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NONMARINE MOLLUSCS FROM THE CHINLE FORMATION, DOCKUM GROUP (UPPER TRIASSIC), OF BULL CANYON, GUADALUPE COUNTY, NEW MEXICO

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INTRODUCTION

The Chinle Formation is an extensive and varied sequence of continental red beds deposited in fluvial, lacustrine, deltaic and floodplain environments across the southwestern United States from Utah and Arizona to north-central Texas. The Chinle is best known for its sporadic but sometimes spectacular assemblages of vertebrates, including early dinosaurs, thecodonts, therapsids, labyrinthodont amphibians and fishes, and for a diverse Late Triassic flora. Although nonmarine molluscs are locally common in the Chinle, they have been relatively little studied; nearly all references are isolated descriptions of a few species or passing mention of molluscs in papers dealing with other aspects of Chinle geology. In this paper, one gastropod and several unionid bivalve taxa are described and discussed from Chinle exposures in Bull Canyon, eastern Guadalupe County, New Mexico. All measured and illustrated specimens considered here are reposited in the University of New Mexico Department of Geology paleontology collection and bear UNM catalog numbers.

LOCATION AND GEOLOGIC SETTING

The Chinle Formation is exposed widely over the Colorado Plateau, reaching thicknesses of more than 500 m in northeastern Arizona and northwestern New Mexico (Stewart et al., 1972). In eastern New Mexico, the Chinle is considered to be the middle formation of the Dockum Group, underlain by the Santa Rosa Sandstone and overlain by the Redonda Formation (Kelley, 1972). Here, the Chinle is divided, in ascending order, into a lower shale member, Cuervo Sandstone Member and upper shale member and has a total thickness of about 300 m. This sequence has been interpreted as representing lacustrine and prodeltaic facies (lower and upper shale members) and thin deltaic and fluvial–deltaic deposits (Cuervo Sandstone Member) associated with the restricted Tucumcari basin (McGowen et al., 1983).

The molluscs described here were collected in 1983 and 1984 from an extensive system of arroyos and badlands developed in the upper shale member of the Chinle at Bull Canyon, southeast of Newkirk, Guadalupe County, New Mexico (Fig. 1). Several locations within a restricted area around the common point of secs. 20, 21, 28 and 29, T9N, R26E, yielded molluscs. All of the specimens discussed here were collected from five localities along the west side of Bull Canyon Creek (Fig. 2). Stratigraphically, the interval sampled is somewhat below the middle of the upper shale member, 65 to 75 m below the Chinle–Redonda contact.

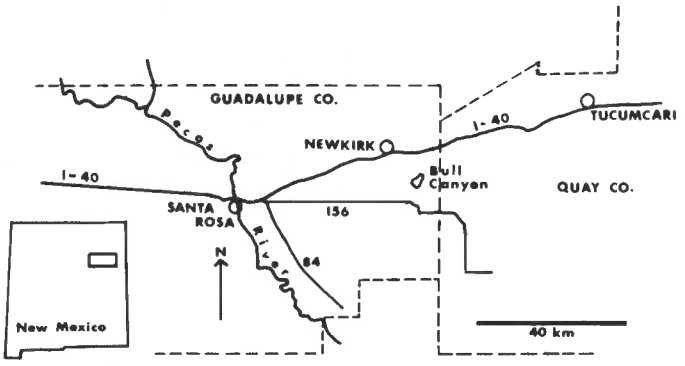


FIGURE 1. Location map of Bull Canyon in eastern Guadalupe County, New Mexico.

