Guide to the late Pennsylvanian paleontology of the Upper Madera Formation, Jemez Springs area, north-central New Mexico

Barry S. Kues

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GUIDE TO THE LATE PENNSYLVANIAN PALEONTOLOGY OF THE UPPER MADERA FORMATION, JEMEZ SPRINGS AREA, NORTH-CENTRAL NEW MEXICO

BARRY S. KUES
Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, N M 87131-1116

Abstract—Late Pennsylvanian (Missourian to middle Virgilian) strata of the upper part of the Madera Formation north of Jemez Springs town are approximately 250 ft thick, and contain diverse faunas from varied marine facies. Although a well known collecting area for decades, relatively little has been published on these fossils. Here, more than 90 taxa from this sequence are briefly described and illustrated, and their stratigraphic ranges indicated mainly by noting their distribution in two reference sections, one near the Jemez Ranger Station and the other opposite Hummingbird Camp, about 4 mi to the north. Most of these taxa are brachiopods (33 species), gastropods (26 species) and bivalves (26 species), but information on fusulinids, corals, bryozoans, cephalopods, scaphopods, rostroconchs, trilobites, echinoids, crinoids and vertebrates is also included. Total diversity is even greater than is indicated here, because some poorly preserved rare species are not included, and the taxonomic composition of some groups, such as bryozoans and corals, remain to be studied. The majority of the species observed in the Jemez Springs Late Pennsylvanian sequence are also present in strata of equivalent age in the Midcontinent region and/or Texas, but some are apparently endemic to the Rocky Mountain area or to New Mexico, and a few are new species. Several distinctive faunal assemblages occur in these strata, characterizing different depositional environments.

INTRODUCTION

Late Pennsylvanian strata of the upper part of the Madera Formation exposed along San Diego Canyon, north of Jemez Springs town, are among the most profusely fossiliferous rocks in New Mexico. Since at least the 1930s, this area has been a favorite collecting area with fossil enthusiasts and paleontology classes, owing to the abundance, easy accessibility, diversity, and good preservation of the marine invertebrate fossils found here. The most recent list of taxa reported from the Madera Formation in the Jemez-Nacimiento Mountains area (Northrop, 1974) cited more than 175 species, and numerous additional taxa have been discovered in the past 20 years. Given the great abundance and diversity of these faunas, it is surprising that only a small percentage of these species have ever been studied, or described and illustrated in the published literature. This paper documents many of elements of the upper Madera fauna in the Jemez Springs area, both to stimulate further study, and to serve as a useful field guide. All specimens discussed and illustrated here are reposited in the University of New Mexico (UNM) Department of Earth and Planetary Sciences paleontology collections.

PREVIOUS STUDIES

The first American to visit and comment upon the geology of the Jemez Springs area was James H. Simpson (1850), who ascended San Diego Canyon with a military expedition in 1849 (see Kues, 1992), but did not note any fossils. During the 19th century, San Diego Canyon was far enough from the usual trade and exploring routes that the geology of the area (except for the hot springs, which attracted interest) was largely ignored. Jules Marcou, the first geologist to explore New Mexico, with the Whipple Expedition in 1853, did not visit the Jemez area. His geologic map of central New Mexico (Marcou, 1858), however, displays the Sierra de Jemez as an elongate structure of granite, surrounded by "Mountain Limestone" (Lower Carboniferous, later shown to be Pennsylvanian) to the east of Guadalupe and San Diego Canyons. The latter area is assigned to the New Red Sandstone (Permian). Although Permian redbeds do crop out extensively in San Diego Canyon, the general inaccuracy of this part of Marcou's map suggests that he drew it based on vague accounts of others.

Owen and Cox (1865), in a publication on the mines of New Mexico, mentioned *Productus cora* (= the productoid brachiopod *Linoproductus*) from the Carboniferous limestone of the Jemez valley. J.S. Newberry, while a geologist on the Macomb Expedition, passed through the Jemez area in September 1859, and noted that the Carboniferous strata "abound in fossils, among which I saw most of those enumerated in the Santa Fe section, and, in addition to these, collected a coral and a crinoid, which are apparently new (Newberry, 1876, p. 118). Neither of these new taxa were ever published upon. Oscar Loew, mineralogical assistant on the Wheeler Expedition, explored San Diego Canyon in 1874. In his report (Loew, 1875), he mentioned well-exposed Carboniferous strata and noted two productoid and one spiriferid brachiopod species. Later, Reagan (1903) and Darton (1910, 1928) cited a few Pennsylvanian species, and Renick (1931) measured a 707-ft-thick section of the "Magdalena Group" 2.7 mi north of Jemez Springs and presented a modest faunal list, mostly brachiopods, identified by G.H. Girty.

The Jemez area Pennsylvanian strata and their faunas were first studied in detail by Henbest and Read (1944) and Northrop and Wood (1946). The first authors measured six stratigraphic sections through the Pennsylvanian and determined the age of the strata utilizing fusulinid biostratigraphy. Northrop and Wood (1946) mapped the entire Nacimiento Mountains-Jemez area, presented stratigraphic sections and extensive lists of invertebrate taxa, and assigned the Pennsylvanian strata and faunas to stages. Read and Wood (1947) summarized the correlation of the Jemez area Pennsylvanian sequence with others in New Mexico. As the stratigraphy became better known, a Morrowan (Early Pennsylvanian) unit with a distinctive fauna was recognized in Guadalupe Canyon and some elements of its fauna were reported by Northrop and Wood (1945), Armstrong (1955) and Armstrong and Mamet (1974), the latter reporting numerous foraminifer species. That unit was eventually named the Osha Canyon Formation (DuChene et al., 1977), with 21 brachiopod and three coral species cited.

Northrop (1961) listed about 160 known taxa from the Pennsylvanian of the Jemez and Nacimiento Mountains, and presented a revised list of about 175 species (Northrop, 1974) that indicated the great diversity of the Pennsylvanian faunas of this area. This list included 1 alga, 39 foraminifer, 2 sponge, 6 coral, 8+ bryozoan, 59 brachiopod, 24 bivalve, 16 gastropod, 6 cephalopod, 1 scaphopod, 2 annelid, 4 trilobite, 6 crinoid, 1 echinoid and 1 vertebrate species. Additional species have been noted since 1974, and some are reported in this paper.

Very few of these species have been adequately documented through description and illustration. By far the most important study yet done on fossils of the Jemez area was Sutherland and Harlow's (1967) description of 18 Virgilian brachiopod species (two of them new) from a 30-40 ft thick shale unit they named the Jemez Springs Shale Member, near the top of the Madera Formation. The only other taxa that have been documented (outside of lists) are the bivalve *Edmondia aspinwallensis* (Herrick, 1900, pl. 3, fig. 13; not mentioned in text); two new fusulinid species, *Triticites jemezensis* and *T. kellyensis* from about 150 ft below the base of the Permian Abo Formation on the north edge of Jemez Springs (Needham, 1937); a new bryozoan, *Cyclotrypa* [now *Fistulipora*] *pelagia*, from 175-275 ft below the base of the Abo, just south of Battleship Rock (Moore and Dudley, 1944); a crinoid, *Schistocrinus* aff. *S. torquatus* Moore and Plummer, from the Jemez Springs Shale Member in Church Canyon (Strimple, 1969); and an unidentified isorophid edrioasteroid from Virgilian strata north of Guadalupe Box (Bell, 1976). Several of the common Jemez area Madera brachiopods were discussed by Alexander (1980, 1986) in connection with studies of shell damage, and Grossman et al. (1993) studied the stable isotope geochemistry of several brachio-

pod species from the Jemez area (see also Mii et al., this volume). Elements of the Jemez Springs Pennsylvanian faunas have also been described in unpublished Master's theses by Bisbee (1932), Lovejoy (1958), and Swenson (1977).

STRATIGRAPHY AND LOCALITIES

The most easily accessible highly fossiliferous exposures of the Madera Formation in San Diego Canyon are slopes and road cuts on both sides of NM-4, north of Jemez Springs town. Excellent Madera outcrops are nearly continuous along and above the highway from Church Canyon (site of Jemez State Monument on the northern edge of Jemez Springs) north to a little past the Rincon fishing access parking lot northwest of Battleship Rock, a distance of about 6 highway miles. Several stratigraphic sections have been measured through the Madera in this area (e.g., Renick, 1931; Henbest and Read, 1944; Northrop and Wood, 1946; Lovejoy, 1958; Swenson, 1977). Reported maximum composite thicknesses for the Madera range from 366 ft (Lovejoy, 1958) to 550-600 ft (Henbest and Read, 1944; Swenson, 1977). Lower Madera (Desmoinesian) strata are well exposed only in the area around Soda Dam, overlying about 100 ft of Atokan Sandia Formation. Exposures along NM-4 from Jemez State Monument to the ranger station, and for several miles north of Soda Dam, are mainly, if not entirely, strata of Missourian and Virgilian (Late Pennsylvanian) age.

The invertebrate taxa described in this paper represent a large majority of the more than 10,000 specimens collected over many years. These specimens were collected mainly from two localities (Fig. 1)—the high slopes east of NM-4 between Church Canyon and the Jemez Ranger Station (= RS section), an outcrop distance of 0.5 mi; and outcrops west of NM-4 opposite the Hummingbird Music Camp (= HC section), about 4.1 highway miles north of the Ranger Station (see also Corrao and Kues, 1996). Preliminary stratigraphic sections (Figs. 2, 3) indicate a thickness of about 250 ft for both sections. Both sections include a 25-40 ft-thick, brachiopod-rich, reddish shale interval (Jemez Springs Shale Member of Sutherland and Harlow, 1967) near the top, just below a massive, fossiliferous gray limestone unit that underlies brick-red, nonmarine shales, siltstones and sandstones of the Abo Formation. The Jemez Springs Shale Member is also exposed near road level west of the highway about 0.3 mi north of the Rincon fishing access parking lot, about 5.7 mi north of the Ranger Station (Rincon locality). Other localities from which fossils mentioned in the text were collected are shown in Figure 1. Based on fusulinid identifications, Henbest and Read (1944) and Lovejoy (1958) determined that Virgilian strata comprise the upper 90-110 ft of the section north of Church Canyon, and Missourian strata extend an additional 130-160 ft below the Virgilian, nearly to the base of the section. Missourian and Virgilian thicknesses in the Hummingbird Camp section to the north are similiar. Restudy of the upper Madera fusulinids would bring their taxonomy up to date, and probably allow more precise placement of the Missourian-Virgilian boundary.

Although the two main stratigraphic sections display general lithological similarities, and some units (e.g., Jemez Springs Shale Member and overlying limestone bed) extend throughout San Diego Canyon, changes in facies and faunas between equivalent parts of the two sections are also pronounced. For example, a nodular gray limestone bed (unit RS-9) containing abundant specimens of the large gastropod *Euomphalus plummeri* at the Ranger Station locality is absent at Hummingbird Camp, and a brown shale unit (HC-1) dominated by the high-spired gastropod *Stegocoelia (Hypergonia)*? sp. at Hummingbird Camp

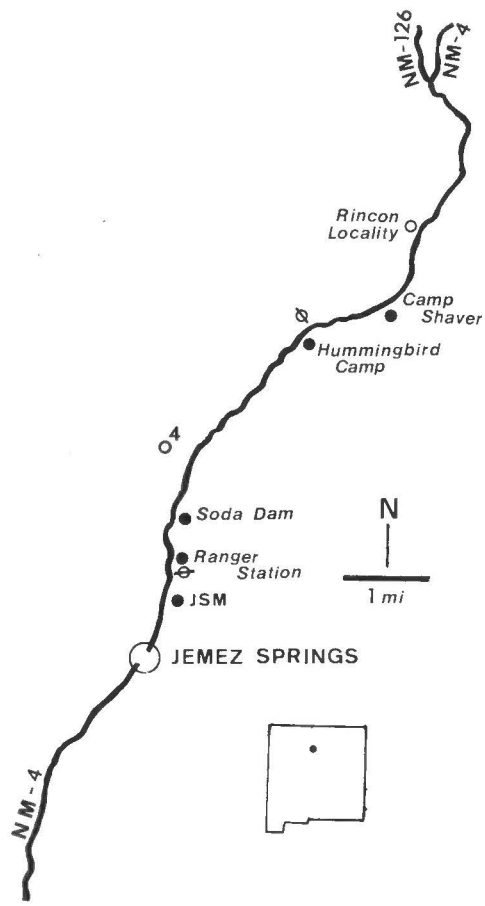

FIGURE 1. Reference map of Jemez Springs area, showing Pennsylvanian localities mentioned in text. The two major reference sections are indicated by barred open circles; 4 = locality 4 of Lovejoy (1958) and section 7 of Swenson (1977); JSM = Jemez State Monument.

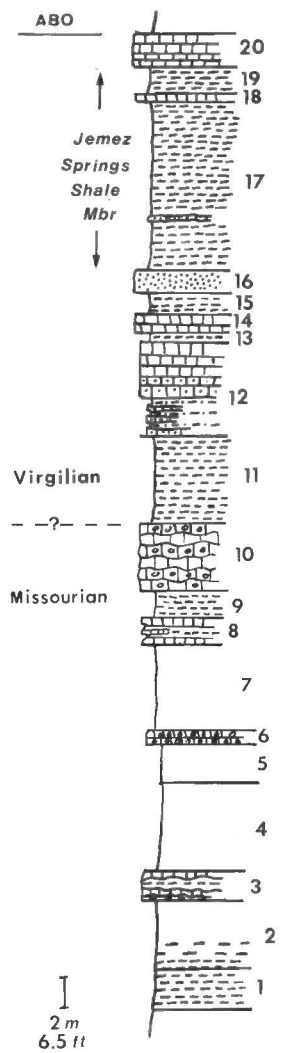

FIGURE 2. Generalized stratigraphic section of upper Madera Formation opposite Hummingbird Camp; units lacking lithological symbols are covered.

is absent to the south. In general, Missourian strata are mainly marine limestones, with lesser thicknesses of marine shales, whereas Virgilian strata are primarily nonmarine and marine gray, red and brown shales, with subordinant limestones. In both sections, the Virgilian is marked by two or three nonmarine shale-to-marine limestone transgressive cycles, the youngest of which is the Jemez Springs Shale-overlying limetone sequence, at the top of the Madera Formation (see Yancey et al., 1991; Swenson, this volume).

The age of the Madera-Abo boundary (top of the highest marine limestone) in the Jemez Springs area is probably middle Virgilian. The youngest fusulinids noted by Henbest and Read (1944) are *Triticites kellyensis*? Needham, *T.* aff. *T. plummeri* Dunbar and Condra, and a variety of *T. ventricosus* (Meek and Hayden), which suggested a Virgilian age to these authors. Analysis of the Jemez Springs Shale brachiopods and additional fusulinid evidence suggested correlation to the Shawnee or lower Wabaunsee Groups (middle Virgilian) of the Midcontinent (Sutherland and Harlow, 1967). Additional evidence for an approximately middle Virgilian age for the top of the Madera Formation is the abundant large bivalve *Myalina (Orthomyalina) slocombi* Sayre, in the Jemez Springs Shale Member. This is the most common Missourian-Virgilian myalinid in North America (Newell, 1942). Its range extends through the lower Virgilian before it is gradationally supplanted by *M. (O.) subquadrata* Shumard, a species characteristic of the upper Virgilian to lower Wolfcampian in the Midcontinent (Newell, 1942) and elsewhere in New Mexico (e.g., Kues, 1991b). Despite the reported occurencce of *M. (O.) subquadrata* in the upper Madera of the Jemez region (e.g., Lovejoy, 1958; Northrop, 1974), I found no specimens that could be assigned definitely to that species among many hundreds of specimens of *M. (Orthomyalina)*. Apparently, by the time typical members of *M. (O.) subquadrata* had evolved (late Virgilian), sedimentation in the Jemez area had become nonmarine, with the deposition of the lower beds of the Abo Formation.

