UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

The Biostratigraphy and Paleoecology of the Gerster Limestone (Upper Permian) in Nevada and Utah

By

Bruce R. Wardlaw

Open-File Report 77-470
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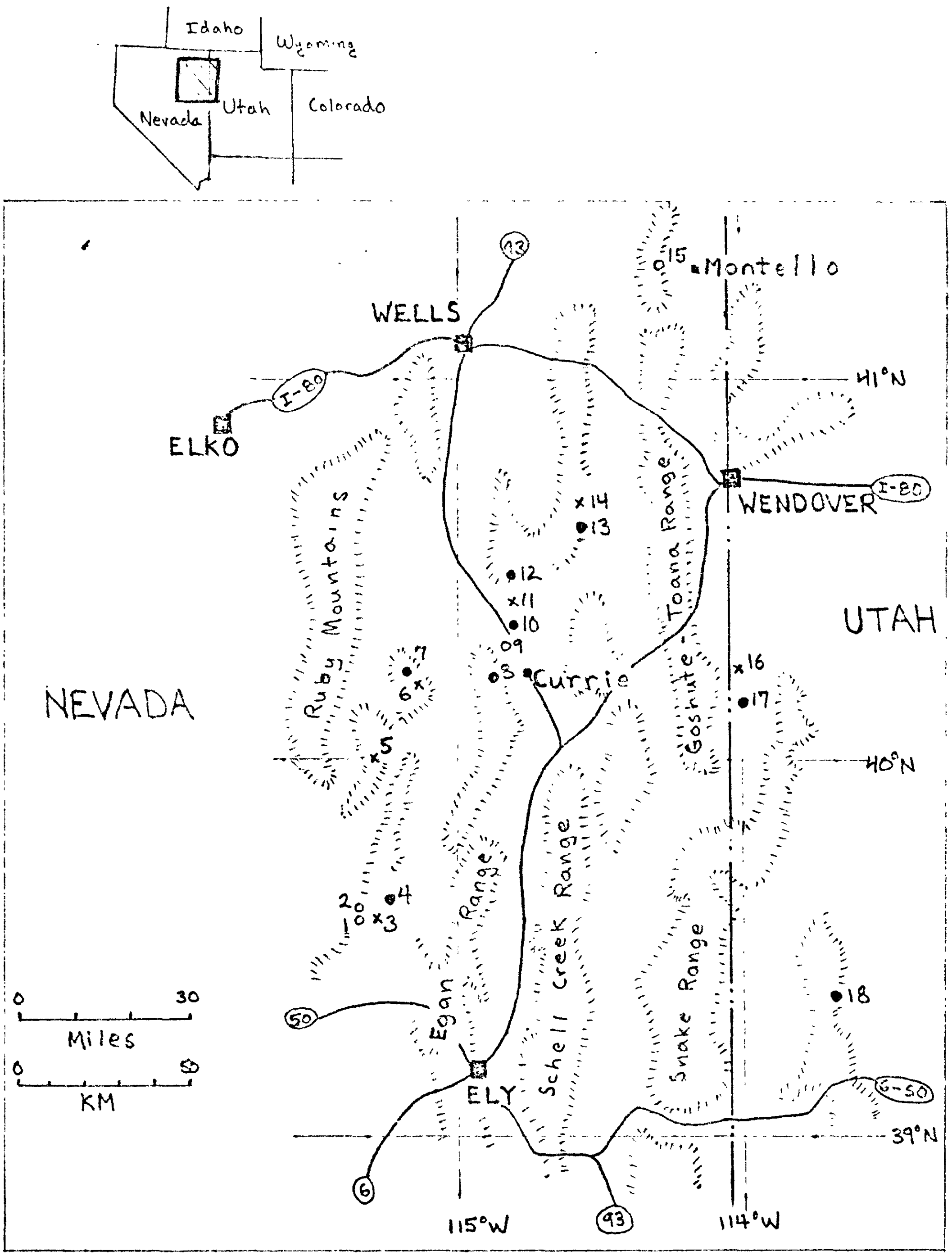

Fig. 1

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Fig. 1. Location of sections studied of the Gerster Limestone. A solid circle represents a section extensively collected to obtain the silicified fauna. An open circle represents a measured section only sparsely collected. An "x" represents an unmeasured section examined generally to determine the stratigraphic relationships of the Gerster. Section 5 is the type locality of many of Meek's described species from the Gerster.

	Sections extensively collected
4	Central Butte Mountains
7	Medicine Range
8	Cherry Creek Range
10	Sheeprock Ridge
12	Spruce Mountain
13	Southern Pequop Mountains
17	Gerster Gulch
18	Confusion Range
	Other Measured Sections
1	Central Butte Mountains
2	Central Butte Mountains
9	Phalen Butte (Palomino Ridge)
15	Montello Canyon, Leech Mountains
	Other Locales Examined
3	Central Butte Mountains, Sides' Section
5	Maverick Springs Range, Meek's Locale
6	High Bald Peak, Medicine Range
11	"Currie Ravine"
14	Southern Pequop Mountains, Yochelson and Frazer Locale
16	Gold Hill

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This report is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

THE BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE GERSTER LIMESTONE (UPPER PERMIAN) IN NEVADA AND UTAH

BY BRUCE R. WARDLAW

ABSTRACT

The Gerster Limestone contains three minor lithofacies, the packstone, wackestone, and mixed facies, differentiated largely on the basis of the carbonate matrix and mud content of the rocks. Five biostratigraphic zones ranging in age from Roadian-Wordian to Wordian are, in ascending order, the *Thamnosia*, *Kuvelousia*, transition, *Yakovlevia*, and upper zones.

The Gerster was probably deposted in a protected coastal basin separated from the Phosphoria Basin by a shallow marine positive area. The brachiopod fauna is divided into fifteen bioassociations. The fauna is part of a continental margin suite of faunas distributed from west Texas to the Canadian Arctic and belongs to the Tethyan-nonreef biogeographical province.

INTRODUCTION

A study of the Gerster Limestone of Nevada and Utah appeared interesting for the following reasons: (1) its age was uncertain--estimates have ranged from Word to uppermost Permian; (2) there were many reports of abundant and usually silicified brachiopods, but no one had studied them in detail since F. B. Meek (1877); (3) the Gerster, a carbonate facies closely associated with the Phosphoria Formation, might provide additional data on the paleoecology and paleogeography of the economically important Phosphoria; (4) the fauna seemed to represent a marine flat-bottom assemblage of low diversity, which might provide information valuable to general diversity studies. Accordingly, a study of the Gerster and its brachiopod fauna was undertaken.

The location of the sections of the Gerster studied for this project are shown in figure 1.

Field work was done in August 1970, June through August 1971, and July 1973. Blocks of most brachiopod-bearing beds were collected to be etched in HCl. The blocks averaged about 100 lbs and ranged from 60 to 200 lbs in weight. Two slabs were cut from each rock. One slab was used for quantitative sedimentary analysis and one for polishing for visual inspection. Hand samples were collected of those beds not bearing brachiopods in case

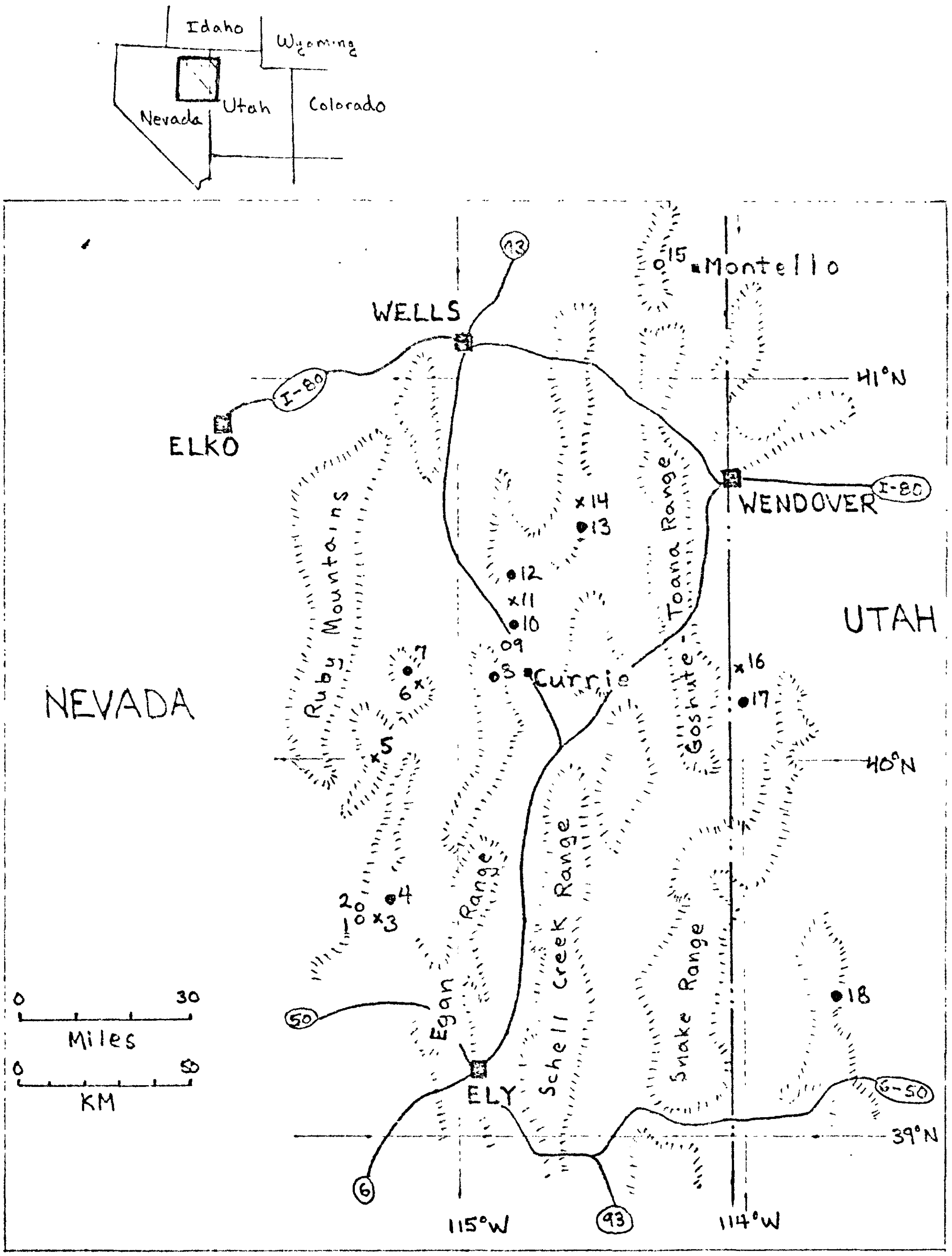
Idaho
Wyoming
Utah
Colorado
Nevada
WELLS
ELKO
I-80
93
Montello
15
41°N
WENDOVER
I-80
Ruby Mountains
Toana Range
Goshute
UTAH
NEVADA
Currie
14
13
12
11
10
9
8
7
6
5
4
3
2
1
16
17
18
40°N
Egan Range
Schell Creek Range
Snake Range
0 30
Miles
0 50
KM
50
ELY
6-50
39°N
6
93
115°W
114°W

Fig. 1

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more information was needed beyond their field identification.

The Gerster study proved to be rewarding in all four areas of initial interest. The brachiopods correlate well with those of the Word Formation in west Texas. The fauna was much more diverse than expected, containing elements common to North America, Greenland and Asia. The Asian elements include Waagenites, Hemiptychina, Echinalosia, and Rostranteris.

The Gerster Limestone is composed of three minor lithofacies, the packstone, wackestone, and mixed. Correlation of the distribution of the brachiopods to the distribution of lithofacies was examined. Comparison to other brachiopod distribution studies is hindered by the lack of good lithologic work. The results are presented here in hopes that they may be used in future studies.

The Gerster Limestone was deposited in a fairly low energy, shallow subtidal basin connected to the Phosphoria Basin. Variations in thickness and a biostratigraphic zonation are combined to show the subsidence, sedimentation, and erosion patterns of the basin in which the Gerster was deposited.

The most useful result of this study is the biostratigraphic scheme proposed. The zonation was not noticed initially in the field, but discovered by laboratory research. The zonation was then tested by reexamining the

the sections first studied and examining a few new ones. The vast collections of the Phosphoria Formation and related rocks are now being examined to further test the zonations. The possible ecological control of the zonation can be examined because the Phosphoria is composed of many different lithofacies which represent different environments of deposition that are not in the Gerster. Initial study reveals the zonation is not controlled by local lithofacies.

A provincial scheme for mid-Permian (Roadian-Wordian stages of Furnish, 1973) faunas of North America and Greenland is here proposed, based on similarity clustering, presence of diagnostic faunal elements, and diversity coefficients. The Gerster fauna is a member of the Tethyan-nonreef province.

Previous Work: The Gerster was first studied by the U.S. Geological Exploration of the 40th Parallel that traveled through the center of the Gerster outcrop area. Meek (1877) described the brachiopods collected by the survey, many of which were from the Gerster.

Nolan (1935) proposed the name Gerster for a unit of thin-bedded, fossiliferous, sandy and shaley limestones exposed at Gerster Gulch in the Gold Hill mining district, Utah. Hose and Repenning (1959) were the first to identify the Gerster at another locality, the Confusion

Range. They erected the Park City Group, which includes, in ascending order, the Kaibab Limestone, the Plympton Formation, and the Gerster Limestone, for the rocks in Nevada and adjacent Utah approximately equivalent to the Phosphoria, Park City and Shedhorn formations.

Steele (1960) made the first regional synthesis and dated the Gerster as Capitanian. Figure 2 is an isopachous map from Steele for what he interpreted as Guadalupian aged rocks in Nevada and adjacent Utah. He included both the Plympton and Gerster, and the Garden Valley Formation to the west. Steele gave the name "Butte-Deep Creek depocenter" to the northeast-trending region of thick accumulations. In the present study, the trend of the region of thick deposits of the Gerster (compare fig. 11) was found to be nearly perpendicular to the trend shown by Steele. The thickest combined section of Plympton and Gerster measured was only 1790 feet (Hose and Repenning, 1959, and this report).

Hodgkinson (1961) attempted to clarify the Permian stratigraphy of the area. He proposed a new name, the Indian Canyon Formation, for the upper Plympton largely on the basis of an erratically distributed chert pebble conglomerate. The formation name has been rejected by most subsequent workers in the area (Collinson, 1968, Yochelson and Fraser, 1973).

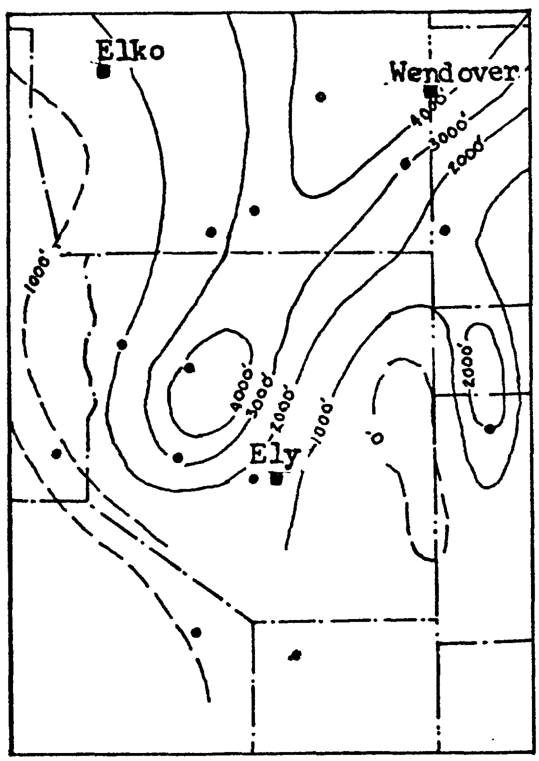

Fig. 2. Isopachous map of Guadalupian aged rocks in Nevada and adjacent Utah modified from Steele (1960).

Bissel (1964) gave another regional synthesis indicating the location of numerous sections and providing a very general biostratigraphy for each. Many of the sections measured by Bissel are structurally complicated, which caused him to give exagerated thicknesses (i. e. Medicine Range, Collinson, 1968; central Butte Mountains, Sides, 1966). Bissel did, however, locate many new sites where the Gerster could be found and studied.

Roberts and others (1965) also located many sections and developed the regional lithofacies relationships of the area (fig. 3). The lithofacies were defined generally on the qualitative data of the dominant rock type.

Collinson (1968) correctly showed the complex structural relations of the Gerster in the Medicine Range. He showed that previous workers had erroneously measured much repeated section. Soon afterwards in many unpublished reports, workers were finding previously reported thicknesses to be grossly exaggerated.

Acknowledgments: I would like to give special thanks for the assistance and guidance of my thesis advisor, F. G. Stehli, Case Western Reserve University. R. E. Grant, G. A. Cooper and J. W. Collinson helped considerably in advising the completion of this project. In the field work I was assisted by my brother Kirk Wardlaw and, to a lesser

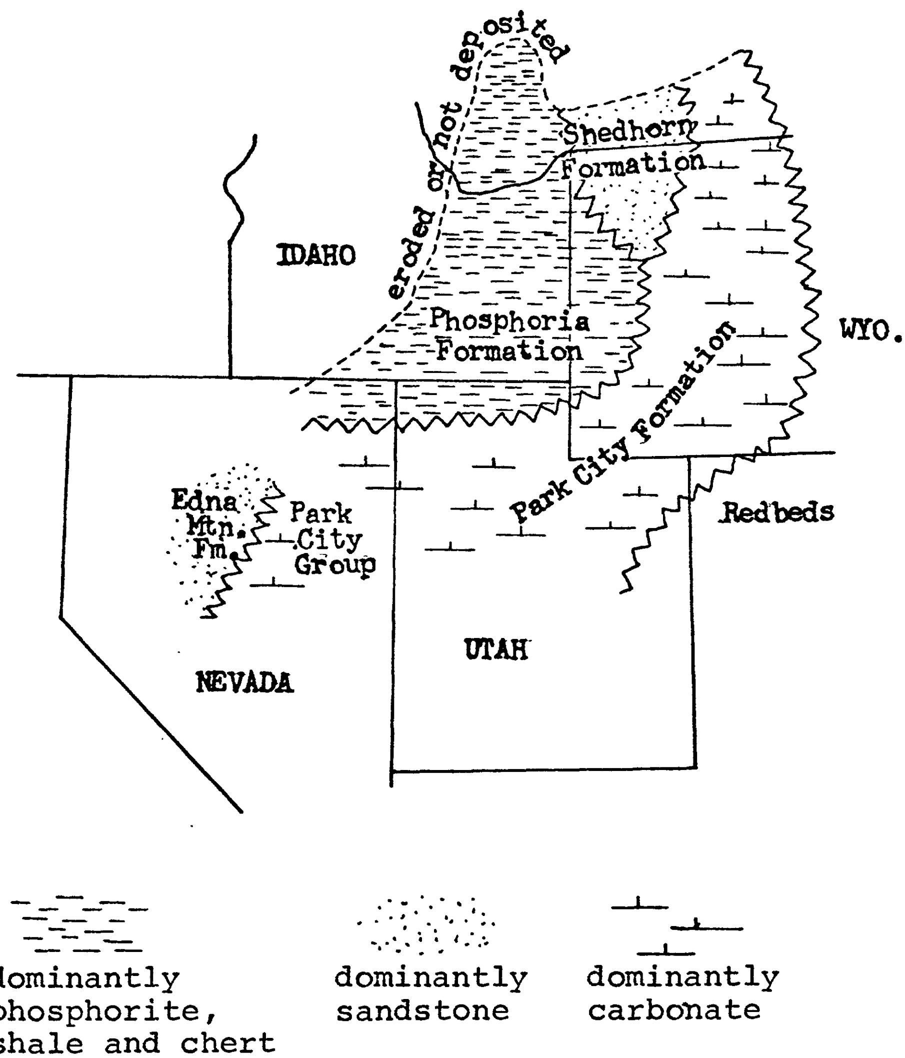

Fig. 3. Lithofacies map showing the intertonguing relationships between the Phosphoria Formation and the Park City Group. Modified from Roberts and others, 1965, p. 1941.

degree, by J. W. Collinson, Kris Kendall, Larry Mayer, John and Emily Mercantel, Art and Kit Browning, Mary Baird, and F. G. Stehli. Financial assistance was provided by G. S. A. Penrose Bequest Research Grants 1450-70, 1511-71, and 1667-72 and by F. G. Stehli. J. T. Dutro also helped in reading parts of the manuscript.

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STRATIGRAPHY

The Gerster is sandwiched between the Permian lower Park City Group (Kaibab Limestone and Plympton Formation) below and the Lower Triassic Thaynes Formation above. The interformational relationships and the general lithologies are depicted in figure 4.

The Kaibab and Plympton Formations: The name Kaibab was proposed by Darton (1910, p. 21; subsequently redefined by McKee, 1938) and the Plympton Formation was named by Hose and Repenning (1959, p. 2181). In a study of the Plympton lithic units, Browning (1973) suggested that its dolomites, cherts and siltstones indicate deposition in a sabkha-like supratidal environment which was occasionally invaded by intertidal and subtidal conditions represented by micritic dolomites with micritized and recrystallized marine fossil fragments. Other environmentally important criteria found locally in the upper part of the Plympton are silicified algal-mat stromatolites, chert-pebble dolomites, and limey dolomite lenses containing an intertidal molluscan assemblage (Yochelson and Fraser, 1973). Browning (1973) suggested that in this supratidal-shallow subtidal environment there were migrating Mg-enriched brines that might have dolomitized the upper Kaibab. The Kaibab is the thickest carbonate in the Kaibab-Plympton sequence, and only its upper portion is completely

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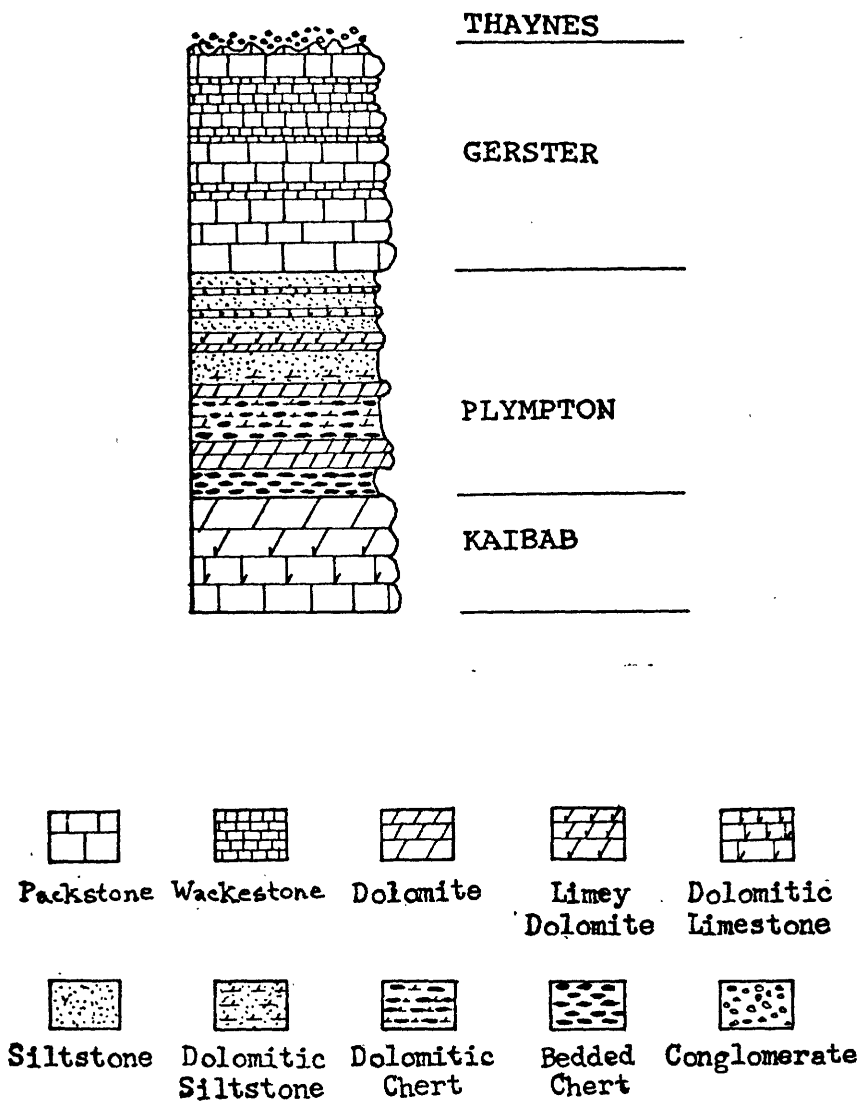

Fig. 4. The generalized stratigraphic and lithologic characters of the Park City Group and overlying Thaynes Formation.

dolomitized while less thick carbonates in the lower Plympton are completely dolomitized, showing only ghosts of marine fossils. Thick carbonate beds in the Plympton become less dolomitized and contain well-preserved marine fossils near the top of the formation. It appears that the thick carbonate beds represent marine transgressions in a sequence dominated by supratidal and intertidal sedimentary environments. The beds in the lower part of the Plympton were more exposed to the circulating Mg-enriched brines than the beds in the upper part of the Plympton, and therfore were more completely dolomitized. The dolomitizing solutions were only able to penetrate to the upper portions of the thick Kaibab, thereby dolomitizing only its upper part.

The uppermost thick carbonate bed in the Plympton is a silty dolomitic limestone that contains well-preserved brachiopods similar to those found in the Gerster Limestone. This fact was recognized by Collinson (1968), who included the upper part of the Plympton in the Gerster Limestone, largely for faunal reasons. This upper carbonate, because of its close faunal and lithic resemblance to the Gerster, is here considered a tongue of the Gerster. In some Plympton sections there exist several recognizable tongues of the Gerster. The lower thick carbonates of the Plympton also represent subtidal carbonates but their affinities to local formations are obscured because they are more completely dolomitized.

The Gerster Limestone: The bulk of the Gerster overlies the Plympton. The contact is conformable, as evidenced by their intertonguing relationship. The Gerster is a rather monotonous unit of cherty, silty, fossiliferous limestones with a few siltstones. Subtle differences in facies can be recognized on the basis of silt content and abundance of carbonate mud. These will be discussed in detail in the section on sedimentology. An isopachous map of the Gerster (fig. 11) shows what will be called the Gerster Basin in this paper. It is defined by the thin deposits that now form a northwest-trending ridge to the north, and by the loss of Upper Permian outcrops to the south. Another basin, north of the Gerster in Idaho, Utah, Wyoming, and Montana (Sheldon, 1963), is called the Phosphoria Basin. Together these basins compose the Phosphoria-Park City Sedimentary Basin.

The Thaynes Formation: The Thaynes Formation was first proposed by Boutwell (1907, p. 448); in Nevada it is represented by limestones, calcareous siltstones, and calcareous sandstones (Collinson, 1968). It overlies the Gerster disconformably, as evidenced by channels into the Gerster, crosscutting beds, lag deposits, and a basal conglomerate with Gerster lithologies and fossils as cobbles and pebbles. Erosional trends of the upper part of the Gerster Limestone will be discussed after the biostratigraphy of the Gerster is developed.

SEDIMENTOLOGY

The Gerster rocks are made up of cherty, silty, skeletal, and often pelletal wackestone and packstone. Glauconite is present locally and silt becomes the dominant constituent in some places. Calcitic brachiopod spines are common throughout the sequence. Three minor lithofacies can be differentiated by the percentage of packstone and wackestone beds making up the sequence. The lithofacies are:

1. The packstone facies, dominated by cherty, silty, skeletal, and locally pelletal packstones with a minor amount of wackestone. Sequences assigned to this facies contain at least 75 percent packstone beds as determined by field and polished slab identifications.

2. The wackestone facies, dominated by cherty, silty, skeletal, and usually pelletal wackestones with a minor amount of packstone. Sequences contain at least 75 percent wackestone beds.

3. The mixed facies, composed of interbedded cherty, silty to very silty, skeletal, and often pelletal wackestones and packstones with some siltstones. This facies is defined as including those sequences in which neither packstone nor wackestone dominate more than 75 percent of the sequence. Both wackestones and packstones tend to be equally abundant. Siltstones are common in

this facies.

The distribution of these lithofacies is shown in figure 5.

The succession of lithofacies is similar in most sections. The typical section, from bottom to top, contains a packstone facies, then a mixed-wackestone sequence, then another packstone, and finally a mixed facies. The southern Pequop Mountains apparently lack the upper part of the succession. Neither a packstone nor a wackestone facies could be differentiated in the upper part of the section in the central Butte Mountains, owing partly to poor exposure.

Burrows are common in all lithofacies. They are usually chertified. They represent the remains of what must have been an abundant infauna. Such preservation suggests deposition under low-energy conditions. Rarely, crossbedding and graded beds are found in the packstone facies indicating occasional strong currents and high-energy conditions. The brachiopods and other fossils are broken and abraded in the lower tens of feet of each section, suggesting high-energy conditions in the lower part of the basal packstone facies.

Slabs of rocks collected for brachiopods were analyzed for weight percent insoluble residue, sand and greater size fraction, and silt and clay size fraction.

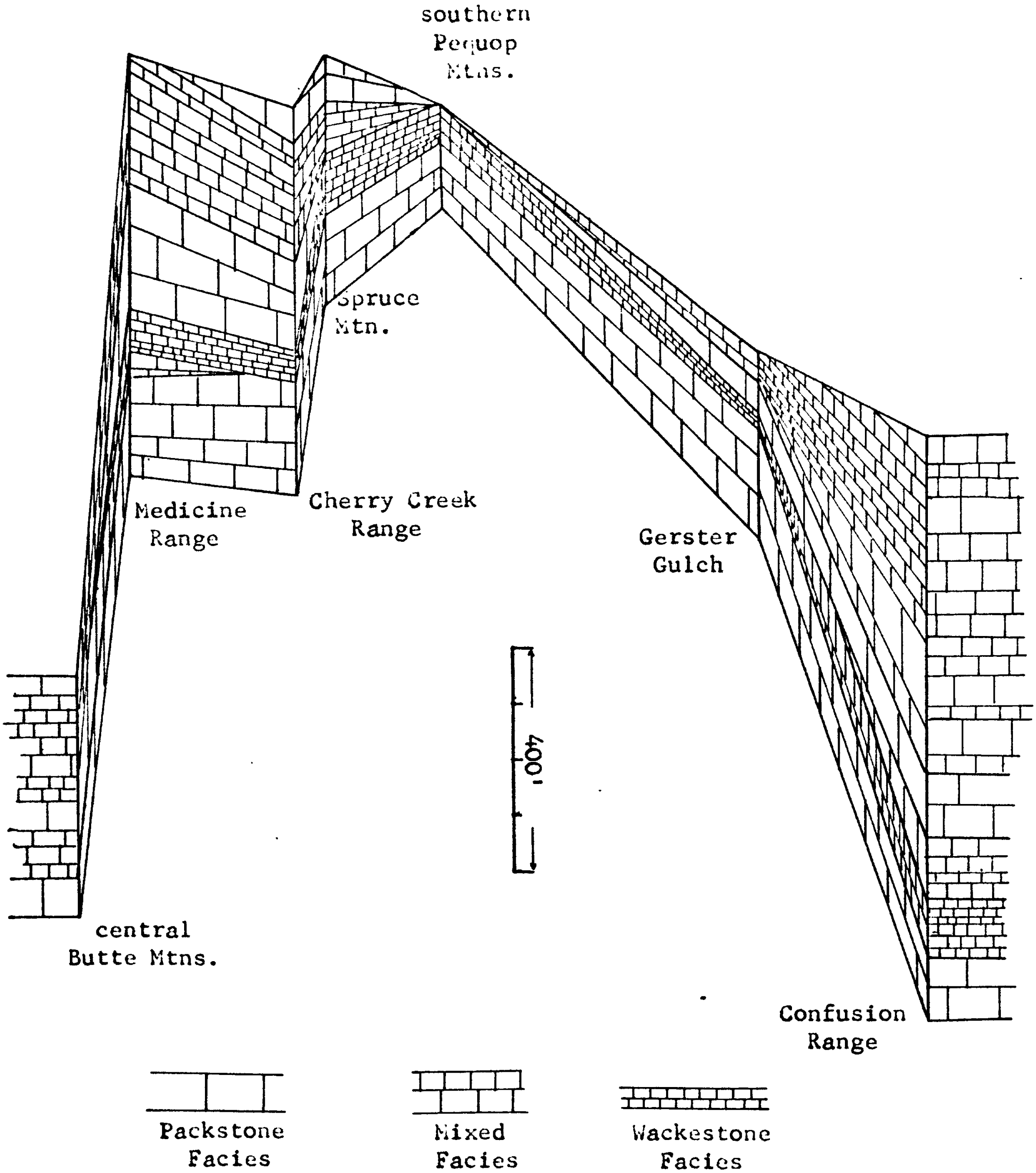

Fig. 5. Fence diagram showing distribution of lithofacies in the Gerster Basin.

