considerably higher shell. This is likely a new species.

***Goniasma lasallensis* (Worthen)**

The few isolated specimens of this small, high-spired species (Fig. 5O) from unit 29 are incomplete and severely weathered, but display the characteristics of the species; specimens in unit 39 are cross sections through the shell (Fig. 5P). The whorl surfaces are marked by a sharp peripheral carina about two-thirds of the distance from the upper to lower suture. The broad upper whorl surface slopes steeply from the upper suture, is flat to slightly concave, and bears no ornamentation. The lower whorl surface is inclined adaxially and displays a small spiral lira immediately below and slightly inset from the carina, marking the base of the selenizone, and a second spiral lira is present just above the lower suture. The earliest whorls and juvenile specimens have a pair of sharp lirae at the periphery, the highest of which enlarges with growth to become the carina.

Goniasma lasallensis ranges from the Desmoinesian (e.g., Kues and Batten, 2001) through the Virgilian in New Mexico, and is abundant in the Laborcita and Red Tanks Formations (Kues, 1991a).

***Stegocoelia (Hypergonia)*? sp.**

One specimen on the surface of a limestone slab from unit 39 is very narrow, high spired and small. About 6.5 whorls are preserved, having a height of 3.0 mm. The whorls are relatively convex in profile, with the periphery rounded at about mid-height or a little lower and bearing a strong, but not carinate, spiral lira. Three additional finer spiral lirae occupy the upper whorl surface and two lirae are present between the periphery and the lower suture. Little of the surface is preserved well, and growth lines and a possible selenizone were weathered away, making generic determination questionable, but this specimen is unlike any others encountered in the Bursum type section.

Cephalopods

Fragments of the shells of orthoceroid nautiloids assigned to *Mooreoceras* are moderately common in unit 29 and are discussed below. One small, laterally compressed ammonoid was

also collected from unit 29, but it is so heavily recrystallized that neither sutures nor external ornamentation were preserved.

***Mooreoceras* sp.**

Moderately large, straight-coned nautiloids in unit 29 (Figs. 5R, S) include fragments up to 54 mm long, with a maximum diameter of 12 mm and including about 25 chambers. Another specimen of similar length represents the early part of the shell and expands very gradually to a maximum diameter of 9 mm, with 22 chambers. The septa are gently and evenly arcuate and in one specimen (Fig. 5S) having a diameter of 16 mm, a small (1.5 mm wide), round siphuncle is situated slightly below the center of the septum.

These specimens are quite similar to, but a little smaller than, the specimen Girty (1909, pl. 12, figs. 2-2b) called *Orthoceras* sp., from the Bursum in Abo Canyon. Miller and Youngquist (l949, pl. 35, figs. 1-3) redescribed and refigured this specimen, assigning it to *Mooreoceras* on the basis of its slightly ventrally located siphuncle. These authors also reported specimens of *Mooreoceras giganteum* Clifton from the Hueco Limestone of Otero County, New Mexico. Typically, this is a much larger species than the Bursum fragments would suggest, but it is possible that these specimens represent the earlier, narrower parts of much larger shells.

Trilobites

A few fragments of small trilobites were collected from unit 29. These include one mold of a partial pygidium and several small portions of the cephalon. Although a fair number of trilobite species are known from the Permian of New Mexico and west Texas, and they have recently been studied (e.g., Brezinski, 1991, 1992), the specimens at hand are too incomplete for reliable identification.

Echinoderms

Crinoid stem fragments are rare in units 6, 2l, and 29.

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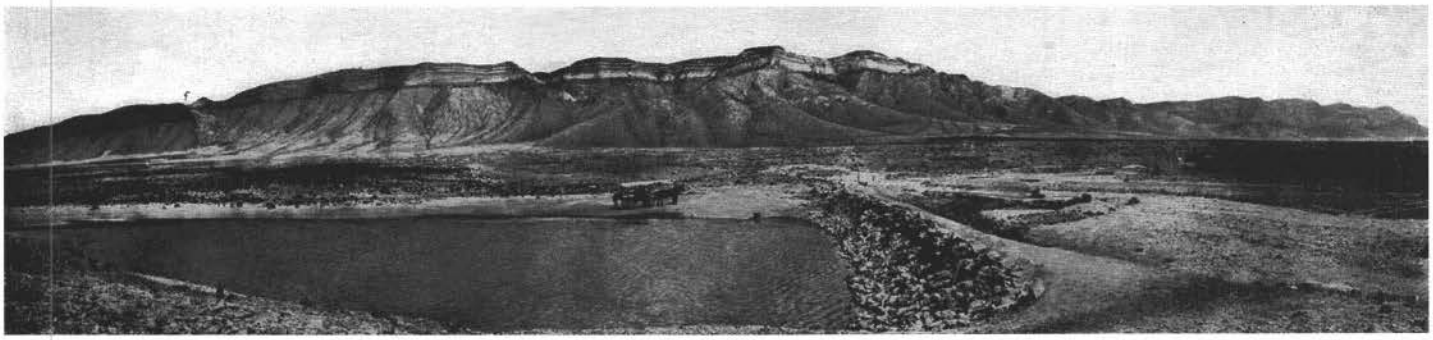

Panoramic photograph of the Sierra Oscura at a point near the center of T.6 S., R. 5 E. Photo from Darton (1928).