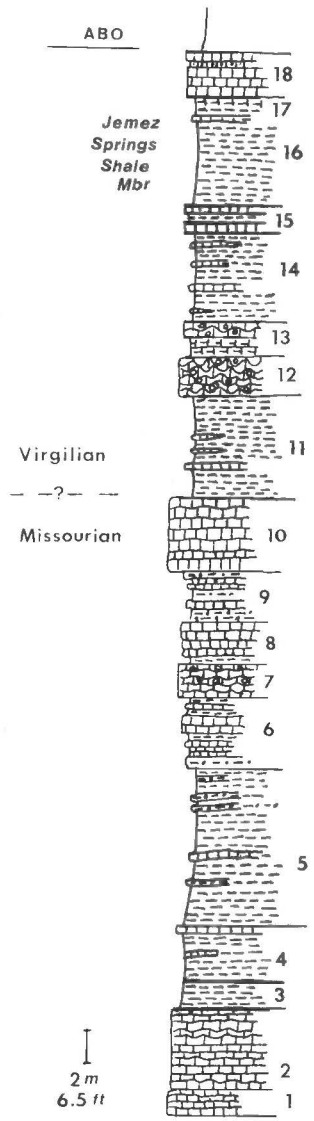

FIGURE 3. Generalized stratigraphic section of upper Madera Formation south of the Jemez Ranger Station.

MISSOURIAN-VIRGILIAN FAUNAS

More than 90 taxa of Missourian-Virgilian fossils from the Jemez Springs area are briefly described and illustrated below. Brachiopods, gastropods and bivalves comprise most of these taxa. Among these groups are perhaps 15 additional species that are not considered here because of rarity and/or poor preservation. No attempt was made to study intensively the taxa of other groups, such as fusulinids, sponges, corals and bryozoans, but some observations are reported. Clearly, much additional study is required in order to fully understand the taxonomic composition of these highly diverse faunas.

The invertebrate assemblages of the upper Madera Formation vary considerably from facies to facies. A few comments concerning the distinctive assemblages of species observed through this sequence are included below, but detailed study and comparison of these assemblages, and their relationships to specific depositional environments, remain to be done. Likewise, the Missourian faunas differ in significant ways from those of the Virgilian, although many species range through both stages. The range of each species is indicated in its description; stratigraphic distribution and age of the species are indicated mainly by reference to their occurrence in the two main stratigraphic sections, near the Jemez Ranger Station, and opposite Hummingbird Camp (Figs. 2, 3).

Fusulinids

Fusulinid foraminifers are abundant in some limestone units of the upper Madera. As noted earlier, the work of Needham (1937) and Henbest and Read (1944) should be supplemented by more detailed studies utilizing modern taxonomic concepts. The main fusulinid in the Jemez Springs Shale and underlying Virgilian units is *Triticites,* which has an elongate fusiform shape and reaches a maximum width of about 5 mm (Fig. 4.1).

Sponges

A few sponge remains, mostly small mats of spicules, have been collected from the upper Madera near Jemez Springs. These specimens are under study by J. Keith Rigby, Brigham Young University, Utah.

Corals

Small, solitary rugose corals are the only forms present in the upper Madera Formation of the Jemez Springs area. They are rare to uncommon in many of the units, including both shales and limestones, from near the base of the sequence to the Jemez Springs Shale. Typically, specimens are narrowly conical in shape and up to about 20 mm high, and many are sharply bent (Fig. 4.2), owing to a change in their orientation on the sediment surface as they grew. Externally, they display coarse growth annulations and low, longitudinal ribs. Numerous genera of late Paleozoic rugosans have these general features.

Bryozoans

Bryozoans are present in nearly all marine units in the upper Madera Formation, but because of the special techniques required to study and identify them in detail are not extensively treated here. Two units containing abundant bryozoans are worthy of note. Unit HC-4 (Missourian) at Hummingbird Camp is a gray, argillaceous limestone with great numbers of bryozoans, together with many *Composita* specimens and lesser numbers of other brachiopods, and a moderate diversity of bivalves and gastropods. The most abundant bryozoans are large, typically bluntly branched fistuliporoid colonies (branches up to 25 mm in diameter; Figs. 4.3, 4.4), probably *Fistulipora*. This taxon also forms thin sheets encrusting crinoid stems, *Composita,* and even fenestrate bryozoan colo-

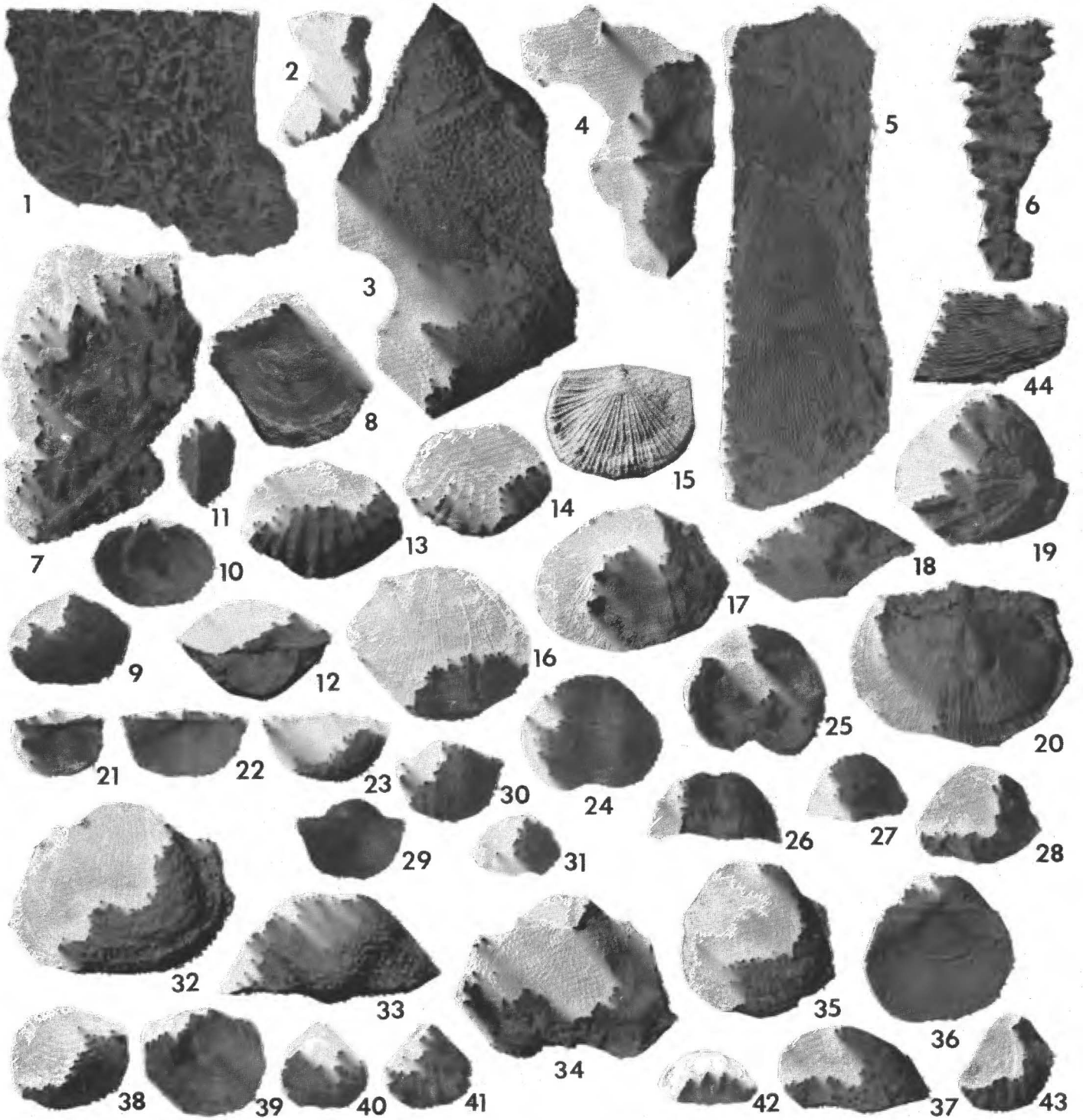

FIGURE 4. Invertebrate fossils from the upper Madera Formation near Jemez Springs, NM. RS, Ranger Station section; HC, Hummingbird Camp section. Fusulinids: 1, *Triticites* specimens on bedding plane, UNM 12,570, unit RS-13, x1. Coral: 2, solitary rugose coral, UNM 12,571, Jemez Springs Shale Member (unit RS-16), x1. Bryozoans: 3,4, *Fistulipora* sp., close view of colony surface, UNM 12,573, x3, and entire colony fragment, UNM 12,572, x1, both from unit HC-4. 5, large fenestrate colony, UNM 12,574, Jemez Springs Sh. Mbr., Rincon locality, x1. 6, 7, *Rhombopora* sp., multi-branched colony, UNM 12,575, x1.5, and many broken branches on slab, UNM 12,576, x1, both from unit HC-1. Brachiopods: 8, *Orbiculoidea* sp., internal view of partial brachial valve, UNM 12,577, unit RS-5, x2. 9-11, *Rhipidomella carbonaria*; 9, 10, external and internal views of an unusually wide brachial valve, UNM 12,578, x2; 11, side view of an articulated specimen, UNM 12,579, x2, both from unit RS-13. 12-14, *Meekella striatocostata*, posterior, brachial, and pedicle views, UNM 12,580, unit RS-9, x1. 15, *Derbyia texana*, brachial valve, UNM 12,581, Jemez Springs Sh. Mbr. (unit RS-16), x1. 16-19, *Derbyia bennetti*; 16-18, brachial, pedicle and posterior views, UNM 12,582; 19, side view of a strongly convex specimen, UNM 12,583; both from Jemez Springs Sh. Mbr. (unit RS-16), x1. 20, *Derbyia* cf. *D. plattsmouthensis*, brachial valve, UNM 12,584, Jemez Springs Sh. Mbr. (unit RS-16), x1. 21, *Neochonetes granulifer*, brachial valve, UNM 12,585, unit HC-11, x1. 22, 23, *Neochonetes "transversalis,"* brachial and pedicle valves, UNM 12,586, Jemez Springs Sh. Mbr. (unit RS-16), x1. 24-27, *Kozlowskia splendens*; 24, 25, pedicle and brachial views, UNM 12,587; 26, 27, front and side views, UNM 12,588; both from unit RS-5, x1. 28, *Hystriculina* cf. *H. wabashensis*, oblique front view of pedicle valve, UNM 12,589, unit RS-5, x1. 29-31, *Hystriculina armata*, brachial, pedicle and side views, UNM 12,590, Jemez Springs Sh. Mbr. (unit RS-16), x1. 32-34, *Pulchratia symmetrica*, pedicle, back, and brachial views, UNM 12,593, unit RS-11, x1. 35-37, *Juresania nebrascensis*; 35, pedicle valve, UNM 12,591, x 1.2; 36, 37, brachial and side views, UNM 12,592, x1, both from Jemez Springs Sh. Mbr. (unit RS-16). 38, 39, *Cancrinella boonensis*, pedicle and brachial views, UNM 12,594, Jemez Springs Sh. Mbr. (unit RS-16), x1. 40-42, *Wellerella immatura*, brachial, pedicle, and front views, UNM 12,595, unit HC-11, x2. 43, *Hustedia* sp., brachial view, UNM 12,596, unit HC-11, x2.5. 44, *Isogramma* sp., external view of small valve fragment, UNM 12,686, unit HC-11, x1.

nies. Small branches of *Rhombopora* are moderately common in unit HC-4, together with fragments of many fenestrate colonies (Fig. 4.5), of which *Septopora* is most common.

Unit HC-1, a grayish brown shale, contains vast numbers of *Rhombopora* colonies (Figs. 4.6, 4.7), suggesting that the seafloor supported dense growths of these bryozoans. Within this shale are thin horizons composed entirely of *Rhombopora* branches cemented together—a bryozoan coquina. The remainder of this fauna is dominated by molluscs, chiefly the gastropod *Stegocoelia (Hypergonia)*? sp. and the bivalve *Myalina (Orthomyalina) slocombi.*

Brachiopods

Brachiopods are the most abundant and conspicuous fossils of the upper Madera Formation in the Jemez Springs area, especially in limestone and calcareous shale units. Sutherland and Harlow (1967) comprehensively described the unusually well-preserved brachiopod fauna (18 species) of the Jemez Springs Shale Member near the top of the Madera, but numerous other taxa are present in the strata below this unit. In the short descriptions to follow, W = width; L = length, and T = thickness. Unless otherwise stated, measurements of costae density were made on the anterior central part of the pedicle valve.

Orbiculoidea sp.

Specimens of this inarticulate brachiopod (Fig. 4.8) are very rare. Its valves are circular, very thin, and about 7-15 mm in diameter. The brachial valve rises to a subcentrally located point. Ornamentation consists of numerous very fine, and several high, sharp, widely-spaced concentric lirae.

Rhipidomella carbonaria (Swallow)

This small orthid (Figs. 4.9 - 4.11) has valves of nearly equal convexity, with sharp, high beaks and numerous (6-7/5 mm) fine radial costellae on the valve surfaces. A typical specimen is 9.5 mm wide, 8.2 mm long, and 6.1 mm thick at the umbos; average W/L = 1.15 and T/L = 0.75. It is an uncommon species, collected only from a restricted interval (units HC-11, RS-13) of latest Missourian or earliest Virgilian age.

Isogramma sp.

Isogramma is an aberrant brachiopod of uncertain, possibly strophomenoid affinities, characterized by thin, highly porous valves and external ornamentation consisting of many fine, sharp, concentric ridges. Pennsylvanian occurrences, mainly from Texas (e.g., Cooper, 1952; Wardlaw et al., 1987) are often restricted to small shell fragments identical to specimens recovered from unit HC-11 of the Jemez sequence. The Jemez fragments (Fig. 4.44) are as much as about 20 mm wide, 1-2 mm thick, and bear many sharp parallel ridges (about 2 ridges/mm) on their external surface. The internal surface of these fragments is covered with tightly packed, round to subpolygonal pores, or punctae, that range from about 0.1 to 0.4 mm in diameter, separated from each other by narrow walls, producing a honeycomb-like pattern. These punctae are also visible among the external ridges where they have been weathered, exactly as in Texas specimens illustrated by Wardlaw et al. (1987, pl. 1, fig. 17). Several Pennsylvanian species are known, and they may attain valve widths of considerably more than 100 mm, but the fragmentary nature of the Jemez specimens precludes specific identification. The only previous report of *Isogramma* from New Mexico was from Desmoinesian strata in the Sangre de Cristo Mountains (Sutherland and Harlow, 1973).

Meekella striatocostata (Cox)

Meekella striatocostata (Figs. 4.12 - 4.14) is a very distinctive, relatively small (W up to about 30 mm), highly variable species characterized by a strongly convex brachial valve, unusually high, triangular interarea, and a more gently convex pedicle valve. Ornamentation consists of many fine costellae, with both valves also displaying 8-12 large radial folds or plications, producing a "zig-zag" commissure. The long stratigraphic range and high variability of specimens assigned to *M. striatocostata* may indicate that it actually includes more than one species (Dunbar and Condra, 1932; Cooper and Grant, 1974, p. 370). In the Jemez area, this species is present throughout the Missourian and into the lower Virgilian, especially in limestones such as RS-10, but it was not observed above unit RS-12, possibly because shale lithologies dominate much of the Virgilian sequence. In the Midcontinent area, the species ranges into the Early Permian (Dunbar and Condra, 1932).

Derbyia texana Dunbar and Condra

One of at least three species of *Derbyia* in the upper Madera Formation, *D. texana* (Fig. 4.15) is characterized by low, very gently convex valves, low interarea, relatively small size (W typically no more than 25-30 mm), rather coarse, minutely nodose costellae, and maximum valve width at or just anterior to the hingeline. It is uncommon in the Jemez Springs Shale Member, and also occurs about 30-50 ft below that unit (e.g., HC-11, RS-13), to approximately the base of the Virgilian.

Derbyia bennetti Hall and Clarke

D. bennetti (Figs. 4.16 - 4.19) is a medium-sized (W up to about 35 mm) species with strongly convex valves and a moderately high interarea. Greatest width occurs at about midlength and the anterior margin of the valves is often slightly invaginated. Growth was uneven, producing an asymmetrical, somewhat distorted shell with strong concentric growth wrinkes and an obliquely extended rather than subvertical interarea. These features immediately distinguish this species from the smaller, much flatter *D. texana*. *D. bennetti* occurs only in the Jemez Springs Shale Member at the Ranger Station section, but is also present down to basal Virgilian strata (HC-11) at Hummingbird Camp.

