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Calcareous microfossils from the Moenkopi Formation (Triassic, Scythian or Anisian) of central New Mexico

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CALCAREOUS MICROFOSSILS FROM THE MOENKOPI FORMATION (TRIASSIC, SCYTHIAN OR ANISIAN) OF CENTRAL NEW MEXICO

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Abstract—Lacustrine and fluvial sediments of the Moenkopi Formation in the Lucero Mesa area of Cibola County, New Mexico yield charophytes, spirorbid worms and ostracods. Charophytes are represented by two species of *Porochara* and one of ?*Altochara*. The spirorbid is an uncoiled species of *Spirorbis*. The ostracods are represented by two species of *Darwinula*, two species of *Darwinuloides* and one species of *Gerdalia*. The fauna and flora are most abundant in the middle and upper parts of the basal lacustrine unit of the Moenkopi. The middle of the red mudstone unit above this basal unit contains common-to-rare, fluvio-lacustrine microfossils.

Triassic *Darwinuloides* are apparently restricted to Lower Triassic units in the Soviet Union and to the Middle Triassic Buntsandstein of Germany. The presence of this genus in the basal Moenkopi samples suggests an Early to Middle Triassic age for the basal Moenkopi in the Lucero Mesa region. The Moenkopi spirorbid resembles *Spirorbis aberrans* (Hohenstein, 1913), a species from the Middle Triassic of Germany. The charophytes and ostracods suggest a clear but brackish water environment of less than 9 m depth in the lower part of the section sampled.

INTRODUCTION

Hayden and Lucas (1988) identified an outlier of the Moenkopi Formation in the Lucero uplift of central New Mexico (Fig. 1). Hayden (1988) measured several sections at White Ridge (WR) and one section at Mesa Gallina (MG) (Fig. 2). Sediment samples from two of the sections furnished by Hayden contained identifiable microfossil assemblages consisting of three species of charophytes, one species of *Spirorbis* and four species of ostracods (Kietzke, 1988). The most abundant microfossils were recovered from the basal tan, locally limonitic, finely laminated fissile mudstone of the Moenkopi (Fig. 2). Some ostracods were recovered from higher in the Mesa Gallina section (MG-7, unit numbers from Figure 2). A single ?*Darwinula* was recovered from a red overbank deposit (MG-11) of the Chinle Formation, fluvial-dominated rocks above the Moenkopi Formation.

The microfossil samples were disaggregated using a rotary tumbler and sieved through a series of sieves (0.5 to 4.0 Ø). The residues were picked for all identifiable microfossils, which were sorted by morphotype, identified and mounted on micropaleontology slides. Selected specimens were SEM (scanning electron microscope) photographed for illustration and detailed identification purposes. The illustrated and measured specimens are housed in the paleontology collection of the New Mexico Museum of Natural History (NMMNH).

PREVIOUS STUDIES

The local geology and sedimentology of this Moenkopi microfossil locality has been reviewed by Hayden (1988) and is described by Lucas and Hayden (1989). Hayden observed three phases of sedimentation in the Moenkopi of the Lucero region: an initial fluvial/lacustrine phase filling in a possible karst topography on the Permian San Andres Limestone, a second fluvial sheet sand phase and a third phase of higher energy fluvial and ?paleosol development. The initial lacustrine phase has produced the majority of microfossils and locally reaches a thickness of about 9 m. Paleocurrent data suggested to Hayden (1988) a sediment source to the south in the Mogollon highland of southwestern New Mexico and southeastern Arizona. Also of significance was Hayden's discovery of capitosauroid amphibian remains, suggesting an Early to Middle Triassic age for the Moenkopi in this area.

Peck and Eyer (1963) identified the Triassic charophyte *Stellatochara prolata* from beds thought to be Moenkopi Formation. Peck and Eyer (1963, p. 841) were confused about the generic separation of *Stellatochara* and *Porochara*. Their specimens from the Moenkopi lack the inflated and elongated apical cells characteristic of *Stellatochara* (Tappan, 1980) and thus should be transferred to the genus *Porochara*. The great size range of *Porochara prolata* described by Peck and Eyer (1963) suggests that more than one species may be involved. The only other illustrated North American Triassic charophytes are *Stellatochara* and *Altochara* from the Bull Canyon Formation of eastern New Mexico (Kietzke, 1987). The charophytes discussed here were briefly mentioned by Kietzke (1988).

Marine and nonmarine species of *Spirorbis* have been described from the Triassic. Marine species include *Spirorbis valvata* (Goldfuss, 1826–

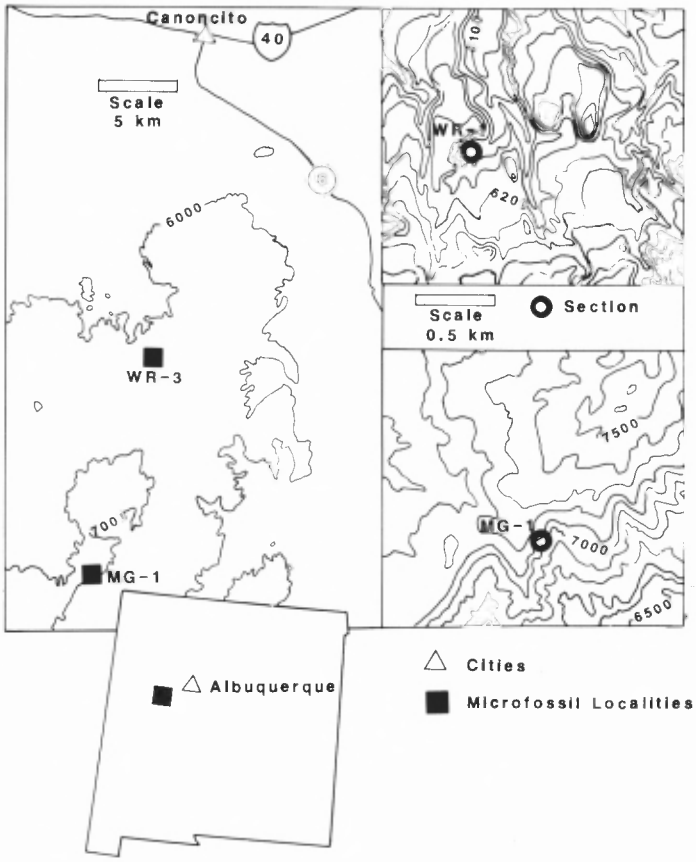

FIGURE 1. Location of the Moenkopi microfossil localities: WR = White Ridge section locality, NW¼ NE¼ NW¼ sec. 36, T7N, R4W, Cibola County, New Mexico. MG = Mesa Gallina section locality, SE¼ NE¼ SW¼ sec. 10, T5N, R4E, Cibola County, New Mexico.

