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# CALCAREOUS MICROFOSSILS FROM THE UPPER TRIASSIC OF NORTHEASTERN NEW MEXICO

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**Abstract**—The Chinle and Sloan Canyon formations of northeastern New Mexico have yielded a small fauna of calcareous microfossils including *Stellatochara*, *Altochara*, *Spirorbis*, *Darwinula* and Limnocytheriinae, genus and species indeterminate. These fossils are the first such fossils reported and illustrated from these formations. The fossils indicate aquatic environments low in turbidity and high in dissolved carbonate. The associated sedimentology suggests the upper shale member of the Chinle Formation was dominated by channel-abandoned "oxbow" lakes, while the Redonda Member of the Chinle and the Sloan Canyon Formation were more lacustrine. The association of *Darwinula*, *Spirorbis* and various charophytes is typical of late Paleozoic freshwater environments suggesting the freshwater Triassic ecosystem was not significantly disrupted by the terminal Paleozoic extinction event.

## INTRODUCTION

The Chinle Formation in east-central New Mexico and the Sloan Canyon Formation in northeastern New Mexico yield a low diversity, but common, microfauna and microflora consisting of two species of charophytes, two species of ostracodes and a single species of spirorbid worm. Although the Triassic microfauna of this region has been mentioned previously (Reiche, 1949; Breed, 1972; Stewart et al., 1972), this is the first detailed study and illustration of the taxa present. The abbreviation UNM refers to the University of New Mexico, Department of Geology.

The charophytes, ostracodes and spirorbid described in this paper were recovered from six localities in northeastern New Mexico, two in the upper shale member of the Chinle Formation, three in the Redonda Member of the Chinle Formation and one in the Sloan Canyon Formation (Fig. 1, Appendix 1). The occurrence of the spirorbid and the charophytes are new records for the Chinle Formation. Freshwater ostracodes have been reported from the Chinle Formation, but have never been identified or illustrated.

## PREVIOUS STUDIES

The charophyte flora of the Triassic of North America is limited to *Stellochara prolata* Peck and Eyer, 1963, from the Moenkopi Formation of Arizona and Colorado. "*Gyrogonites*," first described by Peck (1934) from the upper part of the Chugwater Group of Wyoming, was thought to be of Triassic age. Later, Peck (1953) and Peck and Eyer (1963) revised this age determination to Jurassic. Tappan (1980) mentioned unidentified charophytes from the Triassic of Wyoming. The Peck (1934) reference may be the one alluded to by Tappan. The identification of *Stellatochara* Horn af Rantzien, 1954, in this paper is the second record of the genus in the Triassic of North America, and the identification of *Altochara* Saydakovskiy, 1968, is a new record for the North American Triassic.

Outside North America, the record of Triassic charophytes is somewhat more complete. Triassic charophytes have been reported from the Triassic of Sweden (Brotzen, 1950; Horn af Rantzien, 1953, 1954), Germany (Krause, 1938; Reinhardt, 1963; Kozur and Reinhardt, 1969), the U.S.S.R. (Saydakovskiy, 1962, 1966, 1968; Kiselevskiy, 1967) and possibly Zaire (Groves, 1933).

The only Triassic nonmarine spirorbids reported from North America are from the Upper Triassic of Pennsylvania (Wanner, 1921). Other spirorbids have been reported from North America (Proborski, 1954), but only in marginal marine rocks. They have also been reported from marine Triassic rocks of Germany (Haack, 1923) and Czechoslovakia (Ziegler and Michalik, 1980).

The first ostracodes reported from freshwater Upper Triassic sediments of North America are *Candona*? *rogersi* and *Candona emmonsi* by Jones (1862, p. 126) from the "Lower Mesozoic Estherian shales" of Virginia and North Carolina, and *Candona rogersi* from the Upper Triassic of Pennsylvania. Sohn (1964, p. 40) noted that *Candona*? *rogersi* and *Candona*? *emmonsi* are "probably decalcified films of ostracod shells, and therefore unidentifiable." However, Swain and Brown (1972) restudied the Triassic Ostracoda of the Atlantic Coastal Plain and transferred *Candona*? *rogersi* to the genus *Darwinula*. These authors also described another species of *Darwinula* (*D. subquadrata*)

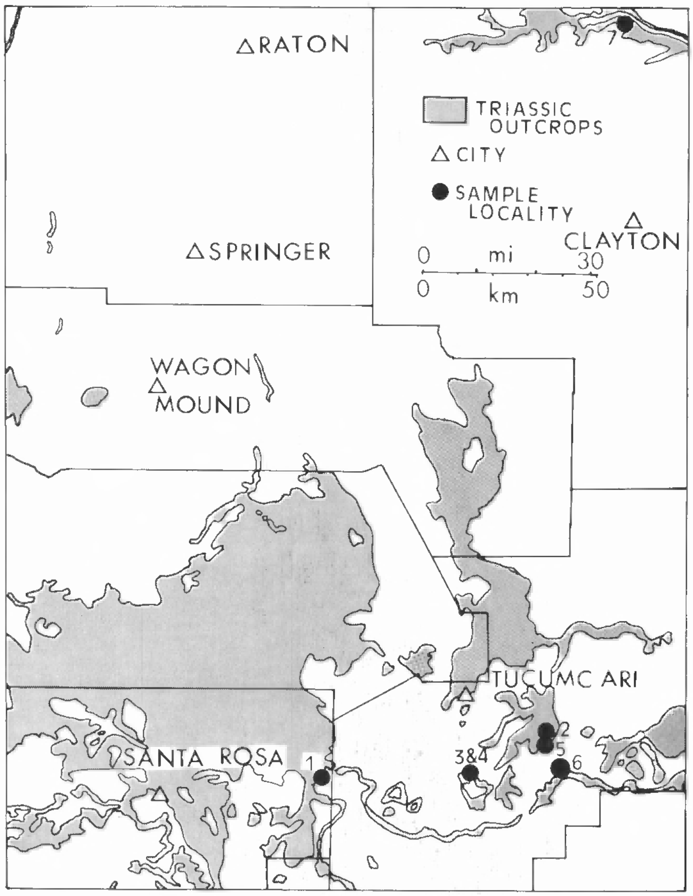



FIGURE 1. Locality map. Locality numbers: 1. Bull Canyon (upper shale member), 2. Revuelto Creek (upper shale member), 3. Trackway (upper shale member), 4. Trackway (Redonda Member), 5. Revuelto Creek (Redonda Member), 6. "shark tooth hill," 7. Sloan Canyon (see Appendix 1 for more detailed information).

from the Cumnock Formation (Newark Supergroup) of North Carolina, and assigned four additional forms to *Darwinula* without specific designations. Sohn (1964) listed the genera *Hungarella, Paracypris*? and *Darwinula*? from the freshwater Triassic deposits of Dodo Creek, Alaska. Sohn (written commun., 1987) noted the *Darwinula*? from Alaska should be considered a suspect occurrence. These reports are the sum of our knowledge of North American Triassic freshwater ostracodes outside of the Southwest.