DISTRIBUTION OF THE MOLLUSCS

Locality 1

Most of the unionid specimens collected or examined during this study were in a ledge-forming, thin (1–2 m), dark red to locally bright gray-green, fine- to medium-grained, well-indurated, quartzose sandstone containing local low-angle planar crossbeds (Locality 1, Fig. 2). This sandstone unit is exposed along the side of a low (5 m) slope for some distance along the western edge of a small tributary of Bull Canyon Creek and represents deposition in a distal-braided-alluvial-plain stream (Kues et al., 1984). Together with the unionids, the unit contained a complete phytosaur skull (*Rutiodon*), part of a second phytosaur skull, numerous bone fragments and teeth, a few gastropods and plant-stem impressions. The unionids from this unit consist almost entirely of

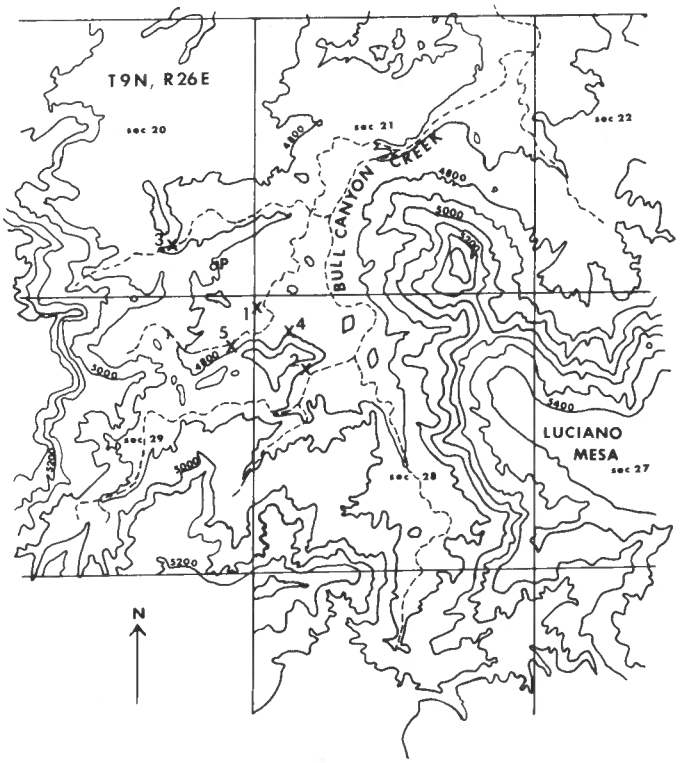


FIGURE 2. Detailed map of part of Bull Canyon, showing five localities from which molluscs were collected from the upper shale member of the Chinle. Locality P is site of phytosaur skull. Numbers along contour lines are elevations in feet; the squares crossing the map are section lines, with each section being 1 mile (1.6 km) wide. Base map drawn from Ima NW USGS quadrangle (U.S. Geological Survey, 1968, 1:24,000).

articulated valves, prohibiting the examination of the internal shell structures. The shells are coarsely recrystallized and somewhat corroded; thus, the fine detail of the external ornamentation is not preserved well. The specimens are, however, essentially complete and are not significantly distorted, allowing reasonably accurate measurement of shell dimensions.

The specimens that were collected from Locality 1 had eroded from the sandstone and were typically found as isolated shells. Large numbers of shells were also preserved within the body of the sandstone unit as well, and in some blocks of sandstone float that had eroded from the main body down a small slope. Shells occur in high concentrations in two thin (less than 10 cm) stratigraphic horizons separated by about 8 cm. The shells of the upper unionid bed were visible at the top of the sandstone unit where it is exposed as a relatively flat ledge for some distance along the side of Bull Canyon Creek (Fig. 3). The unionids visible on this surface were distributed in several local concentrations, each containing more than 100 individuals within an area of about 10 m^2 (Fig. 4). Most of the unionids in this upper horizon were articulated and oriented with the long axis vertical within the sandstone. However, because these specimens were visible only in transverse, cross-sectional views, an "anterior-end-down" position (i.e., the unionid living position) could not be demonstrated. Within each concentration of shells, about 10 to 20% were isolated, disarticulated valves or articulated valves that were open ventrally and sometimes contained part of the valve of another individual between them (Fig. 5).