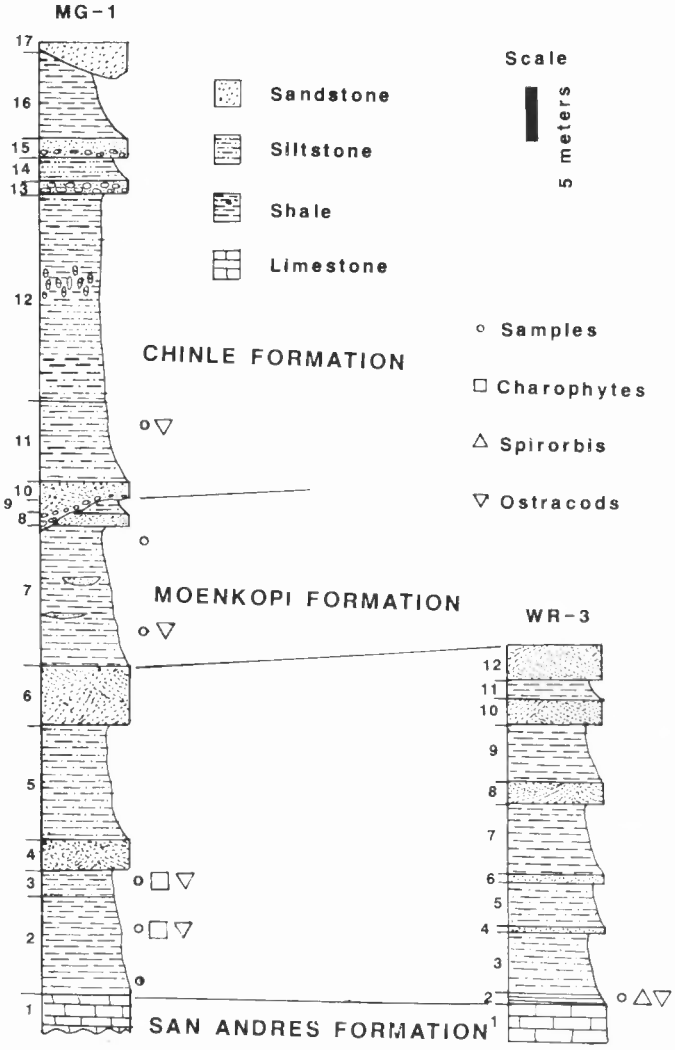

FIGURE 2. Stratigraphic sections of the Moenkopi Formation showing microfossil sampling sites. Sections modified from Hayden (1988). WR = White Ridge Section. MG = Mesa Gallina Section.

1844), *Spirorbis aberrans* Hohenstein, 1913, *Spirorbis phyctaena* Bronnimann and Zanietti, 1972, *Spirorbis zimmermanni* Hack, 1921 and ?*Spirorbis* sp. (Ziegler and Michalik, 1980). The only formally described nonmarine *Spirorbis* species from the Triassic of North America is *Spirorbis inexpectus* Wanner, 1921, from the rift valley deposits of eastern North America. Gall and Granvogel (1967) described a nonmarine species they referred to as "*Spirorbis* cf. *S. pusillus* Martin, 1809" from the Buntsandstein of Germany. They found this species attached to various substrates including plants, bivalves and fish scales. Ball (1980, p. 153) noted that this species was originally considered a Carboniferous species and suggested "the Triassic fresh-water forms comprise a new species rather than a relict population of the Upper Carboniferous species." This, or a similar species, has been described by other workers as *Spirorbis* sp. from Germany (Kelber, 1987) and England (Ball, 1980). The *Spirorbis* sp. described from the Chinle Formation of New Mexico (Kietzke, 1987) is likewise probably this species.

The Triassic nonmarine ostracods of North America are limited to several species of *Darwinula* from the rift valleys of eastern North America (Swain and Brown, 1946). Kietzke (1987) illustrated *Darwinula* spp. and an unidentified limnocytheriine ostracod (?*Lutchevikella*) from the Upper Traissic Bull Canyon and Sloan Canyon formations of eastern New Mexico. All other references to North American Triassic ostracods lack illustrations or descriptions.

The Triassic nonmarine microflora and microfauna outside North America have been much better documented (Kietzke, 1987). The charophytes have been especially useful biostratigraphically and well studied in Germany and the Soviet Union. The ostracods likewise have been extensively studied in the Soviet Union, China and to some extent in Europe.

SYSTEMATIC PALEONTOLOGY

Division Charophyta Migula, 1890
Class Charophyceae Smith, 1938
Family Porocharaceae Grambast, 1962
Subfamily Porocharacoideae Grambast, 1962
Genus *Porochara* Madler, 1955
***Porochara* sp. A**
Figs. 3E, 5A

Description

Gyrogonite small, suboblate to oblate spheroidal, subovoidal to ellipsoidal; 5 cells spiraling counterclockwise, forming 5–8 (usually 6–7) ridges in side view; apical surface with 5 spiral cells joining about a minute pentagonal pore and with a minute bump near their termination; basal view with five spiral cells joining about a minute basal pore; basal surface slightly flatter in side view than apex. Measurements of *Porochara* sp. A (NMMNH P9501–P9502) are given in Table 1.

Occurrence

Porochara sp. A is abundant in the basal lacustrine parts of the Moenkopi (Samples 1M, 1T) of central New Mexico.