Our knowledge of Chinle freshwater Ostracoda is even more limited. Reiche (1949) reported unornamented ostracodes from a small Chinle outlier near Los Ojuelos Spring on the Tome Grant about five km south of the Cordova Ranch, T6N, R4E, Torrance County, New Mexico. Stewart et al. (1972) mentioned an identification of Chinle ostracodes by Peck. A check by the author with the U.S. Geological Survey indicated that Peck was unable to identify the ostracodes (I. G. Sohn, written commun., 1983). In the same report, Sohn noted that he has identified *Darwinula* sp. from the Dinosaur Canyon Member of the Moenave Formation in Coconino County, Arizona. Sohn (written commun., 1987) noted this specimen may no longer exist, and thus the occurrence is suspect. Sohn (written commun., 1983) further noted that "I collected freshwater ostracodes represented by a species of *Darwinula* and an as yet undetermined genus near the base of the Chinle Formation in New Mexico." Breed (1972, p. 19) observed that "ostracods and branchiopods have been collected in the Chinle Formation in Utah and New Mexico, but have not been reported from Arizona." There are several other records of unidentified and undescribed, probably marine ostracodes from the Virgin Limestone Member of the Moenkopi Formation in Utah (e.g., Proborski, 1954).

## STRATIGRAPHY

The stratigraphy of the Triassic rocks of east-central New Mexico was reviewed by Lucas et al. (1985b) and that of northeastern New Mexico by Lucas et al. (1987) and will not be repeated here. The samples processed for microfossils included samples from the Santa Rosa Formation, the Cuervo Member of the Chinle Formation, the upper shale member of the Chinle Formation, the Redonda Member of the Chinle Formation and the Sloan Canyon Formation. Only the latter three units have thus far yielded microfossils. The Chinle and Sloan Canyon formations are considered to be uppermost Carnian to lower Norian in age by Lucas et al. (1985b, 1987).

## PALEOECOLOGY

Two approaches are used to evaluate the paleoecology of the Triassic of northeastern New Mexico as it relates to the microflora and microfauna. The first involves examination of the sampled intervals in terms of their sedimentology and associated megaflora and megafauna to obtain a generalized, large-scale paleoenvironmental setting for the sample sites. The second approach involves utilization of recent analogues of the microflora and microfauna to refine better specific environments in the sampled intervals.

### Upper shale member, Chinle Formation

The microfossils from the upper shale member of the Chinle Formation are restricted to the mudstones, carbonate grit and conglomerate beds immediately overlying channel sandstones. These beds are interpreted as representing small ponds and overbank sands in abandoned channels, somewhat analogous to modern oxbow lakes. This interpretation is based on the following evidence:

1. The mudstones above the channels are fissile and contain numerous calcareous concretions and lenses of sandy, carbonate grit and conglomerate beds. The conglomerates are composed of carbonate concretions and carbonate grit with minor amounts of sand and fragmentary vertebrate fossils suggestive of locally-derived overbank deposits formed during flooding.

2. The shales contain numerous coprolites and locally abundant fish debris as might be expected in a quiet aquatic environment. Other vertebrate remains are rare in the shales and usually restricted to the overbank deposits or the channels. The coprolites of the Chinle Formation have been attributed to amphibians (Case, 1922; Ash, 1978) or fish and phytosaurs (Lucas et al., 1985c). Their variable morphology suggests multiple origins. The freshwater sharks might also be potential candidates, particularly for those coprolites with spiral indentations.

3. Although unionid bivalves are locally abundant in the channels (Kues, 1985), they are rare in the mudstones above the channels. Gastropods are locally common in these mudstones, probably due to a greater tolerance for turbidity and poorer oxygenation in a quiet pond environment.

4. Modern charophytes are found in fresh and brackish waters with a decided preference for mineralized, nutrient-poor, alkaline waters (Olsen, 1944). They are also characteristic of marginally brackish waters (Tappan, 1980). Titus (1983) found modern macrophytic, nonmarine algae, including *Chara,* are most abundant in waters 1.0–5.5 m deep. Although this is a depth range for life sites of charophytes, their oogonia can float and may come to rest at a considerable distance from their sites of origin, hence their occasional occurrence in normal marine environments (Tappan, 1980).

5. Modern Ostracoda of the genus *Darwinula* are considered to be indicative of fresh to brackish water environments (Swain and Brown, 1972). Modern *Darwinula* are found primarily in large lakes with sandy to muddy bottoms (Hoff, 1942). Neustrueva (1977, p. 455) considered fossil *Darwinula* to be "typical of shallow-water, warm, moderately-mineralized lakes with sufficient content of calcium carbonate" and characteristic of "considerably mineralized lakes of semi-arid and arid climatic zones" during the late Permian and Early Triassic in the U.S.S.R.

6. The *Treatise on invertebrate paleontology* (Moore, 1962) listed *Spirorbis* as being found in freshwater and marine environments. Wanner (1926, p. 23) thought the association of *Spirorbis inexpectatus* and *Darwinula rogersi* indicated "a shallow, brackish, or salt-water lake or a tidal estuary" based on the supposed marine affinities of the genera *Spirorbis* and *Darwinula*. Modern polychaetes, including *Spirorbis*, are primarily marine, although some are known from brackish and, rarely, freshwater environments (Ushakov, 1955). Ushakov (1955) and Hartman (1966) observed that modern marine spirorbids are often attached to algae or various hardgrounds, including stones, bivalves, crab carapaces and each other. Population structures of modern marine *Spirorbis* show marked seasonal variations, and individuals rarely live longer than 15–18 months (Seed et al., 1981). Modern freshwater polychaete species usually occur either in relic marine environments (e.g., Lake Baikal) or in environments in close proximity to the sea. This distribution suggested to Pennack (1953) that they were a relatively recent invader of freshwater environments. The Chinle data and my own unpublished data on freshwater early Permian environments suggest that the modern invasion may represent a second incursion by this group into freshwater environments.

In summary, the combination of sedimentology and associated fauna point to a quiet lacustrine environment. The position above channel fills and the locally-derived overbank conglomerate beds suggest an abandoned channel environment such as an oxbow lake.

### Redonda Member, Chinle Formation

The microfauna, ostracodes and rare *Spirorbis* of the Redonda Member of the Chinle Formation are typically found in fissile shales associated with abundant fish scales or branchiopods. Some ostracodes have also been observed in thin sections of thin siltstone beds. The Redonda Member is considered to be a shallow, lacustrine, possibly playa-like environment for the following reasons:

1. Bedding of the unit is laterally continuous and fine-grained, suggesting a low-energy, subaqueous environment.

2. The sedimentary structures include burrows, trails, dinosaur footprints, ripplemarks and mudcracks, all suggesting shallow water and mudflat environments.

3. The locally abundant fish scales and branchiopods also suggest a shallow, possibly locally ephemeral, lacustrine to pond environment.

4. The microfauna consists of rare spirorbids and occasional *Darwinula,* suggesting a similar but less favorable environment for the microfauna than the upper shale member.

In summary, the Redonda Member of the Chinle Formation is thought to represent a shallow, possibly ephemeral lake environment. A modern analogue would be the playa-lake environment.

### Sloan Canyon Formation

The Sloan Canyon Formation has not been directly examined by the author, and the descriptions of the sedimentology are those of Mr. A. Hunt who also provided the samples. The Sloan Canyon Formation is said to resemble generally the Redonda Member of the Chinle Formation, but has a greater preponderance of green rather than red sediments that are less continuous laterally and finer grained overall. Thin beds of laminated limestone occur in the upper part of the formation, and fish-rich bone beds indicate local ponding conditions. The presence of *Darwinula* and charophytes indicates a carbonate-rich, aquatic environment. The absence of *Spirorbis* suggests a restriction on the environment, perhaps a lack of suitable attachment sites.