Derbyia cf. *D. plattsmouthensis* Dunbar and Condra

A relatively large, moderately transverse species of *Derbyia* (Fig. 4.20) is rare in the upper Madera. The brachial valve is moderately convex, whereas the pedicle valve is nearly flat. Maximum valve width occurs well anterior to the hingeline, and is 37 and 47+ mm in the two available specimens. Ornamentation consists of fine, high, sharp costellae of two or three ranks (large alternating with small costellae; 8-11/5 mm). This species is consistently larger than *D. texana* and *D. bennetti*. It also differs from *D. texana* in the midlength position of maximum valve width, and from *D. bennetti* in its much less convex and undistorted valves. The two specimens (from units RS-9 and RS-17) are most similar to *D. plattsmouthensis*, described originally from the lower to middle Virgilian of the Midcontinent region (Dunbar and Condra, 1932).

Neochonetes granulifer (Owen)

This small strophomenid (W = 15-20 mm) is subrectangular in shape (W/L = 1.35-1.50), widest along the hingeline, with a moderately convex pedicle valve and concave brachial valve (Fig. 4.21). Ornamentation consists of many fine, closely-spaced radial costellae (about 10/2 mm) on both valves. Several small spine bases project obliquely from each side of the hingeline. *N. granulifer* is rare in units RS-5, RS-9, and HC-11 (Missourian to earliest Virgilian), above which it is replaced by *N. "transversalis"*.

Neochonetes "transversalis" Dunbar and Condra

As noted by Dunbar and Condra (1932) and Sutherland and Harlow (1967), *N. "transversalis"* intergrades morphologically with *N. granulifer*. *N. "transversalis"* (Figs. 4.22, 4.23) is somewhat larger (W up to 25 mm), has a more transverse shape and higher W/L ratio (typically 1.8 to 2.0), and acutely pointed rather than squared posterolateral areas. About 7 or 8 small spine bases protrude from the hingeline on each side of the beak. In the Jemez Springs collections, *N. "transversalis"* is moderately common in the Jemez Springs Shale and occurs sparingly below that unit to near the base of the Virgilian (e.g., units HC-11, RS-13). A small percentage of the specimens of *N. "transversalis"* in these assemblages approach the less transverse *N. granulifer* morphology.

Kozlowskia splendens (Norwood and Pratten)

These relatively small productoids (Figs. 4.24-4.27) attain a maximum width of about 25 mm at the hingeline (W/L = about 1.3). The pedicle valve is strongly geniculate (unusually convex) posteriorly and possesses a conspicuous median sulcus that begins about 5-7 mm in front of the

small beak. The ornamentation is distinctive—low radial costellae posteriorly (6-8/5 mm) that become obscure on the anterior trail, 4 or 5 coarse, isolated spines, of which one is situated on each lateral flank above the ears and two or three across the front of the trail (usually one on each side of the median sulcus and one within the sulcus), and a few smaller spines scattered on the valve. This species is one of the most common Missourian brachiopods at the Ranger Station section, occurring as high as unit RS-9, but has not been observed in Virgilian strata. In the Midcontinent region, its range is late Desmoinesian through Missourian.

Hystriculina cf. ***H. wabashensis*** (Norwood and Pratten)

Specimens superficially resembling *K. splendens* (Fig. 4.28) occur with that species in units RS-5 and RS-9. Their overall shape is similar to that of *K. splendens,* but they tend to be a little smaller (maximum W = 22 mm), have a more evenly curved, broadly convex pedicle valve, possess fairly numerous (up to 25) small spines across the anterior trail and lateral valve flanks, and lack the few isolated enlarged spines on the anterior trail and above the ears that characterize *K. splendens.* These Missourian specimens are similar to *H. wabashensis* from the Midcontinent area, but are significantly larger; typical members of the species average about 16 mm in width (Dunbar and Condra, 1932).

Hystriculina armata Dunbar and Condra

H. armata (Figs. 4.29-4.31) has the same general form as the preceding two species, but is smaller (typical W = 15-18 mm) and has more delicate, thinner valves. The pedicle valve is strongly convex, with prominent sharp ears, and bears an obscure to moderately deep median sulcus. The brachial valve is strongly concave, more so than in *K. splendens* and *H.* cf. *H. wabashensis.* Pedicle valve ornamentation consists of low, broadly rounded radial costellae that become obscure anteriorly, and many (35-45) conspicuous small spines, including 3-4 along the hingeline and a row of 4-5 along the base of the lateral flanks. *H. armata* is present only in the Jemez Springs Shale, where it occurs in great numbers.

Echinaria moorei Dunbar and Condra

E. moorei (Figs. 5.1-5.3) is a moderately large, spinose productoid; length and width are subequal and typically range from about 35 to 50 mm. The hingeline is relatively short, with the valves expanding laterally towards their widest extent near the anterior margin. The pedicle valve displays pronounced concentric growth bands, each of which is covered by numerous, small prostrate spines. Those spines along the posterior side of a band are largest; several uneven rows of progressively smaller spines develop anteriorly on each band. The brachial valve is moderately concave, displays many narrow growth bands, and is densely covered with several ranks of fine, prostrate spines up to 5 mm long, which extend anteriorly across two to four succeeding bands. This species is uncommon in the Jemez Springs Shale Member, and rare fragments were observed as low as unit RS-8 (upper Missourian) at the Ranger Station section. Sutherland and Harlow (1967) described the Jemez Springs Shale specimens as *E.* cf. *E. moorei* because they differed from the Midcontinent type specimens in being wider and less elongate.

Echinaria semipunctata (Shepard)

Fragments of a much larger species of *Echinaria* (Figs. 5.7-5.8) were collected from low (e.g., RS-5) in the upper Madera sections. More complete specimens have come from unit 7-5 of Swenson (1977), a Missourian bed at Locality 4 of Figure 1. The largest of these specimens is about 90 mm long, or twice as large as *E. moorei. E. semipunctata* also differs from *E. moorei* in having a conspicuous, narrow median sulcus on the pedicle valve that begins not far in front of the beak, and in having its spines confined to one or two major rows towards the posterior side of each growth band. In the Midcontinent area, *E. semipunctata* is most common in the lower Missourian, but ranges into lower Virgilian strata, whereas *E. moorei* becomes common in the upper Missourian and ranges to the top of the Virgilian (Dunbar and Condra, 1932). A similar distribution of the two species occurs in the Jemez Springs area.

Juresania nebrascensis (Owen)

This relatively small, highly spinose species (Figs. 4.35-4.37) is characterized by a fairly strongly convex pedicle valve with steep lateral flanks, an inflated, somewhat quadrate umbo, an obscure median sulcus and a strongly concave brachial valve that has a subquadrate outline. The pedicle valve displays rather wide growth bands, adorned generally with a single row of long, prostrate spines having nodular bases, and intermittent but fairly numerous larger erect spines. Dense clusters of suberect spines are present on the ears. Valve length and width are approximately equal, about 25 mm on a typical fully-grown specimen. This species is moderately common in the Jemez Springs Shale Member and underlying Virgilian strata (e.g., RS-13, RS-14, HC-11), but is rare in Missourian units.

Pulchratia symmetrica (McChesney)

P. symmetrica (Figs. 4.32-4.34) superficially resembles *Juresania nebrascensis* in its high spinosity, but differs in attaining a larger size (maximum width about 40 mm), and in other features. The pedicle valve is less convex, has more gently sloping lateral flanks, and a narrower, less quadrate umbo than *J. nebrascensis,* and the brachial valve is nearly flat to gently concave, rather than strongly concave. The growth bands of the pedicle valve are less distinct than those of *J. nebrascensis,* and they are densely covered with one or two ranks of prostrate spines. There are few erect spines across most of the valve, but clusters of suberect spines are present on the ears and lower lateral slopes. *Pulchratia symmetrica* is generally rare in Missourian strata, but becomes moderately common in unit RS-11, about at the Missourian-Virgilian boundary. The species is restricted to the Missourian in the Midcontinent region (Dunbar and Condra, 1932).

Antiquatonia jemezensis Sutherland and Harlow

Antiquatonia is a medium-sized productoid genus distinguished generally by prominent, closely-spaced radial costae that are conspicuous on the anterior trail, and which are crossed on the posterior third of the pedicle valve by concentric rugae (wrinkles) of about equal size, forming a reticulated, nodose pattern. Moderate numbers of erect spines are present on the pedicle valve, and a distinct row of such spines occurs along the base of the lateral flanks. *A. jemezensis* (Figs. 5.4-5.6) is a relatively small species (W about 30-35 mm; W/L = 1.25), with a strongly convex pedicle valve, especially posteriorly, that has a broad, moderately deep median sulcus, and well-developed ears. The anterior two-thirds of the valve surface is ornamented by strong, closely-spaced, fairly regular costae (8-9/10 mm), and a moderate number of isolated spines. Costae typically increase in size immediately below a spine base. The posterior reticulate part of the pedicle valve surface is strongly nodose at the intersections of the costae and rugae. A row of small spines is present along the hingeline, and on a sharp, prominent ridge that extends obliquely from the hingeline anterolaterally along the base of the lateral slopes. This species is common in the Jemez Springs Shale Member, from which Sutherland and Harlow (1967) first described it, and it is also present is lesser abundance in underlying Virgilian units (e.g., RS-13, HC-11).

Antiquatonia portlockiana (Norwood and Pratten)

A. portlockiana (Figs. 5.9-5.11) attains a width of up to about 40 mm, and is characterized by a broadly convex pedicle valve with a wide, shallow median sulcus, strong posterior reticulation, regular, closely-spaced radial costae (8-9/10 mm), and a few spines scattered across the valve. A spinose ridge along the base of the lateral flanks is variably developed. Compared to *A. jemezensis, A. portlockiana* is larger, has a somewhat less convex pedicle valve with less steeply sloping lateral areas, and fewer spines. A closely related species, *A. crassicostata* Dunbar and Condra, which Sutherland and Harlow (1967) believed to be ancestral to *A. jemezensis,* has a deeper median sulcus and considerably more irregular costae on the anterior trail than *A. portlockiana.* I have not observed *A. crassicostata* in the Jemez Springs area, although it is present in the Sangre de Cristo range (Sutherland and Harlow, 1973). *A. portlockiana* is moderately common in units RS-4 through RS-9 (Missourian) of the Ranger Station section, and is replaced by *A. jemezensis* in the Virgilian.

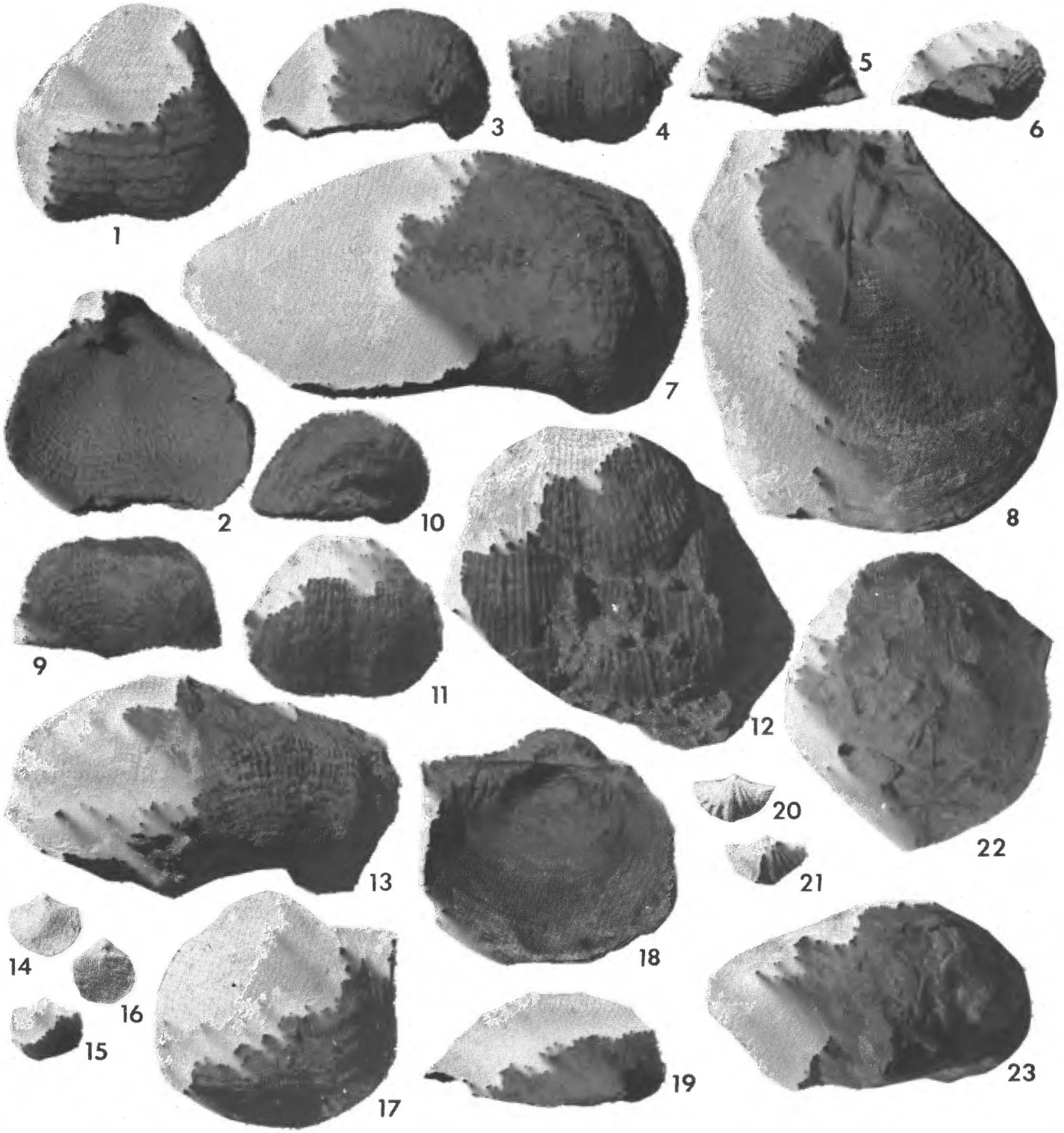

FIGURE 5. Brachiopods from the upper Madera Formation, Jemez Springs area, NM. RS = Ranger Station section; HC = Hummingbird Camp section. All figures x1 unless otherwise indicated. 1-3, *Echinaria moorei*, pedicle, brachial and side views, UNM 12,597, Jemez Springs Sh. Mbr. (unit RS-16). 4-6, *Antiquatonia jemezensis*, top, back and side views of a pedicle valve, UNM 12,600, Jemez Springs Sh. Mbr. (unit RS-16). 7, 8, *Echinaria semipunctata*, oblique side view of pedicle valve, UNM 12,598, and internal view of brachial valve, UNM 12,599, both from unit 7.5 of Swenson (1977). 9-11, *Antiquatonia portlockiana*, back, side, and top views of a pedicle valve, UNM 12,601, unit RS-4. 12, 13, *Reticulatia* aff. *R. americana*, front and oblique back views of a pedicle valve, UNM 12,602, unit RS-8. 14-16, *Crurithyris planoconvexa*; 14, 15, brachial and pedicle views, UNM 12,606; 16, brachial view, UNM 12,607; both from unit HC-11, x1.5. 17-19, *Linoproductus prattenianus*, pedicle, brachial and side views, UNM 12,603, Jemez Springs Sh. Mbr. (unit RS-16). 20, 21, *Punctospirifer kentuckyensis*, brachial and pedicle views, UNM 12,605, Jemez Springs Sh. Mbr. (unit RS-16). 22, 23, *Linoproductus platyumbonus*, top and side views of a pedicle valve, UNM 12,604, unit RS-8.

Reticulatia aff. ***R. americana*** (Dunbar and Condra)

Only two incomplete, distorted specimens of this unusually large productoid were collected, from a thin interval (upper RS-5 and RS-8) in the Missourian part of the upper Madera section. The largest specimen (Figs. 5.12-5.13) is an estimated 65 mm wide and 60 mm long. The pedicle valve is strongly convex posteriorly but less so across the anterior trail. It has strongly reticulate, nodose ornamentation on the posterior 30-40% of the valve, regular, coarse (6/10 mm) costae on the anterior trail, few spines, and an obscure median sulcus. Features of the hingeline, ears and brachial valve were not observed. Originally described from the Midcontinent by Dunbar and Condra (1932), *R. americana* was considered a synonym of *R. huecoensis* by Muir-Wood and Cooper (1960), but later again recognized as a separate, more coarsely ornamented species by Cooper and Grant (1975, p. 1088). The Jemez specimens appear to be more coarsely ornamented that typical specimens of *R. americana*, and better specimens are needed to establish their exact identity.