Slabs were broken up to small pebble size to assure complete etching. Two-hundred-gm samples were then etched at room temperature until all carbonate had been dissolved. Usually four days were required. The samples were agitated occasionally, to assist the etching. The samples were then washed by centrifuging, dried and weighed. The sand and greater size fraction was separated by wet sieving, dried, weighed and inspected. Inspection revealed very little sand in the sand and greater size fraction. Chert, silicified fossils, and silicified rock made up most of the fraction. The rock fragments contained bedding features and fossil constituents but were completely silicified. The results of this analysis are shown in figure 10. Increases in silt and clay seem to correlate with the wackestone and mixed facies, silt and clay being less common in the packstone facies. The sand and greater size fraction (chert) seems to show a random distribution. Figure 6 shows the average silt and clay content for each section contoured over the basin. The highs are located in the middle of the basin and to the southeast. This implies a source to the southeast.

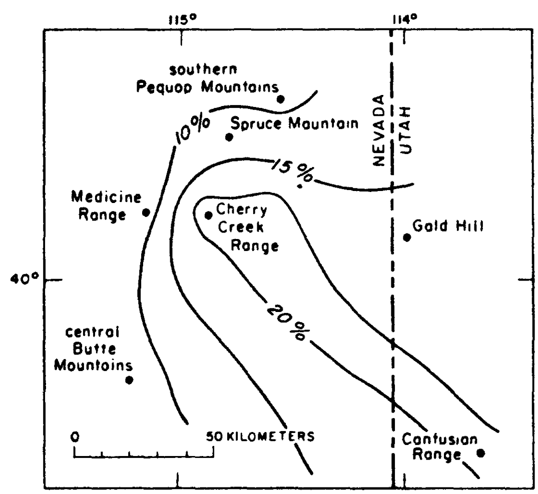

Fig. 6. Average content of silt and clay as weight percent total rock.

BIOSTRATIGRAPHY

The Gerster, including the Gerster tongues in the Plympton, can be divided into five zones based on the brachiopod distributions. The zones are, in ascending order: (1) the *Thamnosia* zone, (2) the *Kuvelousia* zone, (3) the transition zone, (4) the *Yakovlevia* zone, and (5) the upper zone. The zones are largely based on the ranges of three of the large brachiopods: *Thamnosia depressa*, *Kuvelousia leptosa* and *Yakovlevia multistriata*. In the Gerster Basin their ranges do not overlap.

The *Thamnosia* zone is defined as beginning with the first occurrences of *Thamnosia* and extending up to the base of Gerster sedimentation. In the Gerster Basin this zone is confined to the Gerster tongues of the Plympton. The *Kuvelousia* zone encompasses the range (i. e. the first and last occurrences) of *Kuvelousia leptosa* and begins at the base of the Gerster and extends to the last occurrence of *Kuvelousia* in each section. The transition zone is that part of the sequence that is above the last occurrence of *Kuvelousia* and below the first occurrence of *Yakovlevia*; this zone includes the range of *Petasmetherus*. The *Yakovlevia* zone is the range zone of *Yakovlevia multistriata*. That portion of the section remaining above the last occurrence of *Yakovlevia* is designated as the upper zone. *Timaniella* "*pseudocamerata*" also occurs exclusively above Kuvelousia leptosa and appears to range through the transition, Yakovlevia, and upper zones. It is most abundant in the transition zone.

Many faunal elements occur exclusively in, or are diagnostic of a single faunal zone. They are:

1. in the Thamnosia zone, Thamnosia depressa, Rugatia cf. R. occidentalis, Hystriculina n. sp. A, and Rhynchopora taylori;

2. in the Kuvelousia zone, Kuvelousia leptosa, Cenorhynchia n. sp. B, and Phrenophoria n. sp. B;

3. in the transition zone, Petasmetherus n. sp. A, Spiriferella scobina, Rostranteris n. sp. A, and Heteralasma n. sp. A;

4. in the Yakovlevia zone, Yakovlevia multistriata, Heteralosia sp., and Liosotella delicatula; and

5. in the upper zone, Kochiproductus sp., "Grandaurispina" arctica?. and Dielasma spatulatum.

The composite distributions of the fauna are shown in figure 7.

Figure 8 shows the biostratigraphic zones as they exist in sections of the Gerster Limestone, in the Gerster tongues, and in a section in the Leach Mountains composed of an intertonguing sequence of Gerster-Park City carbonate and Phosphoria cherts. The zones are present in all the sections, suggesting that the shorter sections of southern

1	Derbyia sulca (Branson)	28	Composita parasulcata Cooper and Grant
2	Quadrochonetes n. sp. A	29	Cleiothyridina n. sp. A
3	Dyoros n. sp. A	30	Cleiothyridina n. sp. B
4	Waagenites n. sp. A	31	Hustedia elongata n. ssp.
5	Waagenites n. sp. B	32	Odontospirifer n. sp. A
6	Heteralosia sp.	33	Timaniella "pseudocamerata"
7	Echinalosia n. sp. A	34	Spiriferella scobina (Meek)
8	Ctenalosia fixata Cooper and Stehli	35	Xestotrema pulchrum (Meek)
9	Sphenosteges hispidus (Girty)	36	Dielasma phosphoriense Branson
10	Hystriculina n. sp. A	37	Dielasma spatulatum Girty
11	"Echinauris" subhorrida (Meek)	38	Plectelasma n. sp. A
12	Liosotella delicatula Dunbar	39	Plectelasma n. sp. B
13	Thamnosia depressa (Cooper)	40	Hemiptychina quadricostata (Branson)
14	Bathymyonia n. sp. A	41	Rostranteris n. sp. A
15	Bathymyonia nevadensis (Meek)	42	Girtyella?
16	Kochiproductus sp.	43	Heterelasma n. sp. A
17	"Grandaurispina" n. sp. A	44	Crinoids
18	"Grandaurispina" arctica? (Waterhouse)	45	Ramose Bryozoa
19	Kuvelousia leptosa Waterhouse	46	Fenestrate Bryozoa
20	Yakovlevia multistriata (Meek)	47	Cyrtorostra sp.
21	Cenorhynchia n. sp. A	48	Aviculopecten sp.
22	Cenorhynchia n. sp. B	49	Acanthopecten sp.
23	Phrenophoria n. sp. A	50	Girtypecten sp.
24	Phrenophoria n. sp. B	51	Pectenoids indet.
25	Petasmetherus n. sp. A	52	Horn Corals
26	Rhynchopora taylori Girty	53	Rugatia cf. R. occidentalis (Newberry)
27	Composita mira Girty		

occurring once

occurring twice

range defined by three or more occurrences

Fig. 7. Composite distributions of faunal elements in the Gerster based on the faunal distribution chart. Key to chart is above and the chart is on the following page.

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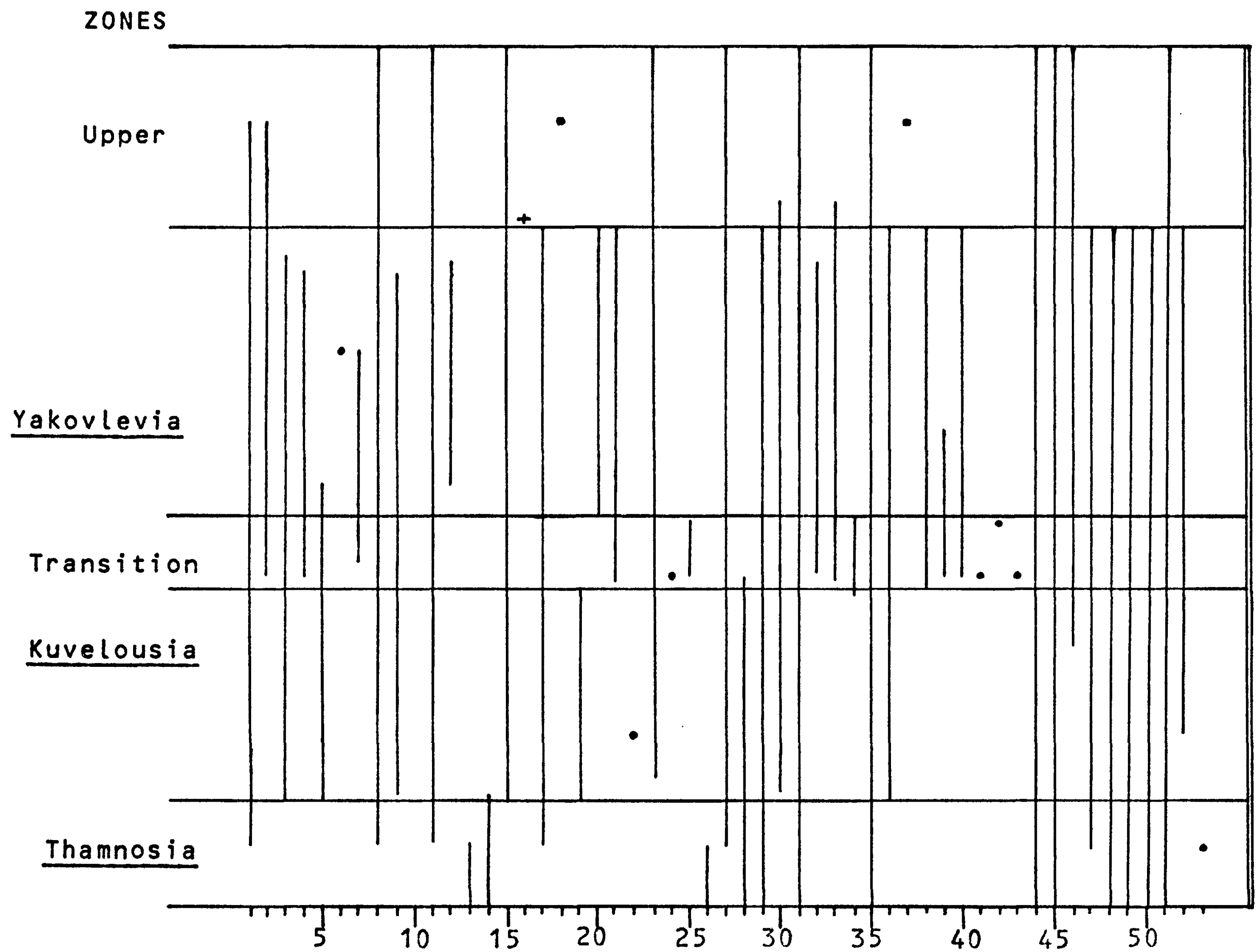
ZONES
Upper
Yakovlevia
Transition
Kuvelousia
Thamnosia
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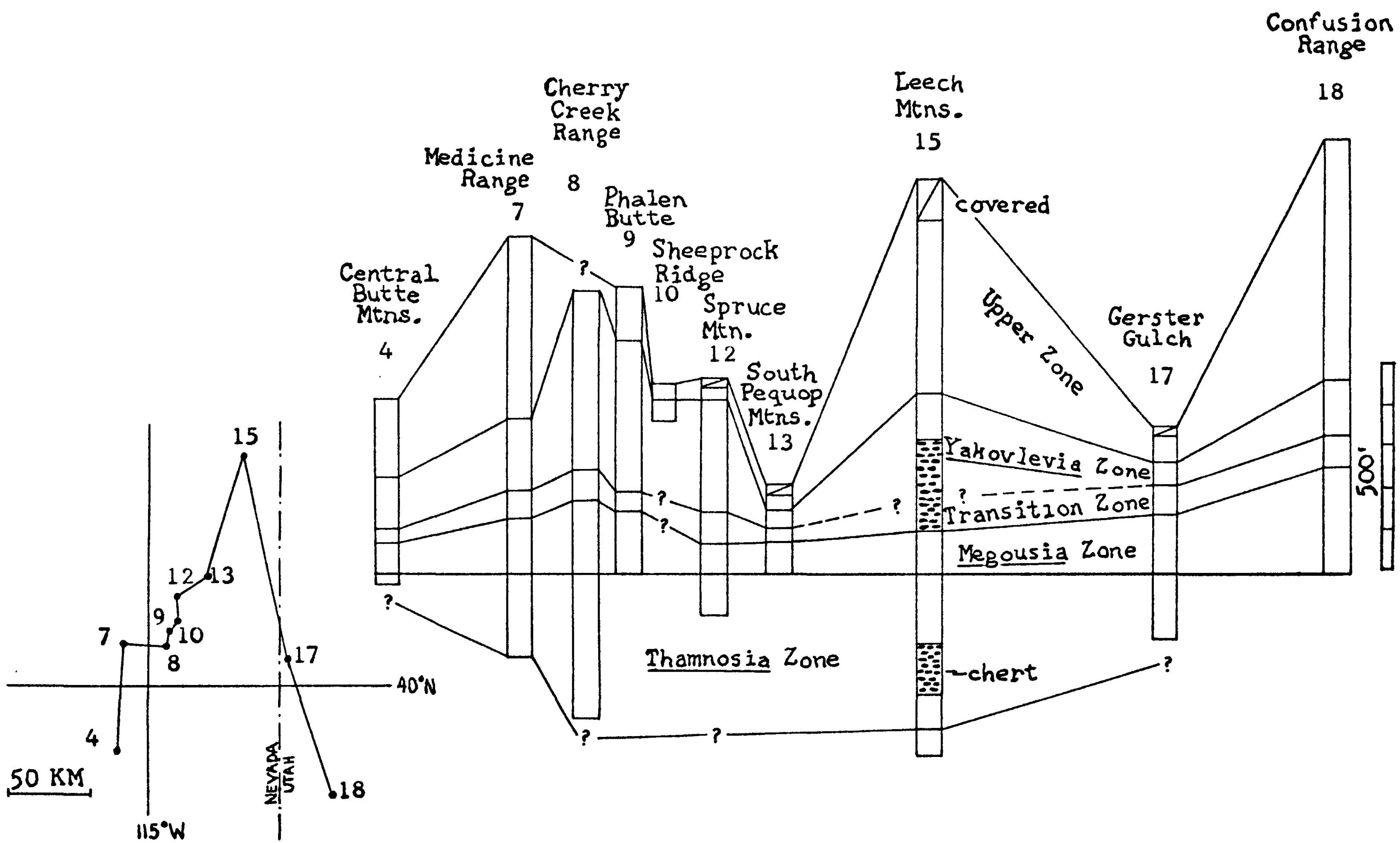


Fig. 8. The distribution of faunal zones in the sections of the Gerster.

Pequop Mountains, Gerster Gulch, and the central Butte Mountains represent lower rates of sedimentation.

The section in the central Butte Mountains is a very misleading one. Sides (1966) measured over 1,600 ft of Gerster. My section is located near Sides' and I also went over his. The base of the formation is well exposed and shows numerous antithetical faults. The remainder of the formation is poorly exposed on a low bench and slope topography. The faunal evidence suggests some beds are repeated. I have reconstructed the section as best I could on the basis of subtle lithic changes and the position of the faunal zones.

The thick upper zone in the Medicine Range, Leach Mountains, and Confusion Range represents either greater subsidence or less erosion or both. The base of the Gerster Limestone follows the relative time lines well, indicating it to be nearly synchronous.

Within the Gerster, the Thamnosia zone is characterized by the lowest diversity, the Kuvelousia zone by moderate diversity, the transition and Yakovlevia zones by highest diversity, and the upper zone by low diversity (fig. 9). A large number of elements stop at the Yakovlevia-upper boundary and there are very few occurrences above it. only the long-ranging elements carry through into the upper zone. Brachiopods and other marine fossils become very

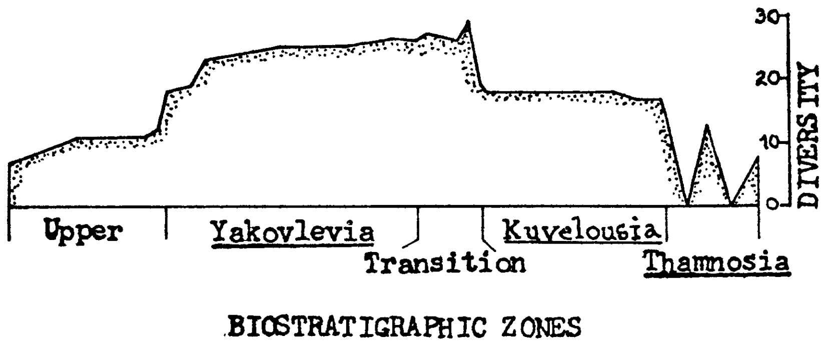


Fig. 9. Brachiopod species diversity in the zones of the Gerster.

rare near the top of the formation. The low diversity of the Thamnosia zone is assumed to be due to the rarity of subtidal conditions in which brachiopods could have lived. The moderate diversity of the Kuvelousia zone is interpreted as a result of the initial establishment of widespread subtidal conditions, and the higher diversities result from the stabilization of these marine subtidal conditions.

Outside the Gerster Basin, Yakovlevia multistriata and Timaniella "pseudocamerata" seem always to occur above Kuvelousia leptosa, thus maintaining the relationships seen in the Gerster and implying that the relationship is a significant time-dependent phenomenon. The ranges of Thamnosia depressa and Kuvelousia leptosa appear to overlap slightly but usually Kuvelousia is found above Thamnosia.

Correlation with Phosphoria Biostratigraphy: The Gerster zones can be identified in the Leach Mountains section whch borders on the Phosphoria regime of sedimentation. Study of the U.S. Geological Survey's vast collections of brachiopods of the Phosphoria (Yochelson, 1968) shows these faunal zones are consistent and widespread. Generalizing, the Phosphoria shows the following zonation, in ascending order:

1. A zone dominated by Peniculauris and Neospirifer with a lower subzone of Anidanthus, and an upper subzone

of Thamnosia.

2. A zone dominated by Bathymyonia nevadensis and "Echinauris" which can be divided into a lower subzone of Kuvelousia leptosa, and an upper subzone of Yakovlevia multistriata, Timaniella, and Sphenalosia.

The Phosphoria, then, has at least one zone lower than the Gerster (i. e. in those beds equivalent to the Kaibab and the lower part of the Plympton) and the faunas of these formations are in need of further study. Though the zonation may be similar in the Phosphoria and Gerster, there are some basic faunal differences. The Gerster does not have Orbiculoidea, Lingula, or Leptodus or the large molluscan fauna of the Phosphoria. The Phosphoria lacks some of the Asian and North American Tethyan elements contained in the Gerster. Further study is needed to elucidate the similarities and differences, and this work is in progress.

Correlation with Yukon and Alaskan Biostratigraphy:

A small flat Yakovlevia (Y. geniculata (Girty)) occurs in the Anidanthus subzone of the Phosphoria. It is very different from the globose Yakovlevia (Y. multistriata (Meek)) that occurs higher in the section. A similar zonation was noticed by Waterhouse (in Bamber and Waterhouse, 1971). He dated the lower Yakovlevia occurrences (zone E) as Asselian and the upper ones as Ufimian (zone F).

The ammonites suggest younger ages (Bamber and Waterhouse, 1971), as does the range of *Yakovlevia* in the North American standard section. Its first occurrence in that section is in the Road Canyon Formation (Ufimian as used by Waterhouse). It is difficult to analyze Waterhouse's work because many of the brachiopods are not described or illustrated in the preliminary report. Often, just his field identifications exist, and they are hard to review critically (i. e., the presence of *Gilledia*). Grant (in Brabb and Grant, 1971) identified a flat *Yakovlevia* (*Y. mammata* (Keyserling)) from the type section of the Tahkandit Formation, which was one of the formations investigated by Waterhouse. Grant also identified a globose *Yakovlevia* (*Y. greenlandica* (Dunbar)) from the Tahkandit Limestone outside the type section, but its exact stratigraphic position was uncertain.

INTERPRETATION

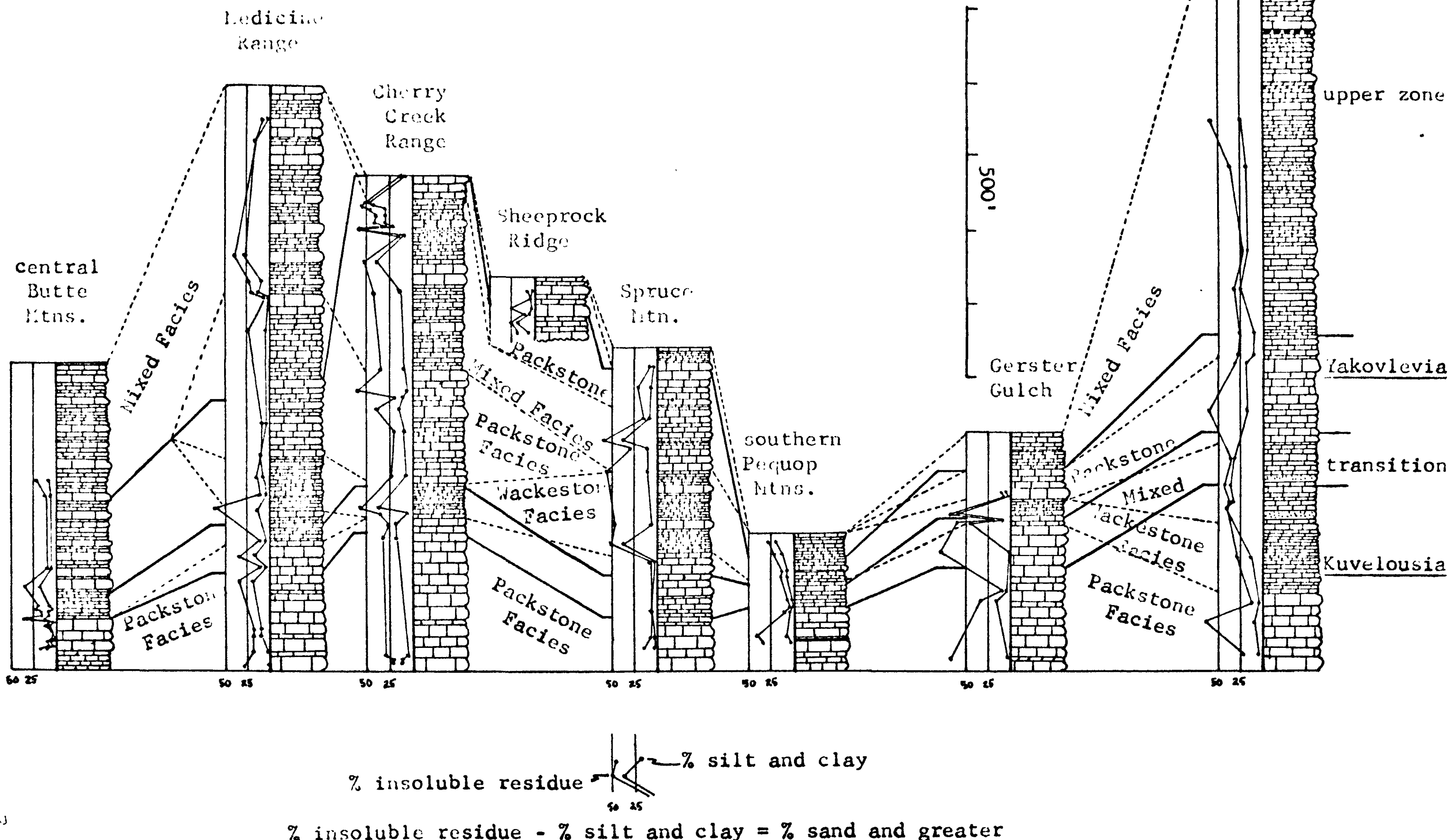
Basinal Synthesis: The compilation of all the sedimentologic and biostratigraphic data is shown in figure 10.

Shallow water depositon of the Gerster is suggested by the intimate relationship of the Gerster subtidal marine limestones with Plympton supratidal and intertidal dolomites, cherts, and siltstones, and by the abundant fauna of the Gerster. The Gerster Limestone is marked by packstones with abraded, transported fossils at its base, representing an initial transgressive high-energy sedimentary environment. Higher in the section the rocks are dominantly wackestones and poorly washed packstones representing a low- to moderate-energy enviromnent. The many preserved burrows also suggest low-energy conditions.

Many biostratigraphic zones are recognized in the Gerster and they seem to exist also in the Phosphoria, which contains many more lithofacies than the Gerster. This evidence suggests the biostratigraphic zones have some time reliability. The thickness of the Gerster below the upper zone was plotted (fig. 11) to reflect the subsidence-sedimentation pattern of the area. The upper zone thickness was separated and plotted to reflect the erosion pattern. Both thickness patterns are similar.

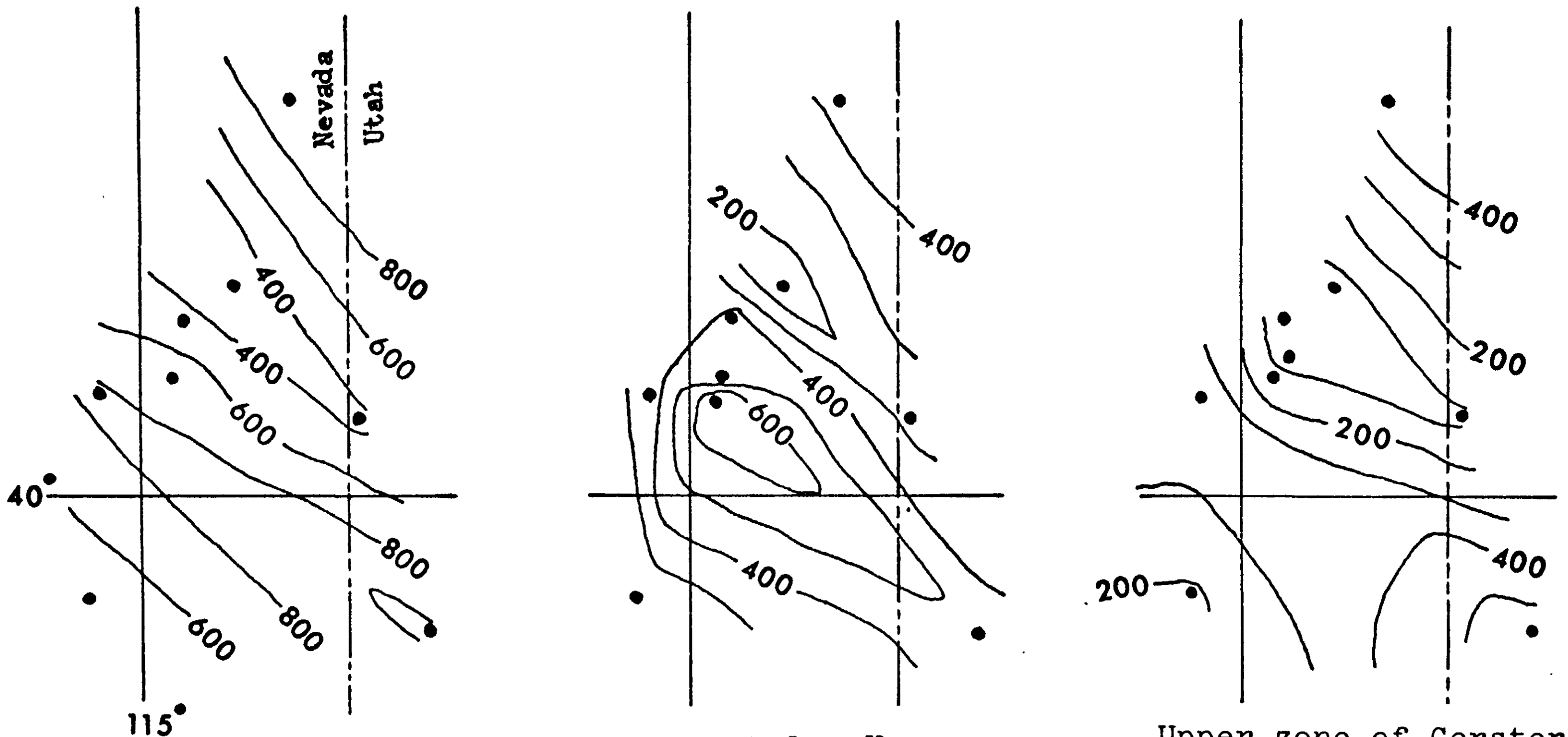
The southern Pequop Mountains and Gerster Gulch sections represent less sedimentation and, possibly, a

Fig. 10. Sedimentologic and biostratigraphic data: biostratigraphic zones (solid lines), lithofacies (dashed lines), lithology of sections, and percentage sand and greater fraction (chart) and silt and clay fraction.



shallow area separating the Gerster Basin from the Phosphoria Basin. The many faunal and lithic differences between the Gerster and Phosphoria support the existence of a minor barrier between the basins. The east- to southeast-trending positive area has also been suggested on the basis of detailed mapping by Fraser (Yochelson and Fraser, 1973) and Mercantel (1973). The thicker section in the Medicine, Cherry Creek, and Confusion Ranges seem to represent deeper water deposits. Overall, the concentration of silt and clay in the thicker sections implies lower energy (basinal) conditions. The thicker sections also have a thick upper zone (i. e., Medicine and Confusion Ranges), whereas the thinner sections have a thin upper zone. In part, the thickness of the upper zone is dependent on sedimentation rates and subsidence, but it also depends on how much erosion took place in Late Permian and Early Triassic time. The great thickness of the upper zone in basinal sections implies less erosion and suggests deposition on more positive areas and exposure to more local erosion in the thinner sections. Erosion may also have been extensive to the southwest of the positive area, in the vicinity of the Cherry Creek Range (fig. 11). The source for silt and clay appears to have been to the southeast.

The Gerster Basin, therefore, appears to have been a



Total Gerster

Gerster below Upper zone showing sedimentation pattern

Upper zone of Gerster, showing erosional pattern

Fig. 11. Isopachous maps of the Gerster Formation.

Sample localities the same as Fig. 1.

shallow basin with low-energy conditions. The sediment-water interface was represented by a soft-bottom sedimentary environment. A low positive marine ridge separated the Gerster Basin from the Phosphoria Basin.

Regional Synthesis: The regional sedimentary scheme is pictured in figure 12.

The Tethyan indicator (Stehli, 1973) *Leptodus* brackets the Gerster Basin to the north and west. The sandstone facies, the Edna Mountain and Shedhorn Formations, have all been interpreted as at least partly supratidal (Roberts and others, 1965; Sheldon, 1963). The Ommeca geanticline in Canada and the Sonoma-Antler orogenic belt were partially positive areas at the time (Douglas and others, 1970; Roberts and others, 1965). They represent the hinge line between the Permian miogeosyncline to the east and eugeosyncline to the west. The redbeds to the east represent terrestrial deposition on low-lying land.

The Gerster apperars to represent a protected coastal basin.

Fig. 12. Paleogeography of the western U.S. and southwestern Canada at of about Gerster Time.