Comparisons

Porochara sp. A is smaller than most other described members of the genus, and although specimens overlap the polar axis length (LPA), equatorial diameter (LED) only slightly overlaps the range of *Porochara prolata* (Peck and Eyer, 1963), and *Porochara* sp. A has generally fewer spiral cells visible in side view. *Porochara* sp. A closely resembles *Porochara ukranica* Saydakovskiy, 1966 from the lower Keuper and upper Ceratitenschichten of central Europe. *Porochara ukranica* is virtually identical to *Porochara prolata* and is probably synonymous with that species. The minute bumps on the end of the spiral cells at the apex may indicate a relationship with the genus *Stellatochara*, although the degree of inflation and lack of extension of these apical cells precludes its placement in that genus.

***Porochara* sp. B**
Fig. 3F, 5B

Description

Gyrogonite minute, oblate spheroidal, ellipsoidal to subovoidal; 5 cells spiraling counterclockwise, forming 6 ridges in side view; apical surface with 5 spiral cells joining about a minute pentagonal pore; basal surface with 5 spiral cells joining about a minute basal pore. Measurements of *Porochara* sp. B (NMMNH P9503–9504) are given in Table 2.

Occurrence

Porochara sp. B is rare in the basal unit of the Moenkopi (MG-2) in central New Mexico.

FIGURE 3. Charophytes and *Spirorbis* from the Moenkopi Formation. A–C, *Spirorbis* n. sp. aff. *S. aberrans*, tube, embryonic chamber, close up of surface, NMMNH P9508, P9509; D, ?*Altochara* sp., side view, NMMNH P9506; E, *Porochara* sp. A, side view, NMMNH P9502; F, *Porochara* sp. B, side view, NMMNH P9504. Bar scales equal 100 microns, except where bar scale equals 10 microns.

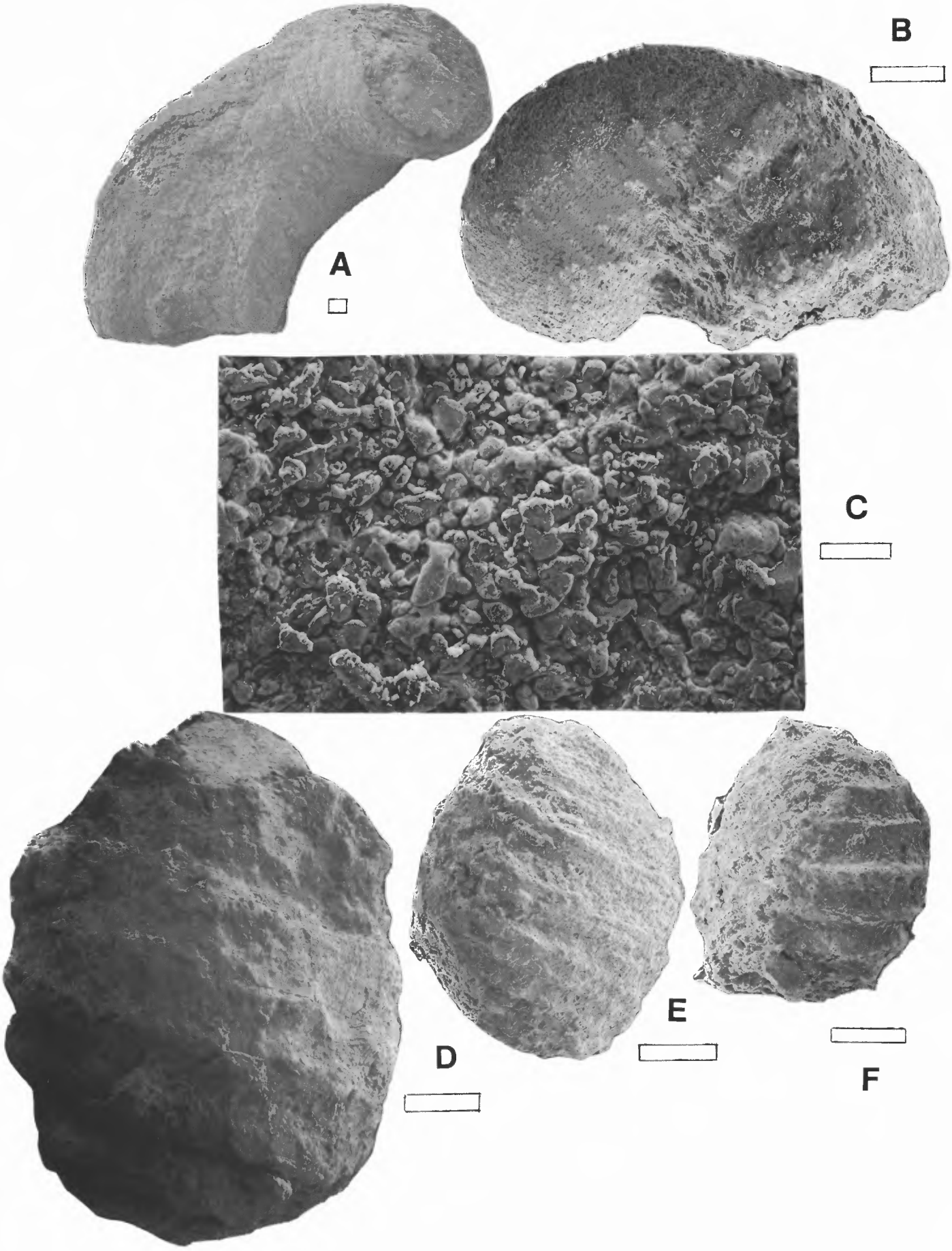
A
B
C
D
E
F

TABLE 1. Measurements of *Porochara* sp. A from Moenkopi unit 1T (=MG-2). L=length, LPA=length of polar axis, LED=length equatorial diameter, AND=length from apical pole to LED, z=number of cells in side view. All measurements are in microns.