Linoproductus prattenianus (Norwood and Pratten)

The productoid genus *Linoproductus* possesses distinctive fine radial costellae that are uninterrupted by concentric ornamentation. *L. prattenianus* (Figs. 5.17-5.19) is a moderately large species, subequal in length and width (maximum W = 45 mm), with a rather gently convex pedicle valve having prominent ears and an obscure median sulcus. Ornamentation consists of regular fine costellae (14-16/10 mm) and numerous scattered spines. A double row of spines is present along the hingeline. This species is moderately common from unit RS-8 up to the Jemez Springs Shale Member at the Ranger Station section, and in units HC-11 through the Jemez Springs Shale at Hummingbird Camp. An unidentified species of *Linoproductus*, of similar size and proportions but with very few spines, is also present in the Missourian part of these sections. Most specimens of *Linoproductus* are broken and distorted because of the fragility of their valves, often making specific identification difficult.

Linoproductus platyumbonus Dunbar and Condra

Although there may be several species of *Linoproductus* in the upper Madera Formation, the only other species that could be positively identified is *L. platyumbonus* (Figs. 5.22-5.23). This large species (L = 60+ mm) is relatively elongate, strongly convex posteriorly, with a subangular umbo that is flattened or bears an obscure median sulcus across its crest. Near the anterior margin, the pedicle valve is raised into a low median fold. Ornamentation consists of fine costellae (about 15/10 mm) and sparse small spines. Numerous small spines are also present along the hingeline, some paired irregularly with slightly larger spines just anteriorly. *L. platyumbonus* is uncommon in the Missourian part of the Jemez Springs sections (units RS-4 to RS-8). These specimens closely resemble those of *L.* cf. *L. platyumbonus* described by Sutherland and Harlow (1973) from the Missourian of the Sangre de Cristo range; this species is confined to the Missourian in the Midcontinent region (Dunbar and Condra, 1932).

Cancrinella boonensis (Swallow)

Cancrinella boonensis (Figs. 4.38-4.39) is a small productoid (typical width about 10 mm), subcircular in outline, with a gently convex pedicle valve ornamented with numerous concentric wrinkles and many small spines. It is moderately common in the Jemez Springs Shale, but is rare in the Missourian to early Virgilian part of the upper Madera Formation.

Wellerella immatura Dunbar and Condra

This small rhynchonellid species (Figs. 4.40-4.42) is broadly triangular in shape, with a sharp, extended pedicle beak. Length and width are about equal (L = 6.7 mm; W = 6.6 mm on the largest specimen). The brachial valve is moderately convex and bears a slightly raised fold having three low, short plications, and three shorter lateral plications on each side of the fold. The pedicle valve is lower than the brachial, and has two prominent plications within a broad sulcus, and three short lateral plications to each side. The plications, particularly on the fold and sulcus, produce a strongly zig-zag commissure. These specimens agree closely with Virgilian specimens from the Sangre de Cristo range described by Sutherland and Harlow (1973). In the Jemez Springs area, this species has been collected only from unit HC-11 (latest Missourian or earliest Virgilian), where it is rare.

Hustedia sp.

The few specimens of *Hustedia* available (Fig. 4.43) are so incomplete or crushed that specific identification is uncertain, but they do display the small size (L about 8 mm), elongate subtriangular shape, large pedicle beak and circular pedicle opening, and about 10 strong plications that characterize the genus. *Hustedia* sp. is rare in the Missourian and lower Virgilian portions of the Madera Formation in the Jemez Springs area.

Composita subtilita (Hall)

This strongly biconvex, oval, unornamented species (Figs. 6.1-6.6, 6.17) is abundant throughout the Missourian and Virgilian near Jemez Springs. Shape, size, and degree of development of the fold and sulcus are highly variable, and several species have been proposed for what Grinnell and Andrews (1964) considered were gradational morphs of a single variable species. Large specimens in the Jemez collections are as much as 35 mm long, and vary from elongate- to transversely oval in shape, with a strong and narrow to low and wide fold and sulcus, and strongly to moderately convex valves. Many smaller specimens are also present; these typically have only a minimal fold and sulcus, are about equal in length and width, and rather gently biconvex. A selection of these morphologies is illustrated; the morphs called *"C. ovata"*, *"C. argentea"* and *"C. trilobata"*, in addition to the typical *C. subtilita* morphs, are present in the Jemez Springs collections.

Crurithyris planoconvexa (Shumard)

This small species (Figs. 5.14-5.16) has a strongly convex pedicle valve with a high, strong beak, and a small triangular pedicle opening beneath the beak. The brachial valve is much smaller, and is gently convex posteriorly and nearly flat anteriorly. A typical specimen is 7.4 mm long, 7.2 mm wide, and 4.3 mm thick. Although most specimens are about as wide as long, some are unusually wide. *C. planoconvexa* is present throughout the Missourian-Virgilian section, and is especially common in units HC-1 and HC-11.

Neospirifer pattersoni Sutherland and Harlow

Neospirifer pattersoni (Figs. 6.7-6.9) is a moderately transverse spiriferid that attains a width of 50-55 mm, with a W/L ratio of about 1.4 to 1.5. Both valves are moderately convex; the umbo and curved beak of the pedicle valve extends considerably beyond the brachial valve, and overhangs a relatively wide, flat interarea with a large triangular pedicle opening. The fold on the brachial valve is relatively narrow; the opposing sulcus is moderately wide and deep. Both valves are covered with radiating costae, of which about 12 occupy the sulcus and 22-26 are present on each lateral area of large specimens. Costae display the fasciculation (or clumping) characteristic of the genus, especially near the fold and sulcus. Each initial costa in this region quickly splits to form a group of three, and the secondary costae typically divide nearer the anterior margin to produce groups of four or five. Small specimens have fewer, higher costae, but the initial phases of costal splitting are always well displayed. Sutherland and Harlow (1967) established this species based upon specimens from the Jemez Springs Shale, in which it is common. The species is also common in some underlying units, including RS-14 and HC-11, low in the Virgilian. Specimens of a *Neospirifer* of similar size and proportions occur low in the Missourian part of the Jemez Springs sections (e.g., unit RS-5), but it is uncertain whether these are conspecific with *N. pattersoni,* or represent a closely related species such as *N. dunbari* King.

Neospirifer alatus Dunbar and Condra

This species is much larger and more transversely alate than *N. pattersoni*. Estimated original width of a nearly complete specimen (Figs. 6.14-6.16) is 80 mm; its W/L ratio is about 1.8. The fold is high and sharp, and the sulcus narrow and deep. About 15 costae occupy the sulcus; lateral costae number 25-30 and are strongly fasciculate. Groups of

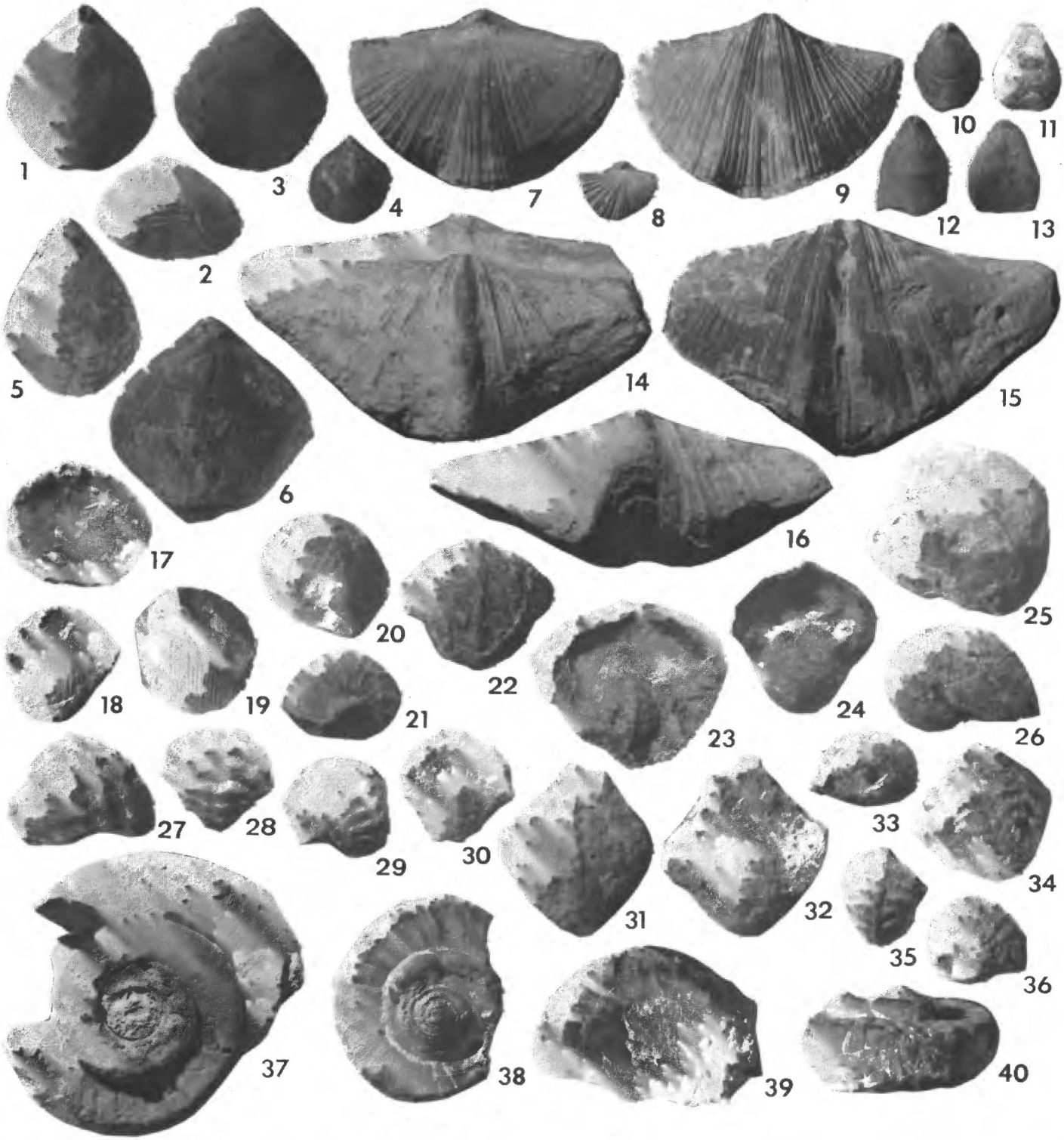

FIGURE 6. Brachiopods and gastropods from the upper Madera Formation, near Jemez Springs, NM. RS = Ranger Station section; HC = Hummingbird Camp section. Brachiopods: 1-6, 17, *Composita subtilita*; 1-3, brachial, front, and pedicle views of a typical specimen, UNM 12,609, Jemez Springs Sh. Mbr. (unit HC-17); 4, brachial view of a small, submature specimen, UNM 12,611, Jemez Springs Sh. Mbr. (unit HC-17); 5, brachial view of a narrow specimen, UNM 12,608 Jemez Springs Sh. Mbr. (unit HC-17); 6, brachial view of an unusually large, wide specimen, UNM 12,610, Jemez Springs Sh. Mbr. (unit RS-16); 17, internal view of a disarticulated brachial valve, UNM 12,620, unit HC-1, all x1. 7-9, *Neospirifer pattersoni*; 7, 9, brachial and pedicle views, UNM 12,612; 8, brachial view of a juvenile specimen, UNM 12,613; both Jemez Springs Sh. Mbr. (unit RS-16), x1. 10, 11, *Beecheria* sp. 1, brachial and pedicle views, UNM 12,616, Jemez Springs Sh. Mbr. (unit HC-17), x1.5. 12, 13, *Beecheria* sp. 3, brachial and pedicle views, UNM 12,617, Jemez Springs Sh. Mbr., Rincon locality, x1. 14-16, *Neospirifer alatus*, brachial, pedicle and front views, UNM 12,614, unit RS-8, x1. Gastropods: 18, *Euphemites* sp. 1, apertural view, UNM 12,618, unit RS-5, x1.5. 19, 20, *Euphemites* sp. aff. *E. vittatus*, apertural and oblique side views, UNM 12,619, unit HC-11, x2. 21-23, *Bellerophon (Bellerophon) wewokanus*; 21, side view, UNM 12,623, x1; 22, top view, UNM 12, 622, x1.2; 23, apertural view of an unusually large specimen embedded in matrix, UNM 12,621, x1; all from unit RS-5. 24-26, *Bellerophon (Bellerophon)* aff. *B. (B.) graphicus*; 24, 26, apertural and side views, UNM 12,624; 25, oblique top view, UNM 12,625; both from unit HC-11, x2. 27, *Pharkidonotus percarinatus*, oblique front view, UNM 12,626, unit HC-11, x1.5. 28-30, *Knightites* sp., top, oblique side, and apertural views, UNM 12,627, Jemez Springs Sh. Mbr. (unit HC-17), x1.5. 31-33, *Retispira tenuilineata*; 31, 32, top and apertural views of a matrix-encrusted specimen, UNM 12,628; 33, side view of an anteriorly incomplete specimen, UNM 12,629; both from unit HC-11, x2. 34, *Retispira eximia*, top view, UNM 12,630, unit HC-11, x1.5. 35, 36, *Retispira* aff. *R. nodocostata*, top and side views, UNM 12,631, x2. 37-40, *Euomphalus plummeri;* 37, top view of a large, incomplete specimen, UNM 12,632; 38-40, top, bottom and side views, UNM 12,633; both from unit RS-9, x1.

costae near the fold and sulcus typically include four or five costae anteriorly. These specimens are similar to the largest Midcontinent species of the genus, named *N. latus* by Dunbar and Condra (1932), but considered a synonym of *N. alatus* by Sutherland and Harlow (1973). Spencer (1967) described from Kansas an ususually alate form *(N. latus lateralis)* that attained a width of more than 80 mm, and the Jemez specimens are of this kind, although with a narrower fold and sulcus. Sutherland and Harlow's specimens of *N. alatus,* from the Missourian of the Sangre de Cristo Mountains, display moderately to very alate shapes; a subspecific name for the more transverse of these forms seems superfluous. This species is uncommon in the Missourian of the Jemez Springs area, ranging from units RS-4 to RS-9.

Punctospirifer kentuckyensis (Shumard)

This small, distinctive spiriferid (Figs. 5.20, 5.21) is typically much wider than long (W/L averages about 1.5, although variable) and attains a maximum width of about 15 mm. The fold is a single flattened plication and the sulcus is bordered by two strong plications. Six to eight additional bold plications occupy each lateral area, and all originate near the hingeline, without subsequent bifurcation. The shell is covered by fine, closely-spaced, raised concentric growth lamellae, which are especially conspicuous on the crests of the plications. Although this species ranges through much of the Pennsylvanian of the Midcontinent (Dunbar and Condra, 1932), and is present as low as the Atokan in the Sangre de Cristo range (Sutherland and Harlow, 1973), specimens from the Jemez Springs area were only recovered from Virgilian strata. It is common in the Jemez Springs Shale Member.

Phricodothyris aff. ***P. perplexa*** (McChesney)

Two small specimens from the Jemez Springs Shale Member represent *Phricodothyris.* The pedicle valve is strongly convex, with a moderately high umbo and curved beak that overhangs the less convex brachial valve. The shells are weathered, but display the concentric growth lamellae and impressions of the characteristic spines associated with these lamellae. The largest specimen is 13.2 mm long and 13.9 mm wide; Sutherland and Harlow (1967) reported specimens as much as 22 mm wide. *Phricodothyris perplexa* has been reported from throughout the Pennsylvanian (Dunbar and Condra, 1932), and is abundant in some New Mexico Desmoinesian units (Kues and Koubek, 1991). It may be that the name should be restricted to the relatively small Desmoinesian specimens (Dunbar and Condra, 1932; Sutherland and Harlow, 1967).

Beecheria spp.