## SYSTEMATIC PALEONTOLOGY

The author believes some of the microfauna described here represent new genera and species. However, these forms are not formally named because publications of relatively limited distribution, such as guidebooks, are not considered to be the correct vehicle for naming new species. The fossils are illustrated and described in informed nomenclature in order to document their presence. Comparisons with North American and some foreign species are included for reference.

Division **Charophyta** Migula, 1890
Class **Charophyceae** Smith, 1938
Family **Porocharaceae** Grambast, 1962
Subfamily **Porocharacoideae** Grambest, 1962
Genus ***Altochara*** Saydakovskiy, 1968
***Altochara*** sp.
Fig. 2C, D

**Description**—Goniotite small, ellipsoidal to subovoidal, prolate spheroidal to subprolate; five cells spiraling counterclockwise, forming eight low ridges in side view; base slightly flattened in side view, composed of the intersection of the five cells around a large pentagonal pore; apex characoid with cells evenly joined about a minute pentagonal pore. Measurements are given in Table 1.

**Occurrence**—*Altochara* sp. is found rarely in the upper shale member of the Chinle Formation at Revuelto Creek (locality 2, Appendix 1).

**Comparisons**—*Altochara* sp. differs from *A. delicata* Saydakovskiy (1968) in being much smaller, less spherical and less flask-shaped, and in having fewer spiral bands in side view. It most closely resembles *A. continua* Saydakovskiy, 1968 and *A. lipatoae* (Kiselevskiy, 1967), but differs in being somewhat more spherical, having a smaller summit pore and a greater equatorial angle. The striking physical resemblance and concurrent geologic and geographic ranges of *A. continua* and *A. lipatoae* suggest possible synonomy.

TABLE 1. Measurements of *Altochara* sp. (in mm). Abbreviations: PA = length of polar axis, LED = greatest equatorial diameter, AND = distance from apical pole to LED, ANI = anisopolarity index (AND/PA), ISI = isopolarity index (PA/LED).

| Spec. No. | PA | LED | AND | ANI | ISI |
|---|---|---|---|---|---|
| Revuelto Creek Loc. upper shale member, Chinle Fm. | | | | | |
| 1 | 0.38 | 0.32 | 0.18 | 48 | 111 |
| 2 | 0.38 | 0.32 | 0.22 | 58 | 120 |
| 3 | 0.37 | 0.34 | 0.16 | 44 | 107 |
| 4 | 0.39 | 0.36 | 0.21 | 54 | 110 |
| 5 | 0.44 | 0.34 | 0.25 | 57 | 129 |
| 6 | 0.38 | 0.36 | 0.20 | 53 | 105 |
| $\overline{X}$ | 0.39 | 0.34 | 0.20 | 56 | 114 |

Subfamily **Stellatocharoideae** Grambast, 1962
Genus ***Stellatochara*** Horn af Rantzien, 1954
***Stellatochara*** sp.
Fig. 2A, B

**Description**—Gyrogonite small, ellipsoidal to subovoidal, prolate to subprolate; ornamented by five spiral cells; in side view, 9–10 spiral cell-ridges apparent; apical view with the five spiral cells prolonged (but not inflated) into short beaks and arranged around a slightly-raised, small, pentagonal pore; basal view with the five spiral cells arranged around a large pentagonal opening. Measurements are given in Table 2.

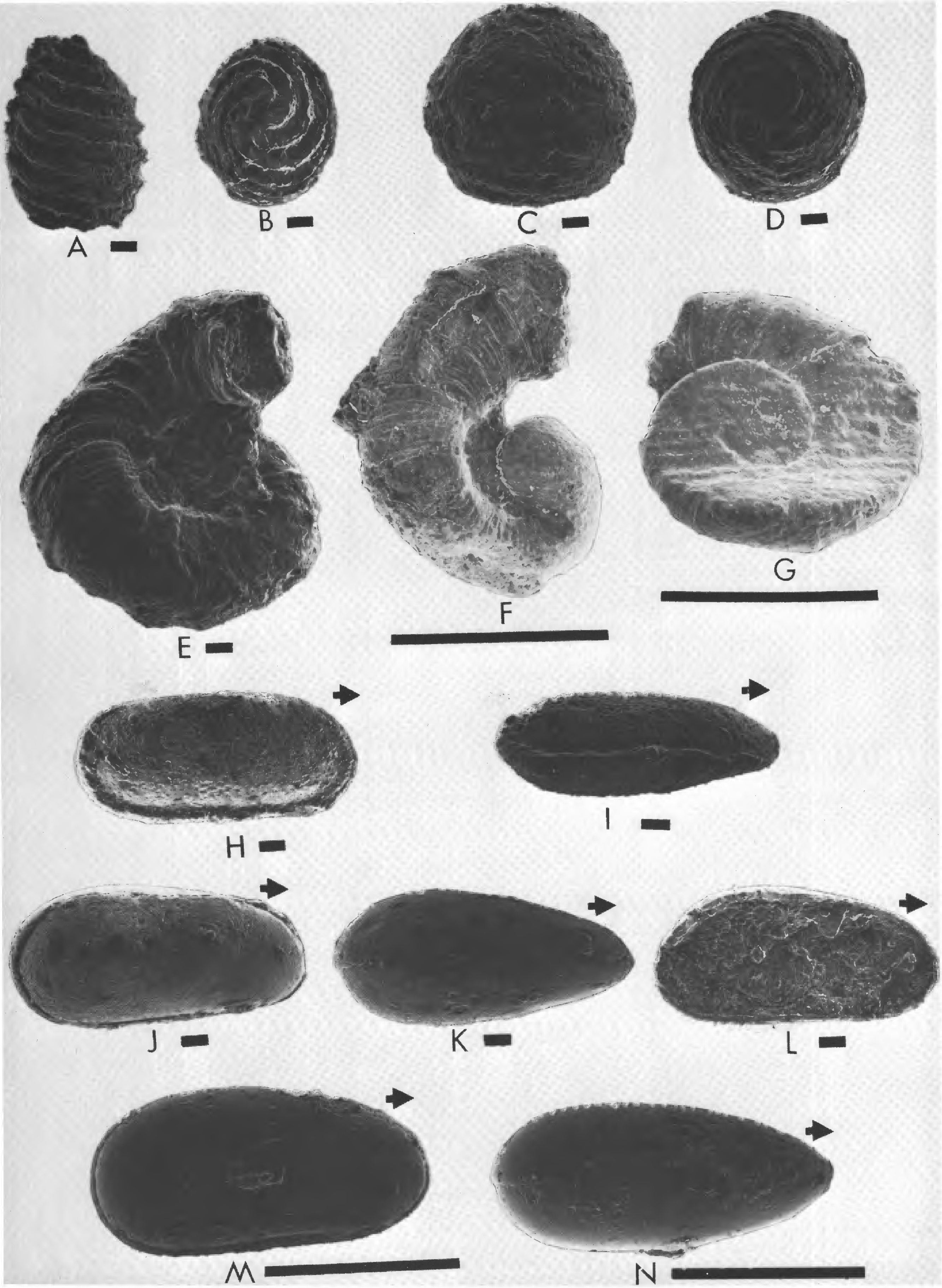
**Occurrence**—*Stellatochara* sp. is found in the upper shale member of the Chinle Formation at Revuelto Creek and in the Sloan Canyon Formation in northeastern New Mexico (localities 2 and 7: Appendix 1). Horn af Rantzien (1956) indicated a range of Pennsylvanian to Jurassic for this genus. Tappan (1980) gave a range of Triassic to Cretaceous for *Stellatochara*. The type species is *S. kimmeridgensis* (Madler) from the Jurassic of Germany.