L	LPA	LED	AND	z
380	350	280	180	7
410	400	270	180	7
400	360	260	160	6
400	380	280	160	7
360	340	280	180	7
350	350	300	200	8
380	350	280	180	7
400	360	280	160	7
370	330	270	180	6
360	340	280	180	6
390	360	250	170	7
340	300	260	170	6
380	340	270	140	7
380	340	280	180	7
390	320	290	140	7
380	340	280	180	6
360	320	280	140	6
370	350	280	160	6
370	350	260	160	7
380	360	280	200	7
360	320	260	160	6
350	330	300	140	6
390	330	300	100	5
380	360	280	140	6
410	370	280	140	6
390	370	290	160	6
340	320	270	140	6
390	360	270	180	6
400	360	280	200	6
360	350	290	180	6
360	340	280	160	5
370	340	270	180	7
380	360	260	200	6
400	360	280	180	7
360	320	250	140	6
370	340	260	160	6
420	400	250	200	7
380	350	260	150	7
360	320	270	160	6
440	400	300	160	6
380	340	270	180	6
350	320	260	120	6
360	320	260	140	6

Comparisons

The minute size of *Porochara* sp. B separates it from all other known members of the genus. The close association of this species with *Porochara* sp. A suggests that these forms may be related. However, they are separable morphologically, with *Porochara* sp. B smaller and rounder and are thus considered separate species. *Porochara* sp. B also lacks the minute apical bumps on the cell tips typical of *Porochara* sp. A.

TABLE 2. Measurements of *Porochara* sp. B from Moenkopi unit 1T (=MG-2). All measurements are in microns.

L	LPA	LED	AND	z
270	250	240	110	6
260	240	270	160	6
300	280	230	100	6

Genus *Altochara* Saydakovskiy, 1968
?*Altochara* sp.
Figs. 3D, 5D

Description

Gyrogonite rather large, suboblate, ellipsoidal, with 5 spiraling cells in side view forming 6–8 low, flattened ridges; apical surface with 5 spiral cells joining about a poorly defined round to slightly pentagonal pore; basal surface with 5 spiral cells joining about a basal pore; base and apex evenly rounded in side view, base more so than apex. Measurements of ?*Altochara* sp. (NMMNH P9505–P9506) are given in Table 3.

Occurrence

?*Altochara* sp. is rare in the middle of the basal unit of the Moenkopi (sample 1M) in central New Mexico.

Comparisons

The poor preservation, rarity and distorted nature of the specimens presently available makes even generic assignment questionable.

Phylum Annelida Lamarck, 1809
Class Polychaetia Grube, 1850
Order Sedentarida Lamarck, 1818
Family Serpulidae Burnmeister, 1837
Subfamily Spirorbinae Chamberlin, 1919
Genus *Spirorbis* Daudin, 1800
***Spirorobis* n. sp. aff. *S. aberrans* Hohenstein, 1913**
Fig. 3A–C

Description

Attached coils formed by an enlarged embryonic chamber followed by a coiled portion consisting of a clockwise coiled area of less than one full coil; unattached portion consisting of a rapidly expanding, uncoiled tube forming a more or less clockwise spiral; surface marked by faint, tightly arranged growth lines making up larger, undulatory, low rings; attachment surface without obvious attachment ornamentation (i.e., plant or bivalve impressions); unattached portion often oval or slightly ?ventrally flattened and turning at an angle at the terminal end; maximum diameter of terminal opening about 1040 μm, average diameter of tube immediately above embryonic chamber 142 μm, average diameter of embryonic chamber 284 μm. No complete specimens have been recovered, with most breaking between the attached and

TABLE 3. Measurements of ?*Altochara* sp. from Moenkopi unit 1T (=MG-2). All measurements are in microns.

L	LPA	LED	AND	z
512	512	675	325	7
525	525	725	325	6
475	475	625	300	6
525	525	650	350	7

unattached portions. Measurements of typical specimens of *Spirorbis* n. sp. aff. *S. aberrans* (NMMNH P9507–P9509) are given in Table 4.

Occurrence

This species is the red shale at the top of the basal lacustrine unit (WR 3-2) of the Moenkopi Formation.

Comparisons

This species differs from most other described Triassic species in being nearly completely uncoiled and in the rapid expansion of the uncoiled portion of the tube. It most resembles *Spirorbis aberrans* Hohenstein, 1913 from the lower Keuper and Muschelkalk of central Europe. Both species are generally uncoiled, and the unattached portions expand rapidly. *Spirorbis* n. sp. differs from *S. aberrans* in having a larger embryonic chamber, less distinct surface ornamentation and an attached coiled portion with less than a complete coil. According to Muller (1982, fig. 14), *Spirorbis aberrans* typically has one to one and one-half coils in the attached portion. The Moenkopi species is also much smaller than the European species. *Spirorbis aberrans* is typically a marine species (Hohenstein, 1913; Ball, 1980; Senkowiczowa, 1985), whereas the New Mexico species is clearly nonmarine.

Spirorbis zimmermanni Haack, 1921 from the middle Buntsandstein is also a largely uncoiled species. The Moenkopi *Spirorbis* differs from *Spirorbis zimmermanni* in having an attached portion with less than a complete whorl, an unattached portion that increases markedly in diameter toward its apex and in having a corkscrew rather than zig-zag uncoiled portion. Also, *Spirorbis zimmermanni* appears to be a marine species.

Phylum Arthropoda
Class Crustacea Brongiart and Desmarest, 1822
Subclass Ostracoda Latreille, 1802
Order Podocopida Muller, 1894
Suborder Darwinulocopina Sohn, 1988
Superfamily Darwinulacea Brady and Norman, 1881
Family Darwinulidae Brady and Norman, 1889
Genus *Darwinula* Brady and Robertson, 1885
***Darwinula* sp. A**
Figs. 4C–D, 6A

Description

Valves elongate oval in lateral view; dorsal margin slightly convex, ventral margin straight to slightly convex; anterior less tumid than posterior; greatest height at point midway from midpoint to posterior margin; right valve overlaps left on dorsal, ventral, posterior and to a lesser extent anterior margins; overlap rather weak; valves inflated ventral of midpoint, parallel to ventral margin; in dorsal view, valves widest slightly posterior of midpoint; anterior margin pointed, posterior margin acutely rounded; muscle-scar field slightly anterior and ventral of midpoint; surface smooth. Measurements of *Darwinula* sp. A (NMMNH P9510-P9512) are given in Table 5.

TABLE 4. Measurements of *Spirorbis* n. sp. aff. *S. aberrans* Hohenstein, 1913 from Moenkopi unit WR 3-2. All measurements are in microns.