Sutherland and Harlow (1967) described rare specimens of *Beecheria* sp. from the Jemez Springs Shale as a possible unnamed new species related to *B. bovidens* (Morton). Larger collections of this genus from that unit include two other species, probably also new. *Beecheria* sp. of Sutherland and Harlow (here called *Beecheria* sp. 1; Figs. 6.10, 6.11) is relatively small and narrow (W/L about 0.70), with a moderately deep pedicle sulcus and moderately convex brachial valve. *Beecheria* sp. 2 is narrower (best preserved specimen has L = 13.9; W = 8.8; T = 8.5; W/L = 0.63; T/L = 0.61); its brachial valve is strongly convex longitudinally along the midline as well as being sharply arched, with steeply sloping lateral areas, and its pedicle sulcus is moderately deep and very narrow. The T/L ratio nearly equals the W/L ratio. *Beecheria* sp. 3 (Figs. 6.12, 6.13) is quite different from both of the forms noted above. It is larger (L = 17.1; W = 12.6; T = 7.8; W/L = 0.74; T/L = 0.46 for the best preserved specimen), expands laterally to a greater extent towards the anterior margin, has a more broadly arched brachial valve that is nearly flat along its midline and a lower T/L ratio, and possesses a wide, shallow sulcus that encompasses most of the width of the pedicle valve towards its anterior end.

All *Beecheria* specimens observed in the Jemez Springs area were collected from the Jemez Springs Shale Member.

Gastropods

Gastropods are abundant in the upper Madera Formation of the Jemez Springs area, but are mainly concentrated in shale units. Preservation is typically rather poor because of post depositional distortion, coarsely recrystallized shells, or total dissolution of the shells, leaving steinkerns. The species described here represent perhaps two-thirds of the total taxa identified in my collections. Those omitted are either extremely rare, or very poorly preserved.

Euphemites sp. 1

Most *Euphemites* shells, especially the numerous specimens from unit RS-5 (Fig. 6.18), are crushed or otherwise distorted, and corroded by weathering. These bellerophontids attain a maximum length of about 22 mm, are apparently evenly rounded, and lack an umbilicus. The early part of the body whorl is slightly compressed laterally, and widens moderately towards the anterior end. Typically, about 14 to 18 strong, sharp, spiral lirae, separated by interspaces 1-1.5 times as wide as a lira, are present on the earliest two-thirds of the body whorl; nodes or diagonal ribs near the umbilical areas are absent. The selenizone, visible on the anterior, non-lirate part of the shell, is relatively wide, flush with or slightly depressed below the shell surface, and bordered by a fine lira on each side. *Euphemites* of this type, but generally with 18-25 spiral lirae, have been assigned by many authors to *E. carbonarius* (Cox), but King (1940) and Yochelson (1960) noted that this species is unrecognizable and the name a *nomen dubium.* The Jemez specimens do not exactly agree with any well-defined Pennsylvanian or Permian species. They range from unit RS-5 to RS-9 (Missourian) at the Ranger Station section, and may also be present in Virgilian strata as well.

Euphemites sp. aff. ***E. vittatus*** (McChesney)

The shell is small (maximum L = 14 mm), globose, non-geniculate, and bears an umbilicus of moderate size (Figs. 6.19-6.20). The body whorl expanded moderately with growth, and the selenizone is inconspicuous and flush with the shell surface. As many as 30 sharp spiral lirae (20-22 at plane of aperture) occur on the body whorl, and near the umbilicus these are supplemented by a few diagonal rows of nodes that in some specimens coalesce into short ribs. These structures extend farther anteriorly than the typical spiral lirae. *E. vittatus,* known mainly from the Virgilian of Texas (King, 1940), is similar, but has fewer (18-22) spiral lirae, a greater number of smaller nodes, and lacks the diagonal ribs of the Jemez specimens. *E. blaneyanus* (McChesney) is also similar, but possesses no more than about 19 lirae. The Jemez specimens are common in unit HC-11 and uncommon in the Jemez Springs Shale Member (HC-17), both of Virgilian age.

Euphemites spp.

Most Virgilian specimens of *Euphemites* from the Hummingbird Camp section are poorly preserved, and specific identification is not possible. The specimens included here are all small (L up to about 13 mm), and doubtless include some specimens of the preceding species on which the umbilical nodes were not visible. In addition, however at least two other species are present, having fewer spiral lirae (about 12 in one form; about 20 in another), and, on a few specimens, a prominent, wide, depressed selenizone bordered by sharp lirae. Better specimens are needed for adequate description, and none are illustrated here.

Bellerophon (Bellerophon) wewokanus Girty

B. (B.) wewokanus is the most common bellerophontid in the lower Missourian part of the Jemez Springs Madera sequence, occurring in great numbers in unit RS-5. The shell is rather globose and expands greatly anteriorly to produce a wide, flaring aperture (Figs. 6.21-6.23). The lateral lips meet the body of the shell with slight curvature; there is no umbilical opening. The selenizone is conspicuously raised, convex, and welt-like throughout growth. Specimens are inevitably crushed or otherwise distorted, corroded by weathering, and most are missing the anterior margin. Nonetheless, they agree in all features except size, with *B. (B.) wewokanus,* first described by Girty (1915) from the upper Desmoinesian Wewoka Formation of Oklahoma. The type specimens attain a maximum width of about 16 mm, whereas the largest Jemez specimen is 28 mm wide at the aperture and 27 mm long.

Bellerophon (Bellerophon) aff. ***B. (B.) graphicus*** Moore

This relatively small (L = 15 mm; W = 14 mm on a typical specimen) species (Figs. 6.24-6.26) is characterized by a shell with a slightly com-

pressed early body whorl that expands moderately anteriorly. The lateral lips are thickened and slightly curved where they meet the whorl sides; there is no umbilical depression. The selenizone is narrow, flat, and slightly raised, and the shell surface bears conspicuous, arcuate, closely spaced, overlapping growth lamellae that cross the selenizone with a strong posterior bend. The anterior lip has a relatively short, broad, median slit. These specimens are closely related to *B. (B.) graphicus* (Moore, 1941) from the Virgilian of Kansas, but differ in having a slightly narrower body whorl and more distinctly lamellate surface ornamentation. Similar specimens occur in the earliest Wolfcampian Laborcita Formation of south-central New Mexico (Kues, 1991a). This species is abundant in lower Virgilian strata (HC-11) and rare in the slightly younger Jemez Springs Shale Member. It differs from *B. (B.) wewokanus* in having a narrower body whorl and aperture, a slightly raised flat (instead of a high rounded) selenizone, and in its lamellate ornamentation.

Among typical specimens of *B. (B.)* aff. *B. (B.) graphicus* in unit HC-11 are a moderate number of specimens with similar ornamentation that are distinctly more laterally compressed, as well as a few specimens with extremely narrow, steep-sided body whorls that resemble the form of *Sinuitina.* Distortion seems not to have been a significant factor. These forms appear to be intergradational, but the endpoints are so different that they cannot possibly belong to the same species. More study is required to assess the relationship of these laterally compressed specimens.

Pharkidonotus percarinatus (Conrad)

These medium-sized bellerophontids (Fig. 6.27) are characterized by their distinctive ornamentation, which includes a raised, nodose selenizone ridge and prominent transverse wrinkles, which may be subnodose at their median ends. Aside from this coarse ornamentation, and fine growth lines, the shells are smooth. Specimens are up to about 27 mm wide. This species is uncommon, and was observed only in units RS-5 and HC-11, indicating a range from lower Missourian to lower Virgilian in the Jemez Springs area.

Knightites sp.

The shell of this distinctive bellerophontid (Figs. 6.28-6.30) is relatively small (W = 12-15 mm), with a flaring aperture and a smooth inductural callus within the aperture. The shell surface is ornamented with fine spiral lirae in two ranks, and prominent nodose transverse wrinkles extending from the umbilical area to near the midline, where they terminate in opposition to those on the other side of the shell. Each wrinkle is swollen into a prominent circular node at its median end, and a second, smaller node near its umbilical end. The selenizone is narrow and low along the midline, below the median nodes of the transverse wrinkles. This distinctive nodose transverse ornamentation is apparently present throughout growth. This undescribed species superficially resembles *Retispira eximia* Yochelson, but the nodose wrinkles are characteristic of *Knightites* (Yochelson, 1960). The few previously described late Paleozoic species of *Knightites* are much larger than the Jemez specimens, and all differ considerably in aspects of shell shape and ornamentation. *Knightites* sp. is uncommon in Virgilian strata (HC-11, Jemez Springs Shale) in the Jemez Springs region.

Retispira tenuilineata (Gurley)

This bellerophontid (Figs. 6.31-6.33) is relatively small (L = 14 mm) and laterally compressed, but expands with growth to form a moderately flaring aperture. The umbilicus is large, circular and open. Ornamentation consists of fine spiral lirae (5-8/mm) that are typically crossed almost imperceptibly by fine growth lines that do not interrupt the lirae. The selenizone is moderately wide, gently convex, flush with the shell surface or slightly raised or depressed, and covered with 10-14 spiral lirae that are finer than those of the shell sides. A swollen, knob-like callus is present just within the aperture. *R. tenuilineata* is common in unit HC-11, but uncommon in the Jemez Springs Shale (HC-17), both Virgilian.

Occurring with typical specimens of *R. tenuilineata* are a few specimens with growth lines that are accentuated into curved transverse lirae of about the same strength as the spiral lirae, and produce small interference nodes and a delicately cancellate pattern as they cross the spiral lirae. Both the spiral and transverse lirae are finer than on such species as *R. bellireticulata* Knight and *R. textiliformis* (Gurley), and the transverse lirae never develop into wrinkles or undulations, as on *R. modesta* (Girty) or *R. eximia* Yochelson. There is intergradation between the dominant spiral ornamentation on typical specimens of *R. tenuilineata,* and the cancellate ornamentation of these specimens; more study is needed to definitely determine their relationships.

Retispira eximia Yochelson

R. eximia (Fig. 6.34) attains a maximum width of about 25 mm, with a body whorl that expands significantly anteriorly and a large inductural callus within the aperture. Ornamentation consists of fine spiral lirae in two ranks, the larger with 2 to 5 smaller lirae between them, and numerous, sharp-crested, gently arcuate transverse wrinkles extending from the umbilical area to near the midline, opposing each other across the depressed selenizone. On small specimens, the transverse wrinkles are fine, scarcely larger than the major spiral lirae, and the selenizone is flush with the adjacent shell surface or slightly raised. *R. eximia* was initially described from the Early Permian (Yochelson, 1960). In the Jemez Springs area it is moderately common in unit HC-11 and is rare in the Jemez Springs Shale (Virgilian). Poorly preserved specimens that may be *R. eximia* were also observed fairly low in the Ranger Station section (RS-5).

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

A fourth bellerophontid with fine spiral lirae and transverse wrinkles is rare in the Jemez Springs Shale. This species (Figs. 6.35-6.36) is small (maximum L = 11 mm), has a narrow, laterally compressed body whorl that expands moderately with growth, and is ornamented with relatively coarse spiral lirae that are crossed by narrow, low, transverse wrinkles. The selenizone is strong, raised, and displays node-like lunulae along its length. The few available specimens are incomplete and poorly preserved. This species is related to *R. nodocostata,* from the Missourian-Virgilian of Illinois, but differs in its conspicuously raised selenizone. The Jemez specimens also closely resemble *R.* n. sp. of Kues (1991a), from early Wolfcampian strata in south-central New Mexico, but that species possesses more numerous, less prominent transverse wrinkles.

Euomphalus plummeri Knight

This species is characterized by its discoidal, low-spired shell, with a very broad, deep ventral umbilicus, and by its large size, up to about 60 mm in diameter (Figs. 6.37-6.40). The lateral margin of the upper whorl surface curves sharply down to the outer whorl surface but lacks a definite carina, as seen in species of *Amphiscapha.* The outer whorl surface is moderately convex, and curves evenly into the strongly convex ventral surface. The Jemez specimens agree closely with those described by Knight (1934), from the Missourian of Texas and Kansas. The distinctive features of the shell are present even on small (W = 15 mm) specimens, allowing discrimination from specimens of *Amphiscapha* of the same size, which have a depressed spire and nearly flat base. *E. plummeri* is abundant in only one unit (RS-9), a tan-gray nodular limestone, in the Jemez Springs area, but ranges from RS-5 to RS-11 (Missourian). Somewhat surprisingly, this is the first report of this impressive species from the Jemez Springs region.

Amphiscapha subrugosa (Meek and Worthen)

A. subrugosa (Figs. 7.1, 7.2) is a small (maximum W = 13 mm), discoidal species with a concave dorsal surface and depressed spire, and a flat to gently concave base. The carina on the lateral edge of the upper whorl surface is strong and undulatory to subnodose, and the basal-lateral flange is conspicuous and somewhat rugose. Growth lines tend to be pronounced and irregular. This species, common in unit HC-11 and uncommon to rare in higher units, including the Jemez Springs Shale, is apparently confined to the Virgilian part of the Madera Formation in the Jemez region.

Amphiscapha cf. ***A. subsulcata*** Knight

This species (Figs. 7.3, 7.4), common in unit RS-5 (Missourian), appears most closely related to *A. subsulcata.* It is relatively large for the genus (maximum W = 23 mm); the spire is depressed in a concave dorsal surface, and the base is gently concave. A well-developed rugose to ir-