Legend:

- Limits of outcrop (eroded or not deposited)
- *Leptodus* localities
- Low lying land
- Carbonate deposition
- Shale and chert deposition
- Sand and silt deposition
- Hinge line of Permian geosyncline (Sonoma-Antler Orogenic Belt to the south and the Ommeca Geanticline in Canada)
- Sporadically outcropping Middle and Upper Permian rocks, generally with similar fusulinids and, if present, similar brachiopods
- Containing a similar fauna to the Gerster and Park City Formations

1 Gerster Basin

2 Phosphoria Formation deposition

3 Park City Formation deposition

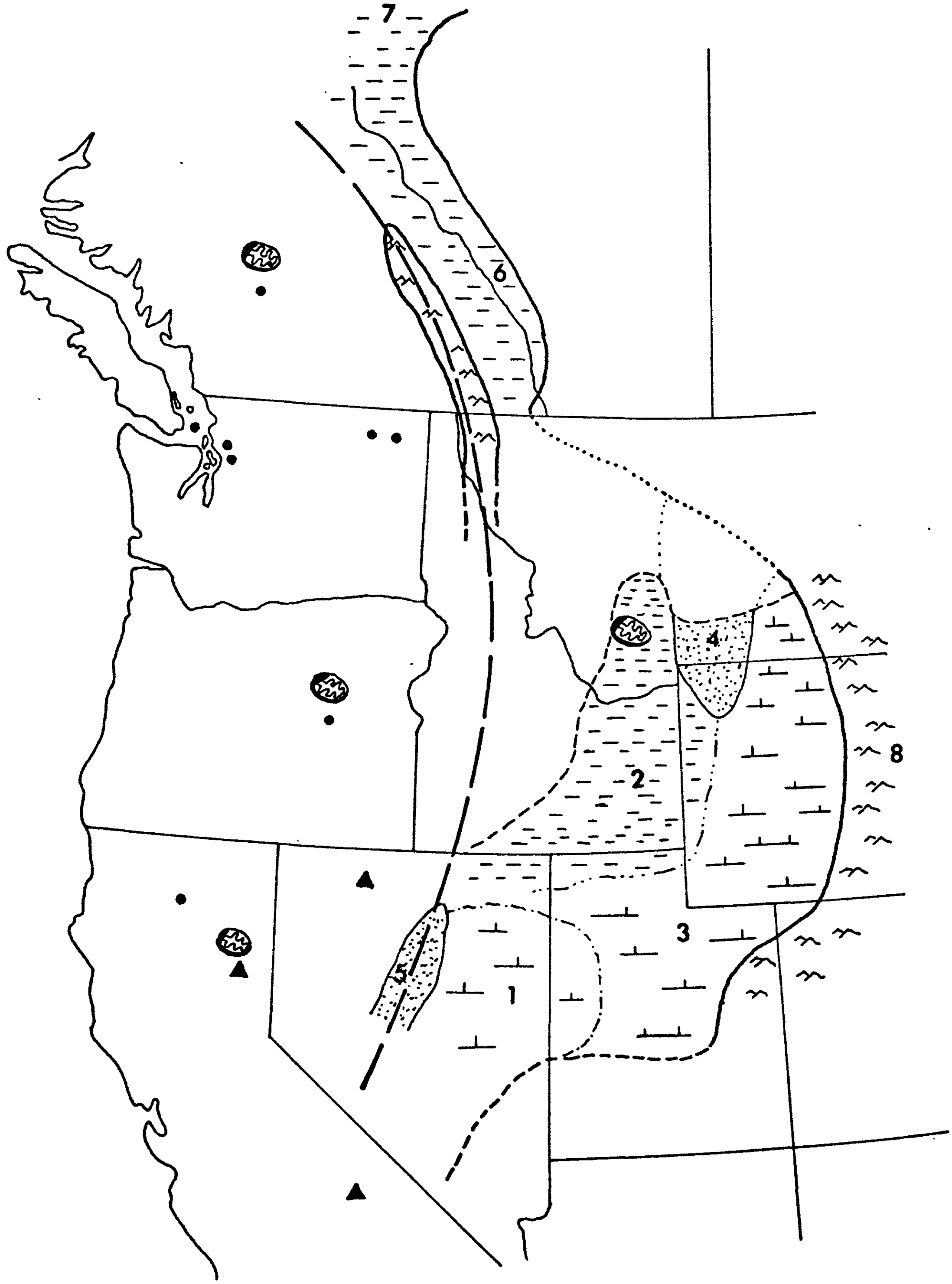
4 Shedhorn Formation deposition

5 Edna Mountain Formation deposition

6 Ishbel Group deposition

7 Belloy Formation deposition

8 Redbeds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AGE AND CORRELATION

The Permian brachiopods of west Texas and adjacent New Mexico are the best collected and described in the world (Cooper and Grant, 1969, 1972, 1974, 1975, 1976a, 1976b). This faunal work provides the opportunity to correlate the Gerster fauna with a very well known standard section. Otsuka Similarity Coefficients were generated in a comparison of the total Gerster fauna and its individual zones to the faunas of the Road Canyon Formation; the China Tank, Willis Ranch, and Appel Ranch Members of the Word Formation; and a lens between the Willis Ranch and Appel Ranch Members; and to the combined faunas of the Word and Cherry Canyon Formations and the combined faunas of the Bell Canyon and Capitan Formations. The coefficient = $\frac{C}{N_1 N_2}$, where C is the elements common to both, N_1 is the total in the first, and N_2 is the total in the second. This coefficient stresses similarity and attempts to smooth out unequal sample sizes.

The individual zones of the Gerster had too few genera to compare well with the much larger west Texas faunas. The total Gerster fauna showed strongest similarity with the Word and, in particular, with the Appel Ranch Member (upper Word). The coefficients are shown in the following table:

Standard section	Similarity to Gerster
Road Canyon Formation	0.324
China Tank Member	.343
Willis Ranch Member	.362
Lens between the Willis Ranch and Appel Ranch Members	.371
Appel Ranch Member	.407
Word-Cherry Canyon formations	.394
Capitan-Bell Canyon formations	.297

The presence in the Gerster of Ctenalosia fixata, found elsewhere only in Word and Capitan age beds in west Texas and New Mexico, adds credence to the proposed age for the Gerster. The occurrence of Thamnosia depressa only in the Wordian beds of El Antimonio, Sonora, Mexico and in the Gerster-Phosphoria Basin suggests their equivalence. The species Liosotella delicatula described by Dunbar (1955) from east Greenland along with Odontospirifer and a globose Yakovlevia point to close correlation with east Greenland. Waagenites, Hemiptychina, and Echinalosia all have their relatives in the Upper Permain of the Salt Range, Pakistan. The genus "Echinauris" is most like the poorly described Spinomarginifera from China; both genera have long anterior spines and a complete brachial marginal ridge.

A significant number of Asian Tethyan elements (i. e., Waagenites, Echinalosia, Hemiptychina and Rostranteris) indicates good communication with the Asian realm, most probably by a strong warm water current analogous to the present Japan Current. Tethyan elements transported by such a current could have become established in the warm protected waters of the Gerster Basin. Close affinity of western faunas with Asia has been indicated previously by the remarkable similarity of the Washington and British Columbia Upper Permian fusulinid faunas to those of Japan (Skinner and Wilde, 1966).

However, this is the first report of many Asian Tethyan elements outside of Asia, and it poses a few problems other than how they got there. Why are they only in Nevada and adjacent areas, and why aren't there more of them? Echinalosia occurs rarely in west Texas and abundantly in the Gerster and Park City Formations. Rostranteris also occurs in the Coyote Butte Formation in Oregon. The other Asian elements occur only in the Gerster and Phosphoria Basins. The Gerster Basin and the parts of the Phosphoria Basin in which these elements occur represent a special environment of warm shallow water, soft bottoms, and low energy. These particular genera could be well adapted to muddy bottom conditions, but lithic and bioassociation data from Asia are too sparse to confirm this.

PALEOECOLOGY

The fauna of the Gerster show a complex bioassociational scheme that is hard to analyze. For instance, Ctenalosia occurs attached to ramose bryozoa and to most of the bigger brachiopods, many of which rarely occur together. The fauna was analyzed most successfully by calculating how frequently each element occurred with another (R-mode clustering). Elements that occur less than five times and localities having just one element were omitted from consideration. To allow comparisons, the Otsuka Similarity Coefficient was used in analyzing the data.

Because most fossil assemblages show little or no evidence of having been transported, the analysis should reflect true life relationships. The common preservation of spiny brachiopods and long articulated crinoid stems indicates these fossils were not transported.

The results of the analysis are shown in table 1. Ramose bryozoa and crinoid columnals were not included in the analysis because they occur in practically every bed of the Gerster. Noticeably obvious bioassociations that were recognized in the field and upon etching the rock all show Otsuka values greater than 0.300. A 0.300 Otsuka value reflects two elements occurring together 30 percent of an averaged value of the number of times they both occur (N_1N_2). Dominant elements within the

	1	2	3	4	7	8	9	11	12	15	17	19	20	21	23	27	28	29	30
1	----	.206	.216	.058	.137	.400	.315	.494	-0-	.463	.500	.241	.113	.216	.176	.339	.249	.368	.337
2		----	.068	.436	.258	.352	.149	.282	.053	.056	.343	-0-	.211	.136	.056	.343	-0-	.285	.269
3			----	.134	.157	.223	.091	.221	-0-	.153	.158	-0-	.129	-0-	.102	.118	.144	.198	.141
4				----	.170	.246	.097	.203	-0-	.055	.281	-0-	.138	-0-	.109	.210	-0-	.281	.303
7					----	.232	.231	.146	.170	.065	.267	-0-	.245	.159	.129	.199	-0-	.249	.180
8						----	.404	.585	.049	.320	.602	.172	.238	.184	.302	.551	-0-	.412	.391
9							----	.351	.098	.075	.346	-0-	.096	.274	.224	.258	.105	.239	.258
11								----	.039	.407	.591	.231	.210	.221	.257	.638	.128	.408	.458
12									----	-0-	-0-	-0-	.138	.134	.219	.294	-0-	.140	.152
15										----	.323	.320	.131	.102	.207	.353	.235	.268	.268
17											----	.141	.245	.315	.215	.448	.122	.444	.507
19												----	-0-	-0-	-0-	.176	.129	.059	.063
20													----	.065	.053	.446	-0-	.203	.219
21														----	.102	.197	.289	.393	.339
23															----	.353	.236	.215	.231
27																----	.182	.489	.401
28																	----	.303	.163
29																		----	.594
30																			----

Table 1. Otsuka Similarity Coefficents for the bioassociational analysis. Integers refer to faunal elements listed in fig. 7.

	31	32	33	35	36	38	39	40	46	52
1	.232	.276	.088	.504	.465	.254	.137	.270	.068	.193
2	.326	.232	.389	.259	.300	.389	.345	.136	.215	.304
3	.180	-0-	-0-	.249	.308	-0-	-0-	-0-	.079	.112
4	.319	.229	.219	.185	.253	.330	.339	.134	-0-	.229
7	.227	.135	.129	.217	.311	.129	-0-	.158	.100	.142
8	.507	.275	.300	.620	.432	.338	.290	.266	.344	.412
9	.395	.311	.148	.352	.450	.298	.347	.274	.116	.327
11	.511	.283	.121	.679	.509	.347	.233	.258	.280	.264
12	.255	.228	.109	.220	.132	-0-	-0-	.258	.085	-0-
15	.122	.087	.042	.521	.352	.147	-0-	.153	.065	.046
17	.530	-0-	.215	.580	.648	.388	.312	.211	.300	.424
19	.107	-0-	-0-	.154	.110	.091	-0-	-0-	-0-	.100
20	.246	-0-	.263	.408	.159	-0-	-0-	-0-	.313	.116
21	.239	.532	.102	.276	.369	.408	.317	.250	.158	.223
23	.147	.261	-0-	.309	.251	.250	-0-	.408	.258	-0-
27	.528	.369	.160	.758	.445	.320	.198	.275	.359	.316
28	-0-	.246	-0-	.198	.280	.353	-0-	.144	.092	-0-
29	.408	.448	.212	.487	.615	.537	.249	.331	.083	.294
30	.304	.602	.173	.446	.627	.518	.357	.426	.089	.315
31	----	.306	.244	.493	.502	.341	.379	.239	.189	.374
32		----	.174	.322	.472	.608	.406	.533	.135	.381
33			----	.164	.251	.167	.128	.102	.193	.091
35				----	.575	.351	.217	.274	.022	.308
36					----	.553	.390	.369	.506	.440
38						----	.516	.510	.129	.365
39							----	.634	.100	.566
40								----	-0-	.336
46									----	.071
52										----

bioassociation yield values greater than 0.350, and rarer elements yield values of 0.300-0.350. Fifteen bioassociations are recognized numerically. The bioassociations are characterized in figure 13.

Dyoros (3), Echinalosia (7), and Liosotella (12) show random distrubutions.

The bioassociation can be classified into four groups: (1) those containing Xestotrema and "Echinauris", (2) those related to the Xestotrema-"Echinauris" group, (3) those containing Plectelasma and no big brachiopods, and (4) Timaniella. The four groups contain a total of 15 associations and subassociations, as listed below and as shown on figure 13.

The Xestotrema-"Echinauris" Group:

1. The "Gerster" association, consisting of "Echinauris", Xestotrema, Composita mira, Ctenalosia, Dielasma, and "Grandaurispina". These are the fossils most often found in the Gerster and occur abundantly in all lithofacies.

2. The "Echinauris" association, consisting of "Echinauris", Xestotrema, Composita mira, Ctenalosia, Dielasma, "Grandaurispina", Cleiothyridina n. sp. A, Cleiothyridina n. sp. B, Hustedia, and Plectelasma n. sp. A. This assemblage occurs in all lithofacies.

3. The Derbyia subassociation A, consisting of Derbyia, "Grandaurispina", "Echinauris", Ctenalosia,

Fig. 13. Key to the bioassociations of the Gerster

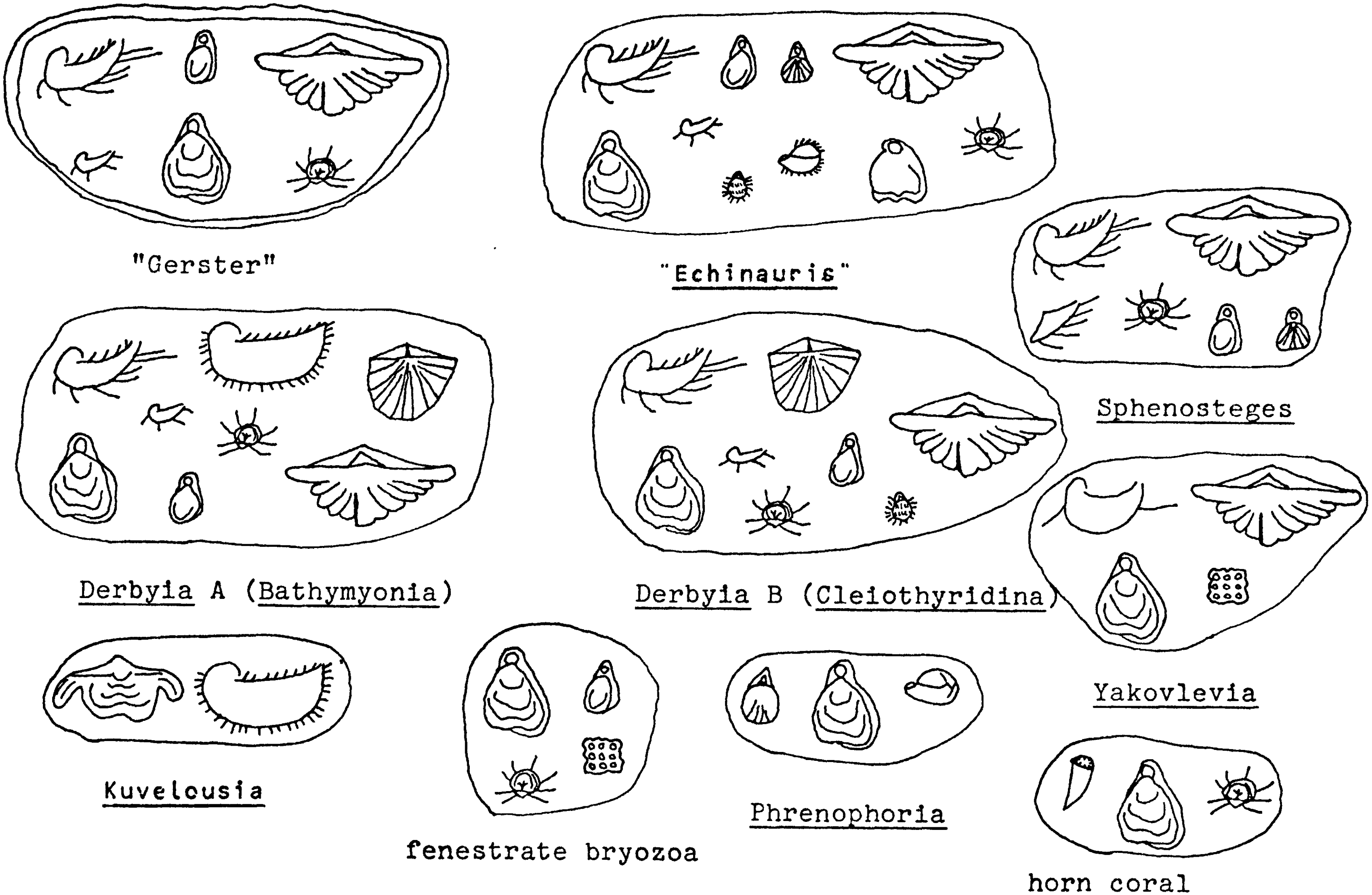


Fig. 13. Bioassociations of the Gerster.

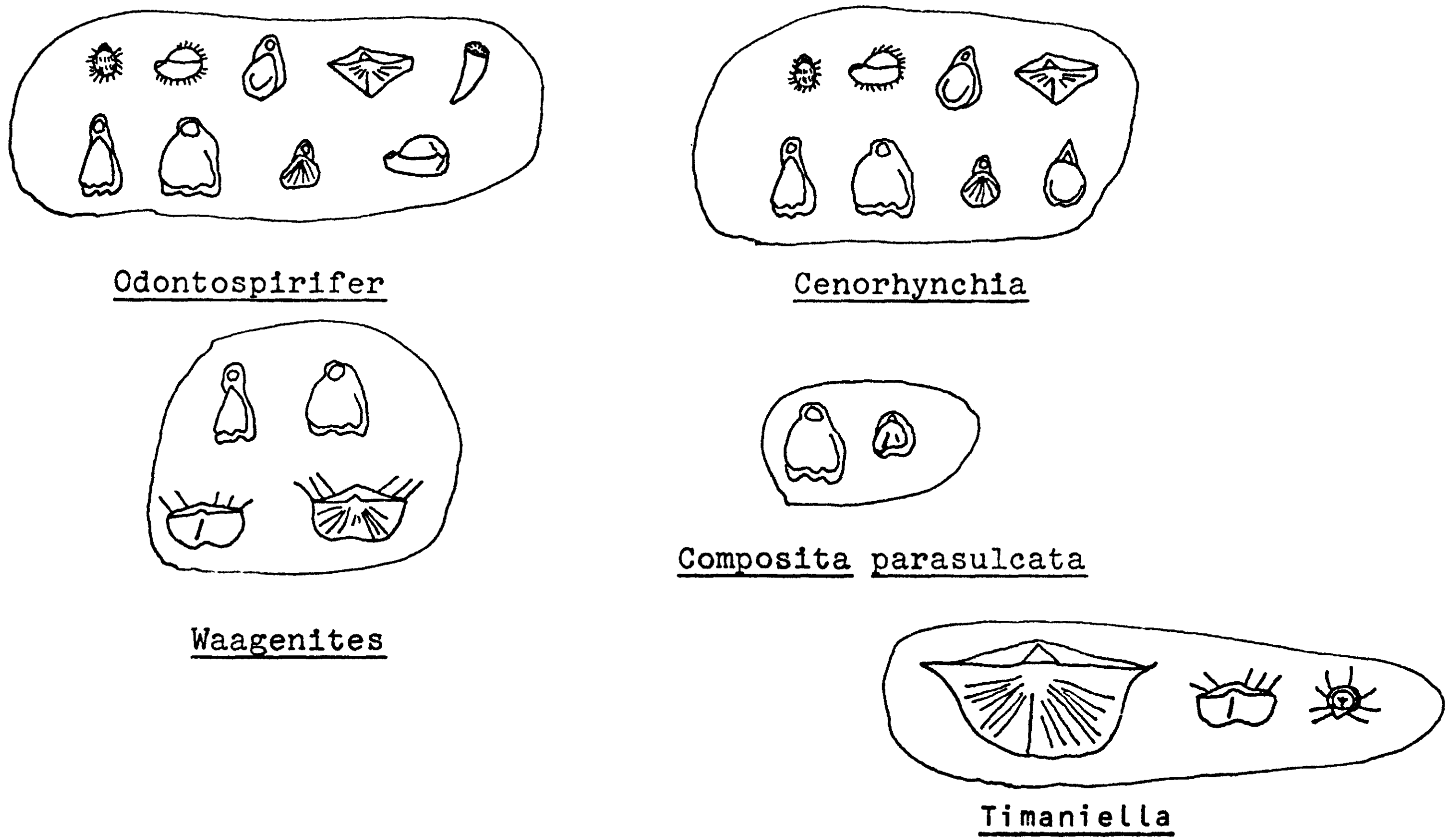


Fig. 13. Bioassociations of the Gerster.

Xestotrema, Dielasma, Composita mira, and Bathymyonia. This is the more common of the two Derbyia subassociations. Both subassociations are commonly found in assemblages in the packstone of the packstone facies and to a lesser degree in the packstone of the mixed facies.

4. The Derbyia subassociation B, as above, but lacking Bathymyonia and containing Cleiothyridina n. sp. A.

5. The Sphenosteges association, consisting of Sphenosteges, Dielasma, Ctenalosia, Hustedia, Xestotrema, and "Echinauris". It occurs in all lithofacies.

The Related Group:

6. The Yakovlevia association, consisting of Yakovlevia, Xestotrema, Composita mira, and fenestrate bryozoa. It is usually confined to silty wackestones.

7. The Kuvelousia association. Kuvelousia rarely occurs consistently with anything except Bathymyonia. Often these are the only fossils in the rock. Kuvelousia rarely occurs outside of the packstone facies.

8. Fenestrate bryozoa association, consisting of fenestrate bryozoa, Composita mira, Ctenalosia, and Dielasma. It occurs in the siltier rocks of all lithofacies.

9. The Phrenophoria association, consisting of Phrenophoria, Composita mira, and Hemiptychina. Phrenophoria is very abundant in places. It occurs in very silty packstones of the packstone and mixed facies.

10. The horn coral association, consisting of a horn coral, Ctenalosia, and Composita mira. It occurs in all lithofacies.

The Plectelasma Group:

11. The Odontospirifer association, consisting of Odontospirifer, Dielasma, both species of Cleiothyridina, both species of Plectelasma, Hustedia, Hemiptychina, and a horn coral. This assemblage is usually in silty pelletal rocks of all lithofacies.

12. The Cenorhynchia association, consisting of Cenorhynchia, Odontospirifer, both species of Cleiothyridina, both species of Plectelasma, Hustedia, and Dielasma. It occurs in all lithofacies.

13. The Composita parasulcata association, consisting of Composita parasulcata and Plectelasma n. sp. A. It occurs in the packstone facies.

14. The Waagenites association, consisting of Waagenites, Quadrochonetes, and both species of Plectelasma. It occurs in silty and very silty wackestones and occasionally in very silty packstones of the wackestone and packstone facies.

The Timaniella Group:

15. The Timaniella association, consisting of Timaniella, Quadrochonetes, and Ctenalosia. It occurs in very silty pelletal rocks of the mixed and packstone facies.

In summary, three lithically controlled groups can be recognized. One that occurs in all lithic types, one that occurs in packstones only, and one that occurs in silty wackestones and very silty packstones. The first group includes the "Gerster", "Echinauris", Sphenosteges, horn coral, and Cenorhynchia bioassociations. The second group includes both Derbyia subassociations, Kuvelousia, and Composita parasulcata bioassociations. The last group includes the Yakovlevia, fenestrate bryozoa, Phrenophoria, Waagenites, Timaniella, and Odontospirifer bioassociations.

The distribution of these bioassociations seems to be controlled by the distribution of relatively clean packstone deposition, representing higher energy deposition in the Gerster; and silt deposition in both packstones and wackestones, representing lower energy deposition. One group occurs separately in each of the two sedimentary regimes and one occurs in both. The group occurring only in the relatively clean packstones is found in the packstone facies and in the thick packstones in the mixed facies. The group occurring in silty rocks is found in the wackestone and mixed facies.

Species diversity within the Gerster shows a marked change with lithofacies. Well collected beds within the packstone facies have an average brachiopod species diversity of 9.00; the most diverse bed contains 18 species and the total species diversity within the facies is 36. Beds within the wackestone facies have an average diversity of 7.88; the most diverse bed contains 17 species, and the total diversity within the facies is 25. Beds within the mixed facies have an average diversity of 6.19; the most diverse bed contains 14 species, and the total diversity within the facies is 26. Though the diversity of brachiopods is low, their abundance is high.

Occurring only in the packstone facies are Dyoros n. sp. A, Waagenites n. sp. B, Heteralosia sp. Bathymyonia n. sp. A, Cenorhynchia n. sp. B, Phrenophoria n. sp. A, Phrenophoria n. sp. B, Spiriferella scobina, Rostranteris n. sp. A, and Heterelasma n. sp. A. Occurring only in the wackestone facies are Kochiproductus sp. and Girtyella?. Occurring only in the mixed facies are Dielasma spatulatum and "Grandaurispina" arctica?. Not occurring in the wackestone facies, but present in the other two facies are Composita parasulcata, Sphenosteges hispidus, and Derbyia sulca. Not occurring in the mixed facies, but present in the other two facies are Petasmetherus n. sp. A and Plectelasma n. sp. B.

The mixed facies shows the lowest diversity per bed. If it were just an interfingering of the packstone and wackestone facies, it should have a diversity value somewhere between the two others. The mixed facies is not only composed of interbedded wackestones and packstones, but also siltstones. This composition represents continually changing environments of deposition. Perhaps the instability of a continually changing environment can explain the anomalously low diversity. The packstone facies represents higher energy, and more stable and much more diverse conditions than the mixed facies. The wackestone facies represents lower energy, but it also represents more stable and more diverse conditions. This hypothesis also explains why the mixed facies would have unique fossil occurrences: because it is not just a fine interfingering of the packstone and wackestone facies, but a separate environmental regime.

Areal brachiopod species diversity trends within the Gerster Basin show an area of relatively high diversity exists in the northeast part of the basin in the Cherry Creek Range, southern Pequop Mountains and Gerster Gulch (fig. 14). Diversities seem to decrease in all directions from this area.

The diversity pattern seems to match the erosional pattern in that the three localities that show the most erosion show the highest diversity. The diversity pattern does not closely fit the silt-basinal pattern, which seeminly precludes the concept expounded by many workers that diversity is related to depth (Yochelson, 1968; Stevens, 1966).

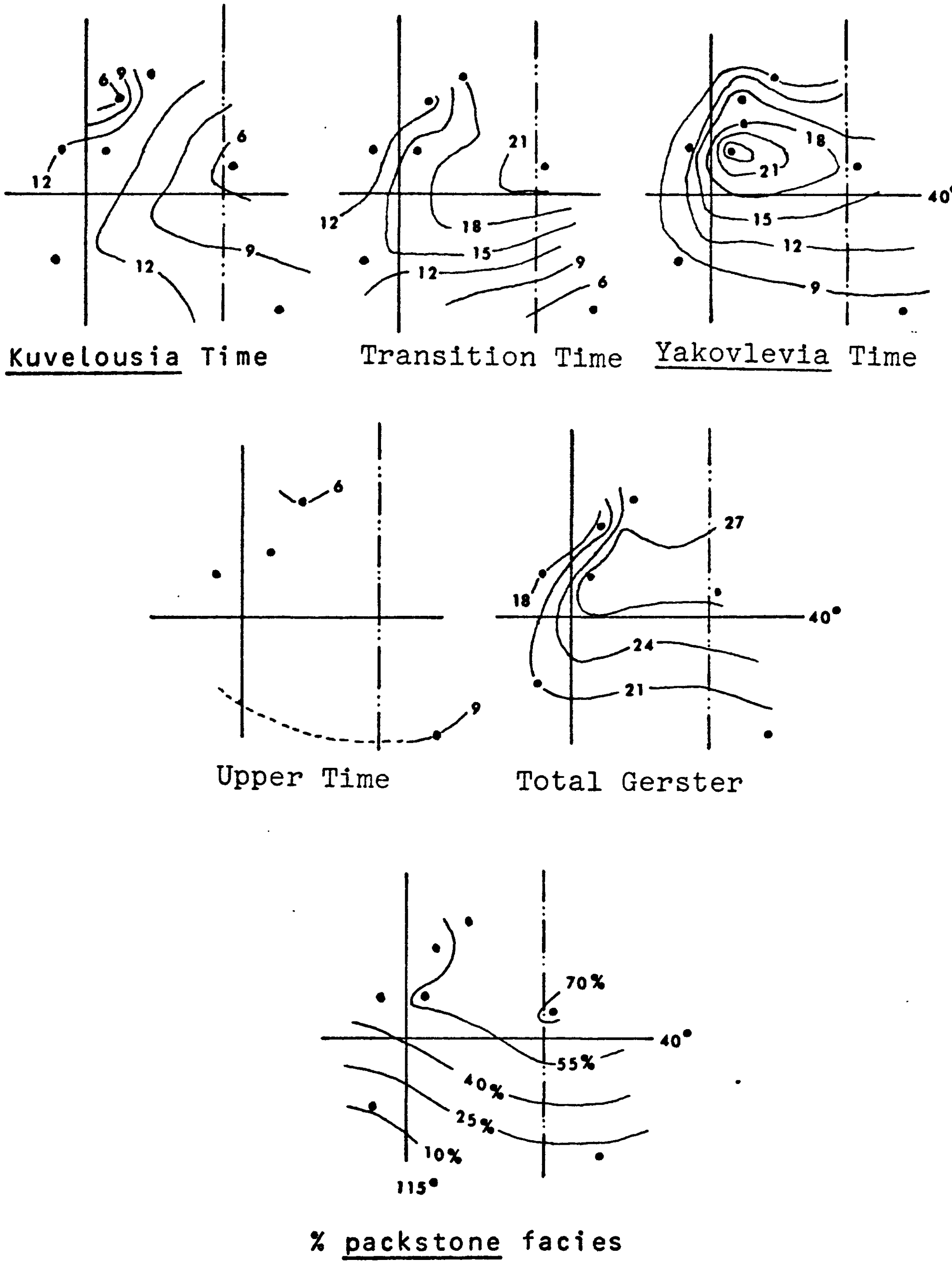


Fig. 14. Areal brachiopod species diversity trends and percent packstone facies of each major section. Sample localities same as Fig. 1.

The pattern does seem to correlate well with the percentage of the sequence that is packstone facies. Those sequences that are more than 55 percent packstone facies show higher diversity (fig. 14). The packstones are more common to the shallow ridge (southern Pequop Mountains and Gerster Gulch) and to a lesser extent to the Cherry Creek Range. The Cherry Creeks seem to be part of the Gerster Basin near the ridge that also experienced the relatively high-energy environment of packstone deposition and, therefore, more diverse conditions. Deposits in the Cherry Creek Range are anomalous because they have high silt content and great thickness ("basinal" aspects), and yet also exhibit high packstone content, high diversity, and moderate erosion ("shallow" aspects). As implied earlier, the true depth differences between basinal and shallow deposits were seemingly not great and, perhaps the "anomalous" Cherry Creek Range reflects current or shelf patterns in the Gerster Basin.

PALEOBIOGEOGRAPHY

Several well-represented mid-Permian faunas have been reported from the western North American continent, the Canadian Archipelago, and Greenland. Faunas from El Antimonio, Sonora, Mexico (Cooper, 1953); Coyote Butte, Oregon (Cooper, 1957); the Tahkandit Formation, Alaska (Brabb and Grant, 1971); Svartevaeg, Axel Heiberg Island, Canada (Stehli and Grant, 1971); and central-east Greenland (Dunbar, 1955) were closely examined at the generic level to see what relationship they have to the Gerster. All contain the enigmatic "Yakovlevia faunas" and are basically Word in age. All the faunas were compared to the Word Formation of the Glass Mountains, Texas. The Oregon fauna appears to be slightly older than the others. It seems to be Road Canyon to lower Word in age and equivalent to the lower Phosphoria Formation faunas in Nevada, Utah, and Idaho.