Embryonic Diameter	Length	Minimum Diameter	Maximum Diameter
220	---	---	---
300	---	---	---
240	---	---	---
320	---	---	---
340	---	---	---
---	800	520	740
---	1080	420	760
---	1200	340	540
---	820	540	1040
---	1460	380	600

TABLE 5. Measurements (above) of *Darwinula* sp. A from Moenkopi unit 1T (= MG-2). All measurements are in microns. Measurements (below) of *Darwinula* sp. A from Moenkopi unit WR 3-2.

Length	Height	Width	Notes
612	308	250	
700	350	250	
712	358	300	
725	400	275	
788	400	300	
630	300	225	
750	370	150	right valve only
725	375	275	
695	375	250	
650	312	275	
675	375	325	
695	350	262	
625	325	250	
600	312	225	
750	400	275	
612	325	250	
712	350	112	left valve only
662	325	250	
662	375	250	
688	350	250	
632	350	275	
575	300	262	
675	375	250	
762	408	425	

Length	Height	Width
588	250	200
350	175	112
675	288	288
650	300	275
550	312	250
725	375	175
662	325	250
725	375	175
600	300	200
750	388	175
638	350	275
625	325	262

Occurrence

Typical representatives are moderately common in the upper part of the basal unit of the Moenkopi Formation (WR 3-2 and MG-2).

Comparisons

Darwinula sp. A resembles in general outline the species *Darwinula subquadrata* Swain and Brown, 1971, from the Late Triassic of the Atlantic coastal plain. *Darwinula* sp. A also resembles *Darwinula* sp. aff. *D. elongata* Lunijak, 1958 of Wicker, 1957, but the Moenkopi species appears to be smooth whereas Wicker's specimens appear to be faintly reticulated. *Darwinula* sp. A also resembles *Darwinula lauta* Schleipher, 1966, from the "Lower" Triassic of the Soviet Union, differing in being more evenly arched dorsally and having less ventral overlap.

?*Darwinula* sp. B
Fig. 4E, 6B

Description

Valves subrectangular-oval in lateral view; dorsal margin slightly convex, ventral margin slightly concave; anterior and posterior margins rounded; greatest height at midpoint; right valve overlaps left slightly along ventral margin, not obvious elsewhere; in dorsal view, greatest

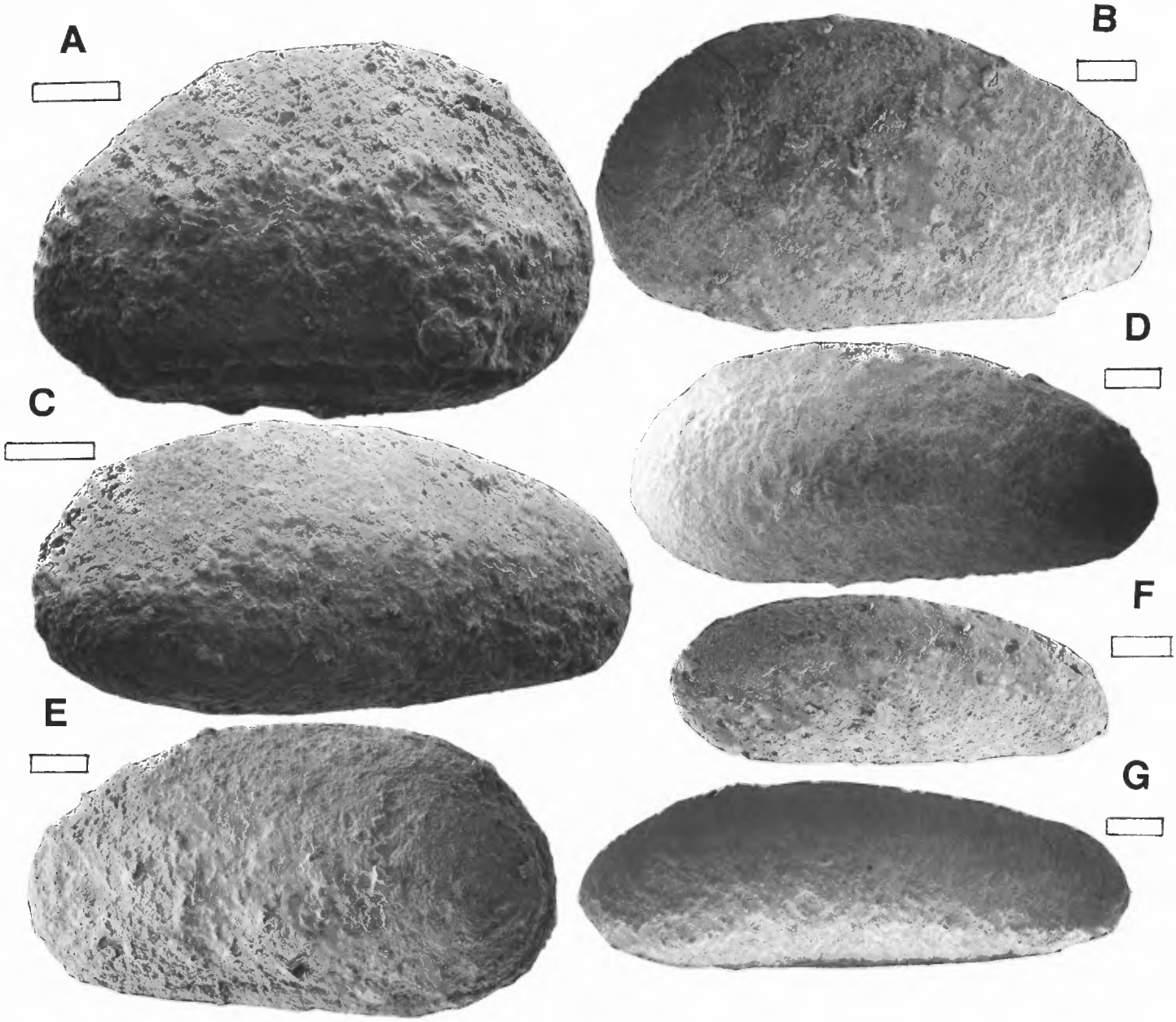

FIGURE 4. Ostracods from the Moenkopi Formation. A, *Darwinuloides* sp. A, left valve, side view, NMMNH P9519; B, *Darwinuloides* sp. B, right valve, side view, NMMNH P9521; C–D, *Darwinula* sp. A, right valves, side views, NMMNH P9511, P9512; E, *Darwinula* sp. B, left valve, side view, NMMNH P9514; F–G, *Gerdalia* sp., right valves, side views, NMMNH P9516, P9517. Bar scales equal 100 microns.

width near midpoint; anterior margin bluntly pointed, posterior bluntly rounded; muscle-scar field not found; surface smooth. Measurements of ?*Darwinula* sp. B (NMMNH P9513–P9514) are given in Table 6.