The lower horizon produced most of the unionid-rich blocks of sandstone that had eroded down the slope (Figs. 6–7). The density of bivalves in some of these blocks reached more than 1000 shells exposed in a square meter of surface area, far greater than the density of shells in the upper horizon. All of the unionids in the lower horizon consisted of articulated shells and nearly all were oriented vertically. As with the unionids of the upper horizon, it was not possible to determine if the anterior or posterior end of the shells was pointed downwards. Field observations suggest that most, perhaps all, of the isolated unionid specimens collected from Locality 1 were derived from the lower horizon by fragmentation and erosion of the displaced blocks.

My original inspection in the field of the directional orientation of the shells in the two beds suggested that there was no pronounced orientation to the shells of the upper bed, but a rather definite alignment of shells in the lower bed. This observation was documented by members of a University of New Mexico paleontology class under the direction of Spencer Lucas, who measured the orientation of numerous shells in both beds. Rose diagrams showing plots of the direction of the ventral margins of the vertical shells indicated a strong alignment to the northeast (vector mean = 45°; vector magnitude = 91%) for the shells in the lower bed, and a much less pronounced alignment to the south for the shells of the upper bed (vector mean = 178°; vector magnitude = 24%). These data indicate a significant difference in the pattern of shell alignment between the two beds.

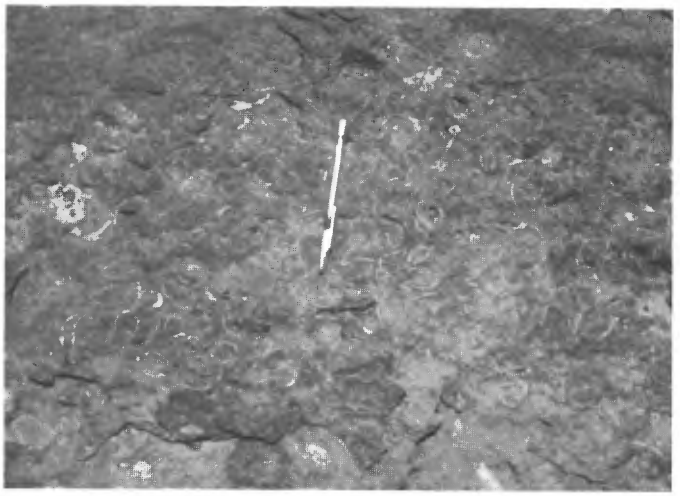


FIGURE 4. A concentration of unionids within the sandstone unit at Locality 1. This is part of the upper unionid bed; note lack of alignment of shells (pen is 17 cm long).

The predominantly vertical orientation and articulated preservation of the shells imply that little postmortem transport had occurred, and suggest that these two thin unionid beds probably represent short-lived, local assemblages rather than long-term concentrations of shells. Data on more specimens and a better understanding of the orientation of individual shells within the sandstone are required before aspects of their paleoecology can be interpreted with confidence. Because there have been virtually no detailed studies of Triassic unionid paleoecology, it is not possible to compare the occurrences reported here with other records in Upper Triassic strata elsewhere in the Southwest.

Localities 2–5

Molluscs were also obtained from a limestone-conglomerate facies about 3 m thick that is above the sandstone unit at Locality 1 and is separated from it by 3 to 5 m of brownish-red mudstone. The fossil-bearing unit is well exposed at the base of the mesas immediately west



FIGURE 3. View (to southeast) of upper surface of sandstone unit near Locality 1; a tributary to Bull Canyon Creek to left. Unionids shown in Figures 4 and 5 are exposed in flat area near center of photo.



FIGURE 5. Close view of several cross sections through unionid shells in upper bed at Locality 1. Most of the shells are vertically oriented and open ventrally. The two open shells at the end of the pen have become interlapped (pen cap is 6 cm long).