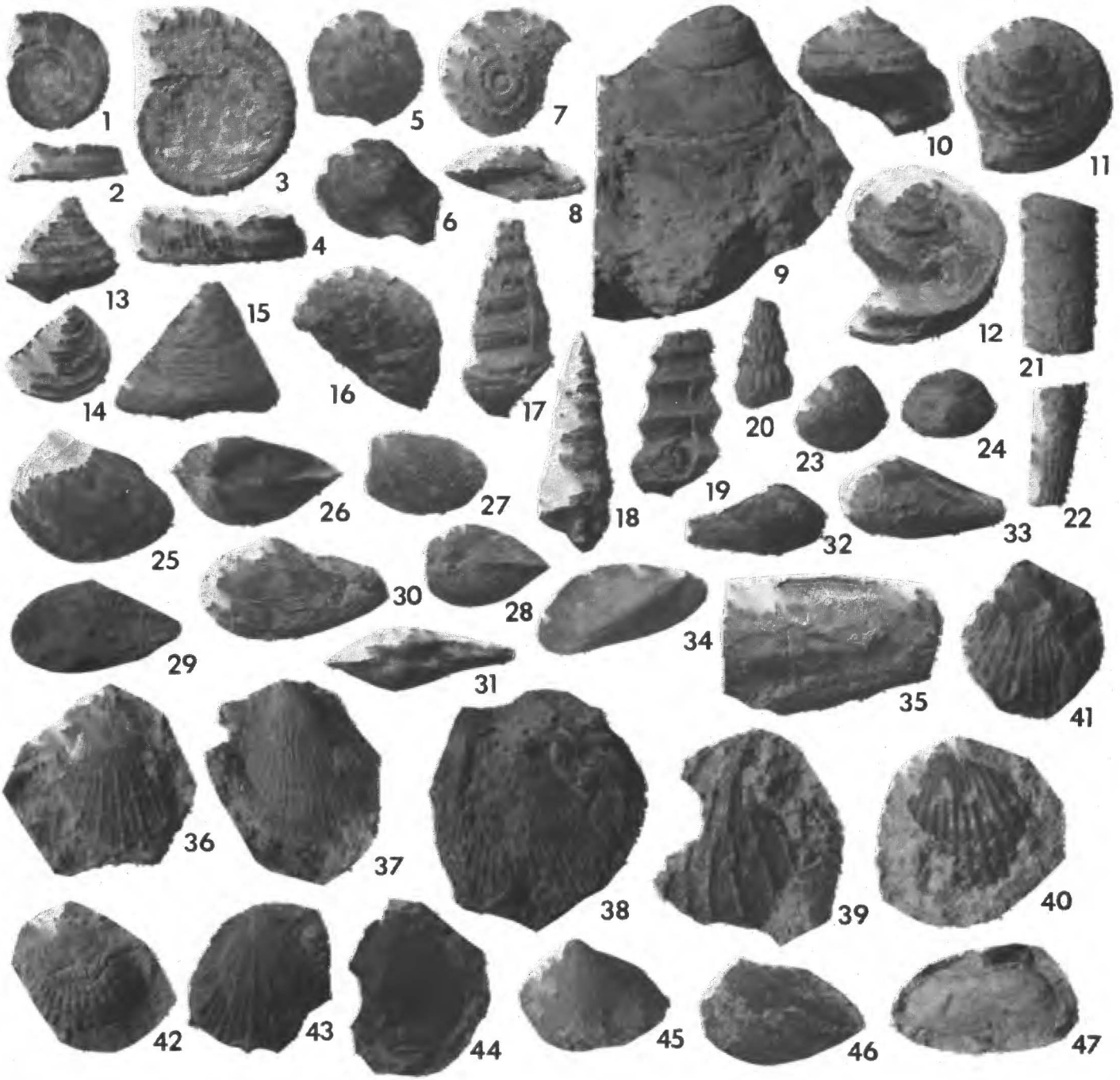

FIGURE 7. Gastropods, scaphopods and bivalves from the upper Madera Formation, Jemez Springs area, NM. RS = Ranger Station section; HC = Hummingbird Camp section. Gastropods: 1, 2, *Amphiscapha subrugosa*, bottom and side views, UNM 12,634, unit HC-11, x1.5. 3, 4, *Amphiscapha* cf. *A. subsulcata*, bottom and side views, UNM 12,635, unit RS-5, x1.5. 5, 6, *Colpites* aff. *C. monilifera*, top and side views of an incomplete specimen, UNM 12,636, x1.5. 7, 8, *Trepospira (Trepospira)* aff. *T. (T.) illinoisensis*, top and side views, UNM 12,637, unit HC-11, x1. 9, *Euconospira* cf. *E. missouriensis*, side view of a partial specimen in matrix, UNM 6743,unit RS-9, x1. 10, 11, *Glabrocingulum (Glabrocingulum)* sp., side and oblique top views, UNM 12,638, unit HC-11, x3. 12, *Worthenia tabulata*, oblique top view of a crushed, matrix-covered specimen, UNM 12,639, unit RS-5, x1.2. 13, 14, *Phymatopleura brazoensis,* side and oblique top views, UNM 12,641, unit HC-11, x3. 15, *Paragoniozona* sp., side view, UNM 12,640, Jemez Springs Sh. Mbr., Rincon locality, x2. 16, *Platyceras (Orthonychia) parvum*, oblique top view, UNM 12,642, unit RS-5, x1. 17, *Stegocoelia (Hypergonia)*? sp. 1, side view, UNM 12,643, unit HC-1, x1.5. 18, *Stegocoelia (Hypergonia)*? sp. 2, apertural view, UNM 12,644, Jemez Springs Sh. Mbr., Rincon locality, x7. 19, *Goniasma lasallensis*, side view of a fragmentary specimen, UNM 12,645, unit HC-1, x1.5. 20, *Pseudozygopleura (Pseudozygopleura)*? sp., side view of a fragmentary specimen, UNM 12,646, Jemez Springs Sh. Mbr., Rincon locality, x1.5. Scaphopods: 21, 22, *Prodentalium* aff. *P. sublaeve*, fragments of mature (UNM 12,647) and early (UNM 12,648) parts of shell, unit HC-11, x1.5. Bivalves: 23, 24, *Nuculavus wewokanus*, left valve and top views, UNM 12,649, unit HC-11, x3.25. 25, 26, *Nuculopsis anodontoides*, right valve and top views, UNM 12,650, unit HC-11, x1.5. 27, 28, *Nuculopsis girtyi*, right valve and top view, UNM 12,651, unit RS-5, x1.5. 29, *Paleyoldia glabra*, matrix-encrusted left valve, UNM 12,652, unit HC-11, x2. 30, 31, *Girtyana arata*, left valve and top views, UNM 12,653, unit HC-11, x1.5. 32, 33, *Polidevcia attenuata*, right (x2.75) and oblique left (x3) valve views, UNM 12,654, unit HC-11. 34, *Volsellina* cf. *V. subelliptica*, right valve, UNM 12,655, unit HC-11, x1.5. 35, *Aviculopinna peracuta*, small shell fragment, UNM 12,656, unit RS-13, x1. 36, *Aviculopecten moorei*, incomplete left valve, UNM 12,661, unit RS-13, x1. 37. *Aviculopecten occidentalis*, incomplete left valve, UNM 12,660, unit RS-13, x1. 38, *Aviculopecten* aff. *A. basilicus*, incomplete left valve, UNM 12,662, unit HC-1, x1. 39, *Aviculopecten* sp., incomplete left valve, UNM 12,663, unit RS-13, x1. 40, 41, *Acanthopecten carboniferus*, incomplete left valves, UNM 12,664 and 12,665, unit HC-11, x2. 42, *Acanthopecten meeki*, incomplete left valve, UNM 12,666, unit RS-8, x1. 43, *Clavicosta echinata*, incomplete left valve, UNM 12,667, Jemez Springs Sh. Mbr. (unit RS-16), x1. 44, *Pernopecten* sp., incomplete left valve, UNM 12,668, unit HC-11, x1. 45, *Schizodus ulrichi*, left valve view of steinkern, UNM 12,669, unit HC-11, x1.5. 46, *Schizodus "meekanus,"* left valve view of steinkern, UNM 12,670, unit HC-11, x1.5. 47, *Permophorus* aff. *P. subcostatus*, right valve view of steinkern, UNM 12,671, unit RS-13, x1.

regularly crenulate carina occupies the lateral margin of the dorsal whorl surface. The outer whorl face is broadly convex, becoming narrowly concave just above the swollen basal-lateral area. Growth lines are strongly and irregularly lamellate, and swing slightly posteriorly across the outer whorl face. The shell of *A.* cf. *A. subsulcata* is larger and lower than that of *A. subrugosa,* and its dorsal corina tends to be more conspicuously crenulated and sharper than that of the latter species. The few previous reports of *A. subsulcata* are from late Desmoinesian to early Missourian strata in Oklahoma (Yochelson and Saunders, 1967).

Colpites aff. ***C. monilifera*** (White)

The best-preserved specimen (Figs. 7.5, 7.6), although incomplete, displays a subglobose, very low-spired shell that is about 14 mm wide and 11 mm high, consisting of 6.5 whorls. The body whorl represents about 90% of the total shell height. The aperture and umbilical area are not preserved. On the later whorls, large, slightly transversely elongate nodes are present just below the suture, but these extend only through the first half of the body whorl. The Jemez Springs specimens differ from the type and referred specimens of *C. monilifera* (see Knight, 1941) mainly in being lower spired and in the limitation of the subsutural nodes to the early part of the body whorl. This species is rare in the Jemez Springs Shale Member.

Trepospira (Trepospira) aff. ***T. (T.) illinoisensis*** (Worthen)

This species is discoidal in shape, very low spired, and attains a maximum diameter of about 30 mm (Figs. 7.7, 7.8). The upper whorl surface is flat to very gently concave and slopes at a low angle outward from the upper suture to a sharp periphery, below which is the gently convex base. A single row of relatively small subcircular nodes occurs just below the suture on the later whorls; about 20-25 nodes are present on the body whorl of large specimens. The narrow selenizone occupies the outer margin of the upper whorl surface. All specimens are incomplete and generally poorly preserved, but shell proportions and ornamentation agree well with *T. (T.) illinoisensis,* a geographically widespread species that ranges from strata of Desmoinesian to possibly Wolfcampian age. The largest Jemez specimens are considerably larger than most specimens referred to *T. (T.) illinoisensis,* but examples of this species as large as 30 mm wide have been reported (e.g., Girty, 1915). *T. (T.) discoidalis* Newell (Missourian of Kansas) attains an even greater size but has a higher spire and more nodes per whorl than the Jemez specimens. *T. (T.)* aff. *illinoisensis* has been collected only from unit HC-11 (lower Virgilian) in the Jemez area, where it is fairly common.

Euconospira turbiniformis (Meek and Worthen)

E. turbiniformis has a medium-sized (W = 31 mm; estimated original H = 25 mm on a representative specimen), broadly conical shell with nearly flat whorl surfaces, a very gently convex base, and a very narrow depressed selenizone situated just above the lower suture that is delineated by a pair of sharp lirae. Ornamentation consists of numerous fine, rounded spiral lirae, crossed by sharp, sinuous, prosocline transverse lirae to form a subcancellate pattern. This species is rare in the Jemez Springs Shale Member and slightly older Virgilian strata.

Euconospira cf. ***E. missouriensis*** (Swallow)

The shell of *E.* cf. *E. missouriensis* (Fig. 7.9) is similar in shape and proportions to that of *E. turbiniformis,* but is much larger (e.g., W = 55 mm, estimated H = 40+ mm for the best preserved specimen). Ornamentation includes relatively coarse, rounded, closely-spaced spiral cords (10-12/5 mm) on the whorl surface, which are crossed by strongly prosocline growth lines that are much weaker than the sharp transverse lirae of *E. turbiniformis.* The selenizone is situated at the base of the whorl surface, and is narrow, but its exact configuration is not well preserved. Other workers (e.g., Sayre, 1930) have noted that the selenizone of *E. missouriensis* was originally described as convex, in contrast to the concave selenizone of *E. turbiniformis,* but it is not possible to evaluate this feature on the Jemez specimens. The differences in ornamentation noted above may be due to degree of weathering of the shell, and it is not certain that the large specimens described here are not simply large representatives of *E. turbiniformis. E.* cf. *E. missouriensis* is rare in unit RS-9 (Missourian).

Glabrocingulum (Glabrocingulum) sp.

The shell (Figs. 7.10, 7.11) is small (W = 9-10 mm) and low spired, with each whorl embracing the previous one nearly up to the narrow, well-defined selenizone on the outer whorl shoulder. The base of the body whorl is gently convex, with a depressed umbilical area partly filled with a low, broad callus. The spiral ornamentation of the upper whorl surface includes a subsutural row of large nodes, a second, smaller subnodose lira, and one or two fine sharp lirae above the selenizone. Many much finer to obscure spiral lirae are superimposed on the major features, but transverse ornamentation is limited to fine growth lines. This species is probably conspecific with *G. (G.)* n. sp. of Kues (1991a), from the earliest Permian Laborcita Formation of south-central New Mexico, and is one of several similar Pennsylvanian-Early Permian species having a low spire and prominent umbilical callus (see Batten, 1989). In the Jemez Springs region, this species is abundant in unit HC-11, and moderately common but poorly preserved in higher Virgilian units.

A second species of *Glabrocingulum*—somewhat larger (W = 12-14 mm), higher spired, and more inflated than *G. (G.)* n. sp.—occurs commonly in the Missourian part of the Madera sequence, especially in unit RS-5. The specimens are poorly preserved and extensively covered with a hard matrix, preventing detailed determination of ornamentation and the nature of the umbilical area.

Worthenia tabulata (Conrad)

This species (Fig. 7.12) has a turreted, moderately high-spired, relatively large shell (W and H are about equal at 27 mm in the largest specimens). The conspicuously nodose selenizone at the whorl shoulder is also distinctive. Ornamentation is mainly spiral lirae on the upper whorl surface, and spiral and transverse lirae of approximately equal strength on the outer whorl face and base of the shell. *Worthenia tabulata* is moderately common in unit RS-5 and HC-11 (lower Missourian to lower Virgilian). Specimens are invariably crushed severely and largely covered with resistant matrix.

Paragoniozona sp.

The single shell collected from the Jemez Springs Shale at the Rincon locality (Fig. 7.15) is slightly distorted and the aperture is crushed. The shell is broadly conical and consists of about six whorls; the whorl profile changes from moderately convex (earliest three whorls) to virtually flat with growth. Height is 11.7 mm, whereas maximum width is 15.7 mm. Ornamentation of the whorl surfaces is limited to about 10-12 spiral rows of isolated, small, round nodes, above a narrow, apparently swollen selenizone at the whorl periphery, just above the suture. The base of the body whorl appears to be nearly flat near the periphery but is depressed in the umbilical area, and bears about eight fine, widely-spaced, non-nodose, spiral lirae. The ornamentation of the whorl surfaces, the profile of both early and later whorls, and the features of the body whorl base are similar to that of *P. nodolirata* Nelson (1947), from the early Pennsylvanian of west Texas. However, on the Jemez specimen, the selenizone is convex rather than depressed, there are many more rows of nodes on the upper whorl surface, and the shell is much larger and has a flatter overall lateral profile than *P. nodolirata.*

Phymatopleura brazoensis (Shumard)

This small (H and maximum W about 8-9 mm), broadly conical species (Figs. 7.13, 7.14) displays distinctive ornamentation consisting of numerous fine spiral lirae crossed by sharp, strongly prosocline transverse lirae to form a minutely subnodose reticulate pattern on the whorl surface, and a row of moderately strong, evenly-spaced, somewhat transversely elongate nodes immediately below the suture. The selenizone is depressed, wide (up to 1/4 of the whorl height), situated near the base of the whorl surface, bordered by a strong spiral lira along its upper and lower margins, contains a fine median spiral lira, and is crossed by conspicuous arcuate transverse lunulae. The base of the shell is slightly convex and is ornamented with many spiral lirae crossed by sinuous transverse lirae. *P. brazoensis* is known mainly from Virgilian and Wolfcampian strata of Texas and Kansas. It is uncommon in unit HC-11 (lower Virgilian) of the Hummingbird Camp section.

Platyceras (Orthonychia) parvum (Swallow)

The shell of this unusual species (Fig. 7.16) is low and expanded rapidly, producing only about one whorl with a large aperture. The apex is curved and hook-like, and the shell is unornamented. The largest example from the Jemez area is about 28 mm long, but the species is rare, apparently limited to units RS-5 and HC-11.

Stegocoelia (Hypergonia)? sp. 1

Vast numbers of this relatively large (H = 25-30 mm), high-spired species (Fig. 7.17) are present in the brown shale unit (HC-1) low in the Missourian of the Hummingbird Camp section, but the shells are invariably poorly preserved and encrusted with matrix and reprecipitated calcite. The whorl surfaces are broadly convex and slightly pendant. Three strong spiral lirae occupy the lower half of later whorls, developing from two centrally located lirae on earlier whorls. There are faint suggestions of a slightly depressed selenizone just above the highest of the spiral lirae, on the upper whorl surface, but the presence of a selenizone remains to be confidently documented, hence the questioned assignment to *Stegocoelia (Hypergonia).* Some specimens have a fine lira some distance below the upper suture, which could mark the upper margin of a selenizone. The specimens typically have an apical angle of 25-30°, but this varies; some specimens expanded rather rapidly with growth and thus have a higher angle and a less narrow form. Likewise, the profile of the whorl surface varies from broadly convex to somewhat angular at the highest of the spiral lirae, which forms a muted carina. In general, this species resembles *S. (H.) wortheni* Knight in being large for the genus, but that species has a less convex whorl profile and four instead of three major spiral lirae low on the whorl.

Stegocoelia (Hypergonia)? sp. 2

This species (Fig. 7.18) resembles *S. (H)*? sp. 1 but is much smaller; its narrow, high-spired shell of 12 whorls attains a maximum height of only about 7 mm. The aperture is small, slightly oval, and gently inclined away from the axis of the shell. The whorl profile is strongly convex and somewhat pendant. Typically, three strong spiral lirae occupy the lower two-thirds of a whorl, the upper two of these being most prominent. A single faint spiral lira is also present just below the suture; the intervening, slightly concave area of shell surface marks the inferred selenizone. Variation in number of lirae is moderate; a few specimens have a fourth lira just above the suture or a second fine lira on the upper whorl surface. Ornamentation begins on the third whorl with development of two strong central lirae; the lowermost and uppermost additional lirae are present by whorl 4. This species bears a strong superficial resemblance to species of *Donaldina,* which, however, lack a selenizone. *Stegocoelia (Hypergonia)?* sp. 2 is moderately common, although difficult to discern because of its small size, in the Jemez Springs Shale at the Rincon locality, and is also sparingly present in unit HC-11, both of Virgilian age.

Goniasma lasallensis (Worthen)

The shell of this distinctive, narrow, high-spired species (Fig. 7.19) is characterized by a steeply-sloping, flat to slightly concave, unornamented upper whorl surface, a prominent sharp carina at the periphery, about two-thirds of the distance to the base of the whorl, and a narrow selenizone bounded above by the carina and below by a smaller spiral lira on the inward-sloping lower whorl face. A second spiral lira often is present just above the lower suture. All specimens are incomplete; fragments indicate an estimated maximum shell height of nearly 30 mm, although most specimens are considerably smaller. This species is uncommon in several units from the lower Missourian to highest Virgilian (Jemez Springs Shale Member) portions of the Madera sequence in the Jemez Springs area.