Otsuka Similarity Coefficients were used in analyzing the data (fig. 15). Most of the faunas cluster in what might be called a Boreal group with the Gerster and the Word faunas separate. The El Antimonio fauna correlates well with the Arctic faunas. Simpson's Coefficient was also used to emphasize the much higher Word Tethyan aspect contained in both the Gerster and El Antimonio faunas that was swamped out in comparing the 86 genera of the Word to the 30 or so in the Gerster and El Antimonio. The Simpson Coefficient is a simple measure of similarity: $\frac{C}{(N_1)}$, where C = the number of elements common to both stations, N_1 = the total number of elements at one station so that $N_1 \geq N_2$. The difference in the values derived from the two coefficients is slight, except for the relationship of the Word to the others, especially to El Antimonio and the Gerster. In these cases, the large differences reflect the fact that El Antimonio and the Gerster have many more genera in common with the Word than with the other localities. The Gerster has more species in common with El Antimonio than with any of the other faunas, which indicates their close alliance. Dendrograms (fig. 15) were constructed by the unweighted average-linkage method of Sokal and Sneath (1963).

The interpretation made from these analyses is shown in figure 16.

Although the data are sparse, a provincial interpretation is constructed on the following arguments:

1. The Coyote Butte fauna consistently clusters with the Boreal group. Boreal is used in the sense of Stehli (1971), meaning cool water. Coyote Butte contains _Leptodus_, thought to be diagnostic of the Tethyan realm (Rudwick and Cowen, 1967; Stehli, 1957, 1973), and _Rostranteris_, also a Tethyan form. _Meekella_, which is

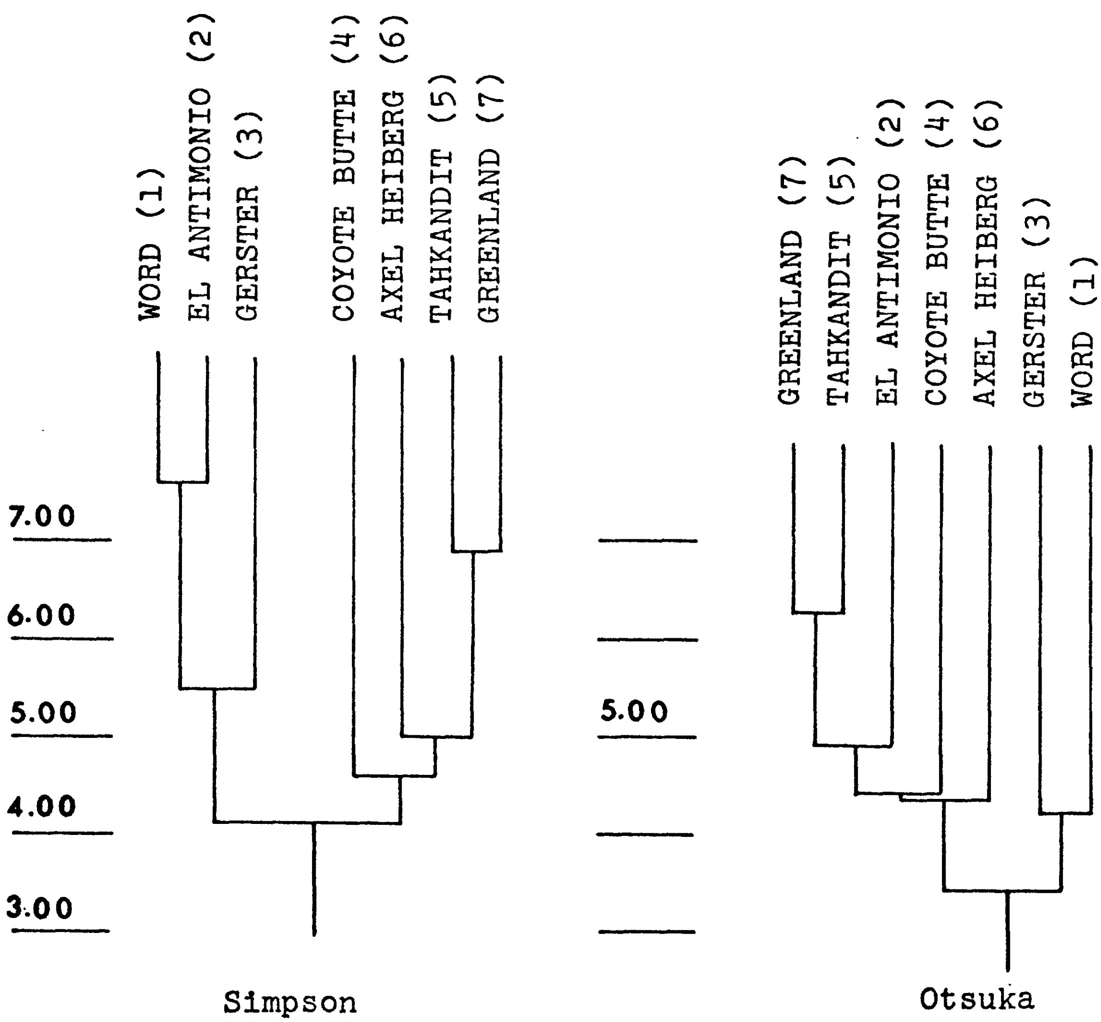
Otsuka

	2	3	4	5	6	7
1	.441	.426	.319	.290	.254	.260
2	--	.452	.428	.525	.407	.461
3		--	.373	.412	.307	.324
4			--	.500	.355	.398
5				--	.530	.630
6					--	.367

Simpson

	2	3	4	5	6	7
1	.76	.61	.49	.46	.46	.45
2	-	.48	.48	.59	.42	.45
3		-	.39	.42	.35	.33
4			-	.51	.42	.45
5				-	.62	.69
6					-	.38

Fig. 15. Otsuka and Simpson Coefficient values for each station and cluster dendrograms.



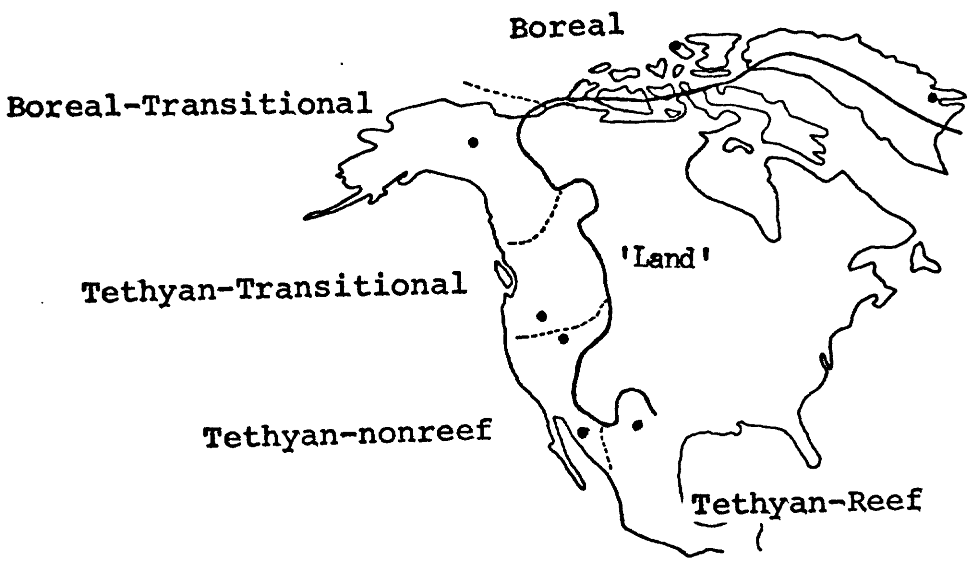


Fig. 16. Middle Permian biogeographical provinces of North America.

present, is thought to range into "temperate" or "marginal Tethyan" (Stehli, 1973) regions. The bulk of the fauna is Boreal in aspect. Cooper (1957) thought the fauna most closely resembled those of British Columbia and Russia, of the faunas known at that time.

2. The faunas of the Cache Creek Group of British Columbia are similar to those of Coyote Butte. Leptodus is present, along with some Tethyan fusulinids.

This "anomalous" mixing of a few Tethyan forms with Boreal forms is thought diagnostic of a transitional province. Because lower temperature restrictions are usually more important to animals, the existence of diagnostic Tethyan faunal elements ("warm water"; Stehli, 1973) suggest "warm water" conditions.

3. The Tahkandit correlates very well with all Boreal, Tethyan-transitional and Tethyan-nonreef faunas. it contains Composita, thought to be a "temperate" or "marginal Tethyan" indicator by Stehli (1973). Though the Tahkandit fauna is dominated by Boreal elements, its abundant relations to the south suggest that it was in the transitional region of the Permian.

4. The Gerster and El Antimonio contain numerous west Texas forms. The Gerster has many forms that are exclusively Tethyan. Neither fauna has the normal Tethyan reef forms.

The absence of Tethyan reef elements in El Antimonio and Gerster faunas indicates that both represent Tethyan level-bottom assemblages, in which reefs were not developed.

5. El Antimonio correlates very well with Tahkandit, suggesting communication along a continental margin. Many forms exist that seem to be diagnostic of this continental margin. A large Thamnosia, Bathymyonia, and Liosotella are examples.

6. The Gerster correlates less well with the Tahkandit than do Coyote Butte and El Antimonio. Local paleogeography of the Gerster Basin suggests the Gerster fauna represents a protected coast fauna whereas the Oregon, El Antimonio, and Tahkandit faunas might represent open-coast faunas.

Further information can be gained by examining diversity data from these locales (Table 2).

Familial diversity is derived using the families recognized in the Treatise on Invertebrate Paleontology, Brachiopoda (Moore, 1965). The "Permian Ratio" is a simple diversity measure: $\frac{\Sigma - C}{C}$, where Σ = the total brachiopod families found and C = the cosmopolitan dominant families found (Stehli and Grant, 1971). The sampling index (Stehli and Grant, 1971) is $\frac{C}{16}$, the number of cosmopolitan dominant families found (C) divided by the number that exist (16).

Table 2.--Diversity data of Middle and Upper Permian localities from Western North America and the Arctic.

Locality	Generic Diversity	Familial Diversity	Average No. of Genera per Family	Permian Ratio"	Sampling Index
El Antimonio	29	21	1.38	0.62	0.81
Gerster	33	19	1.74	0.69	0.81
Oregon	37	24	1.54	0.50	1.00
Tahkandit	36	23	1.56	0.53	0.94
Axel Heiberg	26	20	1.30	0.67	0.75
Greenland	29	20	1.45	0.33	0.94

Both the Gerster and El Antimonio have "Permian Ratios" that would be considered Tethyan (Stehli and Grant, 1971). Coyote Butte, Tahkandit, and Greenland show Boreal "Permain Ratios". The fauna from Axel Heiberg shows a spuriously high "Permian Ratio", owing largely to its low sampling index which reflects an absence of collected cosmopolitan families.

The Gerster contains a unique familial assemblage. Some important cosmopolitan dominant families are missing: particularly, the Schuchertellidae, Dictyoclostidae, Stenoscismatidae, Elythidae, and Overtoniidae. The Dictyoclostidae are also absent from El Antimonio. These families may be temperature independent (i. e., cosmopolitan dominant), but they seem unable to adapt to the stress pressures involved with soft bottoms. The Gerster has the highest genera/family ratio, implying that those families present in the Gerster exploited the environment well. Families well represented in the Gerster are: Chonetidae, Strophalosiidae, Marginiferidae, Linoproductidae, Wellerellidae, and Dielasmatidae. The Wellerellidae are not a cosmopolitan dominant family. Members of Orthotetidae, Echinoconchidae, Athyrididae, Spiriferinidae, and Retziidae are often abundant. The Notothyrididae represent a strictly Tethyan endemic family.

Summary of the Paleoecology of the Gerster: The Gerster was deposited in a shallow protected coastal basin of overall relative low energy. The basin was defined by a shallow area dividing it from the Phosphoria Basin.

The fauna was observed to be segregated into bio-associations that can be separated numerically. The most important physical parameters affecting the bioassociation distribution seem to be those affecting packstone and silt deposition (energy conditions).

The Gerster fauna belongs to the Tethyan-nonreef province of the mid-Permian. Many cosmopolitan elements are missing from this province because of their inability to adapt to soft bottoms.

REFERENCES CITED

Bamber, E. W., and Waterhouse, J. B., 1971, Carboniferous and Permian stratigraphy and paleontology, northern Yukon Territory, Canada: Bull. Canadian Petroleum Geology, v. 19, no. 1, p. 29-250.

Bissel, H. J., 1964, Ely, Arcturus, and Park City groups (Pennsylvanian-Permian) in eastern Nevada and western Utah: Am. Assoc. Petroleum Geologists Bull., v. 48, no. 5, p. 565-636.

Boutwell, J. M., 1907, Stratigraphy and structure of the Park City mining district, Utah: Jour. Geology, v. 15, p. 434-458.

Brabb, E. E., and Grant, R. E., 1971, Stratigraphy and paleontology of the revised type section for the Tahkandit Limestone (Permain) in east-central Alaska: U.S. Geol. Survey Prof. Paper 703, 26 p.

Browning, A., 1973, Sedimentary petrology of the Permian Plympton Formation in eastern Nevada and adjacent Utah: Columbus, Ohio, Ohio State Univ. M.S. thesis.

Collinson, J. W., 1968, Permian and Triassic biostratigraphy of the Medicine Range, northeastern Nevada: Earth Sci. Bull., v. 1, no. 4, p. 25-44.

Cooper, G. A., 1953, Permian fauna at El Antimonio, western Sonora, Mexico: Smithsonian Misc. Colln., v. 119, no. 2, p. 1-111.

______, 1957, Permian brachiopods from central Oregon: Smithsonian Misc. Colln., v. 134, no. 21, p. 1-77.

Cooper, G. A., and Grant, R. E., 1969, New Permian brachiopods from west Texas: Smithsonian Contr. Paleobiology, v. l, p. 1-20.

______, 1972, Permian brachiopods of west Texas, I: Smithsonian Contr. Paleobiology, v. 14, p. 1-231.

______, 1974, Permian brachiopods of west Texas, II: Smithsonian Contr. Paleobiology, v. 15, p. 233-793.

______, 1975, Permian brachiopods of west Texas, III: Smithsonian Contr. Paleobiology, v. 19, p. 795-1921.

______, 1976a, Permian brachiopods of west Texas, IV: Smithsonian Contr. Paleobiology, v. 21, p. 1923-2607.

______, 1976b, Permian brachiopods of west Texas, V: Smithsonian Contr. Paleobiology, v. 24, p. 2609-3159.

Darton, N. H., 1910, A reconnaissance of parts of northwestern New Mexico and northern Arizona: U.S. Geol. Survey Bull, 435, p. 1-84.

Douglas, R. J. W., Gabrielse, H., Wheller, J. R., Stott, D. F., and Belyea, H. R., 1970, Geology of western Canada, chapter 8, in Douglas, R. J. W., ed., Geology and economic minerals of Canada: Canada Geol. Survey Econ. Geology Rept. 1, p. 366-488.

Dunbar, C. O., 1955, Permian brachiopod faunas of central east Greenland: Medd. Gronland, v. 110, no. 3, p. 1-169.

Furnish, W. M., 1973, Permian stage names, in Logan, A., and Hills, L., eds., The Permian and Triassic Systems and their mutual boundary: Canadian Soc. Petroleum Geologists Mem. 2, p. 522-548.

Hodgkinson, K. A., 1961, Permian stratigraphy of northeastern Nevada and northwestern Utah: Brigham Young Univ. Geology Studies, v. 8, p. 167-196.

Hose, R. K., and Repenning, C. A., 1959, Stratigraphy of Pennsylvanian, Permian, and Lower Triassic rocks of Confusion Range, west-central Utah: Am. Assoc. Petroleum Geologists Bull., v. 43, no. 9, p. 2167-2196.

McKee, E. D., 1938, The environment and history of the Toroweap and Kaibab Formations of northern Arizona and southern Utah: Carnegie Inst. Washington Pub. 492, 268 p.

Meek, F. B., 1877, Paleontology: U. S. Geol. Explor. 40th Parallel (King), v. 4, no. 1, p. 50-99.

Mercantel, J., 1973, Upper Pennsylvanian and Lower Permian sedimentation in northeast Nevada: Columbus, Ohio, Ohio State Univ. Ph. D. dissertation.

Moore, R. C., ed., 1965, Treatise on invertebrate paleontology, part H: New York, Geol. Soc. America, 927 p.

Nolan, T. B., 1935, The Gold Hill mining district, Utah: U.S. Geol. Survey Prof. Paper 117, p. 1-172.

Roberts, R. J., Crittenden, M. D., Jr., Tooker, E. W., Morris, H. T., Hose, R. K., and Cheney, T. M., 1965, Pennsylvanian and Permian basins in northwestern Utah, northeastern Nevada and southcentral Idaho: Am. Assoc. Petroleum Geologists Bull., v. 49, no. 11, p. 1926-1956.

Rudwick, M. J. S., and Cowen, R., 1967, The functional morphology of some abberant Strophomenide brachiopods from the Permian of Sicily: Boll. Soc. Paleontologica Italiana, v. 6, no. 2, p. 113-176.

Sheldon, R. P., 1963, Physical stratigraphy and mineral resources of Permian rocks in western Wyoming: U.S. Geol. Survey Prof. Paper 313-B, p. 49-273.

Sides, J. W., 1966, The geology of the central Butte Mountains, White Pine County, Nevada: Palo Alto, Calif., Stanford Univ. Ph. D. dissertation.

Skinner, J. W., and Wilde, G. L., 1966, Permian fusulinids from Pacific northwest and Alaska: Kansas Univ. Paleont. Contr., paper 4, p. 1-64.

Sokal, R. R., and Sneath P. H. A., 1963, Principles of numerical taxonomy: San Francisco, W. H. Freeman and Co., 359 p.

Steele, G., 1960, Pennsylvanian-Permian stratigraphy of east-central Nevada and adjacent Utah, in Intermountain Assoc. Petroleum Geologists 11th Ann. Field Conf. Guidebook, p. 91-113.

Stehli, F. G., 1957, Possible Permian zonation and its implications: Am Jour. Sci., v. 255, p. 607-618.

______, 1971, Tethyan and Boreal Permian faunas and their significance, in Dutro, J. T., ed., Paleozoic perspectives--a paleontological tribute to G. Arthur Cooper: Smithsonian Contr. Paleobiology, v. 3, p. 337-345.

______, 1973, Permian brachiopods, in Hallam, A., ed., Atlas of paleobiogeography: Asterdam, Holland, Elsevier Scientific Publishing Co., p. 143-149.

Stehli, F. G., and Grant, R. E., 1971, Permian brachiopods from Axel Heiberg Island, Cnada, and an indes of sampling efficiency: Jour. Paleontology, v. 45, no. 3, p. 502-521.

Stevens, C. H., 1966, Paleoecologic implications of early fossil communites in eastern Nevada and western Utah: Geol. Soc. America Bull., v. 77, p. 1121-1130.

Yochelson, E. L., 1968, Biostratigraphy of the Phosphoria, Park City, and Shedhorn Formations: U.S. Geol. Survey Prof. Paper 313-D, p. 571-660.

Yochelson, E. L., and Fraser, G. D., 1973, Interpretation of depositional environment in the Plympton Formation (Permian), southern Pequop Mountains, Nevada, from physical stratigraphy and a faunule: U.S. Geol. Survey Jour. Research, v. 1, no. 1, p. 19-32.

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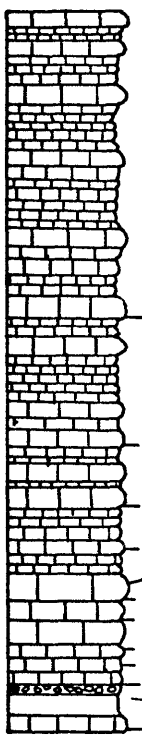

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Lithologic symbols are the same as used in Fig. 4.

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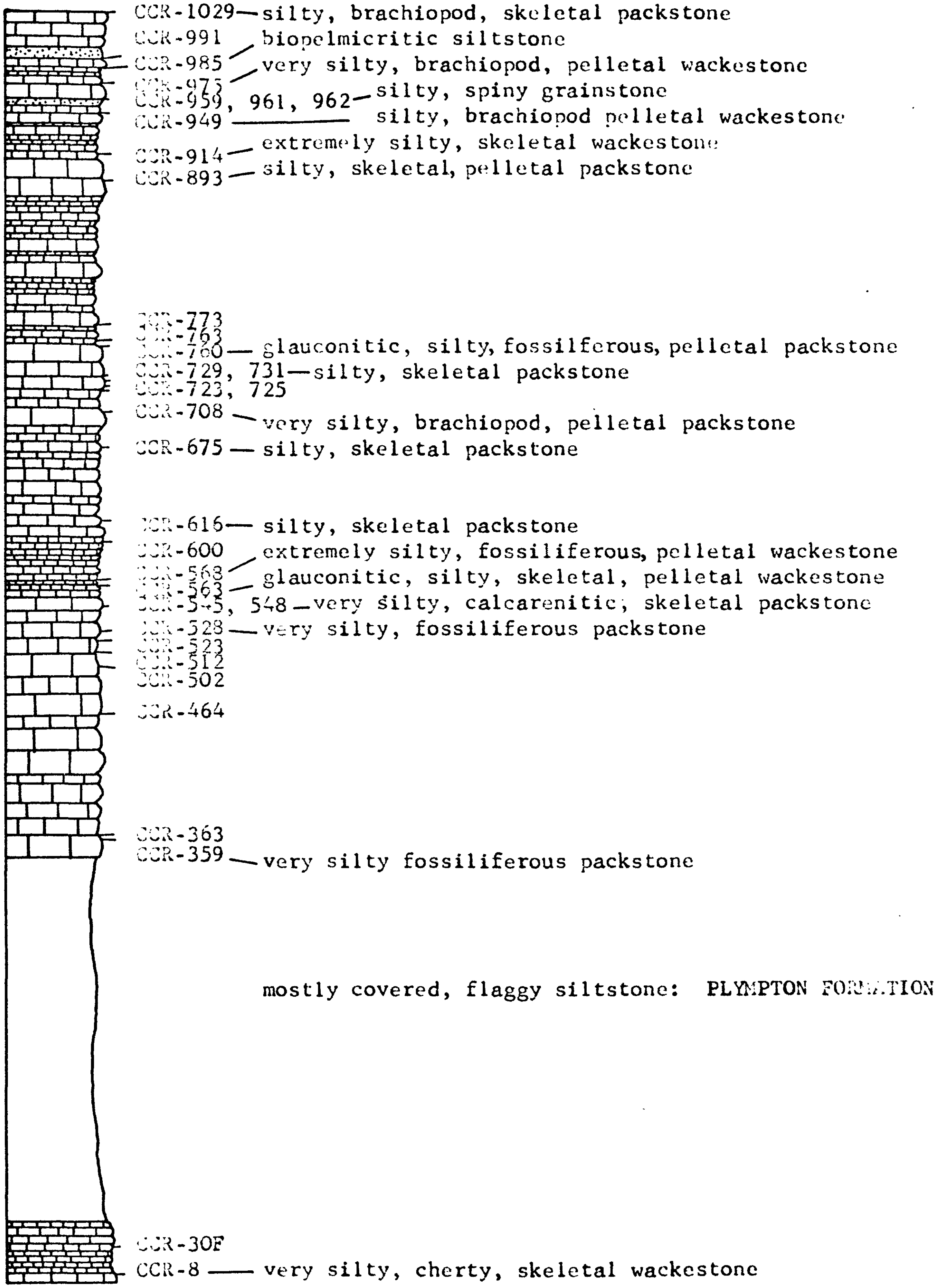

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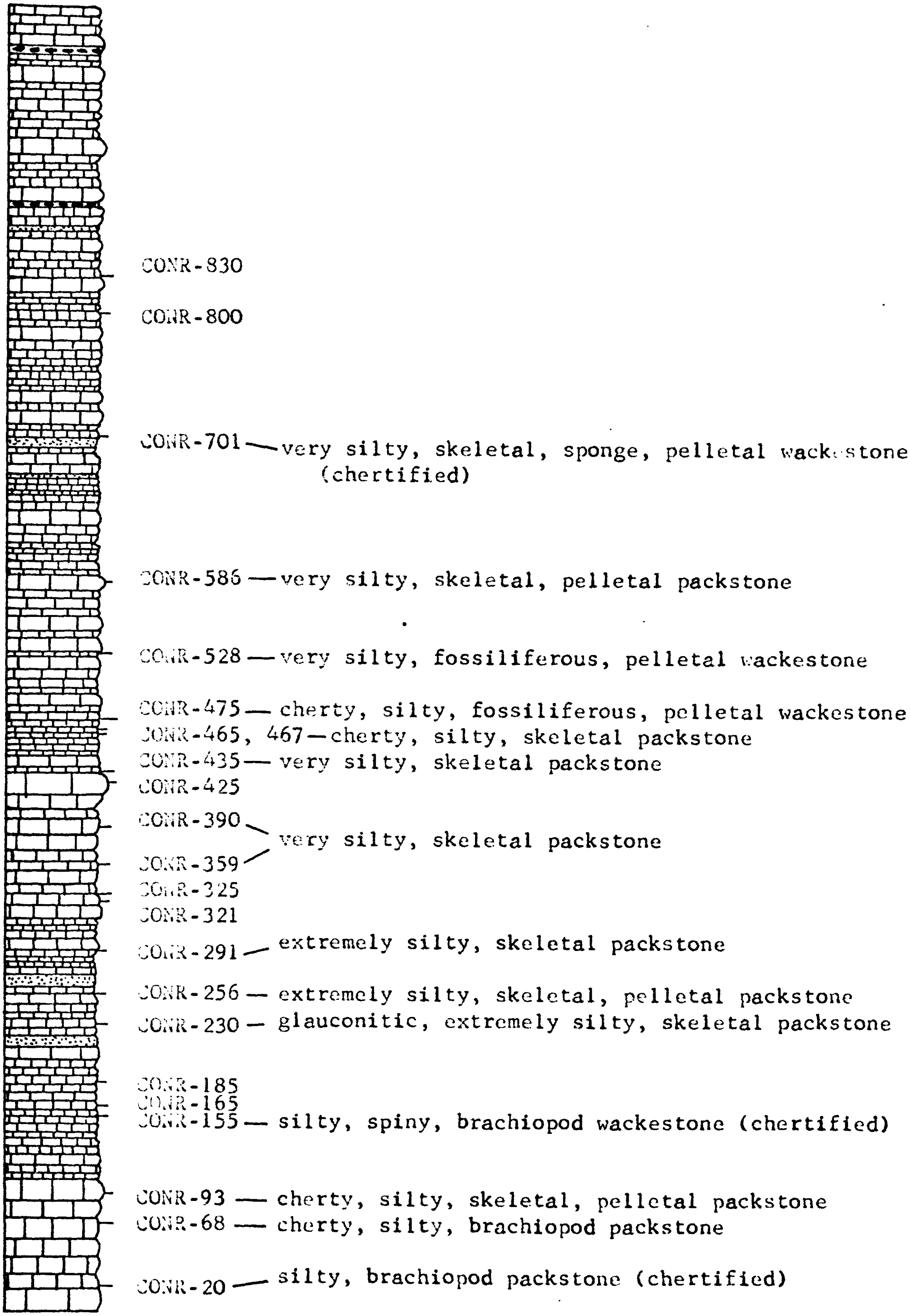

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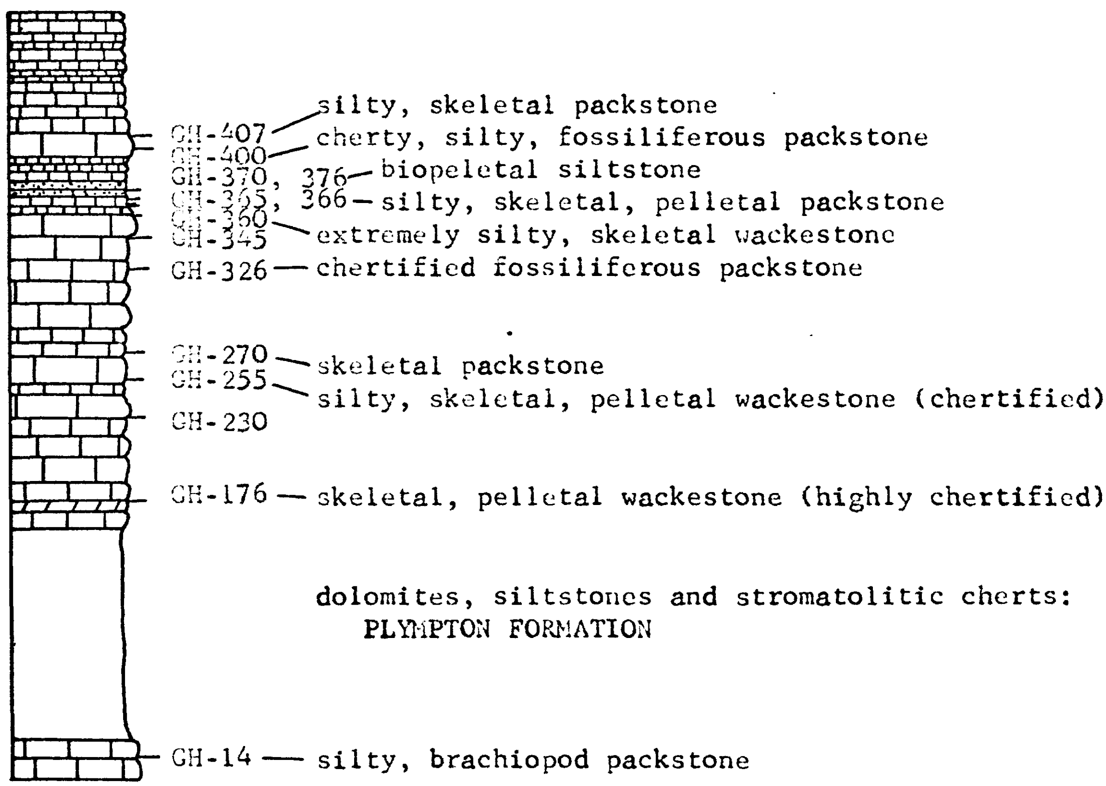