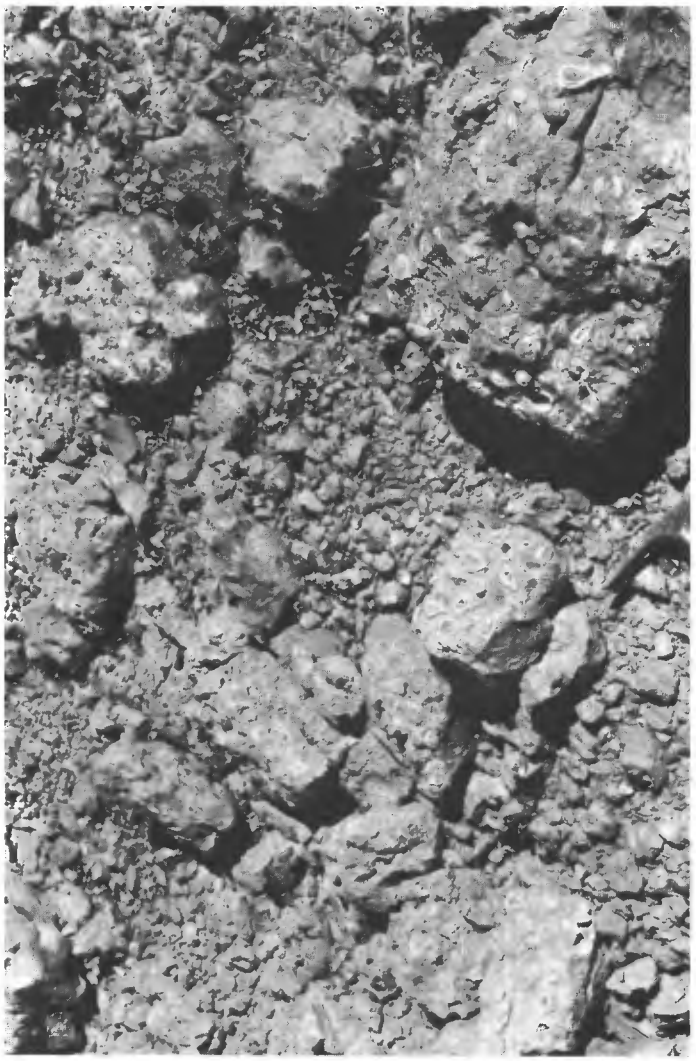


FIGURE 6. Sandstone blocks at Locality 1 containing densely packed unionids from the lower bed. Most isolated specimens illustrated in this paper had eroded from blocks like these. Head of rock hammer at middle right margin is about 14 cm long.

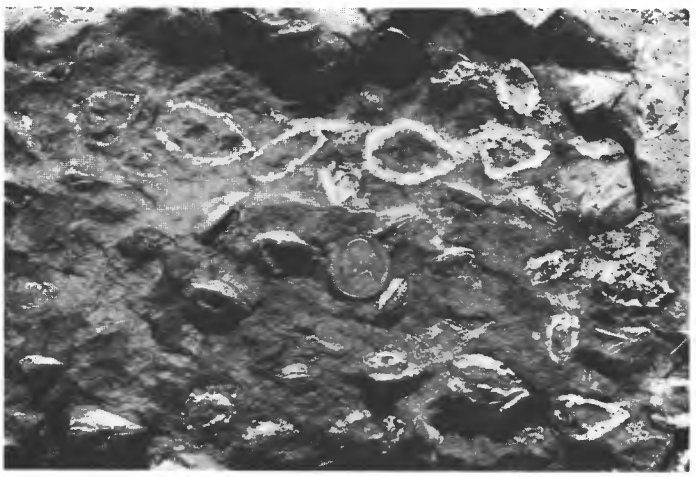


FIGURE 7. Close view of unioids in a block from the lower unionid bed, showing alignment of vertically oriented shells, most of them in cross-sectional view. See nickel for scale.