Pseudozygopleura (Pseudozygopleura)? sp.

Fragmentary specimens of this narrow, high-spired genus (Fig. 7.20) are uncommon in the Jemez Springs Shale Member at the Rincon locality. They are characterized by slightly pendant, convex, whorl profiles and strong, slightly arcuate transverse ribs that extend from the upper to lower sutures of the whorls. The largest specimen was an estimated 15-20 mm high when complete. Poor preservation precludes specific identification.

Scaphopods

Fragments of scaphopod shells are uncommon in the upper Madera Formation; most were collected from unit HC-11. They are typically weathered or covered with matrix, but ornamentation preserved on a few specimens allows assignment to *Prodentalium.*

Prodentalium aff. ***P. sublaeve*** (Hall)

The largest fragment is 27 mm long and tapers slightly from a diameter of 11.0 mm to 9.7 mm along its length. Reconstruction of a complete shell from the fragments at hand indicate a long, narrow shell with an apical angle of about 10° and a maximum length of about 150 mm. At a diameter of 11 mm the shell thickness is 1.5 mm. Ornamentation of the larger fragments (Fig. 7.21) consists of fine, rounded, closely-spaced longitudinal ribs (about 2.5/mm), crossed by finer, closely-spaced growth lines. On small specimens (diameter less than 5 mm), the longitudinal ribs are sharp and widely spaced (about 1.5 ribs/mm) separated by interspaces about twice the width of a rib (Fig. 7.22). These Madera specimens are conspecific with scaphopods from the basal Permian of south-central New Mexico identified as *Prodentalium* aff. *P. sublaeve* by Kues (1991b). This taxon is smaller than *P. raymondi* (Young), and has coarser ribbing than *P. canna* (White).

Bivalves

Bivalves are common in some units, particularly shales, of the Missourian-Virgilian sequence near Jemez Springs. Thin, nearshore marine horizons dominated by myalinids, especially *Myalina (Orthomyalina) slocombi,* are present in units HC-1 and locally within the Jemez Springs Shale Member. A brown shale/siltstone bed near the base of the Ranger Station section (RS-5) lacks myalinids but contains an assemblage of low diversity dominated by *Nuculopsis anodontoides, N. girtyi,* and *Girtyana arata,* together with smaller numbers of a few gastropod taxa. In addition, one unusual, almost coquinoid, concentration of myalinids, pectinids and many other bivalves is present in the thin gray limestone unit RS-13.

Many bivalve taxa are represented by recrystallized shell material, although these specimens are usually crushed or otherwise distorted. Some species are known only from steinkerns. As is true of the gastropods, some bivalves are omitted from discussion here because they are very rare or are poorly preserved.

Nuculavus wewokanus (Girty)

N. wewokanus is a very small species with a triangular, inflated shell, convex ventral margin, and somewhat posteriorly situated high beaks (Figs. 7.23, 7.24). The area along the hingeline in front of and behind the beaks is depressed into an oval lunule and shorter escutcheon, respectively, and the valves are ornamented with fine concentric lirae. A typical specimen is 4.6 mm long, 4.1 mm high, and 3.4 mm wide, but some specimens are higher (L and H subequal). These specimens agree well with those described by Girty (1915) from upper Desmoinesian strata of Oklahoma. They are rare in units HC-1 and HC-11 of the Jemez area.

Nuculopsis anodontoides (Meek)

These nuculoids (Figs. 7.25, 7.26) attain a maximum length of about 20 mm. Nearly all specimens are laterally crushed, with the valves slightly displaced, making exact measurements difficult. The valves are moderately inflated, unornamented except for growth lines, and possess a relatively high beak near the posterior margin. The evenly convex posterior margin is slightly less acute than the anterior margin. A few specimens display their taxodont dentition—numerous small teeth along the hingeline. This species is abundant in some Missourian shale units (e.g., RS-5), and is uncommon in lower Virgilian beds (e.g., HC-11).

Nuculopsis girtyi Schenck

Commonly associated with *N. anodontoides,* the valves of *N. girtyi* (Figs. 7.27, 7.28) differ in being more inflated at the umbo, having a low, strongly curved beak that is closer to (virtually overhangs) the posterior

margin, and in having a slightly lower, more elongate outline. Maximum valve height of *N. girtyi* is anterior to the beaks, rather than at the beak, as in *N. anodontoides.* Most specimens are crushed dorsoventrally instead of laterally. *N. girtyi* is common in unit RS-5, and sparingly present as high as unit HC-11 (early Virgilian).

Paleyoldia glabra (Beede and Rogers)

Although poorly preserved, these medium-sized shells (L = 15-22 mm) agree well with the original description of *P. glabra* by Beede and Rogers (1900). The valves (Fig. 7.29) are compressed, with low, centrally located beaks that are curved posteriorly, a broadly rounded anterior margin, and a lower, tapering, more acutely convex posterior end. Ornamentation consists of widely-spaced, narrow concentric lirae. This species is rare in unit HC-11 and in the Jemez Springs Shale (RS-17).

Girtyana arata (Hall)

This medium-sized species (estimated L = 25 mm; H = 12.3 mm; W = 7.2 mm for a large specimen) has narrow, compressed valves with a moderately inflated umbo, and small, posteriorly curved beaks somewhat closer to the anterior than to the posterior margin (Figs. 7.30, 7.31). These valves are broadly convex anteriorly, but gradually taper posteriorly into a bluntly-pointed extremity. Ornamentation consists of shingled growth increments, with the dorsal edge of each increment raised into a concentric lira. These lirae are fine and closely spaced near the beak, but become stronger and more widely separated ventrally (2-3 lirae/mm, separated by interspaces twice the width of a lira), and become obscure towards the posterior end of the valve. This species differs from *Polidevcia bellistriata,* which also occurs in the Pennsylvanian and Early Permian of New Mexico (Kues, 1984, 1991b), in having much coarser ornamentation and its beaks farther from the anterior margin. *G. arata* is moderately common from unit HC-1 to HC-17 (Jemez Springs Shale), and is common in unit RS-5 of the Ranger Station section.

Polidevcia attenuata (Meek)

Among specimens of *G. arata* in unit HC-11 are a few much smaller specimens (maximum L = 8.5 mm) of *P. attenuata* (Figs. 7.32, 7.33), which have a relatively inflated umbo, a more extended, narrower posterior projection, a strongly concave (rather than nearly straight) posterodorsal margin, and much finer concentric ornamentation (about 6 lirae/mm) in the central part of the valve. These differences clearly distinguish *P. attenuata* from immature specimens of *G. arata* of about the same size. The Jemez specimens agree well with late Desmoinesian to Missourian representatives of *P. attenuata* described by Girty (1915) and Hoare et al. (1979).

Volsellina cf. ***V. subelliptica*** (Meek)

V. cf. *subelliptica* (Fig. 7.34) is relatively small species (L = 19.0 mm; H = 8.7 mm; W = 7.5 mm, for best-preserved specimen) having a mytiloid shape, in which the anterior end of the valve is low, with a small, barely projecting beak near the anterior margin. Posteriorly, the valves become higher, with the dorsal and ventral margins diverging before curving broadly into a spatulate posterior margin. A prominent high umbonal ridge extends with slight curvature from the beaks obliquely across the valve to the posteroventral margin. The Jemez specimens are generally similar to those described by Newell (1942) from the Virgilian of Nebraska and Texas, but appear to have a slightly more acutely rounded posterior margin, slightly more posteriorly located beaks, and a stronger umbonal ridge. This species is rare in unit HC-11.

Aviculopinna peracuta (Shumard)

Only small fragments of this large, narrowly triangular species (Fig. 7.35) were collected from the Jemez Springs Shale Member. Complete shells exceed 200 mm in length, possess a thickened ridge along the dorsal commissure (which is present on some fragments), and are oval to nearly circular in cross section.

Myalina (Orthomyalina) slocombi Sayre

Fragments of this large species (Figs. 8.1-8.6) are abundant in concentrated shell beds within several shale units of the upper Madera section (e.g., HC-1; HC-11; Jemez Springs Shale). An unusually complete right valve (Figs. 8.1, 8.2) has a hinge length of 35 mm and is 66 mm high, but fragments of larger specimens were observed. The valves have a sharp, anteriorly projecting beak, a nearly straight hingeline, strongly concave anterior margin, and a gently convex posterior margin that meets the hingeline at a slightly obtuse to nearly right angle. The umbonal ridge along the anterior margin is moderately convex, more so on left than on right valve. Gerontic specimens have greatly thickened valves and hinge areas that may be more than 20 mm high.

This species is abundant in the Missourian-lower Virgilian of the Midcontinent and Texas regions, where it evolved through transitional forms into *M. (O.) subquadrata* Shumard about in middle Virgilian time (Newell, 1942). The latter species, which is larger and longer, with a shallow sulcus along the posterior margin just beneath the hingeline, was not identified in the upper part of the Jemez sequence. A few specimens of *M. (O.) slocombi* (e.g., Fig. 8.6) display an obscure suggestion of a sinus and are probably transitional between typical members of this species and *M. (O.) subquadrata.*

Septimyalina burmai Newell

This myalinid (Fig. 8.7) is of medium to relatively large size (e.g., H = 42+ mm; hinge L = 34 mm; L along anterior margin = 55+ mm on a large specimen). It has an inclined, subtriangular shape, with a straight to slightly concave anterior margin diverging from the straight, relatively long hingeline at an angle of 60-65°. The hingeline meets the moderately convex posterior margin at an angle of 120°. The umbonal ridge is high and fairly sharp, and extends along the anterior margin, which is the widest part of the valve. Both valves bear strong, widely-spaced growth lamellae, the ventral edges of which may extend outward from the valve surface. *S. burmai* is confined to Virgilian strata in the Jemez Springs area, especially units RS-13 and the Jemez Springs Shale. Newell (1942) did not report it below earliest Wolfcampian strata in the Midcontinent area.

Septimyalina perattenuata (Meek and Hayden)

S. perattenuata (Fig. 8.8) resembles *S. burmai* (small specimens of the two species are virtually indistinguishable), but, based on Jemez area specimens, has smaller, more slender valves, with a more oval rather than triangular shape because of the shorter hingeline, a less prominent umbonal ridge, and less conspicuous growth lamellae on the valve surface. *S. perattenuata* occurs in myalinid shell beds with *M. (O.) slocombi* in shale units HC-1 and HC-11 (Missourian-earliest Virgilian), and is questionably present in the Jemez Springs Shale Member.

Aviculopecten occidentalis (Shumard)

A. occidentalis (Fig. 7.37) attains a height of 25-30+ mm and has a moderately convex left valve, with three ranks of costae, the first two being high, rather sharply rounded, and equalizing in size early in growth, and the third rank developing late and remaining fine at the ventral margin. Typically, the posterior major costa of the valve body develops short hyote spines, as does the anteriormost one to few costae ventrally. The anterior auricle is short, triangular, and bears 10 to 13 small radiating, subspinose costellae, whereas the posterior auricle is more elongate and displays 6-10 finer costellae. Left valves vary in the degree of spine development, some virtually lacking spines anteriorly, with other approaching the more spinose state of specimens here assigned to *A. moorei. A. occidentalis* is moderately common in unit RS-13, and uncommon in other Missourian and Virgilian units (e.g., HC-11).

Aviculopecten moorei Newell

This spinose *Aviculopecten* (Fig. 7.36) attains a height of 25-30 mm. Ornamentation of the left valve includes three ranks of relatively fine costae. The first-order costae are sharply rounded and bear suberect, widely-spaced hyote spines that begin about half of the distance to the ventral margin on the central part of the valve, but develop earlier in growth on the posterior and anterior costae. Second-order costae are slightly smaller (near the ventral margin they are generally subequal in size to the first-order costae), alternate with the first-order costae, and typically bear a few small

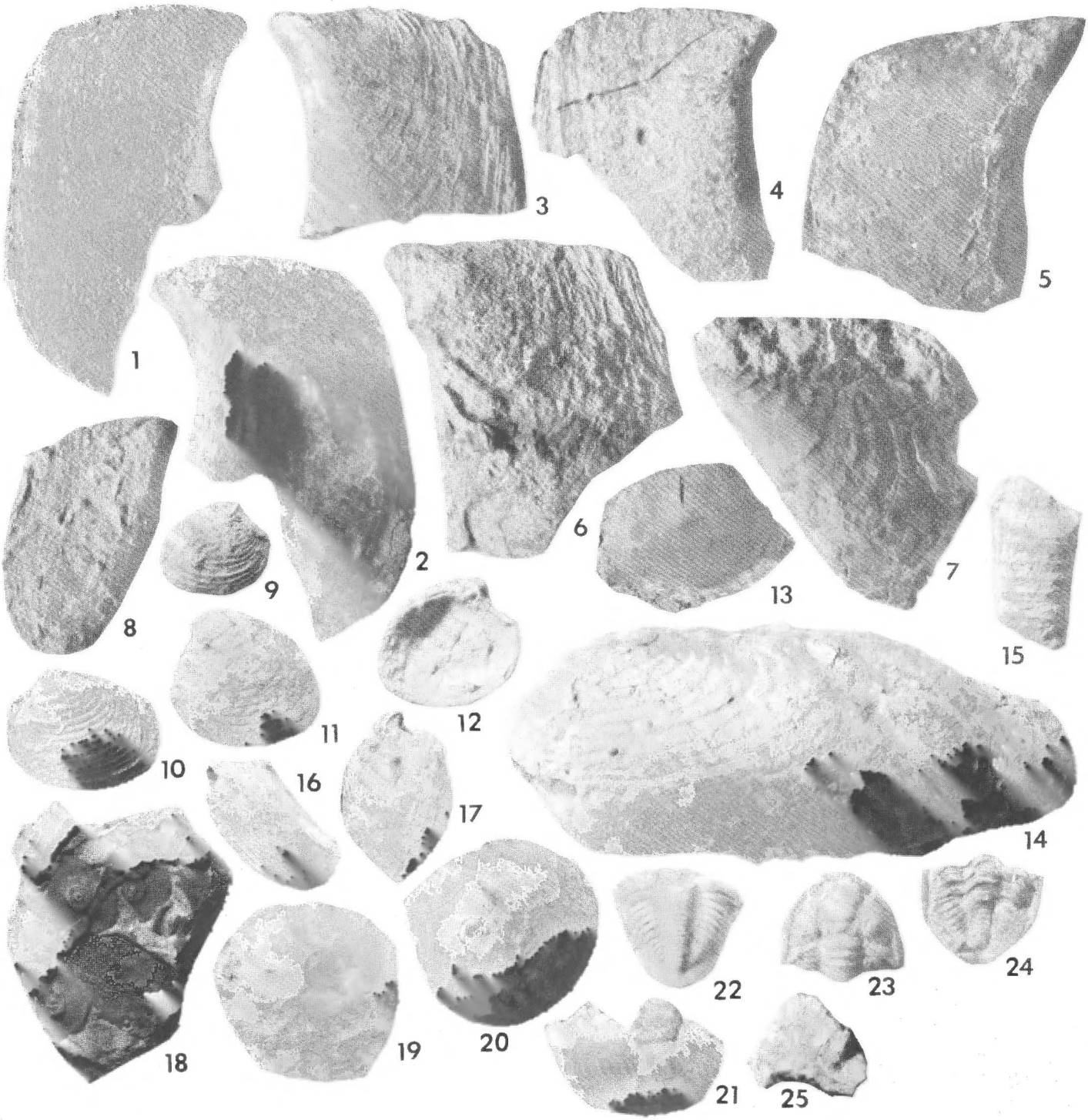

FIGURE 8. Invertebrates from the upper Madera Formation, Jemez Springs area, NM. RS = Ranger Station section; HC = Hummingbird Camp section. Bivalves: 1-6, *Myalina (Orthomyalina) slocombi*; 1-4, external and internal views of a nearly complete right valve (UNM 12,657), upper part of left valve (UNM 12,658), and upper part of right valve (UNM 12,659), Jemez Springs Sh. Mbr., Rincon locality, x1; 5, upper part of right valve, UNM 12,672, unit HC-1, x1; 6, upper part of left valve of a specimen transitional to *M. (O.) subquadrata*, UNM 12,673, unit HC-11, x1. 7, *Septimyalina burmai*, large lamellate left valve, UNM 12,674, unit RS-13, x1. 8, *Septimyalina perattenuata*, right valve, UNM 12,675, unit HC-11, x1. 9, 10, *Astartella concentrica*, right valve of a typical specimen (UNM 12,677) and left valve of a relatively large, elongate specimen (UNM 12,676), both from unit HC-11, x1. 11, 12, *Astartella* sp., external and internal views of left valve, UNM 12,678, unit HC-11, x1.5. 13, *Edmondia* sp., right valve view of steinkern, UNM 12,679, unit RS-13, x1. 14, *Wilkingia terminale,* left valve view of steinkern, UNM 12,680, Jemez Springs Sh. Mbr. (unit RS-16), x1. Nautiloid: 15, Pseudorthoceratidae, fragmentary steinkern, UNM 12,682, unit RS-9, x1. Rostroconch: 16, 17, *Pseudoconocardium* cf. *P. lanterna*, left valve and anterior-bottom view showing denticles along gaping margin of an incomplete specimen, UNM 12,681, unit RS-5, x1.5. Echinoid: 18, Cidarid interambulacral plates and spines, UNM 12,684, unit RS-11, x1. Crinoids: 19, *Sciaidiocrinus*? sp., base of calyx, UNM 6017, upper Madera Formation (unknown level), Church Canyon, just north of Jemez State Monument, x1.25. 20, 21, *Ulocrinus*? sp., bottom and side views of lower calyx, UNM 6021, upper Madera Formation (unknown level), Church Canyon, x1. Trilobites: 22, *Ameura missouriensis*, pygidium, UNM 12,683, unit RS-6, x1.5. 23, 24, *Ditomopyge scitula*, front (cephalon and anterior thoracic segments) and back (pygidium and posterior thoracic segments) of an enrolled specimen, UNM 5026, Jemez Springs Sh. Mbr. (unit RS-16), x2. Chondrichthyan vertebrates: 25, *Petalodus* sp. (shark tooth), UNM 12,685, Jemez Springs Sh. Mbr. (unit HC-19), x1.

spines. A single, fine, nonspinose third-order costa is present between each first- and second-order costa. All costa are separated by interspaces about equal to costa width. The anterior auricle of the left valve bears about eight fine, minutely spinose radiating costellae. These specimens agree in most respects with specimens of *A. moorei* described by Newell (1937) from the lower to middle Virgilian of Kansas and Nebraska. The Jemez specimens (from Virgilian units RS-13 and RS-17) tend to be more spinose, especially on the second-order costae.