**Comparisons**—As noted by Peck and Eyer (1963), the genera *Stellatochara* Horn af Rantzien, 1954 and *Porochara* Madler, 1955 are difficult to differentiate. The major difference is the presence of protruding apical spiral-cell tips in *Stellatochara* and their absence in *Porochara* (Horn af Rantzien, 1954; Tappan, 1980). Examination of the Chinle specimens indicates this feature is not always evident in crushed or worn specimens, and a suite of specimens would be needed to differentiate the genera with certainty.

*Stellatochara* sp. differs from *S. prolata* described by Peck and Eyer (1963) from the Moenkopi of Arizona and Colorado in having a much better developed apical beak, nine to ten spiral cells visible in side view, more angular cells and in being slightly larger. It is smaller than *S. lipatovae* (Saydakovskiy, 1968) and *S. piriformis* Kozur and Reinhardt, 1969. It is larger and less elongated than *S. bulgarica* Saydakovskiy, 1968 and *S. germanica* Kozur and Reinhardt, 1969. It has more spiral cells in side view than *S.*? *thuringica* Kozur and Reinhardt, 1969, *S. schneiderae* Saydakovskiy, 1962 and *S. donbassica* Demin, 1956. It is less spherical and has a less well developed apical beak than *S. subspherica* Kozur and Reinhart, 1969. It differs from *S. sellingii* Horn af Rantzien, 1954 in having fewer and more angular spiral cells

TABLE 2. Measurements of *Stellatochara* sp. (in mm). Abbreviations: PA = length of polar axis, LED = greatest equatorial diameter, AND = distance from apical pole to LED, ANI = anisopolarity index (AND/PA), ISI = isopolarity index (PA/LED).

| Spec. No. | PA | LED | AND | ANI | ISI |
|---|---|---|---|---|---|
| Revuelto Creek Loc. - upper shale member, Chinle Fm. | | | | | |
| 1 | 0.36 | 0.31 | 0.20 | 54 | 118 |
| 2 | 0.36 | 0.31 | 0.18 | 50 | 116 |
| 3 | 0.38 | 0.30 | 0.22 | 58 | 125 |
| 4 | 0.39 | 0.30 | 0.22 | 56 | 130 |
| 5 | 0.34 | 0.26 | 0.17 | 50 | 131 |
| 6 | 0.34 | 0.26 | 0.18 | 53 | 131 |
| 7 | 0.38 | 0.28 | 0.24 | 63 | 136 |
| 8 | 0.39 | 0.29 | 0.18 | 46 | 134 |
| 9 | 0.42 | 0.30 | 0.20 | 48 | 140 |
| 10 | 0.39 | 0.35 | 0.26 | 67 | 111 |
| $\overline{X}$ | 0.38 | 0.30 | 0.20 | 54 | 127 |
| Sloan Canyon Loc. - upper shale member, Chinle Fm. | | | | | |
| Spec. No. | PA | LED | AND | ANI | ISI |
| 1 | 0.44 | 0.38 | 0.24 | 54 | 116 |
| 2 | 0.42 | 0.34 | 0.20 | 48 | 124 |
| 3 | 0.43 | 0.37 | 0.23 | 53 | 116 |
| 4 | 0.42 | 0.40 | 0.28 | 67 | 105 |
| $\overline{X}$ | 0.43 | 0.37 | 0.24 | 56 | 115 |


A
B
C
D
E
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K
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M
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in side view and in having a flatter base. *Stellatochara* sp. most resembles *S. hoellvicensis* Horn af Rantzien, 1954 and *S. maedleri* Horn af Rantzien, 1954 but is slightly larger than either species.

It should be noted that Peck (1957) thought that Horn af Rantzien (1954) had reversed the orientation of *Stellatochara*. However, later workers (e.g., Saydakovskiy, 1962; Kozur and Reinhardt, 1969; Tappan, 1980) believed the original orientation is correct, and that orientation is followed here.

Phylum **Annelida** Lamarck, 1809
Class **Polychaetia** Grube, 1850
Order **Sedentarida** Lamarck, 1818
Family **Serpulidae** Burnmeister, 1837
Subfamily **Spirorbinae** Chamberlin, 1919
Genus ***Spirorbis*** Daudin, 1800
***Spirorbis*** sp.
Fig. 2E, F, G

**Description**—Attached coils form an enlarged embryonic chamber; coiled portion usually of one to one and one-half coils, rarely one-half coil, in a clockwise direction; uncoiled portion either extends in a linear fashion or rises above the coiled portion; rarely, the unattached portion may reattach itself; surface of shell marked by numerous growth lines averaging about 0.02 to 0.01 mm apart, some more pronounced than others; attachment surface more or less flat, covering all or part of the basal surface; some attachment surfaces marked by parallel grooves produced by the relief of the original plant-attachment surface; rarely are specimens attached to other *Spirorbis* specimens; width of attachment surfaces indicate plant parts as narrow as 0.25 mm were utilized; some attachment surfaces were originally wrapped completely around plant (?)stems. Measurements are given in Table 3.

**Occurrence**—*Spirorbis* sp. is abundant in the upper shale member of the Chinle Formation at Bull Canyon and Revuelto Creek (localities 1 and 2: Appendix 1). It is rare in the Redonda Member of the Chinle Formation at the trackway locality at Mesa Redonda and at "shark tooth hill" (localities 4 and 6: Appendix 1).

**Comparisons**—Modern genera of the Spirorbinae are separated on the basis of both soft and hard parts (Ushakov, 1955; Hartman, 1966). *Spirorbis* is separated from *Paradexiospira* Caullery and Mesnil, 1897 and *Dexiospira* Caullery and Mesnil, 1897 by having a sinistrally-coiled tube. The genus *Spirorbis* can be separated from *Laeospira* Caullery and Mesnil, 1897 by having an erect distal end of the tube. The genera *Paralaeospira* Caullery and Mesnil, 1897 and *Laedora* St. Joseph, 1894 are only separable from *Spirorbis* on the basis of soft parts and thus may not be separable in fossil forms.