of Bull Canyon Creek, and collections of several dozen specimens were made at Localities 2 and 3 (Fig. 2). The limestone conglomerate is composed primarily of gray, subrounded, calcareous nodules ranging in size from about 2 mm to several centimeters, in a matrix of red siltstone. Following the interpretation of Stewart et al. (1972) for similar lithologies in the upper part of the Chinle in northwestern New Mexico, Arizona and Utah, this unit is interpreted as lacustrine. Most of the specimens of the gastropod *Triasamnicola pilsbryi* Yen and Reeside collected from Bull Canyon came from this unit. This taxon was especially abundant at Locality 2, whereas unionids were relatively uncommon. Associated fossils at this locality include ostracodes and spirorbid worms. The lacustrine facies at Localities 2–5 also contained phytosaur teeth, scutes and bone fragments, labyrinthodont amphibian scutes, the compressed, serrated teeth of a carnivorous non-phytosaurian thecodont and numerous coprolites, some containing fish scales. The unionids collected from the limestone conglomerate were entirely disarticulated and fragmented specimens eroded from the outcrop and deposited on the surface of the alluvial flats and slopes. Matrix adhering to some of the isolated valves consisted of relatively fine-grained calcareous conglomerate similar to the lithology of the unit from which they had eroded. No in-situ specimens were observed. The preservation of the shell material of these specimens was much better than that of the isolated unionids collected from the sandstone at Locality 1, being very finely instead of coarsely recrystallized and not corroded. In addition, some of the valve fragments included the dentition and delicate external structures such as beak lirae, whereas neither of those taxonomically important features could be observed in specimens from Locality 1.

Summary

McGowen et al. (1983) interpreted the upper shale member of the Chinle Formation as having been deposited in the large, isolated Tucumcari basin, which occupied much of northeastern New Mexico during Late Triassic time. Deltas prograded intermittently into the large lakes that existed within the basin, producing rapid fluctuations in the areal extent of the lakes and in the distribution of fluvial, deltaic and lacustrine environments. McGowen et al. (1983) believed the upper shale member to be lacustrine and prodelta mudstones, but several thin channel sandstones in the Bull Canyon exposures indicate that fluvial environments were also present. There is no evidence in the upper shale member, however, of large-scale, trough-crossbedded sand bodies that would indicate major distributary systems in the area.

The environment during the time the fossils described in this paper lived is best visualized as part of the distal portion of a low delta plain or alluvial plain, near the margins of a large lake. Small streams of low sinuosity flowed across this plain and emptied into the lake, whose shoreline advanced and retreated in response to seasonal and longer-term fluctuations in climate. Vegetation appears to have been relatively sparse, judging from the paucity of plant remains and petrified wood observed in the upper shale member along Bull Canyon Creek. A small number of *Neocalamites* trunk segments were the only identifiable plant fossils discovered. The unionids at Locality 1 lived and were preserved in the sediments of a small fresh-water stream, whereas the molluscs from Localities 2 through 5 were preserved in a lacustrine unit stratigraphically a few meters above the Locality 1 sandstone. The lack of observed in-situ shells in the lacustrine facies, however, makes it difficult to determine whether these organisms actually lived in a lacustrine environment or were transported into it from nearby streams. All evidence suggests that these organisms lived in fresh-water habitats.

PREVIOUS STUDIES

Unionid bivalves were first reported in the Chinle of New Mexico by Cope (1875, p. 81). Most of these fragmentary specimens, from the Gallina area (probably from the Petrified Forest Member of the Chinle, according to Stewart et al., 1972) were described by Meek (1875) as *Unio cristonensis*. Meek noted also that fragments of several other species appeared to be present, and proposed the names *U. gallinensis* and *U. terrae-rubrae* for them, although each was characterized only briefly in a sentence. Cope (1877) illustrated these three species, along

with fragments of another form called *U.* sp. indet., but White (1883, p. 425) commented that the specimens to which the names *U. gallinensis* and *U. terrae-rubrae* had been applied "are really too imperfect to justify application of any specific names." The only subsequent reports of *Unio* from the Triassic of New Mexico are: *U. cristonensis* from the middle Chinle near Fort Defiance, Arizona (Allen and Balk, 1954); specimens apparently of *U. arizonensis,* from near Fort Wingate (Henderson, 1934); and specifically indeterminate specimens of *Unio* from the Chinle 50 km southeast of Las Vegas (Lee, 1907), the Dockum Group of eastern Colfax County (Griggs et al., 1948), the Correo Sandstone Member of the Chinle west of Albuquerque (Silver, 1948), the middle Chinle northeast of Fort Defiance (= *Unio* sp. of Cope, 1877; Allen and Balk, 1954) and the lower Redonda Formation in Quay County (Gregory, 1972).