Occurrence

This species is moderately common in Moenkopi unit 7 (MG-7).

Comparisons

This species is very similar to a *Darwinula* species recently discovered in the Upper Triassic Sloan Canyon Formation of northeastern New Mexico, but lacks the pronounced valve overlap of that species. In these respects it also differs from the similar *Darwinula* spp. described by Sohn and Chatterjee (1979) from the Late Triassic of India. It is also similar to *Darwinula shensiensis* Zhong, 1964 from the Upper Triassic of China (Xu, 1988), again lacking the pronounced overlap of that species.

Genus *Gerdalia* Belousova, 1961
Gerdalia sp.
Figs. 4F–G, 6C

Description

Valves highly elongate, oval; length much greater than height in lateral view; dorsal margin slightly convex, ventral margin very slightly concave; anterior margin acutely rounded, posterior margin evenly rounded; greatest height at about midpoint; right valve overlaps left slightly on ventral and posterior margins; valves inflated in dorsal view with greatest width at point halfway from midpoint to posterior margin; anterior margin pointed, posterior margin acutely rounded; muscle scar field at midpoint; surface smooth. Measurements of *Gerdalia* sp. (NMMNH P9515-P9517) are given in Table 7.

Occurrence

Typical representatives are found in the upper part of unit 1 of the Moenkopi (sample WR 3-2) where it is uncommon.

TABLE 6. Measurements of *Darwinula* sp. B from Moenkopi unit MG-7. All measurements are in microns.

Length	Height	Width
725	400	375
775	412	275
725	388	338
762	400	325
775	412	262
762	375	350
825	425	300
675	350	238
800	400	275
625	325	250
700	388	280
700	400	325

Comparisons

Gerdalia sp. is very similar to *Gerdalia triassiana* Belousova, 1960, a species previously reported from the Lower Triassic of the Soviet Union. This species has also been recently reported from the Middle Triassic of China (Xu, 1988). The Moenkopi species also resembles a species of *Gerdalia* recently found in the Upper Triassic Sloan Canyon Formation of northeastern New Mexico.

TABLE 7. Measurements of *Gerdalia* sp. from Moenkopi unit WR 3-2. All measurements are in microns.

Length	Height	Width
888	375	300
900	350	275
900	325	325
862	275	300

Family Darwinuloididae Molostovskaja, 1979
Genus *Darwinuloides* Mandelstam, 1956
Darwinuloides sp. A
Figs. 4A, 6D

Description

Valves small, subtriangular in lateral view; dorsal margin strongly and evenly convex; ventral margin straight to slightly concave; anterior margin bluntly pointed, posterior margin broadly and evenly rounded; greatest height slightly posterior of midpoint; right valve overlaps left valve along ventral and central dorsal margins, strongest dorsally; valves inflated in dorsal view with greatest width near midpoint; anterior margin pointed, posterior margin rounded; muscle scar field slightly ventral of midpoint; surface smooth to slightly granular; steinkerns are more pointed anteriorly and widest slightly anterior of midpoint. Measurements of *Darwinuloides* sp. A (NMMNH P9518-P9519) are given in Table 8.