Most previous records of Triassic *Spirorobis* known to the author refer to marine species with the exception of *S. inexpectus* Wanner, 1921 described by Wanner (1921, p. 36) as being attached to "surfaces of uncertain nature, or sometimes shells" from the Triassic of Pennsylvania. Wanner (1926) noted *S. inexpectus* Wanner, 1921 on the shells of the freshwater bivalve *Diplodon yorkensis* Wanner, 1921. *Spirorobis* sp. differs from *S. inexpectatus* Wanner in being smaller in size, lacking retractively-radial, surface folds, and in having a generally non-planar unattached growth phase. *Spirorobis* sp. differs from *S. zimmermanni* Haack, 1972, a marine species from the Triassic of Germany, in having a shorter uncoiled portion which does not zigzag as in the later species. Specimens described as ?*S.* sp. Ziegler and Michalik, 1980 from the marine Triassic of Czechoslovakia are poorly preserved, but appear to be much larger than the Chinle species. *Spirorobis phyetaena* Bronimann and Zaninetti, 1972 from Iran, Austria and Italy is based on thin-section material and not readily comparable with the Chinle materials, although it appears to have proportionally smaller embryonic chambers and a greater height to base ratio. Unidentified and unillustrated spirorbids have been reported from marginal marine units in the "Virgin Valley Formation" (= member of the Moenkopi Formation) by Proboski (1954), associated with marine invertebrates including *Aviculopecten*. The specimens from the upper shale member at Revuelto Creek differ from those from Bull Canyon in that they often lack a solid basal attachment surface.

TABLE 3. Measurements of *Spirorbis* sp. (in mm). Abbreviations: Max. = maximum, Diam. = diameter, Apert. = aperture, Embry. = embryonic, No. = number.

| Spec. No. | Max. Diam. | Height | Coil Width | Apert. Diam. | Embry. Diam. | Coil No. | Uncoiled Length |
|---|---|---|---|---|---|---|---|
| Revuelto Creek - upper shale member, Chinle Formation | | | | | | | |
| 1 | 0.62 | 0.14 | 0.25 | 0.16 | ---- | 1.5 | 0.16 |
| 2 | 0.62 | 0.09 | 0.26 | ---- | ---- | 1.0 | ---- |
| 3 | 0.51 | 0.18 | 0.25 | 0.14 | 0.14 | 1.5 | ---- |
| 4 | 0.72 | 0.14 | 0.27 | 0.18 | 0.18 | 1.5 | ---- |
| 5 | 0.56 | 0.15 | 0.25 | 0.16 | ---- | 1.25 | ---- |
| 6 | 0.68 | 0.14 | 0.22 | 0.12 | 0.14 | 1.5 | 0.16 |
| 7 | 0.66 | 0.10 | 0.30 | 0.22 | 0.20 | 1.25 | ---- |
| 8 | 0.62 | 0.13 | 0.20 | 0.18 | 0.18 | 1.25 | ---- |
| 9 | 0.66 | 0.16 | 0.25 | 0.22 | 0.16 | 1.5 | 0.06 |
| 10 | 0.60 | 0.16 | 0.26 | 0.22 | 0.20 | 1.25 | 0.14 |
| $\bar{X}$ | 0.62 | 0.17 | 0.25 | 0.18 | 0.17 | | 0.13 |
| Bull Canyon - upper shale member, Chinle Formation | | | | | | | |
| 1 | 0.70 | 0.14 | 0.24 | 0.20 | 0.06 | 2.0 | 0.22 |
| 2 | 0.56 | 0.16 | 0.26 | 0.26 | 0.16 | 1.5 | 0.26 |
| 3 | 0.56 | 0.18 | 0.23 | 0.22 | 0.20 | 1.25 | 0.08 |
| 4 | 0.90 | 0.13 | 0.26 | 0.22 | 0.18 | 1.25 | ---- |
| 5 | 0.74 | 0.16 | 0.28 | 0.26 | 0.20 | 1.0 | ---- |
| 6 | 0.60 | 0.16 | 0.28 | 0.26 | 0.10 | 0.75 | ---- |
| 7 | 0.74 | 0.22 | 0.26 | 0.24 | 0.16 | 1.0 | ---- |
| 8 | 0.35 | 0.14 | 0.20 | 0.19 | 0.18 | 0.25 | ---- |
| 9 | 0.57 | 0.18 | 0.22 | 0.16 | 0.18 | 1.0 | 0.18 |
| 10 | 0.47 | 0.13 | 0.22 | 0.17 | 0.17 | 0.75 | 0.20 |
| $\bar{X}$ | 0.62 | 0.16 | 0.24 | 0.22 | 0.16 | | 0.19 |

Subclass **Ostracoda** Latreille, 1802
Order **Podocopida** Müller, 1894
Superfamily **Darwinulacea** Brady and Norman, 1889
Family **Darwinulidae** Brady and Norman, 1889
Genus ***Darwinula*** Brady and Robertson, 1885
***Darwinula*** sp.
Fig. 2J–N

**Description**—Valves reniform, elongate oval in lateral view; dorsal margin slightly arched, ventral margin slightly concave; anterior less tumid than posterior; greatest height slightly posterior of midpoint; left valve overlaps right on ventral, anterior and posterior margins, overlap pronounced; posterior half of valve highly inflated in dorsal view; anterior pointed, posterior rounded; overlap in ventral view shows a visible rim on the left valve on which the right valve-margin rests; muscle-scar field in approximate mid-point of valves; surface smooth to very faintly punctuate. Measurements of selected specimens of *Darwinula* sp. are given in Table 4.

**Occurrence**—*Darwinula* sp. is abundant in the upper shale member of the Chinle Formation at Bull Canyon, Revuelto Creek and less

FIGURE 2. Microfossils of the Chinle Formation. A, B, *Stellatochara* sp., UNM, 9536, lateral view (A) and apical view (B), upper shale member, Revuelto Creek locality. C, D, *Altochara* sp., UNM 9537, lateral view (C) and apical view (D), upper shale member, Revuelto Creek locality; E, F, G, *Spirorbis* sp., UNM 9535 (E), upper surface, UNM, 9542 (F), upper surface, UNM, 9543 (G), attachment surface, upper shale member, Bull Canyon locality. H, I, Limnocytheriinae, genus and species indeterminate, UNM 9541, right lateral view (H) and ventral view (I), upper shale member, Bull Canyon locality. J, K, *Darwinula* sp., UNM 9539, right lateral view (J) and dorsal view (K), upper shale member, Bull Canyon locality. L, *Darwinula* sp., UNM, 9540, interior (filled) view, left valve, upper shale member, Bull Canyon locality. M, N, *Darwinula* sp., UNM 9538, left lateral view (M) and dorsal view (N), Redonda Member, shark tooth hill locality. Small bar = 50 μ, large bar = 500 μ, arrow points to anterior.