Aviculopecten aff. ***A. basilicus*** Newell

Two large (H and L = 40+ mm), incomplete left valves (Fig. 7.38) from unit HC-1 have unusually broadly convex to nearly flat-crested primary costae. Hingeline and auricles are not preserved on either specimen, but the size and costation closely resemble that of *A. basilicus,* first described by Newell (1937) from the Virgilian of Kansas and Texas. The Jemez specimens differ, however, in having both major and minor costae on the anterior one-fourth of the valve body develop small but sharp hyote spines ventrally; *A. basilicus* is nearly devoid of spines. This pattern of spine development resembles that of specimens referred here to *A. occidentalis,* but *A.* aff. *A. basilicus* is larger, with less convex left valves, and broader, flatter costae.

Aviculopecten sp.

Only fragments of the left valve (Fig. 7.39) are available, but they indicate a new species of *Aviculopecten* that is relatively large (H = 30+ mm), with a distinctive ornamentation. The left valve displays three ranks of costae, the largest of which are high, sharp, and adorned with coarse, closely-spaced, suberect, hyote spines that arise very near the beak. A single, much smaller, second-order costa that is sparsely- to nonspinose occurs midway between each pair of primary costae. Two to three slightly smaller nonspinose third-order costae are present between each first- and second-order costa, producing a total of five to seven relatively fine costae between the strong, highly spinose, primary costae. This species belongs to a group of aviculopectens having spinose primary costae and generally nonspinose smaller intervening costae, represented by species such as *A. gradicosta* Newell, and *A. mccoyi* (Meek and Hayden). Neither of these species possesses such strongly spinose primary costae, compared to the much smaller, nonspinose second- and third-order costae, as the Jemez species. This species is uncommon in units RS-13 and RS-17 (Jemez Springs Shale) of the Ranger Station section.

Acanthopecten carboniferus (Stevens)

The genus *Acanthopecten* differs from *Aviculopecten* in having relatively coarse ribs of equal size on the left valve, which are periodically interrupted by strong concentric growth lamellae that are raised in a conspicuous arch across each costa. *A. carboniferus* (Figs. 7.40, 7.41) attains a height of about 20 mm, possesses about 15-18 very low, broad costae having a single sharp lira along their crests, and several widely-spaced concentric growth lamellae that form strong, U-shaped structures across each costa. These lamellae typically cross, but do not significantly interrupt the costae. Several incomplete specimens showing the characteristic ornamentation were collected from unit HC-11 and from the Jemez Springs Shale and RS-13 at the Ranger Station section.

Acanthopecten meeki Newell

Specimens of *A. meeki* (Fig. 7.42) typically are about 20 mm high and possess about 20 costae. In contrast to *A. carboniferus,* the costae are higher and lack a sharp median lira on the crests. In addition, the growth lamellae are raised and arched over the costae (rather than being flattened across them), and meet in the narrow interspaces between costae to form sharp spine-like structures. These more prominent lamellae separate individual costae into elongate, narrowly triangular, disconnected segments, each of which begins just below one line of lamellae and broadens gradually to the next line. This species is uncommon in several Missourian and Virgilian units up to the Jemez Springs Shale Member.

Clavicosta echinata Newell

This medium-sized (H = 20-25 mm) pectinid (Fig. 7.43) is characterized by its distinctive ornamentation, consisting of about nine high, rounded, spinose costae, each pair of which is separated by two lower, broader, nonspinose costae. Both left and right valves are convex, the left somewhat more so than the right, and the ornamentation is nearly identical on both valves. *C. echinata* was observed only in the Jemez Springs Shale, but the species ranges from Missourian to Wolfcampian in the Midcontinent area (Newell, 1937).

Pernopecten sp.

A single incomplete left valve (Fig. 7.44) from unit HC-11 represents this pectinid genus from the Jemez area. It is gently convex, about 24 mm high, and displays the short, triangular auricles and smooth external surface characteristic of *Pernopecten*. Better specimens are needed for identification to species.

Schizodus ulrichi Worthen

Small representatives of this long-ranging species (Fig. 7.45) are present in several Missourian-Virgilian units of the Jemez Springs region. They are characterized by moderately elongate, subtriangular, fairly inflated (W/H = 0.6) valves, having high beaks about one-third of the distance from the anterior end, and a gently raised posterodorsal carina along the hingeline. *S. ulrichi* is uncommon to rare in the upper Madera section.

Schizodus "meekanus" Girty

Newell and Boyd (1975) regarded *S. meekanus* as an unrecognizable species; the name is used here in quotation marks to indicate Jemez specimens (Fig. 7.46) having virtually the same elongate shape and extended, very acute posterior margin as the small specimens described and figured by Girty (1899, pl. 72, figs. 7b, c) as *S. meekanus* from the Upper Pennsylvanian of Oklahoma. The best-preserved Jemez specimen is 17.7 mm long, 12.1 mm high, and 8.6 mm wide (L/H = 1.46). This species is more elongate than any specimens of *S. ulrichi* treated by Newell and Boyd (1975), and clearly falls outside the range of variation of that species. *S. texanus,* an Early Permian species, has a relatively high L/H ratio, but differs from *S. "meekanus"* in having higher beaks, a more rounded posterior margin, and a gently convex (rather than relatively sharp) posterior umbonal ridge. *S. "meekanus"* is uncommon in unit HC-11.

Permophorus aff. ***P. subcostatus*** (Meek and Worthen)

Steinkerns having the same general proportions and size (a typical specimen is 25.5 mm long and 11.0 mm high) as *P. subcostatus* (Fig. 7.47) are present only in unit RS-13. The beaks are relatively low and close to the anterior margin, which is rather acutely convex. The hingeline is straight, and the posterior margin is broadly convex. A strong, rather sharp umbonal ridge extends from the beak obliquely across the valve to the posteroventral corner; the posterodorsal area above the ridge is wide and bears one faint median radial lira.

Astartella concentrica (Conrad)

Included here are specimens (Figs. 8.9, 8.10) varying widely in size and shape. Small to medium-sized specimens (up to about L = 15 mm) are closely comparable in size, suboval outline, truncate posterior margin, high beaks, and ornamentation of high, sharp, narrow, widely-separated concentric lirae, to the concept of this species utilized by many previous workers (e.g., Girty, 1915; Hoare et al., 1979). Large specimens (Fig. 8.10; L = 26.1, H = 21.3, and W = 13.4 mm) tend to be more inflated at the umbos and to have a somewhat elongate, subrectangular shape, but with similar ornamentation. As there is gradation in size and shape, these Jemez specimens may represent a single variable species. The species name *A. newberryi* Meek has been used (Hoare et al., 1979) for similarly elongate shells, but the concentric ornamentation of that species is said to be much closer together. Restudy of all American species of *Astartella,* based on large samples and examination of the type specimens, would be useful. *A. concentrica* is common in unit HC-11, and rare in RS-5.

Astartella sp.

A few specimens from unit HC-11 are outside the range of variability displayed by specimens referred to *A. concentrica.* The valves are high

relative to length (L = 15.6; H = 15.0 for largest specimen, Figs. 8.11, 8.12) and subtriangular, with the margin from the beak to the posteroventral corner forming a smooth, moderately convex curve, lacking any hint of truncation of the posterior margin. Ornamentation is similar to that of *A. concentrica,* and the dentition is typical of *Astartella.* This taxon cannot be assigned to any named species of *Astartella.*

Edmondia sp.

The valves (Fig. 8.13) are of moderate size (L = 32+ mm; H = 26 mm for a typical specimen), vaguely elongate-oval in shape, with a high, strong beak situated about one-third of the distance from the anterior to posterior margin. None of the available specimens is complete; thus the outline of the valves is not completely known. Ornamentation is limited to low, broadly-rounded, somewhat irregular, concentric growth wrinkles. Both the antero- and posterodorsal margins slope ventrally from the beak to a greater extent than is typical of *Edmondia* species of this size and general shape. The profile is similar to Late Pennsylvanian specimens described as *E. aspinwallensis* Meek (Beede, 1900, pl. 22, fig. 3) and *E. ovata* Meek and Worthen (e.g., Hoare et al., 1979, pl. 15, fig. 9); no specific assignment is made here. This species is moderately common in unit RS-13.

Wilkingia terminale (Hall)

This easily recognized bivalve (Fig. 8.14) is distinguished by its large size (L exceeds 100 mm), elongate shape, spatulate posterior margin, strongly inflated, very anterior beaks and umbos, and ornamentation of strong concentric wrinkles. All specimens from the Madera Formation in the Jemez area are steinkerns. This species in uncommon in the Jemez Springs Member, and rare in underlying strata.

Rostroconchs

Rostroconchs are a separate, extinct, pseudobivalved class of molluscs, which have their two valves rigidly joined dorsally. Formerly considered aberrant bivalves, rostroconchs are rare in New Mexico Pennsylvanian rocks. Of the two specimens recovered from the Jemez sequence, one is an unidentifiable fragment and the other is briefly described below.

Pseudoconocardium cf. ***P. lanterna*** (Branson)

The single specimen (Figs. 8.16, 8.17) is of medium size (L = 20+ mm), but distorted by dorsal compression. Details of the posterior rostral surface are not visible, and the anterior margin of the shell is absent. Allowing for poor preservation, this specimen closely resembles *P. lanterna,* as described by Branson (1965), Pojeta and Runnegar (1976) and Hoare et al. (1982). The valve body has seven strong, sharp, radial ribs, succeeded anteriorly by 13+ additional but much finer ribs. Fine, concentric, closely-spaced growth lamellae are conspicuous between the ribs, producing a subcancellate appearance. The valves gape widely anteriorly, the gape extending most of the length of the valve, and the widely separated valve margins have numerous sharp denticles (Fig. 8.17). This specimen is from unit RS-5 (Missourian).

Cephalopods

Fragments of nautiloid cephalopods occur sparingly in some of the upper Madera units, but most specimens are incomplete, unidentifiable steinkerns. Straight-coned shells (pseudorthoceratids, probably *Meekoceras* and/or *Pseudorthoceras;* Fig. 8.15) are most common, but incomplete steinkerns of coiled taxa are also present, especially in unit HC-4. One of these specimens had a shell diameter of at least 75 mm when complete. Northrop (1974) reported several nautiloid genera from the Pennsylvanian of the Jemez and Nacimiento Mountains, but no ammonoids. I have not observed even a single ammonoid specimen from the upper Madera of the Jemez Springs area.

Trilobites

Trilobites are uncommon to rare in several units of the Jemez Springs Late Pennsylvanian section, and are represented mainly by isolated pygidia. The two species documented below are both long-ranging stratigraphically (Lower Pennsylvanian-Lower Permian) and wide-ranging geographically (Appalachian basin to the Western Interior) in North America (e.g., Chamberlain, 1969; Pabian and Fagerstrom, 1972; Brezinski, 1988).

Ameura missouriensis (Shumard)

The pygidia (Fig. 8.22) are relatively large (up to 20 mm long), subtriangular, unornamented, and have a wide border around the periphery, especially posteriorly. The median axial lobe is relatively narrow, high, acutely convex across the crest, and consists of about 20 short segments. The pleural lobes are lower, strongly convex, and have 11-12 gently convex segments. The pygidium of *A. missouriensis* is easily distinguished from that of *Ditomopyge scitula* by its greater size, larger number of axial and pleural segments, and complete lack of ornamentation. *A. missouriensis* appears to be more common in the Missourian part of the sequence, but it is present up to the Jemez Springs Shale Member.

Ditomopyge scitula (Meek and Worthen)

Most specimens are isolated pygidia but occasional complete specimens have been found (Figs. 8.23, 8.24). Total body length is about 20 mm. The cephalon is much wider than long, and is characterized by a large glabella followed by a low, rectangular median preoccipital lobe with a small circular lateral lobe on each side; large, posteriorly situated eyes; short genal spines; and a broad, striated doublure. There are nine thoracic segments. The pygidium is short and wide, and bordered by an unornamented margin. Its elevated axial lobe is flattened to slightly concave across the crest and includes 12-13 segments, each of which is ornamented by about seven small, elongate nodes along the central posterior margin. Posteriorly, the three lateral nodes of each segment tend to cluster into a larger, subcircular bump. The pleural lobes are lower, convex, and consist of 7-8 segments, each of which is typically ornamented with several tiny nodes along the posterior margin. These specimens differ slightly in ornamentation from Desmoinesian examples of *D. scitula* from central New Mexico (Kues, 1982), but agree well with members of the species described by Pabian and Fagerstrom (1972), Brezinski and Stitt (1982) and Brezinski (1988). In the Jemez Springs area, *D. scitula* was not observed below unit HC-11 (latest Missourian-earliest Virgilian) and is present in the Jemez Springs Shale.

Echinoderms

Echinoderms are represented both by echinoids and crinoids. Isolated echinoid spines and plates (Fig. 8.18) are moderately common in some units. The spines are typically slender, several centimeters long, bear numerous small spinelets along the shaft, and expand at the base for articulation with the central knob of the interambulacral plates. These are typical late Paleozoic cidaroid remains, of the kind that were assigned to *Echinocrinus* or *Archaeocidaris* by earlier workers. Kier (1965) pointed out that generic assignment of isolated echinoid plates and spines cannot accurately be done.

Most crinoid remains are isolated portions of stems and stem elements, which are present throughout the upper Madera section. Dense lenses of disarticulated crinoid skeletal debris are present locally in some limestone units. Rarely, partial calyxes have been found, but these have not received much attention. Northrop (1974) reported six crinoid genera from the Pennsylvanian of the Jemez and Nacimiento Mountains, three of which were identified by N. Gary Lane. Two of these specimens are illustrated here (Fig. 8.19 - 8.21).

Vertebrates

Vertebrate remains are rare in the marine strata of the Jemez Springs area. A single specimen of a shark tooth, *Petalodus* sp. (Fig. 8.25), was collected from the Jemez Springs Shale Member (unit HC-19). It is about 19 mm long and characterized by its broadly triangular, laterally compressed crown.

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