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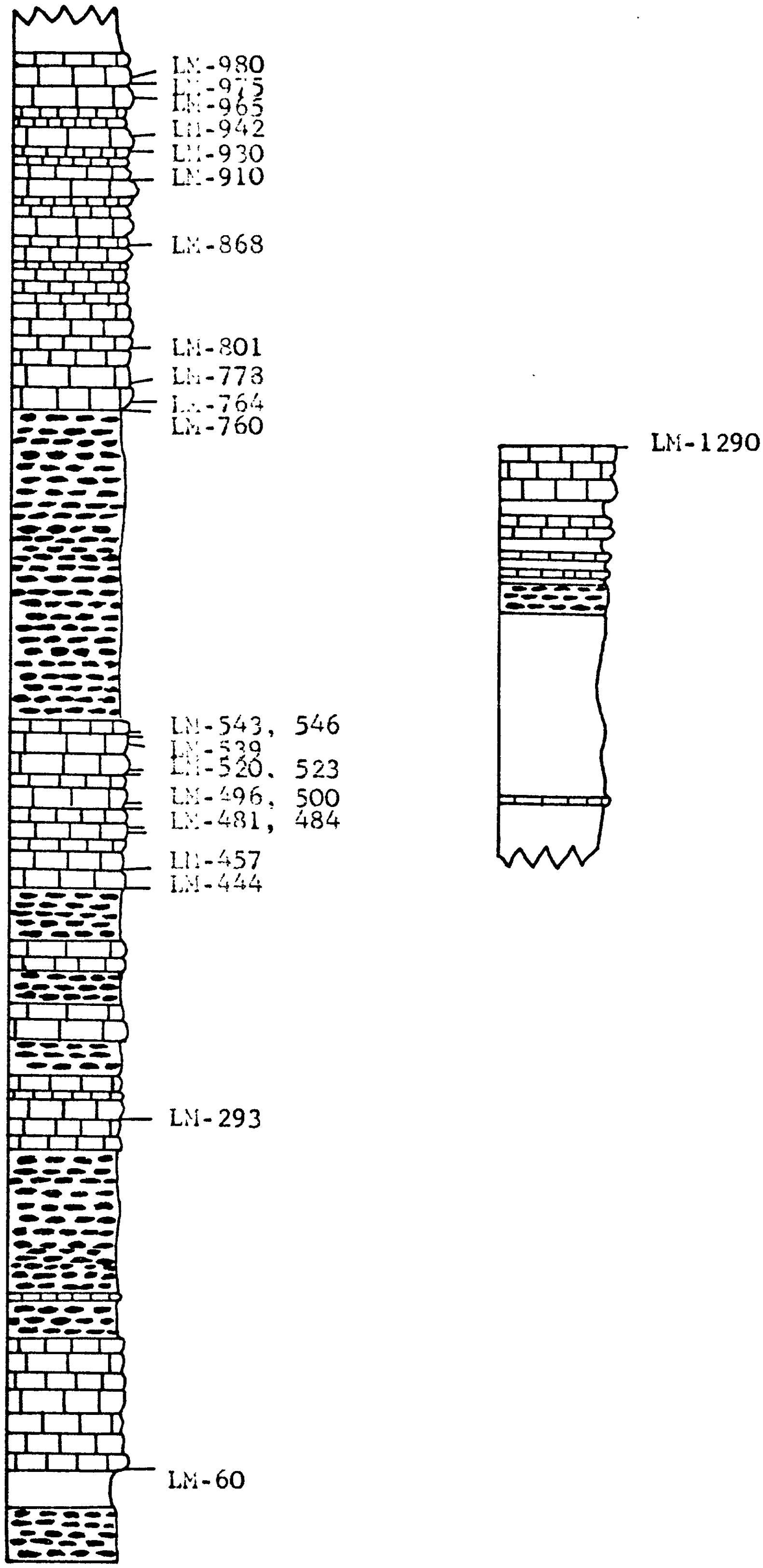

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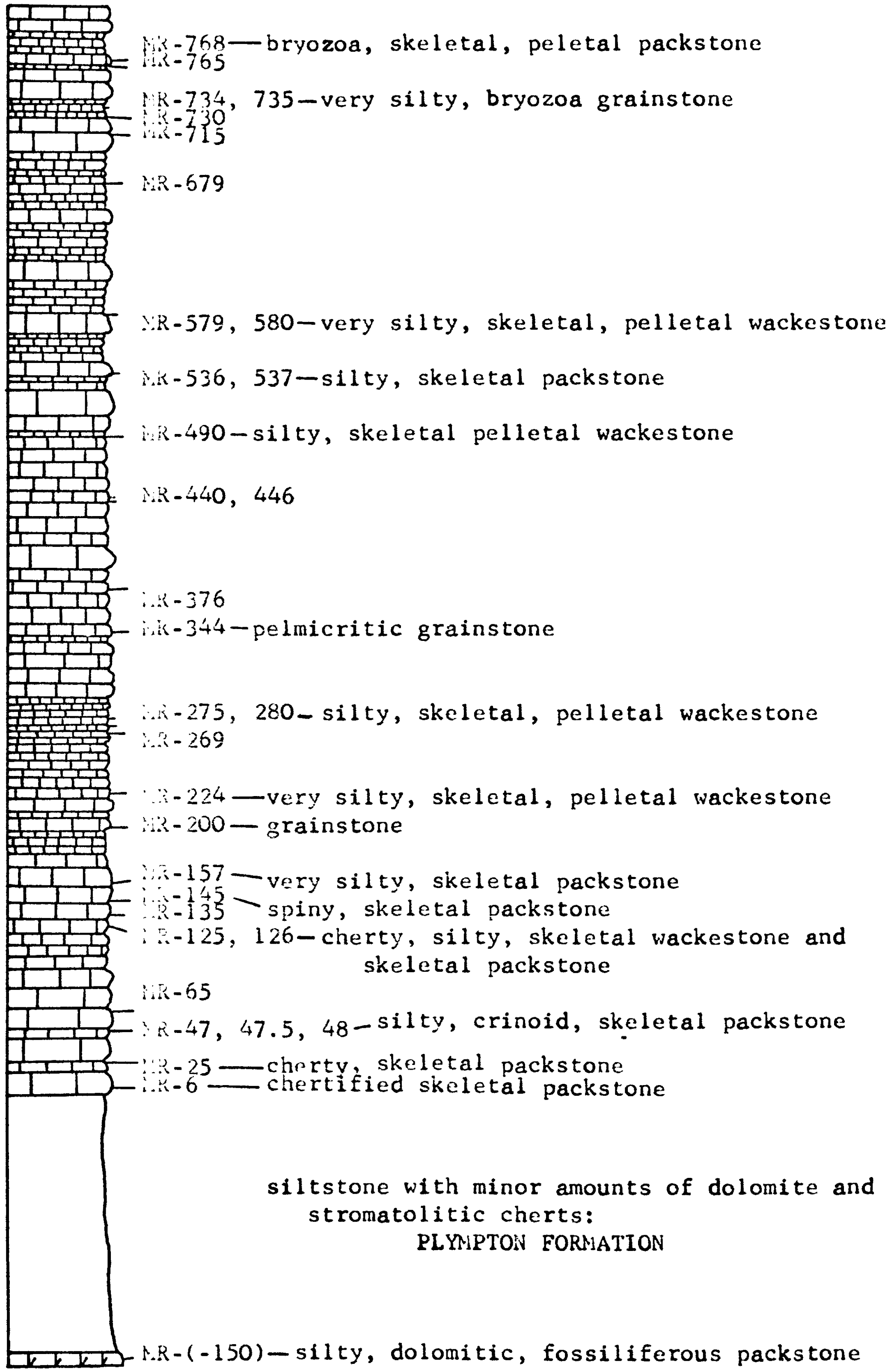

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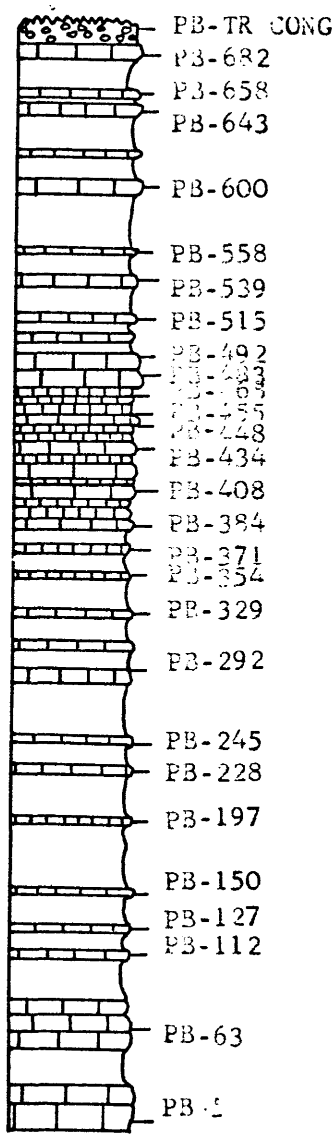

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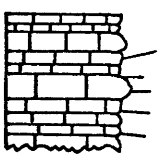

recrystallized fossiliferous packstone
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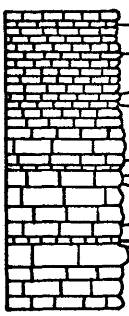
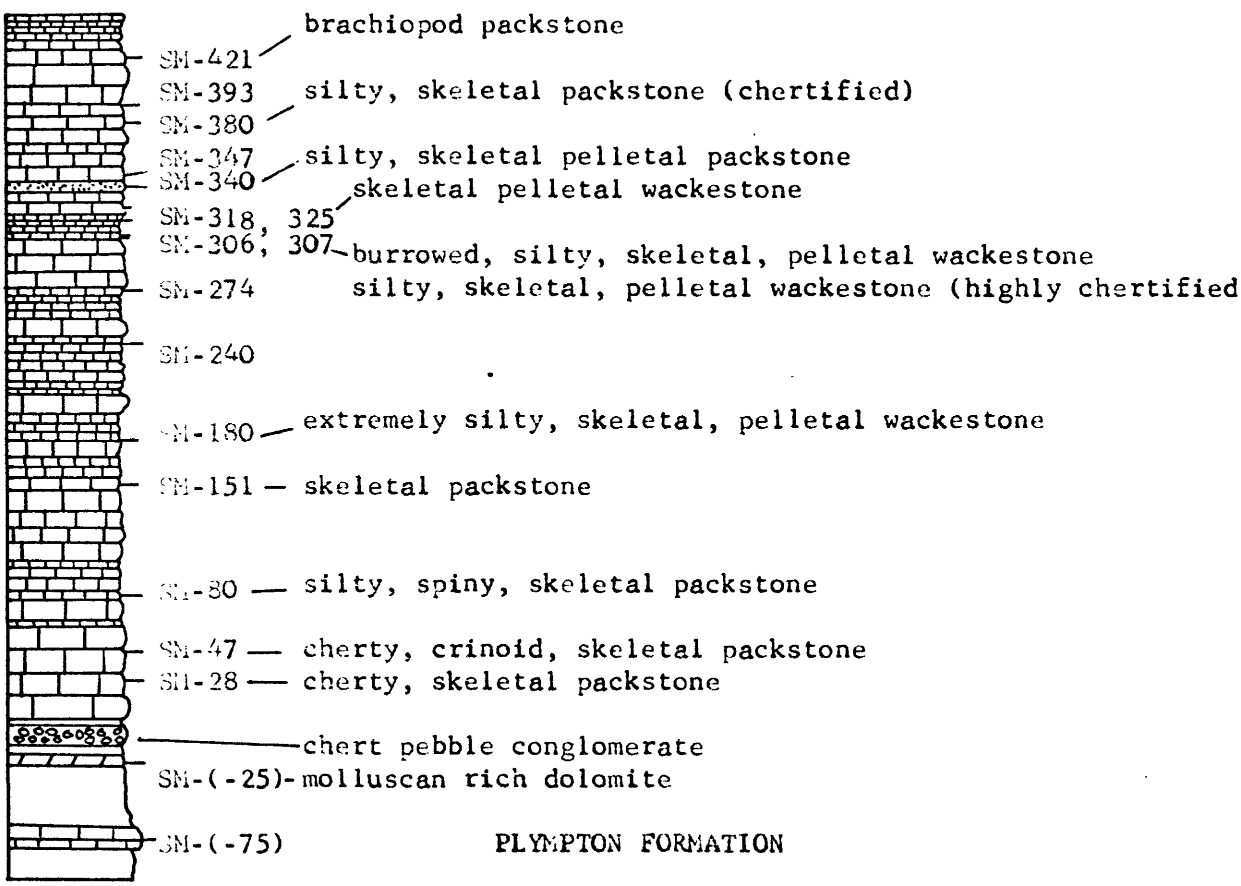
SR-27 — very silty, fossiliferous packstone
SR-12 — silty, cherty, skeletal packstone



SPM-180—very silty, fossiliferous, pelletal wackestone
SPM-162—silty, fossiliferous, pelletal wackestone
SPM-137— mixed silty, skeletal, pelletal wackestone and packstone
SPM-131— glauconitic, silty, brachiopod, pelletal wackestone
SPM-98
SPM-87 and silty, skeletal packstone
SPM-82 silty, spary grainstone
SPM-55 — skeletal packstone
SPM-41, 45-silty, fossiliferous, pelletal wackestone (chertified)
silty, fossiliferous, pelletal packstone (chertified)

SPRUCE MOUNTAIN



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FAUNAL KEY

1 *Derbyia sulca* (Branson)
2 *Quadrochonetes* n. sp. A
3 *Dyoros* n. sp. A
4 *Waagenites* n. sp. A
5 Waagenites n. sp. B
6 *Heteralosia* sp.
7 *Echinalosia* n. sp. A
8 *Ctenalosia fixata* Cooper and Stehli
9 *Sphenosteges hispidus* (Girty)
10 *Hystriculina* n. sp. A
11 *"Echinauris" subhorrida* (Meek)
12 *Liosotella delicatula* Dunbar
13 *Thamnosia depressa* (Cooper)
14 *Bathymyonia* n. sp. A
15 *Bathymyonia nevadensis* (Meek)
16 *Kochiproductus* sp.
17 *"Grandaurispina"* n. sp. A
18 *"Grandaurispina" arctica*? (Waterhouse)
19 *Kuvelousia leptosa* Waterhouse
20 *Yakovlevia multistriata* (Meek)
21 *Cenorhynchia* n. sp. A
22 *Cenorhynchia* n. sp. B
23 *Phrenophoria* n. sp. A
24 *Phrenophoria* n. sp. B
25 *Petasmetherus* n. sp. A
26 *Rhynchopora taylori* Girty
27 *Composita mira* Girty
28 *Composita parasulcata* Cooper and Grant
29 *Cleiothyridina* n. sp. A
30 *Cleiothyridina* n. sp. B
31 *Hustedia elongata* n. ssp.
32 *Odontospirifer* n. sp. A
33 *Timaniella "pseudocamerata"*
34 *Spiriferella scobina* (Meek)
35 *Xestotrema pulchrum* (Meek)
36 *Dielasma phosphoriense* Branson
37 *Dielasma spatulatum* Girty
38 *Plectelasma* n. sp. A
39 Plectelasma n. sp. B
40 *Hemiptychina quadricostata* (Branson)
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42 *Girtyella*?
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46 Fenestrate Bryozoa
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53 *Rugatia* cf. *R. occidentalis*

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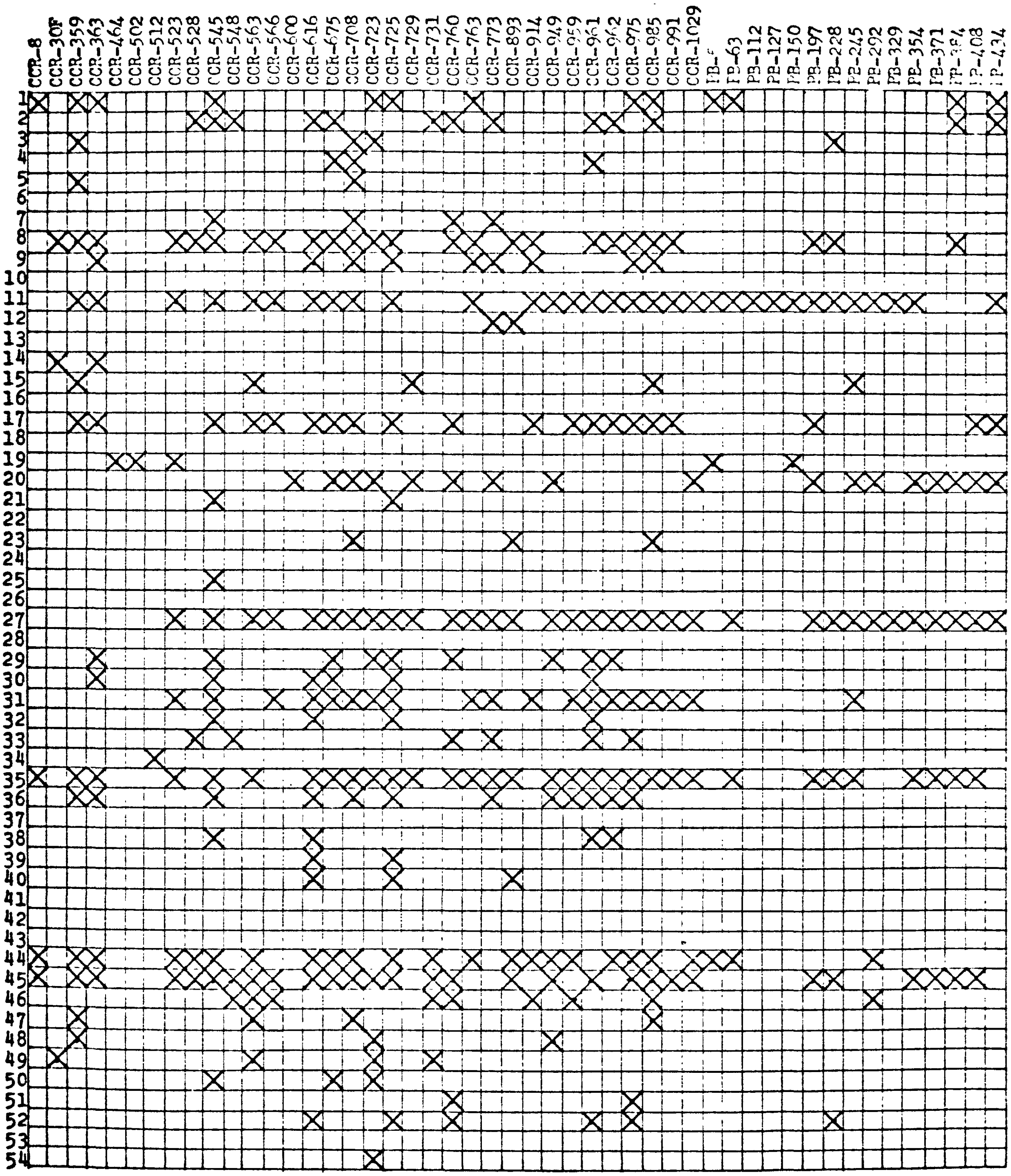
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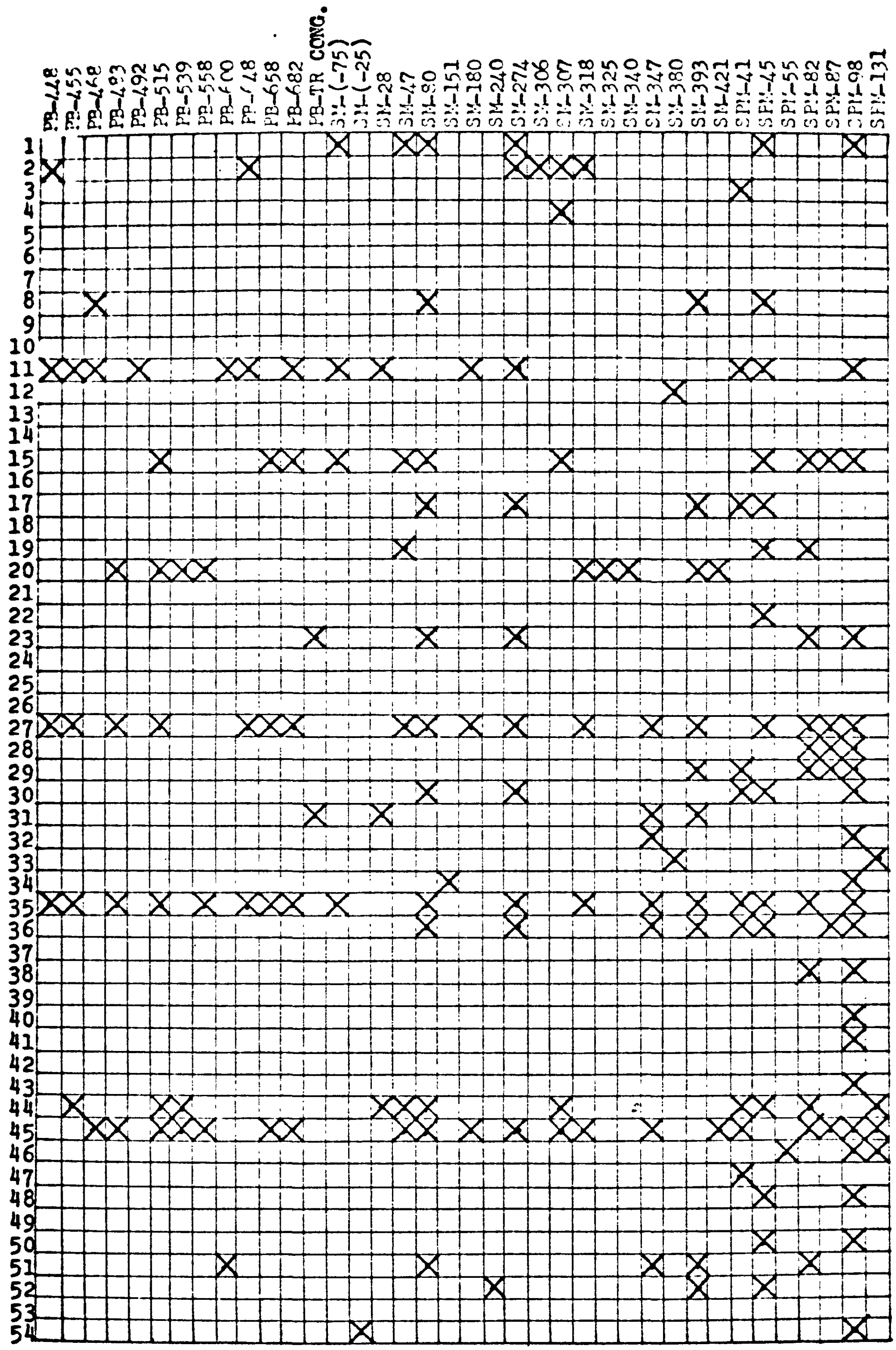

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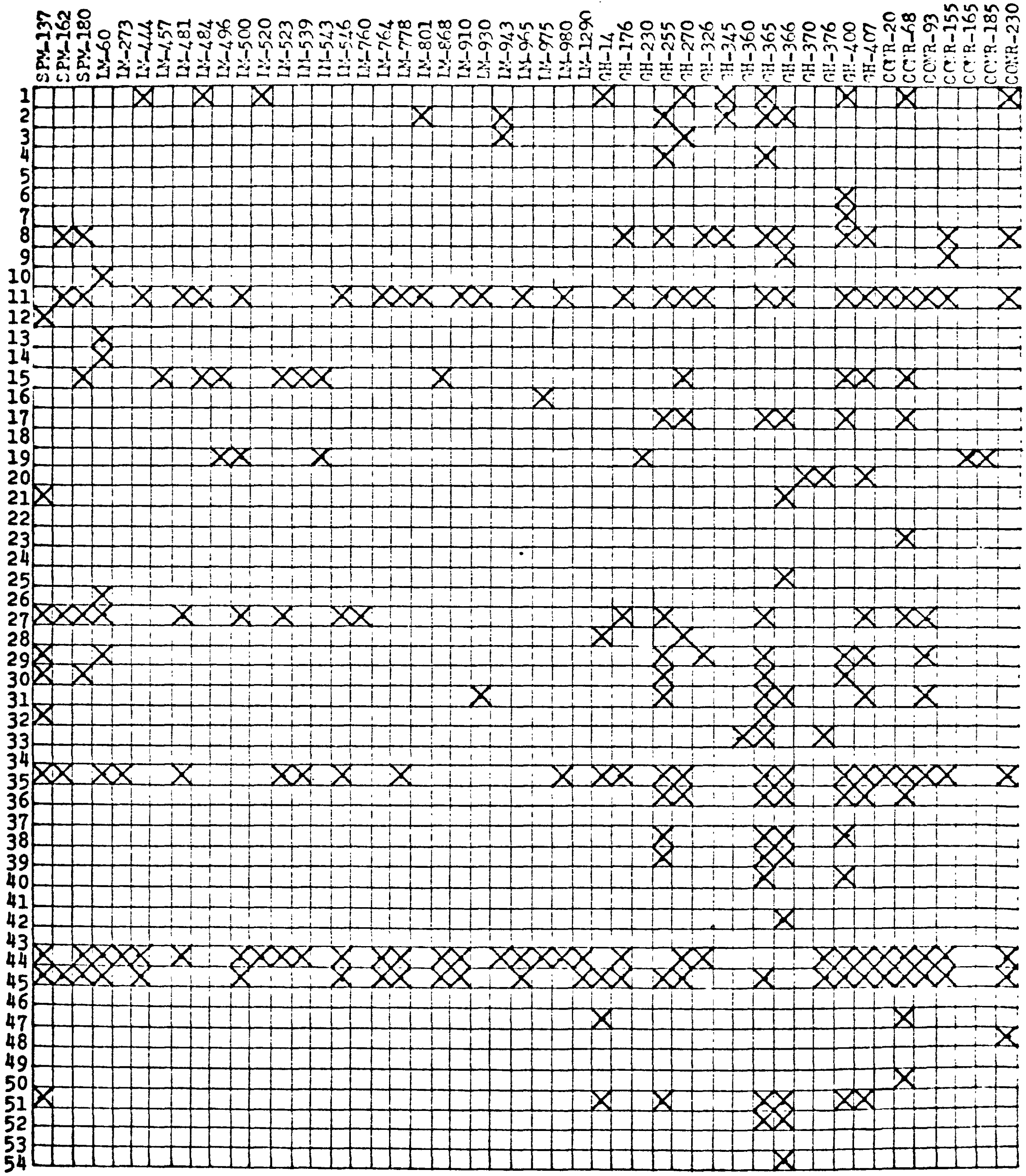
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Encrusting Bryozoa

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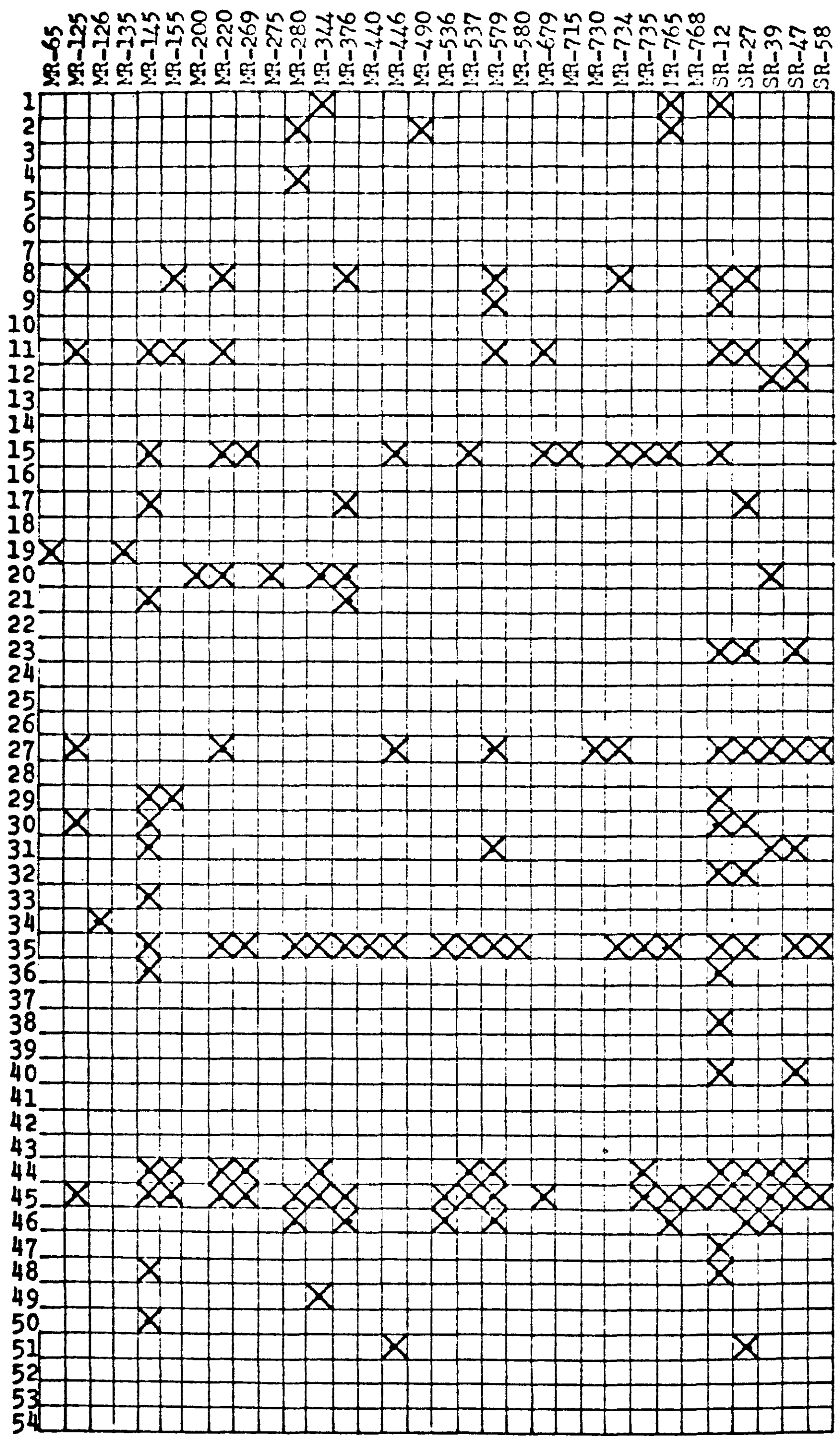
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PLATE DESCRIPTIONS

PLATE 1

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Derbyia sulca (Branson) (1-12): 1-2, dorsal and dorsal interior views, CCR-723b, showing wide specimen with sulcus developed; 3-4, ventral and ventral interior views, CCR-725e, typical specimen; 5-12 showing range of variability of species; 5, dorsal view, CBM3-72a; 6, dorsal interior view, CCR-725f, showing cardinalia; 7, ventral interior view, MR-48b, showing elongate form; 8, dorsal view of young specimen, CBM3-116j; 9-10, ventral and ventral interior, CCR-725g; 11-12, ventral and dorsal views of partial specimen, CCR-545a, showing hindered lateral growth, also, with *Ctenalosia* attached in 11.

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PLATE 1

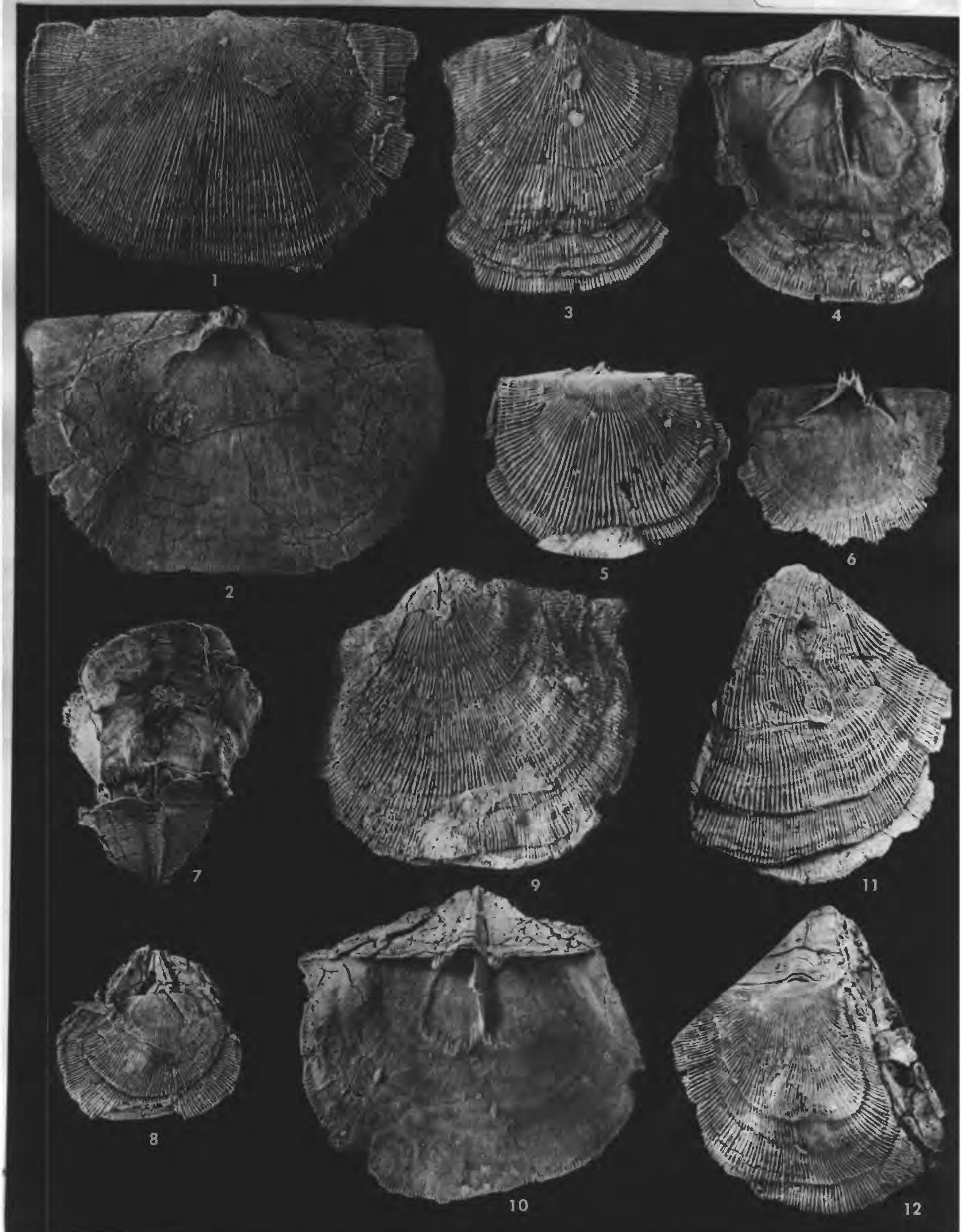

PLATE 2

All Figures 1x Unless Specified Otherwise

Dyoros n. sp. A (1-9): 1-2, ventral view, ventral interior view, 2x, CCR-708a, geniculated specimen showing spinose interior; 3-4, dorsal view, dorsal interior, 2x, CCR-708b, specimen with well developed fold and sulci and faint median septum; 5-7, dorsal view, dorsal interior, 1x and 2x, CCR-708c, specimen with well preserved interior; 8-9, ventral view of juvenile showing hinge spine bases, 1x and 2x, CCR-708d.