TABLE 4. Measurements of *Darwinula* sp. (in mm).

| Spec. No. | Length | Height | Width |
|---|---|---|---|
| Revuelto Creek - upper shale member, Chinle Formation | | | |
| 1 | 0.75 | 0.40 | 0.30 |
| 2 | 0.67 | 0.36 | 0.27 |
| 3 | 0.69 | 0.34 | 0.29 |
| 4 | 0.66 | 0.33 | 0.24 |
| 5 | 0.74 | 0.37 | 0.30 |
| 6 | 0.73 | 0.36 | 0.31 |
| 7 | 0.73 | 0.36 | 0.31 |
| 8 | 0.72 | 0.33 | 0.32 |
| 9 | 0.64 | 0.37 | 0.28 |
| $\bar{X}$ | 0.70 | 0.36 | 0.29 |
| "shark tooth hill" - Redonda Member, Chinle Formation | | | |
| 1 | 0.90 | 0.48 | 0.25 (right valve) |
| 2 | 0.98 | 0.55 | 0.25 (left valve) |
| 3 | 0.92 | 0.50 | 0.45 |
| 4 | 0.92 | 0.48 | 0.42 |
| 5 | 0.90 | 0.45 | 0.40 |
| 6 | 0.68 | 0.30 | 0.28 |
| 7 | 0.98 | 0.52 | 0.42 |
| 8 | 0.95 | 0.48 | 0.40 |
| 9 | 0.62 | 0.32 | 0.30 |
| $\bar{X}$ | 0.87 | 0.45 | 0.38 |
| Sloan Canyon - Sloan Canyon Formation | | | |
| 1 | 0.87 | 0.45 | 0.10 (left valve) |
| 2 | 0.60 | 0.32 | 0.15 (right valve) |
| 3 | 0.78 | 0.45 | 0.28 (right valve) |
| 4 | 0.85 | 0.42 | 0.30 |
| 5 | 0.55 | 0.30 | 0.22 |
| 6 | 0.62 | 0.32 | 0.31 |
| 7 | 0.70 | 0.35 | 0.18 (left valve) |
| 8 | 0.75 | 0.40 | 0.18 (left valve) |
| 9 | 0.80 | 0.38 | 0.06 (left valve) |
| 10 | 0.65 | 0.38 | 0.08 (left valve) |
| 11 | 0.95 | 0.50 | 0.12 (right valve) |
| $\bar{X}$ | 0.74 | 0.39 | 0.28 |
| Bull Canyon - upper shale member, Chinle Formation | | | |
| 1 | 0.53 | 0.27 | 0.15 (left valve) |
| 2 | 0.36 | 0.19 | 0.16 |
| 3 | 0.53 | 0.26 | 0.22 |
| 4 | 0.55 | 0.30 | 0.27 |
| 5 | 0.55 | 0.28 | 0.28 |
| 6 | 0.54 | 0.24 | 0.24 |
| 7 | 0.67 | 0.33 | 0.28 |
| 8 | 0.70 | 0.34 | 0.30 |
| 9 | 0.56 | 0.30 | 0.24 |
| 10 | 0.54 | 0.28 | 0.25 |
| $\bar{X}$ | 0.55 | 0.28 | 0.25 |

common at the trackway locality at Mesa Redonda (localities 1, 2 and 3: Appendix 1). They are also found less commonly in the Redonda Member of the Chinle Formation at "shark tooth hill," Revuelto Creek and the trackway locality at Mesa Redonda (localities 4, 5 and 6: Appendix 1). They are also abundant in the Sloan Canyon Formation in northeastern New Mexico (locality 7: Appendix 1).

**Comparisons**—*Darwinula* sp. differs from *D. rogersi* (Jones, 1862) in having a less tumid anterior, a concave ventral margin and a pronounced left-over-right overlap. It differs from *D. subquadrata* Swain and Brown, 1972 in having a gently arched rather than a subparallel dorsal margin, pronounced left-over-right valve overlap and a concave rather than flat ventral margin. As noted by Sohn (1969), the number of Triassic species of *Darwinula* worldwide is substantial. The present species differs from most of the previously described species in its pronounced posterior inflation, concave ventral margin and the nature of the left-over-right overlap. *Darwinula* sp. most closely resembles the specimens illustrated by Sohn and Chatterjee (1979) from the Upper Triassic of India. Unfortunately, these specimens were recovered from coprolites and are abraded and broken, making close comparisons tenuous.

**Discussion**—Examination of Table 4 indicates considerable difference in size between the various populations of *Darwinula* from the Chinle and Sloan Canyon formations. The specimens from the Sloan Canyon Formation and those from the upper shale member of the Chinle Formation at Revuelto Creek are about the same size; those from the upper shale member at Bull Canyon are smaller; and those from the Redonda Member at "shark tooth hill" are larger. Whether the Bull Canyon or "shark tooth hill" specimens represent different species or ecotypic variants has not been resolved.

The left-over-right valve overlap of the present species is the opposite of that indicated in the *Treatise on invertebrate paleontology* (Moore, 1961). However, as noted by Sohn and Chatterjee (1979), this feature has been noted in both modern and fossil *Darwinula* species and is of subgeneric importance at best. This feature is variable within the various populations of *Darwinula* sp. and may serve to separate species. Markhovan (1963, p. 30) noted that although the left valve is typically the larger, "in the type species the right valve is larger."

Superfamily **Cytheracea** Baird, 1850
Family **Cytheriidae** Baird, 1850
Subfamily **Limnocytheriinae** Sars, 1925
**Genus and species indeterminate**
Fig. 2H, I

**Description**—Subrectangular, elongate-oblong in lateral view; dorsal margin slightly convex, ventral margin nearly straight, anterior and posterior margins evenly rounded, anterior margin slightly less tumid than posterior margin; left valve slightly overlaps right valve, especially on ventral and dorso-posterior margins; surface marked by a weak single, shallow, subvertical sulcus, which is centered slightly posterior of the center of the valves; valves are inflated posterior of this sulcus and less so anterior of the sulcus; valve edges are impressed ventrally; surface finely reticulated with the coarsest reticulations anterior and posterior of the central carapace, reticulations about 0.01–0.02 mm; dimorphism, hinge structure and muscle-scar pattern unknown. Measurements of the four specimens of this species recovered from the upper shale member at Bull Canyon and the single specimen from the Redonda Member at "shark tooth hill" are given in Table 5.

**Occurrence**—This limnocytheriine is a rare component of the fauna in the upper shale member of the Chinle Formation at Bull Canyon and in the Redonda Member of the Chinle Formation at "shark tooth hill" (localities 1 and 6: Appendix 1).

**Comparisons**—The ostracodes *Theriosynoecum* Branson, 1936, *Metacypris* Brady, 1970, *Bisulcocypris* Pinto and Sanguinetti, 1958, *Cytheridella* von Daday, 1905 and *Gomphocythere* Wicher, 1957 are a complex of freshwater Mesozoic to Recent genera of Ostracoda of controversial relationships and generic definition (Pinto and Sanguinetti, 1958, 1962; Markhoven, 1963; Branson, 1966). The form discussed here is referred questionably to this group since it lacks the highly

TABLE 5. Measurements of Limnocytheriinae, genus and species indeterminate (in mm).

| Spec. No. | Length | Height | Width |
|---|---|---|---|
| Bull Canyon - upper shale member, Chinle Formation | | | |
| 1 | 0.60 | 0.30 | 0.24 |
| 2 | 0.60 | 0.31 | 0.27 |
| 3 | 0.64 | 0.32 | --- |
| 4 | --- | 0.28 | 0.20 |
| $\bar{X}$ | 0.61 | 0.30 | 0.24 |
| "shark tooth hill" - Redonda Member, Chinle Formation | | | |
| 1 | 0.55 | 0.25 | 0.20 |

inflated posterior (sexual dimorphism) and surface nodes that are typical of most genera of this group. It most closely resembles the Jurassic (Todilto Limestone, New Mexico) species *"Metacypris" todiltoensis* described by Swain (1946). Pinto and Sanguinetti (1962) were uncertain of the position of this species and called it genus incertus. These specimens differ from *"Metacypris" todiltoensis* in having slightly concave ventral margins, less tumid anterior margins, slight left-over-right valve overlap and pronounced indentation of the ventral margins.