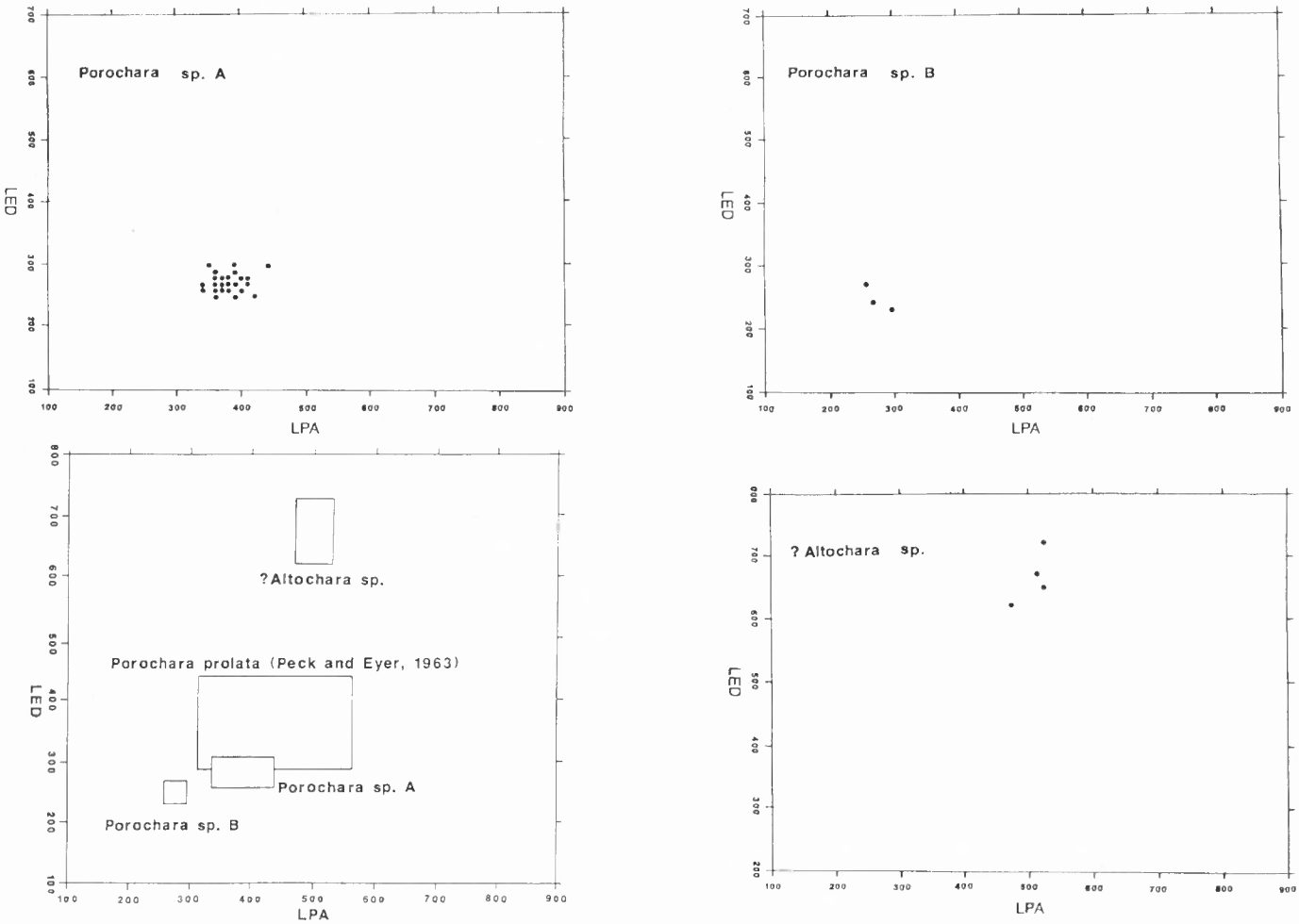

FIGURE 5. Scatter diagrams of Moenkopi charophytes and *Spirorbis*. For charophytes, LED = length of equatorial diameter, LPA = length of polar axis. All measurements are in microns.

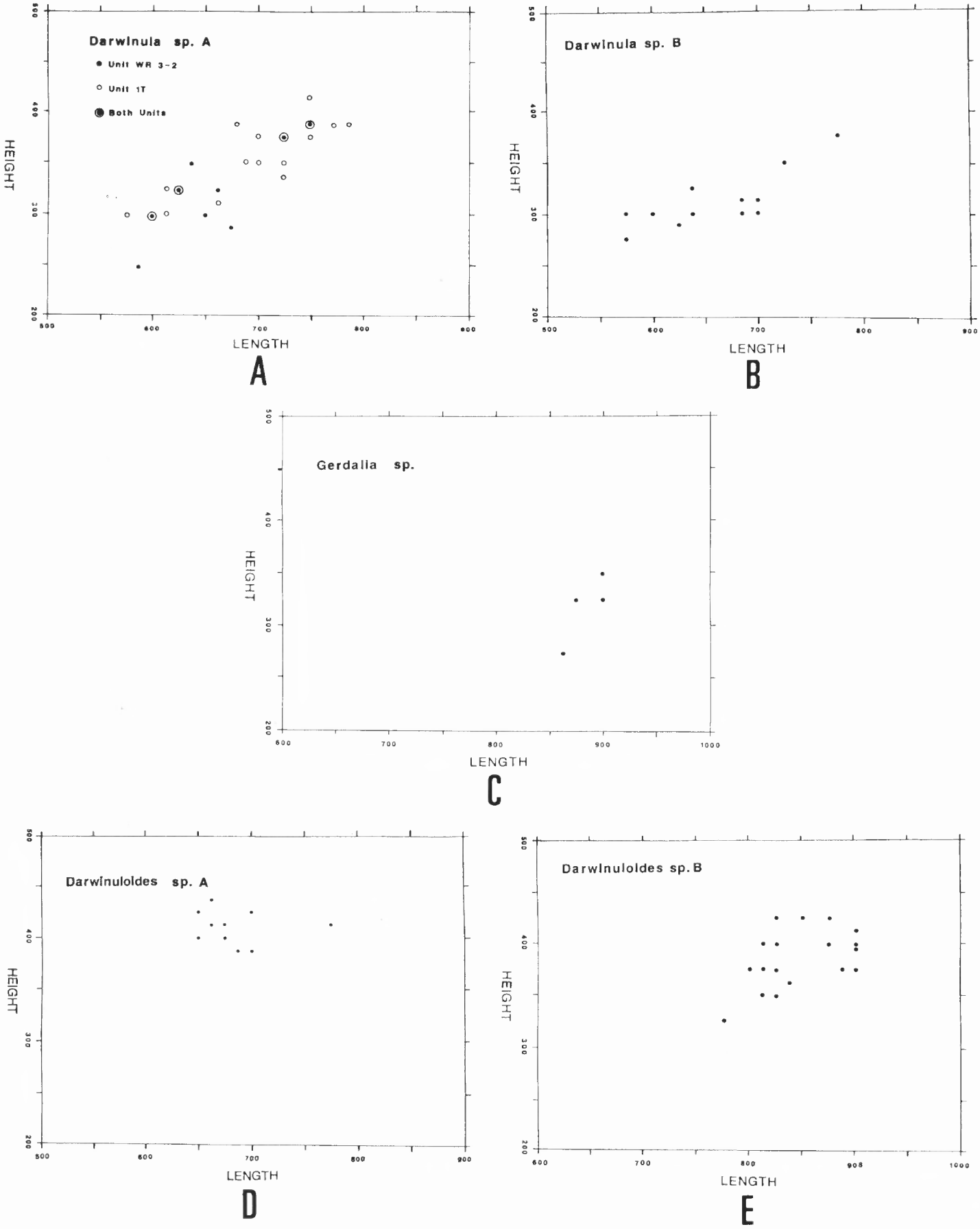

FIGURE 6. Scatter diagrams of Moenkopi ostracods. All measurements in microns.

TABLE 8. Measurements of *Darwinuloides* sp. A from Moenkopi unit 1T (=MG-2). All measurements are in microns.

Length	Height	Width
675	412	275
650	425	275
688	425	375?
675	438	250
670	412	275
638	400	275
675	395	275
688	388	275

Occurrence

This species is found in the basal unit of the Moenkopi (MG-1).