Quadrochonetes n. sp. A (10-22, 54): 10-12, ventral interior, 2x, ventral and lateral views, CCR-731a, type specimen; 13-14 & 54, dorsal, lateral and ventral view of young adult showing spine bases, CCR-731b; 15-16. ventral and ventral interior, 2x, CCR-731c, showing median septum; 17-22 showing variations of dorsal valve; 17-18, dorsal interior, 2x, and dorsal view, CCR-731d; 19 & 22, dorsal and dorsal interior views of young adult, CCR-731e; 20-21, dorsal and dorsal interior, 2x, of young adult, CCR-731f.

Waagenites n. sp. A (23-48): 23-27, ventral, dorsal, posterior, anterior and lateral views, CCR-708e, type specimen with fascicostate ornament and lamellose ventral anterior; 28-34 complete juvenile specimens in increasing size; 28-29, ventral and dorsal views showing spine bases, CCR-708f; 31-32. ventral and dorsal views, CCR-708g; 33-34, ventral and dorsal views, CCR-708h; 35-36, ventral and ventral interior views, CCR-708i, poorly preserved adult specimen showing interior; 37-38, dorsal and dorsal interior, 2x, GH-365h, young adult showing lack of endospines and long breviseptum; 39-44 & 47-48 juveniles showing presence of endospines, decreasing with age, with very few in 48; 39-40, ventral interior view, 1x, 2x, CCR-708j; 41-42, dorsal interior, 1x, 2x, CCR-708k; 43-44, ventral interior, 1x, 2x, CCR-708l; 47-48, ventral view, ventral interior, 2x, CCR-708n; 45-46, dorsal interior, 2x, dorsal view, CCR-708m, adult specimen with complete loss of endospines.

Waagenites n. sp. B (49-53, 55-59): 49-50, ventral interior, 2x, ventral view, CCR-708o, type specimen showing ventral internal and external ornament with concentric allignment of endospines; 51, ventral view of juvenile, CCR-708p; 52-53. ventral and dorsal views, CCR-708q, complete decorticated specimen with costae barely visible on dorsal valve; 55-56, dorsal interior, 2x, dorsal view, CCR-708r, showing endospinose ornament and muscle scars; 57, ventral view, CCR-708s, poorly preserved gerontic specimen; 58-59, dorsal view and dorsal interior, 2x, CCR-708t, excellently preserved dorsal valve showing endospines.

Waagenites grandicostatus (Waagen) (60-72) (for comparison): 60-61, dorsal and ventral views, REG-k, complete specimen; 62-65 dorsal valves showing occasionally bifurcating costae and endospinose interior; 62-63, dorsal and dorsal interior views, REG-l; 64-65, dorsal and dorsal interior views, REG-m; 66-72 ventral valves showing pustulose exterior and endospines alligned with internal concentric growth lines; 66-67, ventral interior, 2x, ventral view, REG-n; 68-69, ventral view, 2x, ventral interior, REG-o; 70-72, ventral interior, 2x, ventral view, 1x, 2x, REG-p.

PLATE 2

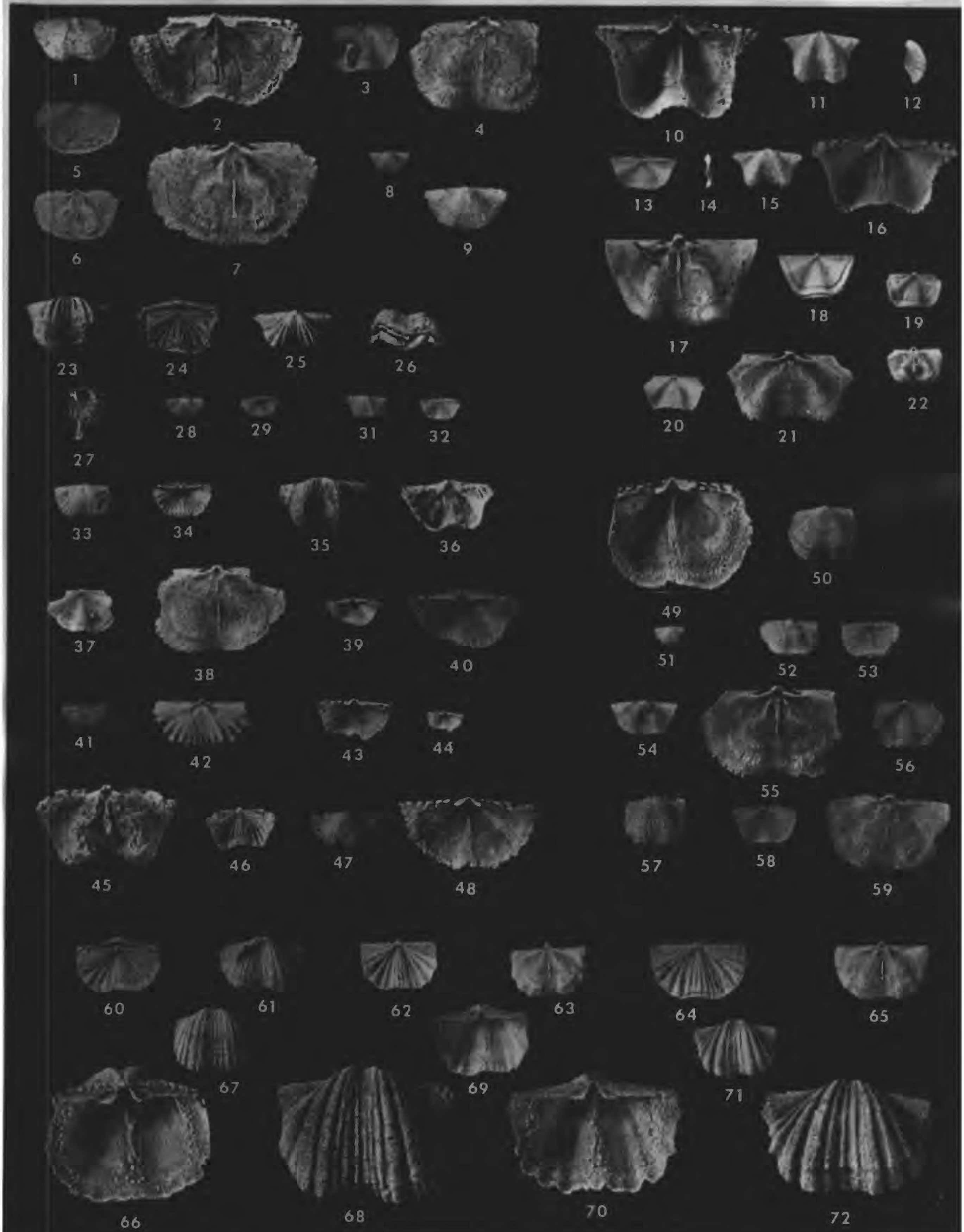
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PLATE 3

All Figures 1x Unless Specified Otherwise

Echinalosia n. sp. A (1-22): 1, ventral view, CCR-708u, showing external ornament; 2, ventral interior view, CCR-708v. showing interior with marginal ridge; 3-4, ventral interior, 1x, 2x, CCR-708w. showing muscle platform and dental plates, specimen attached to dorsal valve of Yakovlevia; 5, ventral interior, CCR-708x, attached to Yakovlevia; 6, ventral interior view, CCR-708y, showing muscle platform and interarea; 7, dorsal view of young attached to adult, CCR-708z; 8, ventral interior of juvenile attached to Composita, CCR-708aa; 9-22 growth sequence of dorsal valves showing variability of exterior ornament and cardinal process and internal development of median septum and muscle platform; 9-10, dorsal interior of young specimen, CCR-708bb; 11-12, dorsal interior of young specimen, 1x, 2x, CCR-708cc; 13-14, dorsal interior of young adult, 1x, 2x, CCR-708dd; 15-17, dorsal view, dorsal interior, 1x, 2x, CCR-708ee; 18-19, dorsal interior, dorsal view, 2x, showing numerous spine bases. CCR-708ff; 20-22, dorsal interior, 2x, dorsal view, 2x, 1x, showing spine bases, CCR-708gg.

Echinalosia indica Waagen (23-39) (for comparison): 23-27, 30-31 showing external ornament; 23-24. dorsal and ventral views, REG-q; 26-27, dorsal and ventral views of young adult, REG-r; 30-31, dorsal and ventral views, REG-u; 28-29. 34-39 dorsal valves showing external spines and variability of cardinal process, muscle platforms and brachial loops; 28, dorsal interior, REG-s; 29, dorsal interior, REG-t; 34, dorsal interior, REG-w; 35, dorsal view, REG-x; 36-37, dorsal interior, 1x, 2x, REG-y; 38-39, dorsal interior, 1x, 2x, REG-z; 32-33, ventral interior, 2x, 1x, REG-v, showing interarea, teeth and muscle platforms.

Heteralosia sp. (40-46): 40-44, posterior, ventral, posterior of ventral interior, 1x, 2x, GH-400c, showing ornament, muscle platform and internal ridge; 45-46, ventral interior and ventral view, GH-400d, showing muscle platform and attachment to a bryozoa.

Ctenalosia fixata Cooper and Stehli (47-78): 47-48, specimens attached to "Echinauris", 2x, 1x, ventral interior and dorsal views, MR-47a, showing complete specimen and muscle platform and denticulate hinge;

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49-51, stereo pair of dorsal view and posterior view, CCR-975b, attached to bryozoa; 52-57, 71-74 showing variability in external ornament and shape, highlighting development of bifurcating costae in 53, large cicatrix of attachment in 56 and 71; 52-53, ventral and dorsal views, CCR-773a; 54-55, ventral and dorsal views, CCR-773b; 56, ventral view showing large cicatrix of attachment, CCR-725h; 57, dorsal view, attached to *Cleiothyridina* n. sp. B, CBM3-116b; 71-72, posterior and ventral views, CCR-975c; 73-74, ventral and dorsal views, CCR-545f; 75-77, ventral view, ventral interior, 1x, 2x, CCR-545g, showing spines circling cicatrix of attachment and internal muscle platform; 58-59, ventral interior, 2x, 1x, CBM3-86a, showing muscle platform and denticulate hinge, attached to *Derbyia*; 60-70. 78 showing variability of dorsal valve, in external ornament with development of costae and lamellae and in internal development of muscle platforms, median ridge and brachial ridges; 60, dorsal view, CCR-725i; 61, dorsal interior, CCR-545b; 62, dorsal interior, CCR-725j; 63-64, dorsal view, dorsal interior, 2x, CCR-545c; 65-66, dorsal view, dorsal interior, 2x, CCR-545d; 67-68. dorsal interior, 1x, 2x, CCR-545e; 69-70, dorsal interior, 1x, 2x, CCR-708hh; 78, dorsal view, CCR-962c.

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PLATE 3

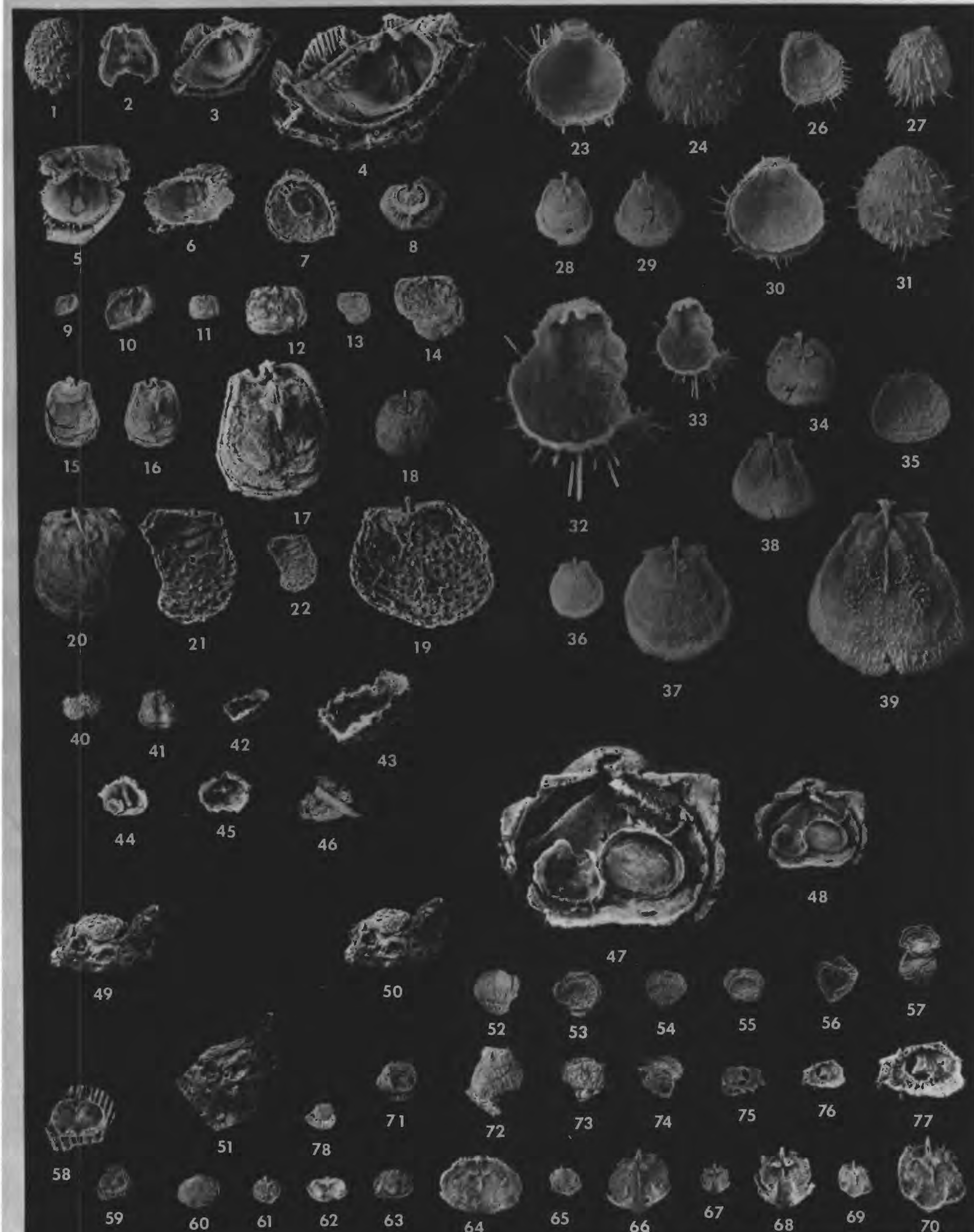
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PLATE 4

All Figures 1x Unless Specified Otherwise

Sphenosteges hispidus (Girty) (1-18): 1-2, dorsal and ventral views, CCR-975d. showing shape of decorticated specimen; 3-4, lateral and posterior views, CCR-708ii, showing spine arrangement of partially crushed specimen; 5, ventral view, CCR-708jj, showing ventral spines; 6-7, dorsal and ventral views, CCR-708kk, showing external ornament of well preserved fragment; 8-9, ventral and dorsal views, CBM3-116k, crushed specimen showing ornament and spine row near margin of flanks; 10-11, ventral and ventral interior views, CCR-708ll, showing external ornament and faint internal muscle scars; 12, ventral view, CCR-975e, decorticated specimen; 13-18 showing dorsal valves with minute ears and variability of the cardinal process, median septum and muscle scars; 13-14, dorsal interior, 1x, 2x, CCR-708mm; 15-16, dorsal interior, 1x, 2x, CCR-708nn; 17-18, dorsal, dorsal interior, 2x, CCR-708oo.

Liosotella delicatula Dunbar (19-35): 19-20, dorsal and ventral views, CCR-773c, complete specimen; 21, ventral view, CCR-773d, showing spines and faint costae; 22-23, ventral and ventral interior views, CCR-773e, showing external ornament and internal muscle platform; 24-29 showing external ornament and internal muscle scars and endospines; 24-26, ventral view and ventral interior, 1x, 2x, slightly tilted, CCR-773f; 27-29, ventral interior, 2x, ventral and lateral views, SM-347d; 30-35 showing partially preserved dorsal valves to point out most internal features; 30-31, dorsal interior, 1x, 2x, CCR-773g; 32-33, dorsal view, dorsal interior, 2x, CCR-773h; 34-35, dorsal interior, 1x, 2x, CCR-773i.

"*Echinauris*" *subhorrida* (Meek) (36-46): 36-39, dorsal view stereo pair, ventral view stereo pair, CCR-563a, small specimen showing external ornament with spines on both valves; 40-41, dorsal view stereo pair, CBM3-116l, showing spinose nature; 42-44, showing anterior spine cluster; 42, dorsal view, CCR-975f; 43-44, dorsal and ventral views, CCR-975g; 45, ventral view, CCR-563b, showing spine bases to anterior spine cluster; 46, dorsal view, CCR-975h, large complete specimen with fairly smooth dorsal valve.

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<u>Hystriculina</u> n. sp. A (47-52): one specimen showing sparse spine arrangement, marginal ridge and pedicle endospines; 47-48, stereo pair, ventral view, 49, lateral view, 50, dorsal view, 51-52, stereo pair, dorsal view, 2x, LM-60a.

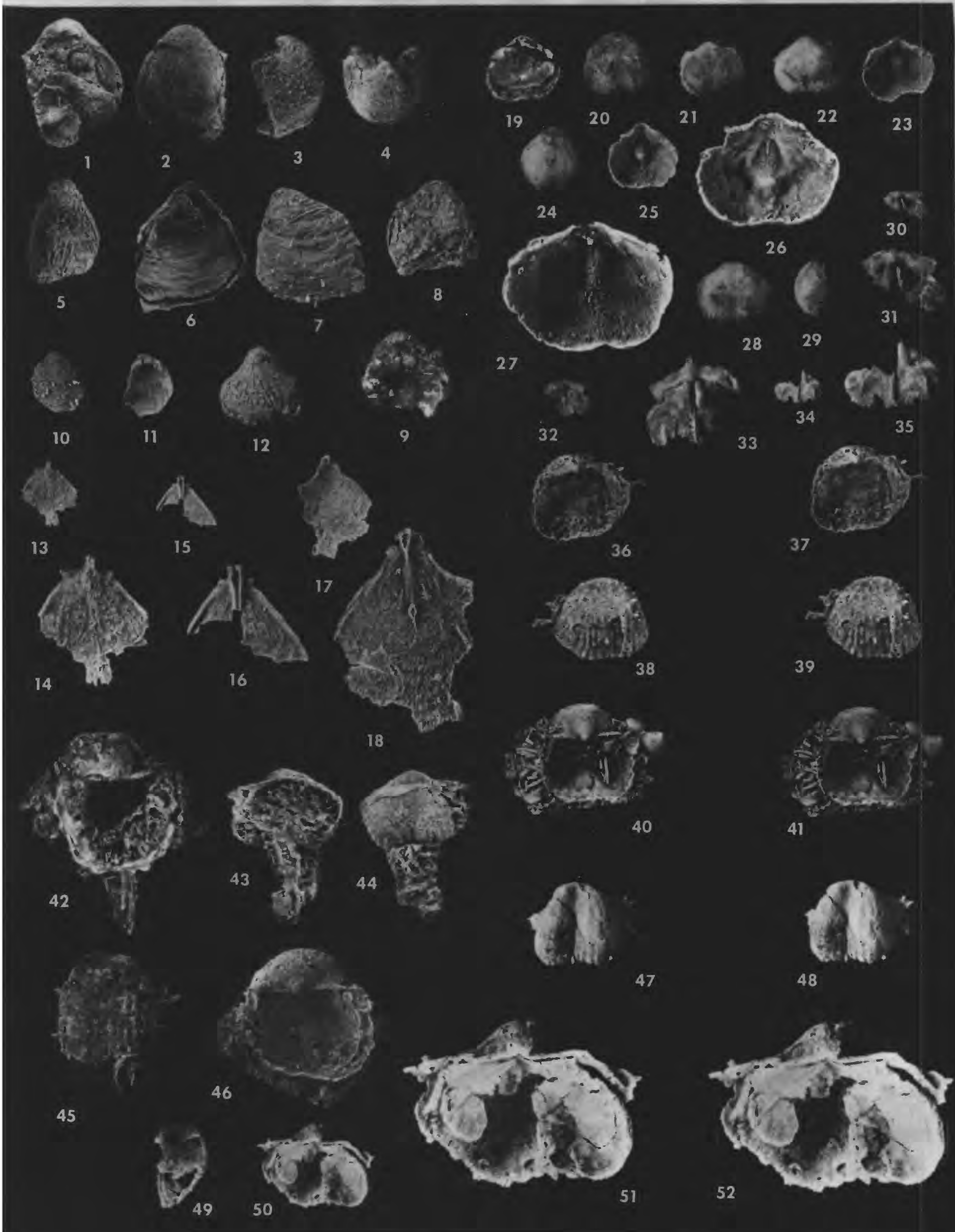
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PLATE 5

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"*Echinauris*" *subhorrida* (Meek) (1-33): 1-13 showing variability in external ornament and shape; 1-2, posterior-dorsal view showing numerous spines bases on dorsal valve, ventral view, CCR-563c; 3-4, dorsal view and ventral view, CCR-563d; 5, dorsal view, GH-400e; 6-7, ventral and dorsal view, CCR-545h; 8, ventral view, CCR-563e; 9, ventral view, CCR-563f; 10, ventral anterior showing spine bases, CCR-545i; 11, ventral view, CCR-975i; 12, ventral view, CCR-545j; 13, dorsal view, CCR-975j; 14-16, ventral view, ventral interior and oblique ventral interior view, GH-400f, showing marginal ridge, crenulated near hinge and *Ctenalosia* attached internally; 17, ventral interior, CCR-563g, showing muscle scars; 18-20, ventral and two ventral interior views, CCR-563h, showing muscle scars and anterior of interior; 21-33 dorsal valves showing variation in cardinal process, complete marginal ridge and zygidium along with internal and external ornament; 21, dorsal interior, CCR-563i; 22-23, dorsal interior, 1x, 2x, CCR-563j; 24-25, dorsal interior, 1x, 2x, CCR-545k; 26-28 & 33, oblique dorsal and dorsal interior views, oblique dorsal view showing zygidium, 2x, dorsal view, 2x, CCR-563k; 29, dorsal interior, CCR-545l; 30-32, dorsal interior, dorsal, 2x, dorsal interior, 2x, CCR-545m.

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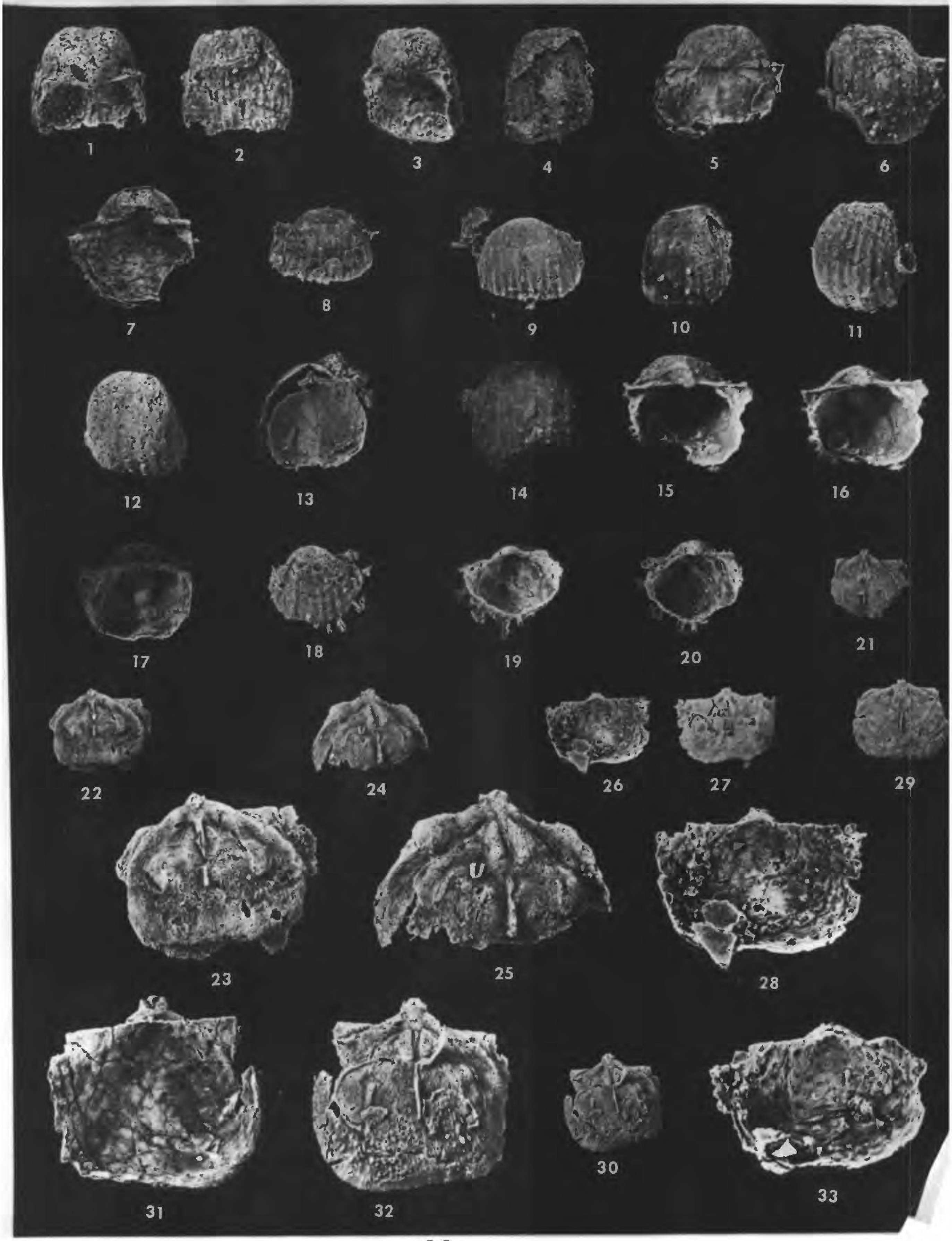
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PLATE 6

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Thamnosia depressa (Cooper) (1-22): 1-12 showing shape and external ornament higlighted by spine cluster on flanks (11) and antero-median (12); 1-3, dorsal, ventral and lateral views, LM-60b; 4, anterior view, LM-60c; 5-7, dorsal, ventral and lateral views, LM-60d; 8-9, lateral and ventral views, LM-60e; 10-12, oblique lateral, posterior and anterior views, LM-60f; 13, ventral interior, LM-60g, showing lateral ridge; 14-15, showing ventral muscle scars; 14, ventral interior, LM-60h; 15, ventral interior, LM-60i; 16, dorsal valve showing spine bases, LM-60j; 17-22 dorsal valves showing variability of cardinal process, muscle scars, high lateral ridge, breviseptum, internal and external ornament and endospinose trail; 17, dorsal interior, LM-60k; 18, dorsal interior showing elevated lateral ridge, LM-60l; 19, anterior view showing internal portion of dorsal trail, LM-60m; 20-21, dorsal and dorsal interior views, LM-60n; 22, dorsal interior, LM-60o.

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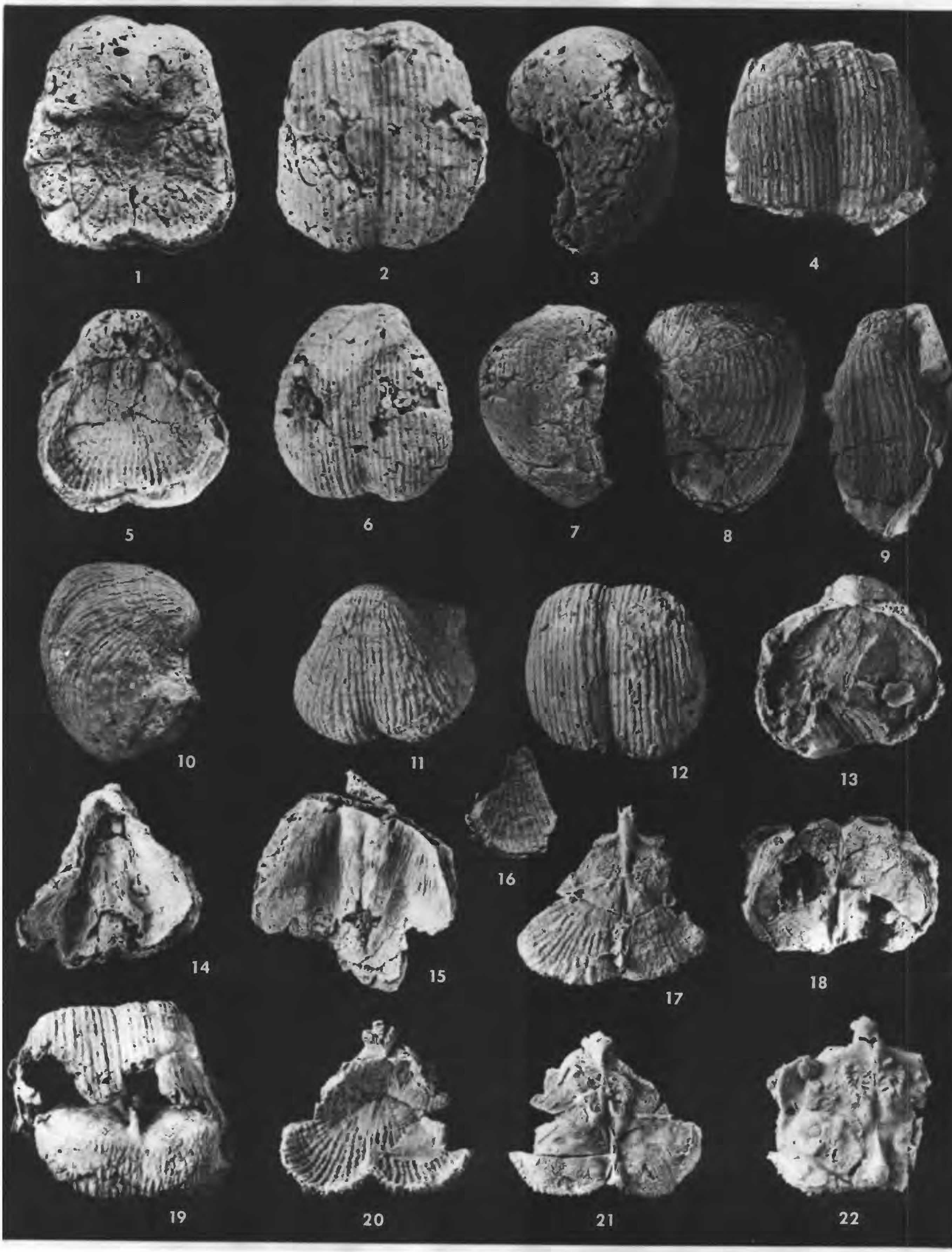
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PLATE 7

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Bathymyonia nevadensis (Meek) (1-19): 1-10 showing variability in external ornament and internal muscle scars; 1, oblique lateral view, CCR-729e; 2-3, ventral and ventral interior, MR-48c; 4-5, ventral and ventral interior, MR-48d; 6, vnetral interior, MR-48e; 7-8, ventral and lateral view, MR-48f; 9, vnetral view, MR-48g; 10, ventral view, MR-48h; 11, dorsal view showing spines, GH-400g; 12-14, dorsal view, dorsal valve alone, dorsal interior, MR-48i, complete and disarticulated specimen showing cardinal process and anterior projections of muscle platforms; 15-19 dorsal valves showing variability in cardinal process, lateral ridge, and muscle platforms; 15-16, dorsal and dorsal interior, CCR-729f; 17-18, dorsal and dorsal interior, MR-48j; 19, dorsal interior, GH-400h.