**Discussion**—SEM examination of this limnocytheriine indicates the reticulation of the valves is a structural feature, not an artifact of preservation.

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## REFERENCES

Ash, S. R., 1978, Coprolites; *in* Ash, S. R., ed., Geology, paleontology, and paleoecology of a Late Triassic lake, western New Mexico: Brigham Young University, Geology Studies, v. 25, pp. 69–73.

Bilan, W., 1969, Characeae from Keuper sediments of the Kolbark District: Rocznik Polskiego Towarzystwa Geologicznego [Annales de la Societe Geologique de Pologne], v. 39, pp. 433–454.

Breed, C. W., 1972, Invertebrates of the Chinle Formation: Museum of Northern Arizona, Bulletin 47, pp. 19–22.

Branson, C. C., 1966, Freshwater ostracode genus *Theriosynoecum:* Oklahoma Geology Notes, v. 26, pp. 87–96.

Bronimann, P. and Zaninetti, L., 1972, On the occurrence of the serpulid *Spirorbis* Daudin [Annelidae, Polychaetia, Sendentarida] in thin sections of Triassic rocks of Europe and Iran: Rivista Paleontologie [Milan], v. 78, pp. 67–90.

Brotzen, F., 1950, The geological results from borings at Hollviken. Part 2, Lower Cretaceous and Trias: Sveriges Geologiska Undersökning, v. 505, pp. 4–48.

Case, E. C., 1922, New reptiles and stegocephalians from the Upper Triassic of western Texas: Carnegie Institution of Washington, Publication 321, 84 pp.

Grambast, L., 1963, Charaphytes du Trias, État des connaissances a'quises, intérêt phylogénétique et stratigraphique: Bureau Recherches Géologiques Minieres, Mémoires 15, pp. 567–569.

Groves, J., 1933, Pars 19: Charophyta.; *in* Jongmans, W., ed., Fossilium catalogus II: Plantae: Berlin, W. Junk, pp. 1–74.

Haack, H. W. von, 1923, Zur Stratigraphie und Fossilfuhrung des Mittleren Buntsandsteins in Norddeutschland: Jahrbuch der Preussische Geologische Landesanstalt, v. 42, pp. 560–594.

Hartman, O., 1966, Polychaeta, Myzostomidae and Sedentaria of Antarctica: American Geophysical Union, Antarctic Research Series, Publication 1414, v. 7, 158 pp.

Hoff, C. C., 1942, The ostracods of Illinois, their biology and taxonomy: Illinois Biological Monographs, v. 14, 196 pp.

Horn af Rantzien, H., 1953, De geologiska resultanten fram borrningarna rid Hollviken, Charophyta from the Middle Trias of the boring Hollviken, II, preliminary account: Sveriges Geologiska Undersokning, v. 47, pp. 1–16.

Horn af Rantzien, H., 1954, Middle Triassic Charophyta of South Sweden: Opuscula Botanik Societas Botanik Lundenss, v. 1, pp. 5–81.

Horn af Rantzien, H., 1956, An annotated check-list of genera of fossil Charophyta: Micropaleontology, v. 2, pp. 343–356.

Jones, T. R., 1862, North American lower Mesozoic Cypridae; *in* Jones, T. R., ed., A monograph of the fossil Estheriae: Appendix: London, Palaeontographical Society, pp. 123–127.

Kiselevskiy, F. Y.,' 1967, Novye dannye o nizhnetriasovykh kharofitakh Prikaspiyskoy vpadiny [New data on the Lower Triassic charophytes of the Precaspian basin]: Voprosy Geologii Yuzhnogo Ural i Povolzh'ya, Saratovsk Universitet, v. 4, pp. 37–44.

Kozur, H. and Reinhardt, P., 1969, Charophyten aus dem Muschelkalk und dem unteren Keuper Mecklenburgs und Thüringens: Deutsche Akademie der Wissenschaften, Berlin, Montsberichte, v. 11, pp. 369–386.

Krause, P. G., 1938, Die Tiefbohrung Tilsit-Waldhof: Jahrbuch Preussische Geologie Landesanstalt, v. 59, pp. 370–422.

Kues, B. S., 1985, Non-marine molluscs from the Chinle Formation, Dockum Group (Upper Triassic) of Bull Canyon, Guadalupe County, New Mexico: New Mexico Geological Society, Guidebook 36, pp. 185–196.

Lucas, S. G., Hunt, A. P. and Hayden, S. N., 1987, The Triassic system in the Dry Cimarron Valley, New Mexico, Colorado and Oklahoma: New Mexico Geological Society, Guidebook 38.

Lucas, S. G., Hunt, A. P. and Kietzke, K. K., 1985[a], *Neocalamites* forest in the Upper Triassic of Bull Canyon, New Mexico: New Mexico Geological Society, Guidebook 36, pp. 8–9.

Lucas, S. G., Hunt, A. P. and Morales, M., 1985[b], Stratigraphic nomenclature and correlation of Triassic rocks of east-central New Mexico: a preliminary report: New Mexico Geological Society, Guidebook 36, pp. 171–185.

Lucas, S. G., Oakes, W. and Froehlich, J. W., 1985[c], Triassic microvertebrate locality, Chinle Formation, east-central New Mexico: New Mexico Geological Society, Guidebook 36, pp. 205–212.

Markhovan, F. P. C. M. von, 1963, Post-Paleozoic Ostracoda: their morphology, taxonomy, and economic use: New York, Elsevier Publishing Company, v. 1, 204 pp. v. 2, 478 pp.

Moore, R. C., ed., 1961, Treatise on invertebrate paleontology, part Q, Arthropoda 3, Crustacea, Ostracoda: Lawrence, Geological Society of America and University of Kansas, 442 pp.

Moore, R. C., 1962, Treatise on invertebrate paleontology, Part W, Miscellanea: Lawrence, Geological Society of America and University of Kansas, 259 pp.

Neustrueva, I. Y., 1977, Ostracod biofacies in Paleozoic and Mesozoic lake sediments of the USSR: International Symposium on ostracodes, Proceedings, no. 6, pp. 451–458.

Olsen, S., 1944, Danish Charophyta, chronological, ecological, and biological investigations: Botanik Skrifter, v. 3, 740 pp.

Peck, R. E., 1934, Late Paleozoic and early Mesozoic Charophyta: American Journal of Science, series 5, v. 27, pp. 49–55.

Peck, R. E., 1953, Fossil charophytes: Botanical Review, v. 19, pp. 209–227.

Peck, R. E., 1957, North American Mesozoic Charophyta: U.S. Geological Survey, Professional Paper 294-A, 44 pp.

Peck, R. E. and Eyer, J. A., 1963, Pennsylvanian, Permian, and Triassic Charophyta of North America: Journal of Paleontology, v. 37, pp. 835–844.

Pennack, R. W., 1953, Freshwater invertebrates of the United States: New York, Ronald Press Company, 769 pp.

Pinto, I. D. and Sanguinetti, Y. T., 1958, *Bisulcocypris,* a new Mesozoic genus and preliminary note about its relation with *Metacypris* and allied forms: Sociedad Brasiliera Geologia, Boletim, v. 7, pp. 75–90.