Comparisons

Darwinuloides sp. A resembles *Darwinuloides lii* Schleipher, 1966 from the Lower Triassic Baskunchak Series of the Caspian Depression in the USSR. It differs in being less pointed anteriorly and more rounded posteriorly, in having a less arched dorsal margin, and in being much larger. *Darwinuloides* sp. A differs from *Darwinuloides avroni* Schleipher, 1966 in being more evenly rounded dorsally and lacking the acutely angular dorsal margin of the later species. *Darwinuloides* sp. A is also very similar to an unnamed ostracod species from the middle Buntsandstein of Germany (Wicker, 1962, pl. 7, fig. h). *Darwinuloides* sp. A differs primarily in being slightly less blunt anteriorly and lacking the distinct dorsoanterior angulation of the latter species. A similar, though smaller species appears to occur in the lower Buntsandstein (Berger, 1961, pl. 2, fig. 5) under the name "Ostracod Nr. 12." These steinkerns are much less pointed anteriorly than is typical of *Darwinuloides* sp. A steinkerns.

***Darwinuloides* sp. B**
Figs. 4B, 6E

Description

Valves medium to small, elongate subtriangular in lateral view; dorsal margin strongly and evenly convex; ventral margin straight to slightly concave; anterior margin bluntly pointed, posterior margin evenly rounded; greatest height slightly posterior of midpoint; right valve overlaps left very slightly along ventral margin; valves slightly inflated in dorsal view with greatest width posterior of midpoint; anterior pointed, posterior acutely blunt; muscle scar field slightly posterior of midpoint; surface smooth to slightly granular. Measurements of *Darwinuloides* sp. B (NMMNH P9520–P9521) are given in Table 9.

Occurrence

Darwinuloides sp. B is uncommon in the basal Moenkopi unit (WR 3-2).

Comparisons

Darwinuloides sp. B is similar to an unnamed ostracod illustrated by Berger (1961, pl. 1, fig. 1, specimen on far right of figure), but differs in having its greatest height more posterior and in having a more rounded posterior end in side view.

CORRELATIONS

The microfossils of the Moenkopi of the Lucero uplift in central New Mexico support an Early to Middle Triassic age for the unit. This correlation is based on the similarity of the charophytes of the genus *Porochara* to *Porochara prolata*, on the similarity of the ostracods to Lower and Middle Triassic ostracods of Europe and the Soviet Union (particularly the presence of *Darwinuloides*), and on the similarity of the Moenkopi *Spirorbis* to *Spirorbis aberrans* from the Middle Triassic of central Europe.

TABLE 9. Measurements of *Darwinuloides* sp. B from Moenkopi unit WR 3-2. All measurements are in microns.

Length	Height	Width
875	325	325
825	425	275
825	400	312
825	350	325
900	412	288
815	375	275
900	388	275
838	362	300
900	400	250
812	350	288
875	400	250
812	400	275
825	375	275
875	425	288
825	375	250
800	375	275
850	425	225
775	325	275
900	375	300

Porochara sp. B from the Moenkopi is similar to *Porochara prolata* from the Holbrook Member of the same formation as noted earlier in this paper. It is also similar to *Porochara ukranica* Saydakovskiy from the Vetluka Series of the Donets Basin of the USSR. Saydakovskiy (1966) considered this unit to be of Early Triassic age. This genus is lacking in all other charophyte floras from the Upper Triassic of New Mexico (Kietzke, 1987). In Europe, this genus does not extend above the lower Keuper (Kozur and Reinhardt, 1969). In Upper Triassic floras of New Mexico, *Stellatochara* is the dominant genus (Kietzke, 1987). According to Tappan (1980), *Porochara* is absent in the interval from the Middle Triassic to the Middle Jurassic. While this apparent hiatus does not preclude the discovery of Late Triassic species of *Porochara*, it suggests the genus would be unusual in and probably a rare component of rocks of that age. Clearly, the presence of *Porochara* in the Moenkopi strata in New Mexico is strong evidence for its correlation with the Moenkopi of Arizona and suggests an Early to Middle Triassic age for the unit based on the known range of the genus elsewhere. It should be noted that the Holbrook Member of the Moenkopi is considered Middle Triassic (early Anisian) in age based on vertebrate evidence (Morales, 1987).

The ostracods also provide evidence for an Early to Middle Triassic age for the Moenkopi Formation in New Mexico. The most significant ostracod in this regard is the genus *Darwinuloides*, which first appears in the Middle Carboniferous and continues as a significant part of the freshwater ostracod fauna into the Triassic. It is present in the Lower and Middle Triassic of the Soviet Union (Schleifer, 1966) and central Europe (Berger, 1960; Wicker, 1962). The fauna from the middle Buntsandstein (Wicker, 1962, pl. 7, fig. h) is particularly interesting since it contains a species quite similar to *Darwinuloides* sp. A from the Moenkopi, as indicated previously. Wicker (1962, fig. 5) illustrated a species he identified as "?*Darwinuloides* sp. 805" from the Rhät of Germany. This species is illustrated in dorsal view and is highly inflated, unlike any other described species of the genus and does not belong to

this genus. An earlier illustration (Wicker, 1951, pl. 1, figs. 19a, b) includes an oblique view indicating a flattened ventral surface, further suggesting that it does not belong to *Darwinuloides*. *Darwinuloides* is thus restricted to rocks of Middle Carboniferous to Middle Triassic age. The presence of *Gerdalia* restricts its range to the Triassic.

The Moenkopi *Spirorbis* is very similar to *Spirorbis aberrans* from the Muschelkalk and lower Keuper (Middle Triassic) of Germany. This species has also been reported from the Polish highlands Muschelkalk fauna (Senkowiczowa, 1985). Although the tendency of some *Spirorbis* species to uncoil is known in species ranging from the Devonian to the Recent (Muller, 1982), the similarity of the Moenkopi species to *Spirorbis aberrans* in surface ornamentation, coiling direction and other morphologic features suggests a close relationship. Uncoiled *Spirorbis* species have not been found in New Mexico Upper Triassic faunas except for occasional aberrant individuals (Kietzke, 1987). The uncoiled *Spirorbis* from the Moenkopi thus adds some support for a Middle Triassic age.

In summary, the microfossil evidence suggests the Lucero uplift Moenkopi is correlative with the upper Moenkopi (Holbrook Member) of the Colorado Plateau and that both units are roughly correlative with the middle Buntsandstein to lower Keuper interval of Europe. Further refinement of Triassic microfossil biostratigraphy should allow greater refinement of these correlations in the future.

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