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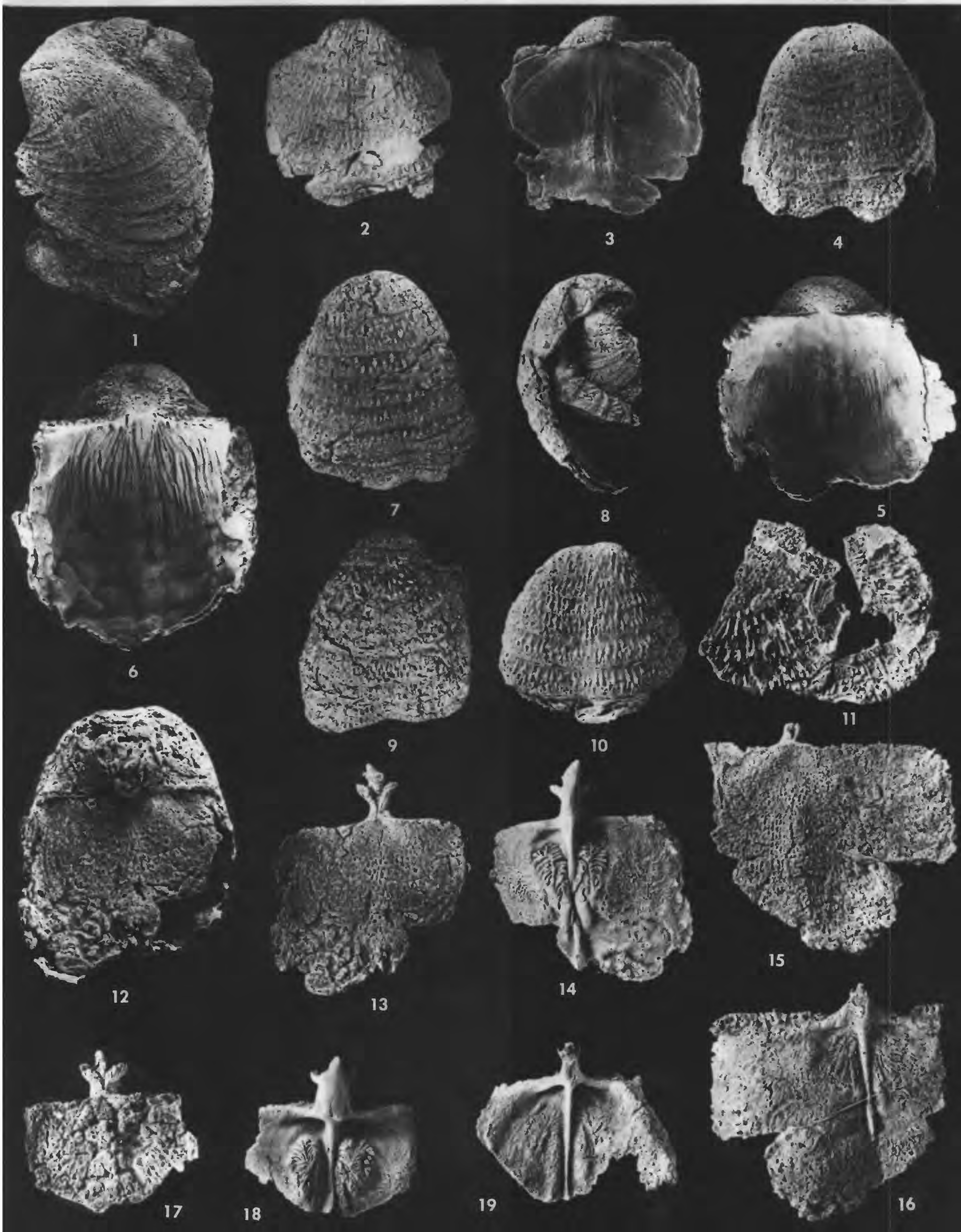
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PLATE 8

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Bathymyonia nevadensis (Meek) (1-5): 1-5 young adults showing ornament of overlapping spine ridges and absence of banding and internal ventral muscle scars (3); 1-2, dorsal and ventral views, CBM3-65b; 3-5, ventral interior, stereo pair, ventral view, MR-48k.

Bathymyonia n. sp. A (6-20): 6-13 showing external ornament and denticulate nature of hinge; 6-7, dorsal and ventral views, LM-60p; 8-9, dorsal and ventral views, LM-60q; 10-11, dorsal and ventral views, LM-60r; 12-13, dorsal and ventral views, LM-60s; 14-17 showing external ornament and internal muscle scars; 14-15, ventral and ventral interior views, LM-60t; 16-17, ventral and ventral interior views, LM-60u; 18-20 showing variability in cardinal process and muscle scars and denticulate hinge; 18, dorsal interior, LM-60v; 19, dorsal interior, LM-60w; 20, dorsal interior, LM-60x.

Kochiproductus sp. (21-28): 21-26 showing external ornament; 21-23, dorsal, ventral and posterior views, CONR-466a; 24-26, anterior, ventral and lateral views, CONR-466b; 27, dorsal valve, CONR-466c, with partly broken cardinal process; 28, cast of ventral interior, CONR-466d, showing muscle impressions.

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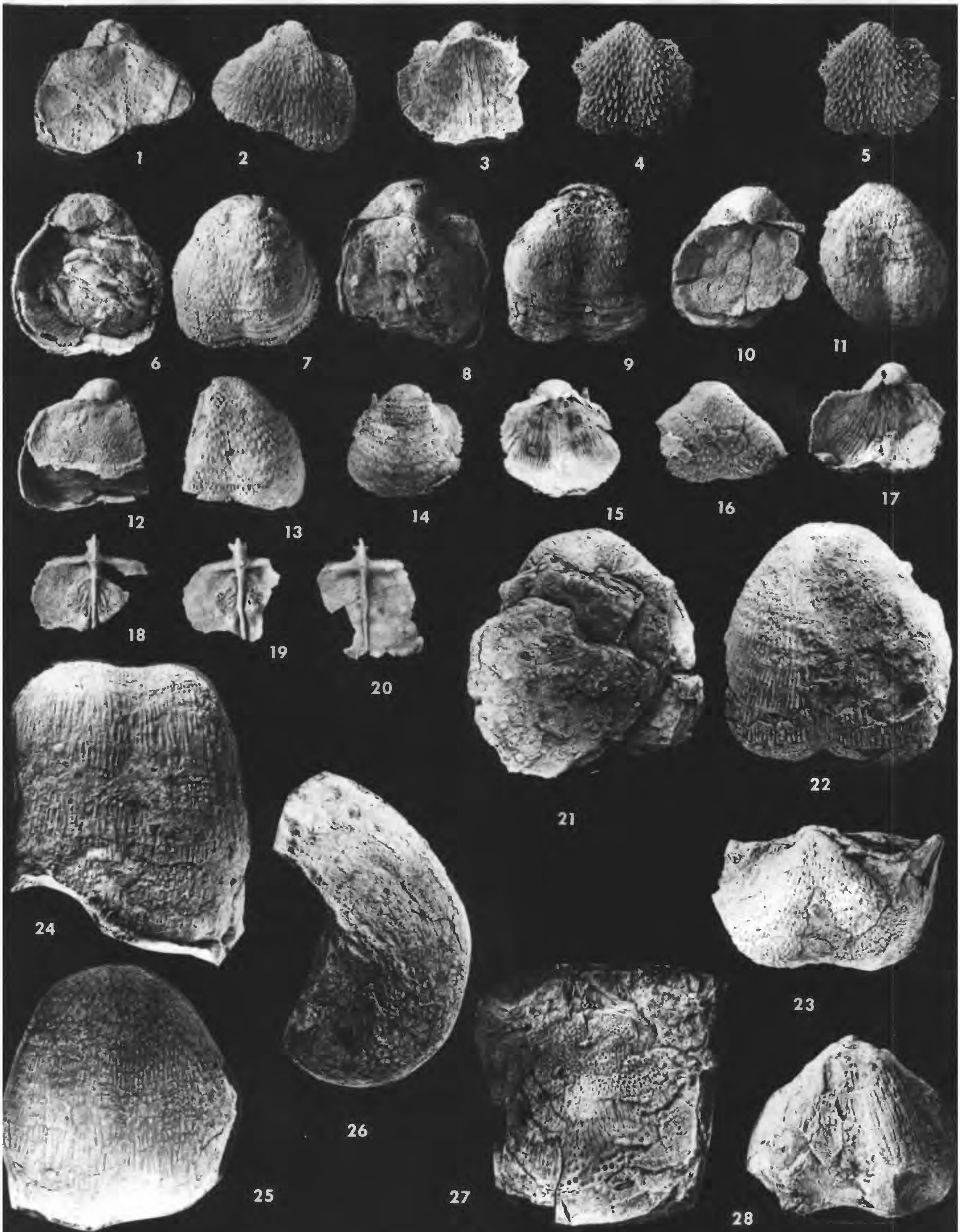
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PLATE 9

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"Grandaurispina" n. sp. A (1-48): 1-25 showing variability in external ornament, size and shape highlighting spine arrangement; 1-2, dorsal and ventral views, CBM3-116m; 3-4, ventral, dorsal, 2x, CBM3-116n; 5-8, stereo pairs, dorsal, 2x, ventral views, CCR-725k; 9-10, dorsal and ventral views, CCR-563l; 11-12, dorsal and ventral views, CCR-725l; 13-14, dorsal and ventral views, CCR-725m; 15-16, dorsal and ventral views, CCR-725n; 17-18, dorsal and ventral views, CCR-725o; 19, ventral view, CCR-725p; 20, ventral view, CCR-725q; 21, ventral view, CCR-725r; 22, ventral view, CCR-725s; 23, ventral view, CCR-725t; 24, posterior view, CBM3-116o; 25, ventral view, CCR-725u; 26-33, 36-39 ventral valves showing external ornament and faint internal muscle scars; 26-27, ventral and ventral interior views, CCR-725v; 28-29, ventral and ventral interior views, CCR-725x; 30-31, ventral and ventral interior views, CCR-725y; 32, ventral interior view, CCR-725z; 33, ventral interior, CCR-563m; 36-37, ventral interior, 1x, 2x, CCR-563o; 38-39, ventral interior, 1x, 2x, CBM3-116q; 34-35, 40-48 dorsal valves showing variability in cardinal process, lateral ridges (with nearly complete marginal ridge in 41), muscle platforms, median septum, and external ornament, also showing fine endospines; 34, dorsal interior, CCR-563n; 35, cardinal process, CBM3-116p; 40-41, dorsal view, dorsal interior, 2x, CBM3-116r; 41-42, dorsal interior, 1x, 2x, CCR-725aa; 43-44, dorsal view, dorsal interior, 2x, CCR-563p; 45-46, dorsal interior, 1x, 2x, CCR-725bb; 47-48, dorsal interior, 1x, 2x, CCR-725cc.

"Grandaurispina" arctica? (Waterhouse) (49-62): 49-52 showing external ornament size and shape; 49-51, stereo pair, ventral view, dorsal and posterior view, CONR-701f; 52, posterior view, CONR-701g; 53-62 showing typical state of preserved specimens with small size, external ornament and smooth ventral interior; 53-54, ventral and ventral interior views, CONR-701h; 55-56, ventral interior and ventral views, CONR-701i; 57-58, ventral and ventral interior views, CONR-701j; 59-60, ventral and ventral interior, CONR-701k; 61-62, ventral and ventral interior, CONR-701l.

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Kuvelousia leptosa Waterhouse (63-70): 63-66, dorsal, interior, ventral and separated dorsal valve views, CBM3-65c, showing external ornament, ventral muscle scars and dorsal denticulate hinge; 67-68 showing external ornament; 67, dorsal view, CBM3-65d; 68, oblique dorsal view, CBM3-65e; 69-70, dorsal and ventral views, CONR-256a, large specimen showing wing.

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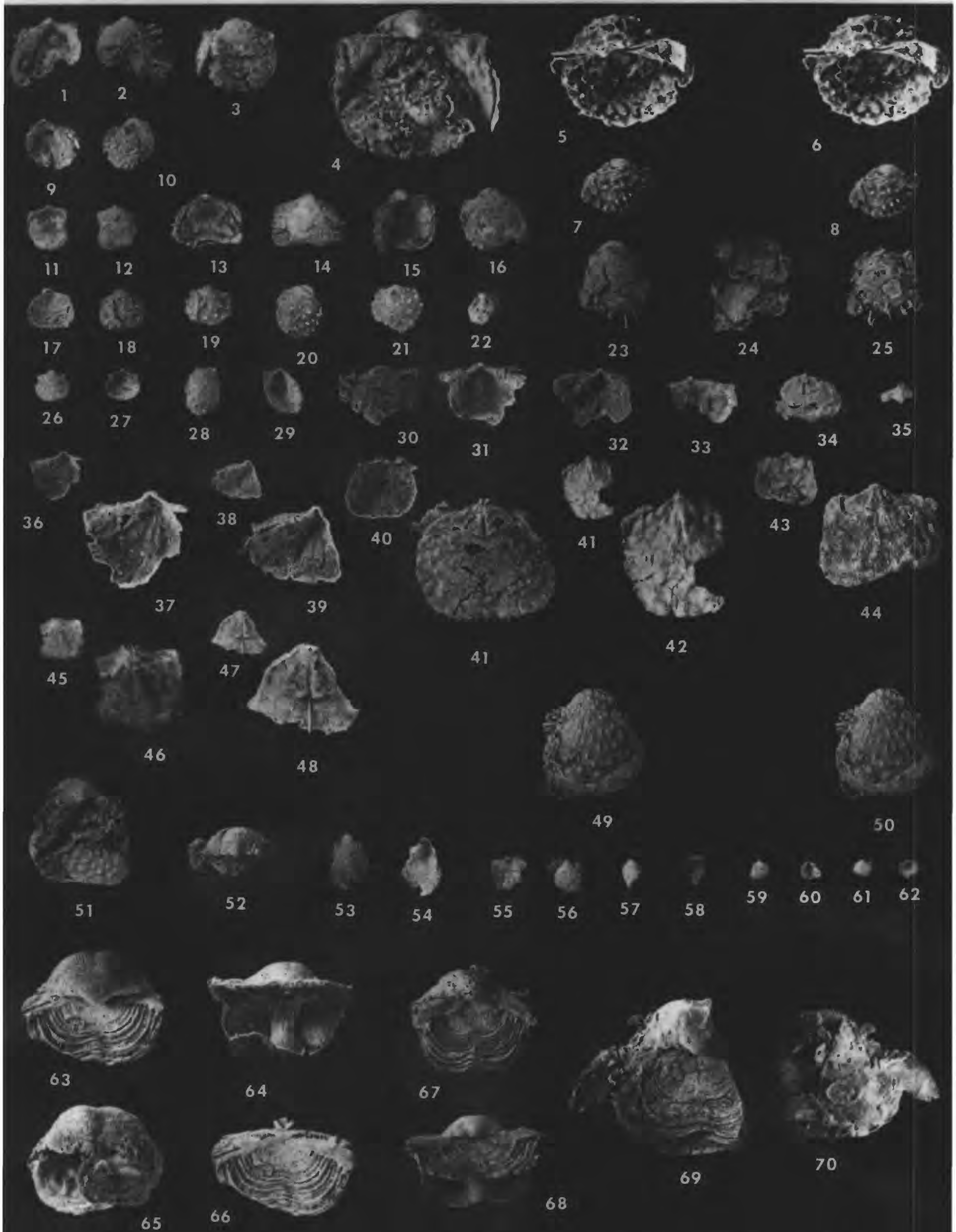
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PLATE 10

All Figures 1x Unless Specified Otherwise

Kuvelousia leptosa Waterhouse (1-15): 1-2 showing interior views of articulated specimens; 1, interior view, CBM3-65f; 2, interior view, CBM3-65g; 3-9 ventral valves showing external ornament, internal denticulate hinge and pronouncely dendritic adductor scars, with *Ctenalosia* attached in 8; 3-4, ventral and ventral interior views, CBM3-65h; 5-6, ventral and ventral interior views, CBM3-65i; 7-8, ventral and ventral interior views, CBM3-65j; 9, ventral interior view, CBM3-65k; 10-15 dorsal valves showing variability in cardinal process, muscle scars, brachial ridges, median septum, marginal ridge and external ornament; 10-11, dorsal and dorsal interior views, CBM3-65l; 12, dorsal interior view, CBM3-65m; 13, dorsal interior, CBM3-65n; 14, dorsal view, CBM3-65o; 15, dorsal interior view, CBM3-65p.

Kuvelousia sphiva Waterhouse (16-51) (for comparison): 16-26, 30 ventral valves showing variability of size, shape, external ornament, internal ornament, muscle scars, denticulate hinge and marginal ridge (23), ranging from small (26) to largest specimen (25); 16-17, ventral and ventral interior views, FGS-a; 18-19, ventral and ventral interior views, FGS-b; 20-21, ventral and ventral interior views, FGS-c; 22-23, ventral and ventral interior views, FGS-d; 24 & 30, ventral, ventral interior, 2x, FGS-e; 25, ventral interior view, FGS-f; 26, ventral interior view, FGS-g; 27-29, 31-51 dorsal valves in growth sequence showing variability of external ornament, cardinal process, median septum, marginal ridge, muscle scars, brachial ridges and platform anterior to cardinal process with thick marginal ridge in 50; 27, dorsal view, FGS-h; 28-29, dorsal and dorsal interior views, FGS-i; 31-32, dorsal, dorsal interior, 2x, FGS-j; 33-34, dorsal, dorsal interior, 2x, FGS-k; 35-36, dorsal and dorsal interior views, FGS-l; 37, dorsal interior view, FGS-m; 38-41, dorsal interior, 1x, 2x, and dorsal view FGS-n; 42-43, dorsal and dorsal interior views, FGS-o; 44-45, dorsal and dorsal interior views, FGS-p; 46-47, dorsal and dorsal interior views, FGS-q; 48-49, dorsal and dorsal interior, FGS-r; 50, dorsal interior, FGS-s; 51, dorsal interior, FGS-t.

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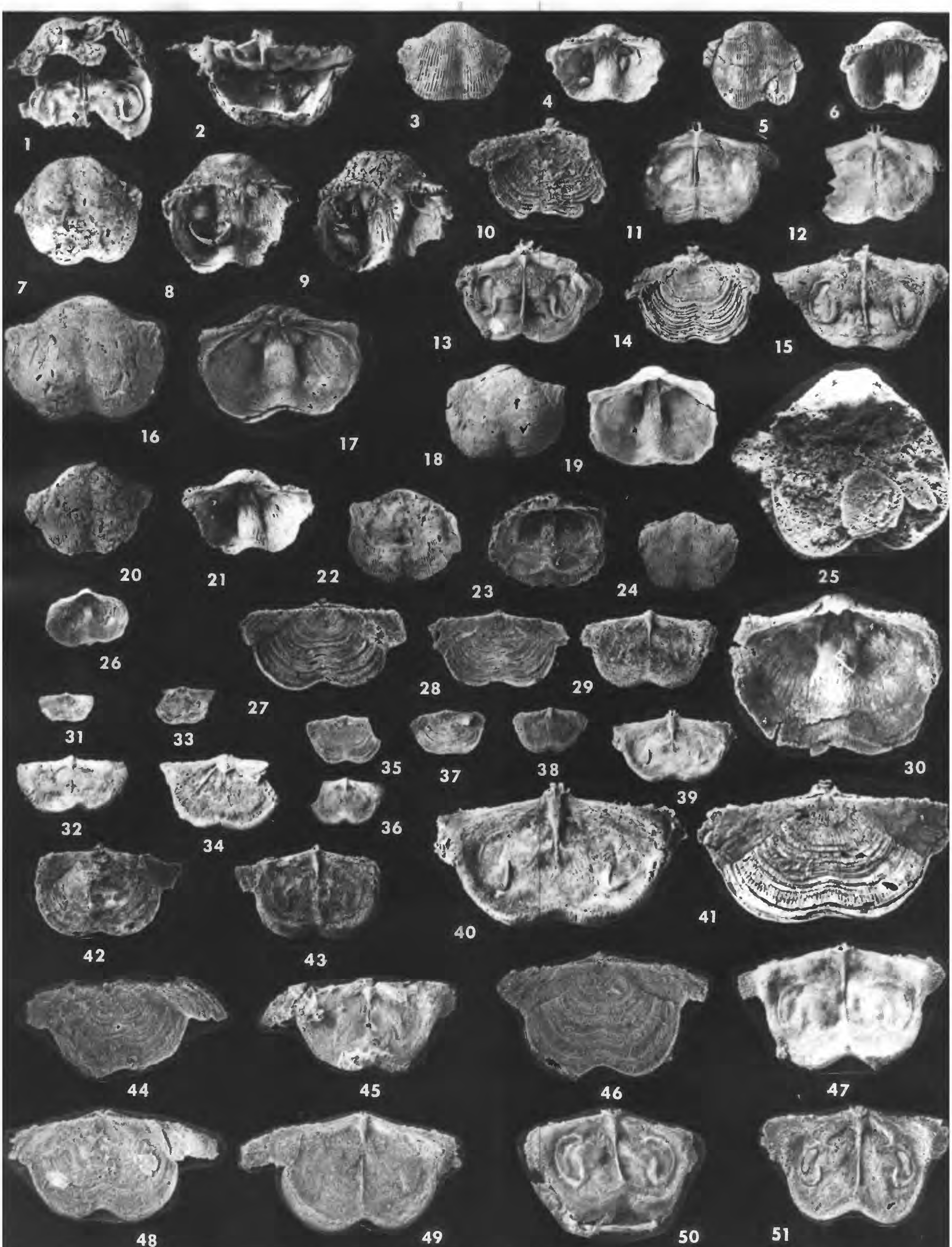
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PLATE 11

All Figures 1x Unless Specified Otherwise

Yakovlevia multistriata (Meek) (1-27): 1-11 showing external ornament and shape with spine arrangement; 1-3, anterior, ventral and lateral views, CCR-708pp; 4-5, ventral view, stereo pair, CCR-760b; 6-8, ventral, dorsal and lateral views, CCR-729c; 9-10, ventral and dorsal view, CCR-729d; 11, ventral view, CCR-708qq; 12-13, 19 showing ventral muscle scars; 12, ventral interior, CCR-729e; 13, ventral interior, CCR-760c; 19, ventral interior, CCR-760d; 14-18 complete specimen and disarticulated showing ventral muscle scars and dorsal muscles scars, cardinal process and brachial ridges, dorsal, ventral, ventral interior, dorsal interior, posterior view of dorsal interior, CCR-723c; 20-27 dorsal valves showing variability in cardinal process, median septum, muscle scars and brachial ridges with spinose termination of brachial ridges well shown in 22 & 25, zygidium shown in 21, and ornament of long trail in 27; 20-21, dorsal interior and dorsal views, CCR-723d; 22, dorsal interior, CCR-723e; 23, dorsal interior, CCR-708rr; 24, dorsal interior, CCR-723f; 25, dorsal interior, CCR-760e; 26, dorsal interior, CCR-708ss; 27, anterior-dorsal interior view, CCR-760f.

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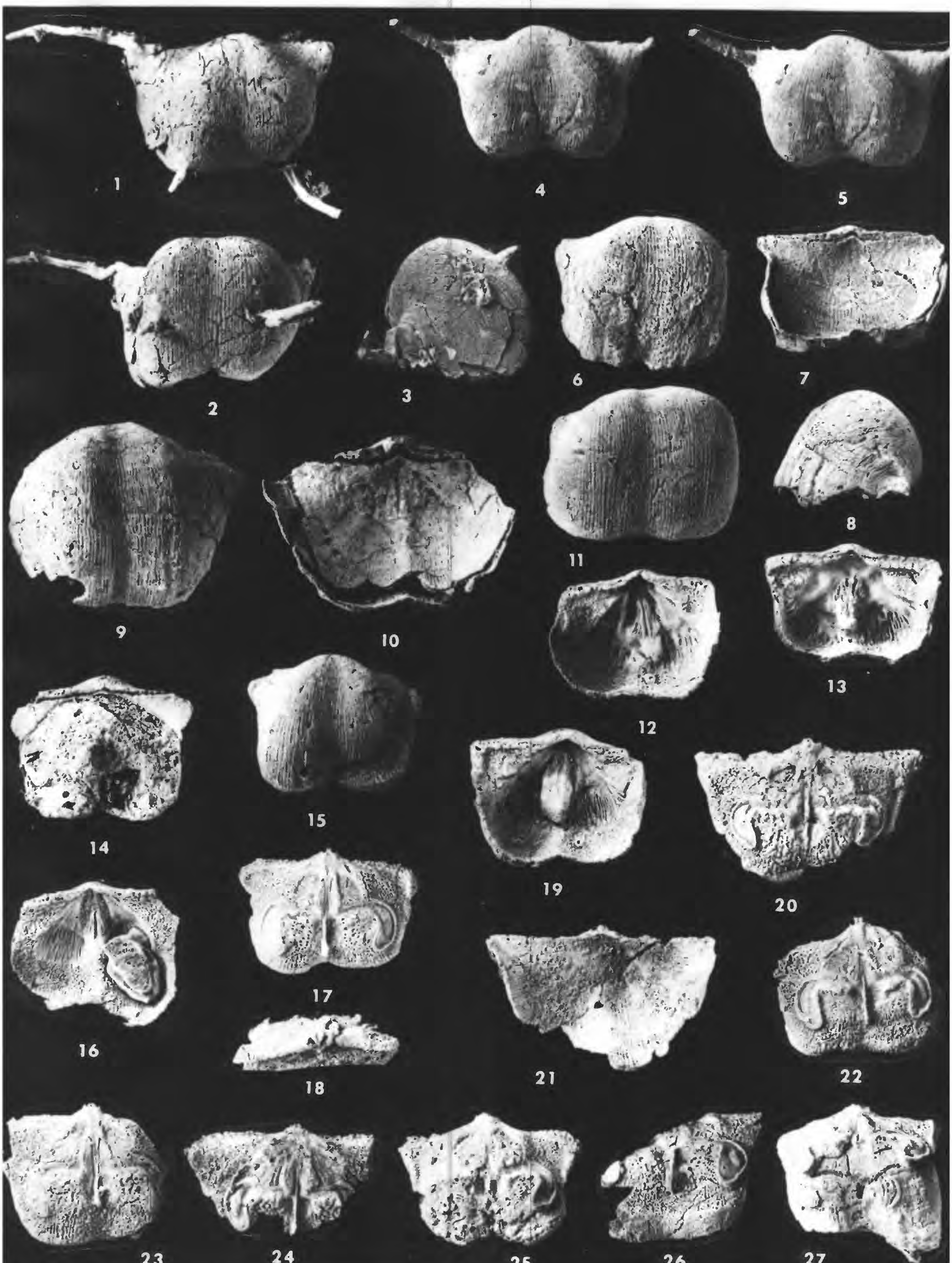
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PLATE 12

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Phrenophoria n. sp. A (1-32): 1-12 showing variability in external ornament with conjunct deltidial plates in 1 & 4; 1-3, dorsal, ventral and anterior views, SR-12c; 4-6, dorsal, ventral and anterior views, SR-12d; 7-9, dorsal ventral and anterior views, CCR-708pp; 10-12, ventral, dorsal and anterior views, CCR-708qq; 13-15 juvenile specimens in growth sequence; 13, dorsal view, SR-12e; 14, dorsal view, SR-12f; 15, dorsal view, SR-12g; 16-18 ventral valves showing teeth; 16, ventral interior view, SR-12h; 17-18, ventral interior view, 1x, 2x, SR-12i; 19-22 interior views showing dental plates and hinge plate; 19-20, interior view, 1x, 2x, SR-12j; 21-22, interior view, 1x, 2x, SR-12k; 23-26, 29-32 showing variability in brachial hinge plate; 23-24, dorsal interior view, 1x, 2x, SR-12l; 25-26, dorsal interior view, 1x, 2x, SR-12m; 29-30, dorsal interior, 1x, 2x, SR-12o; 31-32, dorsal interior, 1x, 2x, SR-12p; 27-28, interior view showing crura, 1x, 2x, SR-12n.

Phrenophoria n. sp. B (33-49): 33-42 showing variability in external ornament with conjunct deltidial plates in 33; 33-34, dorsal and ventral views, CBM3-72b; 35-36, anterior and dorsal views, CBM3-72c; 37-39, dorsal, ventral and anterior views, CBM3-72d; 40-42, dorsal, ventral and anterior views, CBM3-72e; 43-46 ventral valves showing muscle scars and dental plates; 43-44, ventral interior view, 1x, 2x, CBM3-72f; 45, ventral interior view, CBM3-72g; 46, ventral interior, CBM3-72h; 47-49 dorsal valves showing hinge plate; 47, dorsal interior, CBM3-72i; 48-49, dorsal interior, 1x, 2x, CBM3-72j.

Cenorhynchia n. sp. A (50-85): 50-60 showing variability in external ornament with disjunct deltidial plates in 50 & 53; 50-52, dorsal, 2x, ventral and anterior views, CCR-725dd; 53-54, dorsal, 2x, anterior views, CCR-725ee; 55-57, anterior, dorsal and ventral views, CCR-725ff; 58-60, dorsal, ventral and anterior views, CCR-725gg; 61-65, 68-71 growth sequence showing variability of species; 61, dorsal view, SPM-98hh; 62, dorsal view, SPM-98ii; 63, dorsal view, SPM-98jj; 64, dorsal view, SPM-98kk; 65, ventral view, CCR-725hh; 68, dorsal view, CCR-725kk; 69, dorsal view, CCR-725ll; 70, dorsal view, CCR-725mm; 71, dorsal view, SPM-98ll; 66-67 ventral valves showing teeth and obscure muscle

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scars; 66, ventral interior view, CCR-725ii; 67, ventral interior, CCR-725jj; 72-85 dorsal valves showing great variability in hinge plate with crura faintly shown in 83; 72-73, dorsal interior, 1x, 2x, CCR-725nn; 74-75, dorsal interior, 1x, 2x, CCR-725oo; 76-77, dorsal interior, 1x, 2x, CCR-725pp; 78-79, dorsal interior, 1x, 2x, CCR-725qq; 80-81, dorsal interior, 1x, 2x, CCR-725rr; 82, dorsal interior, CCR-725ss; 83, interior view, SPM-98mm; 84-85, dorsal interior, 1x, 2x, CCR-725tt.

Cenorhynchia n. sp. B (86-106): 86-93 showing external ornament; 86-88, dorsal ventral and anterior views, SPM-45a; 89-90 & 92, dorsal, ventral and anterior views, SPM-45b; 93, dorsal view, SPM-45c; 94-95 juveniles of species; 94, dorsal view, SPM-45d; 95, dorsal view, SPM-45e; 96, ventral interior, SPM-45f, showing teeth; 97-106 showing variability in hinge plate with posterior thickening shown in 104 & 106; 97-98, dorsal interior, 1x, 2x, SPM-45g; 99-100, dorsal interior, 1x, 2x, SPM-45h; 101-102, dorsal interior, 1x, 2x, SPM-45i; 103-104, dorsal interior, 1x, 2x, SPM-45j; 105-106, apical interior view, 1x, 2x, SPM-45k.