Pinto, I. D. and Sanguinetti, Y. T., 1962, A complete revision of the genera *Bisulcocypris* and *Theriosynoecum* (Ostracoda) with the world geographical and stratigraphical distribution (including *Metacypris, Elpidium, Gomphocythere,* and *Cytheridella*): Rio Grande do Sul Universidad, Escola de Geologia, Publicaceon Especial 4, 115 pp.

Proborski, S. J., 1954, Virgin Formation (Triassic) of the St. George, Utah area: Geological Society of America Bulletin, v. 65, pp. 971–1006.

Reiche, P., 1949, Geology of the Manzanita and north Manzano Mountains, New Mexico: Geological Society of America Bulletin, v. 60, pp. 1183–1212.

Reinhardt, P., 1963, Charophyten aus dem unterkeuper Thuringens: Geologue, v. 12, pp. 224–229.

Saydakovskiy, L. Y., 1962, Kharofity iz triasovykh pestrotsvetov Bor'shogo Donbassa [Charophyta from the Triassic mottled rocks of the Greater Donbas]: Doklady Akademiya Nauk SSSR, v. 146, pp. 1141–1144.

Saydakovskiy, L. Y., 1966, Biostratigrafiya triasovykin otlozheniy yuga Russkoy platformy [Biostratigraphy of the Triassic deposits in the south of the Russian Platform]: Trudy Geologicheskiy Institut Akademiya Nauk SSSR, no. 143, pp. 93–144.

Saydakovskiy, L. Y., 1968, Kharofity iz triasa prikasplyskoy vpadiny [Charophyta from the Triassic of the Caspian Depression]: Paleontologicheskiy Zhurnal, v. 1968, pp. 95–110.

Seed, R., Elliot, M. N., Broaden, P. J. S. and O'Conner, R. J., 1981, The composition and seasonal changes among the epifauna associated with *Ficus serratus* in Strangford Lough, Northern Ireland, U.K.: Cahiers de Biologie Marine, v. 22 pp. 243–266.

Sohn, I. G., 1964, Significance of Triassic ostracodes from Alaska and Nevada: U.S. Geological Survey, Professional Paper 501-D, pp. 40–42.

Sohn, I. G., 1969, Triassic ostracodes from Makhtesh Ramon, Israel: Israel Geological Survey, Bulletin 44, 71 pp.

Sohn, I. G. and Chatterjee, S., 1979, Freshwater ostracodes from Late Triassic coprolite in central India: Journal of Paleontology, v. 53, pp. 578–586.

Stewart, J. H., Poole, F. G. and Wilson, R. F., 1972, Stratigraphy and origin of the Chinle Formation and related Upper Triassic strata in the Colorado Plateau region: U.S. Geological Survey, Professional Paper 690, 336 pp.

Swain, F. M., 1946, Middle Mesozoic nonmarine Ostracoda from Brazil and New Mexico: Journal of Paleontology, v. 20, pp. 543–555.

Swain, F. M. and Brown, P. M., 1972, Lower Cretaceous, ?Jurassic, and Triassic Ostracoda from the Atlantic Coastal region: U.S. Geological Survey, Professional Paper 795, 55 pp.

Tappan, H., 1980, The paleobiology of plant Protista: San Francisco, W. H. Freeman and Co., 1028 pp.

Titus, J. E., 1983, Submerged macrophyte vegetation and depth distribution in Chenango Lake, New York: Torrey Botanical Club, Bulletin, v. 110, pp. 176–183.

Ushakov, P. V., 1955, Polychaeta of the Far East Seas of the U.S.S.R.: Izdatel'stvo Akademii Nauk SSSR, Moskva-Leningrad [keys to the fauna of the U.S.S.R.], no. 56, 432 pp. [translation from original by Jean Salkind, 1965, the Israel Program for Scientific Translations, 419 pp.].

Wanner, H. E., 1921, Some faunal remains from the Trias of York County, Pennsylvania: Academy of Natural Sciences, Philadelphia, Proceedings, v. 73, pp. 25–37.

Wanner, H. E., 1926, Some additional faunal remains from the Trias of York County, Pennsylvania: Academy of Natural Sciences, Philadelphia, Proceedings, v. 78, pp. 21–28.

Ziegler, V. and Michalik, J., 1980, Late Triassic serpulids (Annelida, Polychaetia, Sedentarida) in the western Carpathians: Geologicky Zbornik-Geologica Carpathica, v. 31, pp. 627–640.

## APPENDIX 1: LOCALITY LIST

**1.** Bull Canyon locality: NW1/4 and NE1/4 NW1/4, sec. 28, T9N, R26E, Guadalupe County, New Mexico. Stratigraphic position: Equivalent to unit 3C (Lucas et al., 1985b, fig. 1), upper shale member, Chinle Formation. Associated megaflora and megafauna: *Neocalamites*, Gastropoda, Bivalvia, coprolites, fish fragments, Amphibia, Reptilia (Kues, 1985; Lucas et al., 1985a, c). Microfauna: *Spirorbis* sp., *Darwinula* sp., Limnocytheriinae, genus and species indeterminate.

**2.** Revuelto Creek locality: NW1/4 NE1/4 SE1/4, sec. 16, T10N, R33E, Quay County, New Mexico (UNM locality 1089). Stratigraphic position: upper shale member, Chinle Formation. Associated megafauna: fish fragments, Amphibia, Reptilia. Microflora and microfauna: *Stellatochara* sp., *Altochara* sp., *Spirorbis* sp., *Darwinula* sp.

**3.** Trackway locality: Mesa Redonda, SW1/4 NW1/4 and NW1/4 SW1/4, sec. 27, T9N, R31E, Quay County, New Mexico. Stratigraphic position: Units 1 and 2 (A. Hunt, unpublished section), upper shale member, Chinle Formation. Associated megafauna: coprolites, Reptilia. Microfauna: *Darwinula* sp.

**4.** Trackway locality: Mesa Redonda, SW1/4 NW1/4 and NW1/4 SW1/4, sec. 27, T9N, R31E, Quay County, New Mexico. Stratigraphic position: Unit 9 (A. Hunt, unpublished section), Redonda Member, Chinle Formation. Associated megafauna: unknown. Microfauna: *Spirorbis* sp., *Darwinula* sp.

**5.** Revuelto Creek locality: Upper Revuelto Creek, NE1/4 SW1/4 SW1/4, sec. 14, T9N, R33E, Quay County, New Mexico. Stratigraphic position: middle Redonda Member, Chinle Formation. Associated megafauna: *Cyzicus* (*Lioestheria*) sp., coprolites, fish fragments. Microfauna: *Darwinula* sp.

**6.** "Shark tooth hill" locality: SW1/4 NE1/4, sec. 28, T98N, R34E, Quay County, New Mexico. Stratigraphic position: fish bed, Redonda Member, Chinle Formation. Associated megafauna: fish fragments, Reptilia. Microfauna: *Darwinula* sp., Limnocytheriinae, genus and species indeterminate, *Spirorbis* sp.

**7.** Sloan Canyon locality: NW1/4, sec. 12, T35N, R35E, Union County, New Mexico. Stratigraphic position: Sloan Canyon Formation. Associated megafauna: freshwater-shark fragments, fish, Amphibia, Reptilia. Microflora and microfauna: *Stellatochara* sp., *Darwinula* sp.