Petasmetherus n. sp. A (107-120): 107-116 showing variability in external ornament; 107-109, dorsal view, 1x, 2x, and ventral view, GH-366n; 110-112, dorsal view, 1x, 2x, and ventral view, GH-366o; 113-114, dorsal and ventral view, SPM-98ff; 115-116. dorsal and ventral view, SPM-98gg; 117-118, ventral interior, 1x, 2x, GH-366p, showing teeth; 119-120, dorsal interior, 1x, 2x, GH-366q, showing divided hinge plate.

Rhynchopora taylori Girty (121-126): 121, dorsal view, LM-60y, showing open delthyrium; 122, ventral view, LM-60z, showing costae; 123, ventral interior, LM-60aa, showing dental plates; 124, anterior of ventral interior, LM-60bb. showing internal ridges; 125-126, dorsal interior, 1x, 2x, LM-60cc, showing hinge plate and septalium.

Hustedia elongata n. ssp. (127-133): 127-133 showing variability in external ornament with greatest length shown in 133; 127-128, dorsal and ventral views, GH-255a; 129-130, dorsal and ventral views, GH-255b; 131-132, dorsal and ventral views, CCR-616a; 133, oblique view showing maximum length, CCR-975a.

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Cleiothyridina n. sp. A (134-155): 134-153. 155 showing variability in external ornament, size and shape and preservation of spines; 134-135, dorsal and ventral views CBM3-116c; 136-138, ventral, dorsal view, 1x, 2x, SPM-98a; 139-140, dorsal and ventral views, SPM-98b; 141-143, dorsal, 2x, 1x, and ventral view, SPM-98c; 144-146, dorsal, 2x, 1x, and ventral view, SPM-98d; 147 & 155, dorsal and ventral views, CBM3-64b; 148-150, dorsal, 2x, 1x, and ventral view, SPM-98e; 151-153, dorsal, 2x, 1x, and ventral view, SPM-98f; 154, dorsal interior, CCR-675a, showing apically perforate hinge plate.

Cleiothyridina n. sp. B (156-172): 156-169. showing variability in external ornament, size and shpe and preservation of spines with geniculated anterior (161); 156-159, dorsal and ventral views, 2x, 1x, GH-400a; 160-161, dorsal and oblique anterior views GH-366a; 162-163, dorsal and ventral views, GH-365a; 164-165, dorsal and ventral views, GH-366b; 166-167, dorsal and ventral views, GH-366c; 168-169, ventral view showing attached *Ctenalosia fixata*, dorsal view, CBM3-116a; 170, ventral interior, CBM3-116b, showing "marginal ridge"; 171-172, dorsal interior, 1x, 2x, CBM3-64a, showing apically perforate hinge plate.

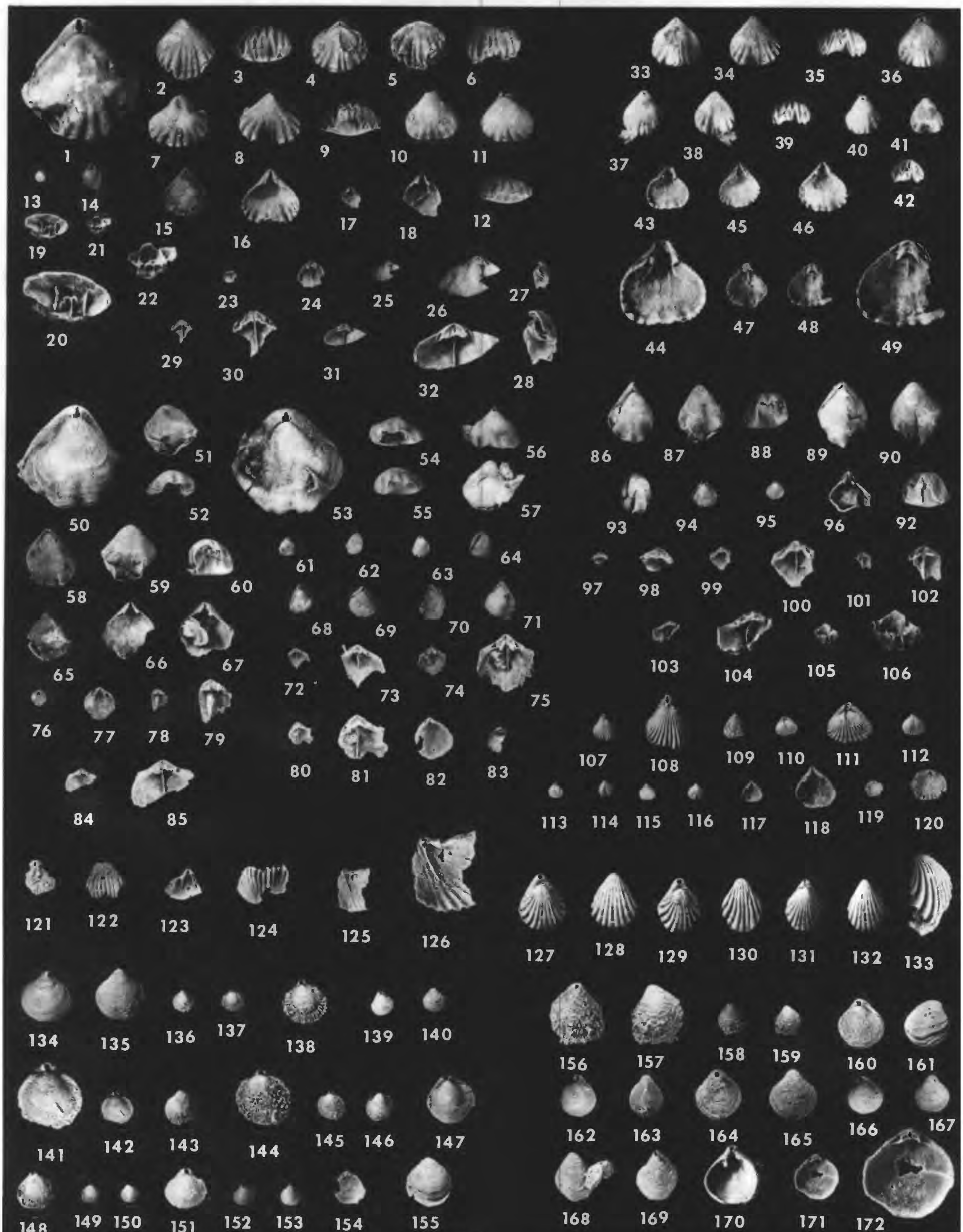
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PLATE 13

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Composita mira Girty (1-23): 1-8 showing external ornament and variability in size and shape, 7-8 showing largest specimen; 1-2, dorsal and ventral views, CCR-725c; 3-4, dorsal and ventral views, CCR-675b; 5-6. dorsal and ventral views, CCR-725d; 7-8, oblique dorsal and ventral views, CCR-723a; 10-19 growth sequence showing variability with size; 10, dorsal view, CCR-616b; 11, dorsal view, CCR-616c; 12-13, dorsal and ventral views, CCR-616d; 14-15, dorsal and ventral views, CCR-962a; 16-17, dorsal and ventral views, CCR-962b; 18-19, dorsal and ventral views, CCR-616e; 20, ventral interior, SM-347b, showing muscle scars and dimpled interior; 9 & 21 dorsal valves showing hinge plate, muscle scars and dimpled surface, 9 with "marginal ridge" developed; 9, dorsal interior, CCR-675c; 21, dorsal interior, SM-347c; 22, dorsal interior showing mantle canals, SM-393a; 23, dorsal interior showing small protuberence extending out from under hinge plate, SM-274a.

Composita parasulcata Cooper and Grant (24-31): 24-27 showing external ornament, size and shape; 24-26, dorsal, ventral and lateral views, SPM-82a; 27, ventral view, SPM-98g; 28-29, ventral and ventral interior, CBM3-116d, showing "marginal ridge"; 30-31, dorsal and dorsal interior views, GH-14a, showing hinge plate and obscure muscle scars.

Odontospirifer n. sp. A (32-46): 32-25, ventral view, 2x, 1x, ventral interior, 1x, 2x, CCR-725a, showing exterior ornament, shape and size, denticulate hinge, median septum and small delthyrial plate; 36-38, dorsal interior, 2x, 1x, dorsal view, CCR-725b, showing sockets on hinge, crural plates, cardinal process and external ornament; 39-41 showing external ornament, size and shape; 39-40, ventral and dorsal views, GH-365b; 41, dorsal view, GH-365c; 42-43, dorsal view and dorsal interior, SM-347a, showing variability in dorsal ornament; 44-46, ventral view, ventral interior, 1x, 2x, SPM-137a, long specimen showing ornament and internal detail with small delthyrial plate.

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Timaniella "*pseudocamerata*" (47-57): growth sequence, pustules well shown in 55; 47-48, dorsal and ventral views SPM-131a; 49-50, dorsal and dorsal interior views, SPM-131b; 51-53, ventral view, 1x, 2x, and ventral interior, SPM-131c; 54-57, dorsal view, 1x, 2x, and dorsal interior, 1x, 2x, SPM-131d.

Spiriferella scobina (Meek) (58-68): growth sequence; 58, dorsal interior, SPM-98p; 59, ventral view, SPM-98q; 60-61, ventral and ventral interior, SPM-98r; 62, dorsal interior, SPM-98s; 63, ventral view, SPM-98t; 64-65, ventral and ventral interior, SPM-98u; 66, dorsal view, SPM-98v; 67, dorsal view, SPM-98w; 68, dorsal view, SPM-98x.

Xestotrema pulchrum (Meek) (69-73): growth sequence; 69, dorsal view, CBM3-116e; 70, dorsal view, CBM3-116f; 71-72, dorsal and ventral view, CBM3-116g; 73, dorsal view, CBM3-65a.

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PLATE 13

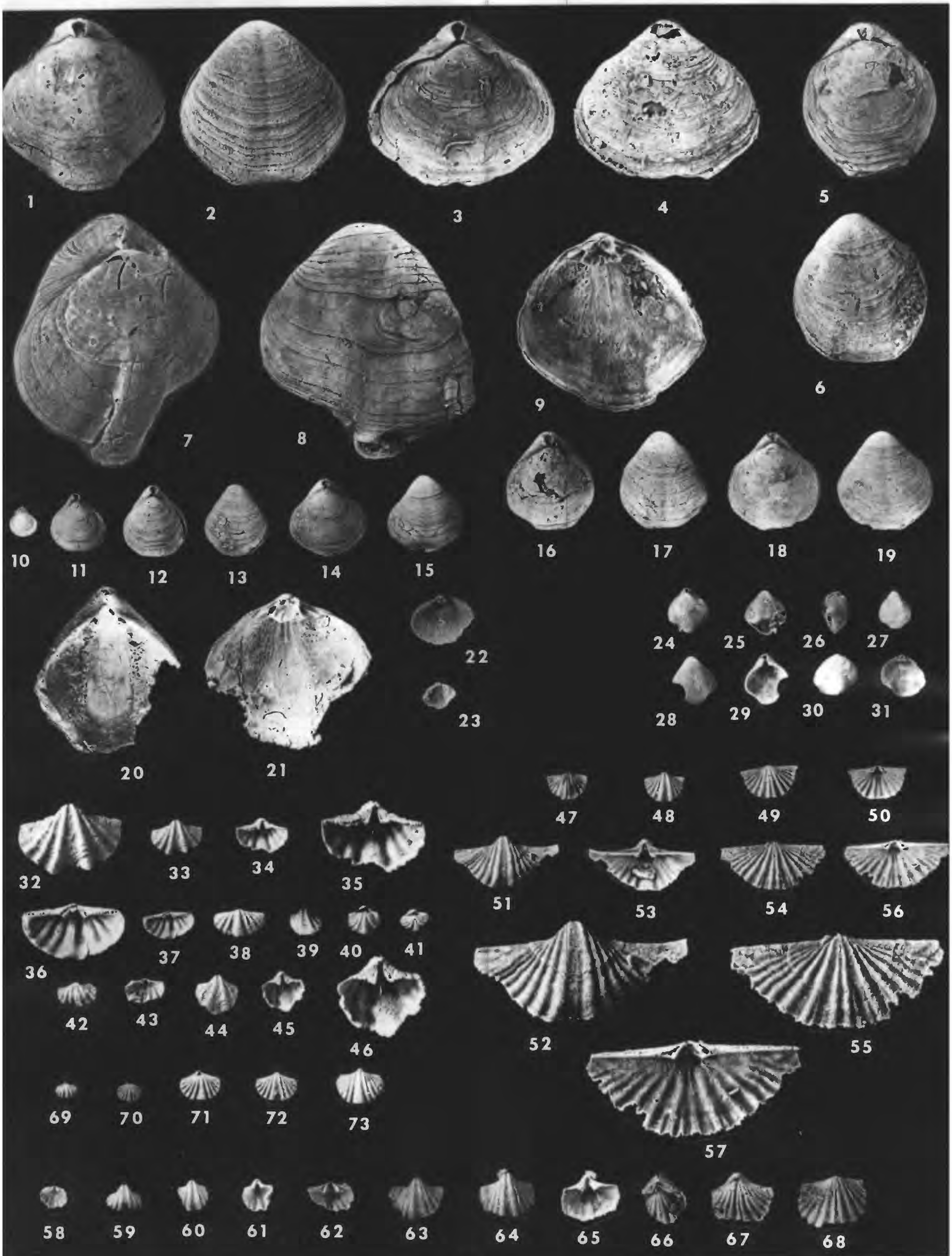
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PLATE 14

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Timaniella "pseudocamerata" (1-15): 1-4, 7-8, 11 showing variability in external ornament, size and shape, many Ctenalosia attached along with small T. "pseudocamerata" in 4; 1-2, dorsal and ventral views, SPM-131e; 3-4, dorsal and ventral views, CCR-528a; 7-8, dorsal and posterior views, CCR-528c; 11, dorsal view, CCR-528d; 5-6, dorsal and ventral views, CCR-528b, showing young alate adult with pustules preserved; 9-10, 12-13 ventral valves showing external ornament and internal detail, with large teeth, denticulate hinge and round muscle field, delthyrial plate present in 10, absent in 13, perforation of apical callosity barely visible in 13; 9-10, ventral and ventral interior, SPM-131f; 12-13, ventral and ventral interior, CCR-528e; 14-15, dorsal and dorsal interior, CCR-528f; poorly preserved specimen showing external ornament, denticulate hinge, crural plates, cardinal process and large inner socket ridge acting as an accessory tooth, Quadrochonetes in internal residue.

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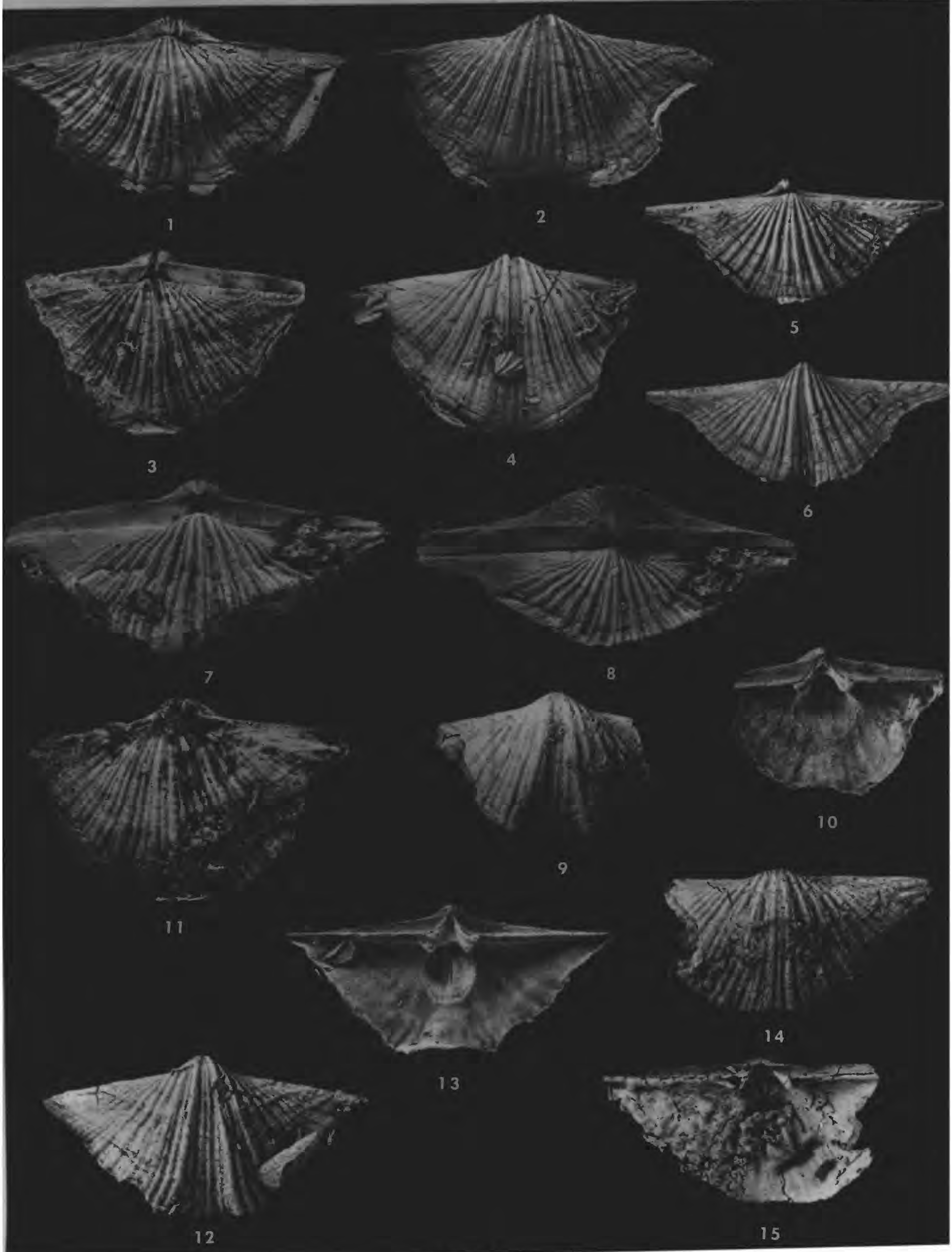
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PLATE 15

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Spiriferella scobina (Meek) (1-15): 1-2, dorsal and ventral views, USNM-644a, cotype; 3, ventral view, USNM-644b, cotype; 4-5, dorsal and ventral views, MR-126a, showing pustules in 4; 6, ventral interior view, SPM-98y, large, poorly preserved ventral valve showing denticulate hinge and lateral margin; 7-12 ventral valves showing external ornament, denticulate hinge, thick teeth, medianly raised delthyrial plate and round muscle field; 7-8, ventral and ventral interior, SPM-98z; 9, ventral interior, SPM-98aa; 10-11, ventral interior and oblique ventral interior view showing thick dental plates, SPM-98bb; 12, ventral view, SPM-98cc; 13-15 dorsal valves showing external detail, crural plates and thickened inner socket ridge acting as an accessory tooth; 13, dorsal interior, SPM-98dd; 14-15, dorsal and dorsal interior, SPM-98ee.

Xestotrema pulchrum (Meek) (16-26): 16-17, dorsal and ventral views, CCR-729a, showing external ornament, size and shape; 18, dorsal view, CCR-729b, small adult; 19-20, 25-26 dorsal valves showing external and internal detail with "marginal ridge" shown in 20; 19-20, dorsal and dorsal interior views, CCR-760a; 25-26, dorsal and dorsal interior views, SM-80a; 21-22, 23-24 ventral valves showing external ornament and high median septum, curved dental plates and minute delthyrial plate; 21-22, ventral and ventral interior views, CCR-675d; 23-24, ventral and ventral interior, MR-48a.

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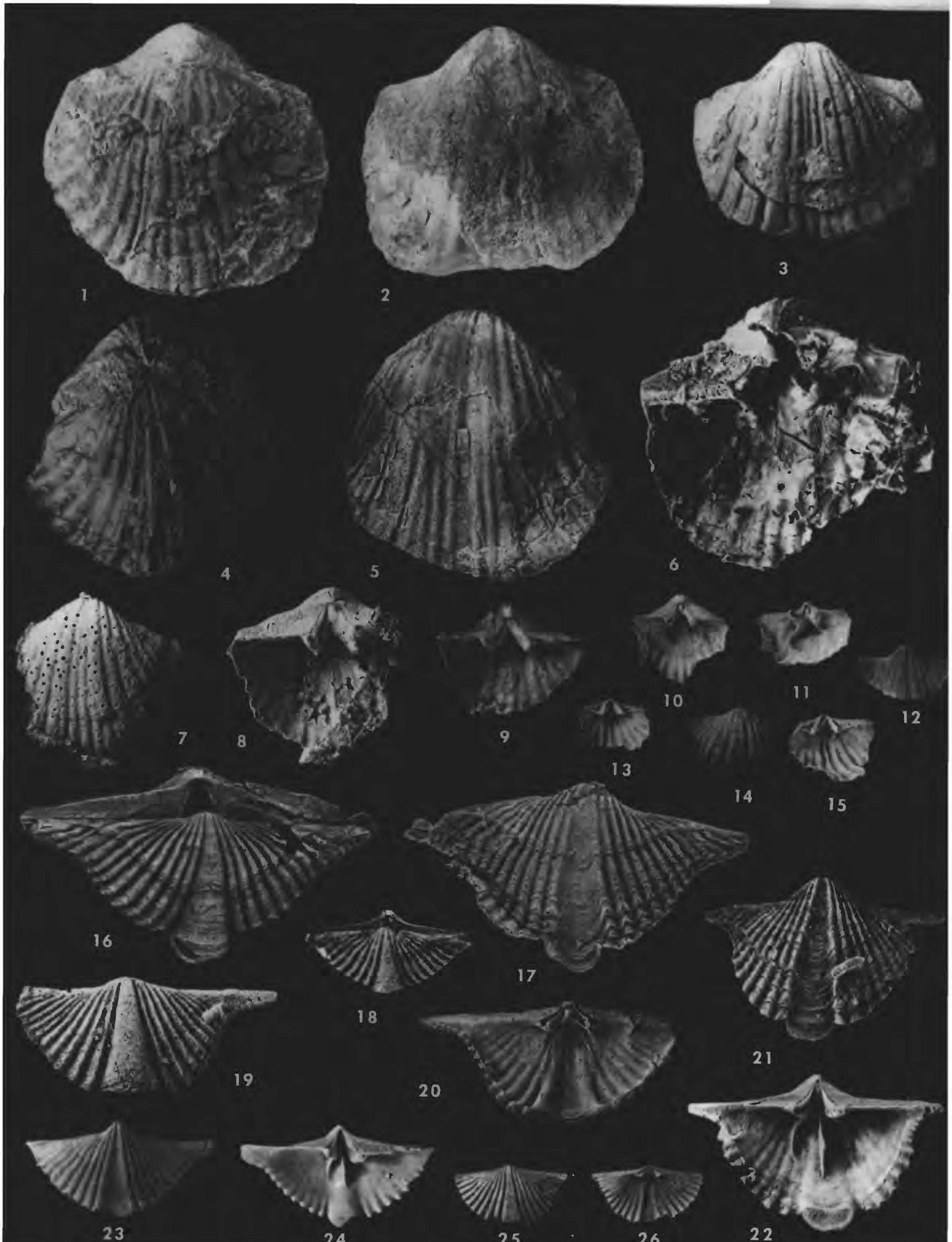
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PLATE 16

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Dielasma phosphoriense Branson (1-15): 1-12 showing variability in preservation, external ornament, size and shape, 10, 11 & 12 being juveniles; 1-2, dorsal and ventral views, CBM3-116h; 3-4, dorsal and ventral views, GH-255c1; 5-6, dorsal and ventral views, GH-366f; 7-8, dorsal and ventral views, CCR-616f; 9, dorsal view, CCR-616g; 10-11, dorsal and ventral views, CBM3-116i; 12, dorsal view, SR-12a; 13, dorsal interior, GH-366g, showing hinge plate; 14-15, interior view showing crushed loop, GH-365d.

Dielasma spatulatum Girty (16-21): 16-18, 20 showing preservation, external ornament, size and shape; 16-17, dorsal and ventral views, CONR-701a; 18, dorsal view, CONR-701b; 20, cluster of *Dielasma* and one *Xestotrema*, prominently showing dorsal view, CONR-701e; 19 & 21 dorsal interior views showing hinge plates; 19, dorsal interior, CONR-701c; 21, dorsal interior, CONR-701d.

Plectelasma n. sp. A (22-33): 22-24, dorsal, ventral and anterior views, GH-366h, showing external ornament, size and shape, and plications of type specimen; 25-28, dorsal, anterior and interior view, 1x, 2x, GH-365f, showing external features with part of ventral valve removed to show Dielasmid hinge plate; 29-33 dorsal valves showing faint anterior plications on geniculated portion of valve (30 & 31) and dorsal interior with Dielasmid hinge plate and small oval adductor scars; 29-30, dorsal interior and anterior views, GH-366i; 31-33, dorsal anterior and interior view, 1x, 2x, GH-366j.

Plectelasma n. sp. B (34-47): 34-41, 46-47 showing variability in external ornament, size and shape; 34-36, dorsal, ventral and anterior views, GH-366k; 37-39, dorsal, ventral and anterior views, GH-255d; 40 & 47, dorsal and ventral views, CCR-616i; 41 & 46, ventral and anterior views, GH-365g; 42-43, ventral and ventral interior views, GH-366l, showing external detail and teeth; 44, dorsal interior, GH-366m, showing Dielasmid hinge plate.

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Hemiptychina quadricostata (Branson) (48-63): 48-53, showing small complete specimens; 48-50, dorsal view, 2x, 1x, ventral view, GH-365e; 51-53, dorsal view, 1x, 2x, ventral view, SR-12b; 54-55, 58-59; 54-55showing external features, dorsal and ventral views, 58-59 valve broken open to show crura and lack of dental plates, interior view, 1x, 2x, GH-400b; 56-57, interior view showing Dielasmid hinge plate and teeth, SPM-98o; 61-63, ventral, ventral interior, 1x, 2x, CCR-616b, showing lack of dental plates and anterior plications.

Hemiptychina himalayensis (Davidson) (64-83) (for comparison): 64-76 showing external detail and specifically the relationship of number of plicae with size; 64-65, 70, dorsal, ventral and anterior views, REG-a; 66-67, 72, dorsal, ventral and anterior views, REG-b; 68-69. 74, dorsal, ventral and anterior views, REG-c; 71, dorsal view, REG-d; 73, dorsal view, REG-e; 75-76, dorsal and anterior views, REG-f; 77-78, interior view showing lack of dental plates, 1x, 2x, REG-g; 79-80, interior view showing loop, 1x, 2x, REG-h; 81, dorsal interior, REG-i, showing teeth; 82-83, internal view showing hinge plates and articulation, 1x, 2x, REG-j.

Rostranteris n. sp. A (84-94): 84-89, dorsal view, 1x, 2x, ventral view, 1x, 2x, interior view, 1x, 2x, SPM-98nn, showing external detail and crura and lack of dental plates; 91-92, dorsal view, 1x, 2x, SPM-98oo, showing foramen; 93-94, dorsal interior showing lack of dental plates, SPM-98pp.

Girtyella? (95-98): 95-98 showing hinge plate; 95-96, dorsal interior, 1x, 2x, GH-366c; 97-98, dorsal interior, 1x, 2x, GH-365d.

Heterelasma n. sp. A (99-114): 99-103, 108 showing external detail, size and shape of adults and juveniles; 99-101, dorsal, ventral and lateral views, SPM-98h; 102-103, dorsal and ventral views, SPM-98i; 108, dorsal view, SPM-98k; 109-110, dorsal view, 1x, 2x, SPM-98l, showing foramen; 111-114showing hinge plate and dental plates; 111-112, interior view, 1x, 2x, SPM-98m; 113-114, interior view, SPM-98n; 104-107, dorsal view and interior, 1x, 1x, 3x, SPM-98j, showing external detail and loop.

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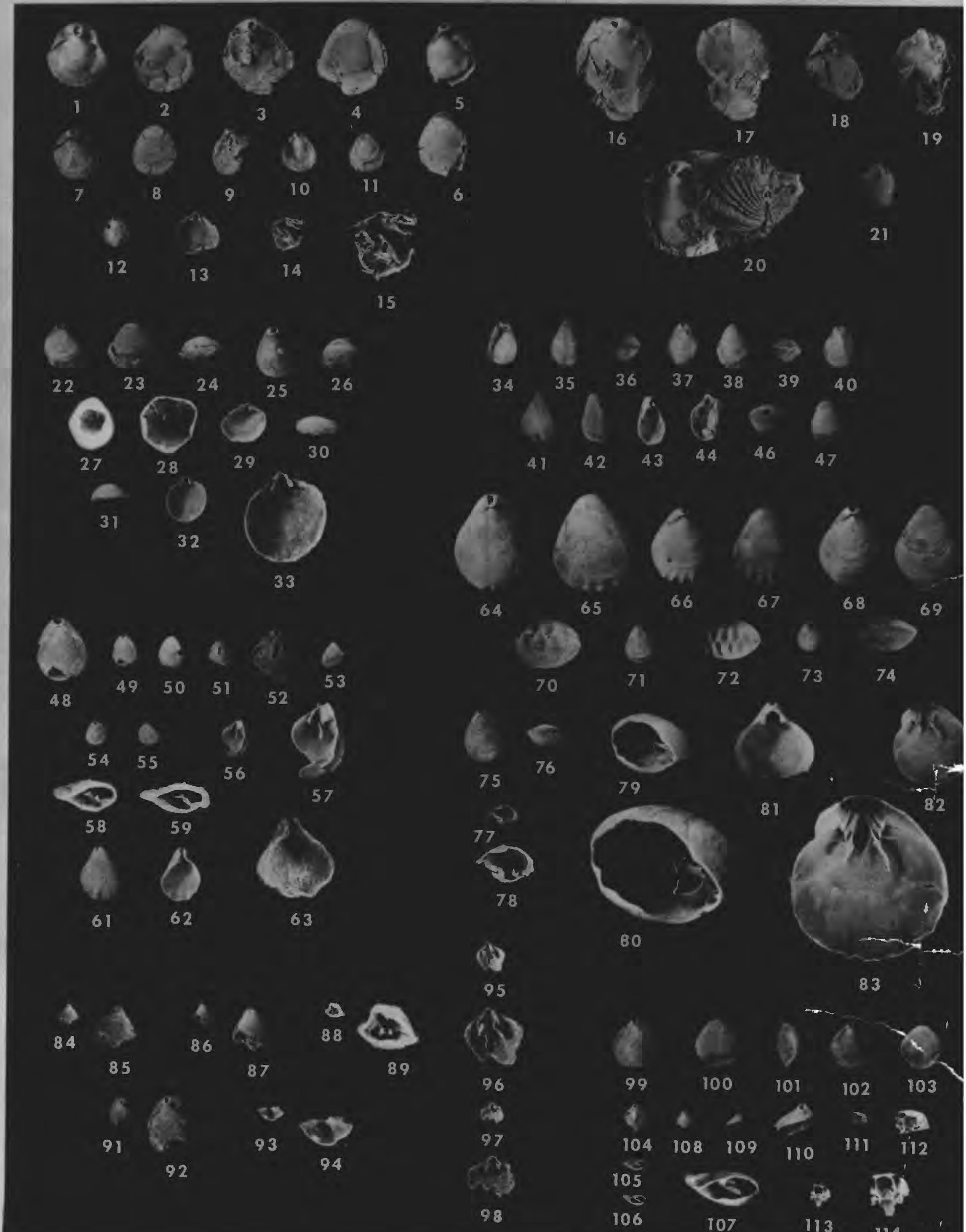
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