Several additional species of nonmarine bivalves from the Chinle or Dockum in areas adjacent to New Mexico are known. Reeside (1927) described *Diplodon gregoryi* from the Shinarump Member of the Chinle in northeastern Arizona, and Henderson (1934) added *Unio thomasi* and *U. arizonensis* from the Triassic of Apache County, Arizona. Occurrences of Chinle nonmarine bivalves in Arizona were summarized by Breed (1972), and those of the Colorado Plateau by Stewart et al. (1972). Simpson (1896) described four species, *Unio subplanatus, U. dumblei, U. graciliratus* and *U. dockumensis,* from the Dockum Group of north-central Texas, and Reeside (1927) added *Diplodon? haroldi* to the Dockum fauna. Marshall (1929) established the genus *Antediplodon* to include the last three of Simpson's species, the new genus being distinguished from *Unio* primarily by the presence of radiating riblets on the beak. All three of the Texas Dockum species assigned by Marshall to *Antediplodon* were subsequently reported from the Chinle of Arizona and Utah (Stewart et al., 1972). This would strongly suggest the presence of one or more of the Dockum species in New Mexico, a point verified in this study. Moreover, the specimens referred by Meek (1875) and Cope (1877) to *U. gallinensis, U. terrae-rubrae* and *U.* sp. indet. all possess radiating riblets on their beaks, and very probably represent one or more of the Dockum species of *Antediplodon.*

Gastropods are relatively rare in the Chinle and equivalent units in the southwestern United States. Robinson (1915), Yen and Reeside (1946), and Yen (1951) described a total of six new species from Utah and Arizona; the few other reports of Chinle gastropods are summarized by Stewart et al. (1972). The only previous report of Triassic gastropods in New Mexico known to me is in a footnote (Northrop in Silver, 1948, p. 72) mentioning the presence of "undescribed species of several genera, such as *Scalez* or *Viviparus,* and possibly *Amnicola* or *Valvata"* in a limestone bed in the "shale member" of the Chinle Formation in the Mesa Gigante area west of Albuquerque. The whereabouts of these specimens is unknown (Northrop, oral comm. 1983).

CLASSIFICATION

The problem of accurately determining the taxonomy of fossil unionaceans is formidable. Many features of unionacean soft anatomy, such as gill and foot structure, nature of marsupia, union of mantle lobes, completeness of siphons and morphology and behavior of the parasitic glochidium larvae that are used by malacologists on modern unionaceans cannot be utilized by paleontologists because they are not preserved. Heard and Guckert (1970) have pointed out that the use of shell features—generally the only characteristics of taxonomic importance available in fossil bivalves—is of limited value in unionacean taxonomy and does not adequately reflect the phylogenetic relationships of these animals as interpreted from the reproductive structures of modern taxa.

Even if shell features are utilized in taxonomic studies, there are additional difficulties. Ecological factors, especially water movement and type of substrate, may produce considerable variability in preservable skeletal features within a single modern species (Haas, 1969). Indeed, McMichael and Hiscock (1958) remarked that the "vicissitudes of the environment over large areas . . . lead to immense variability in shell shape within a single species" (p. 374), and noted that fresh-water bivalves are "remarkably plastic in response to environmental factors, and the distinction between ecophenotypic differences and genetic and species differences is difficult" (p. 381). This potential for ecophenotypic variation may be accentuated by the wide geographic ranges and diverse environments in which some modern species live. For example, the modern species *Elliptio dilatatus* was stated by La Rocque (1960) to inhabit bodies of water ranging from creeks to large rivers to the Great Lakes, and to be equally common in mud, sand and gravel substrates. To add even further to the difficulties in interpreting modern unionacean species, the males and females of some species differ dramatically in shell shape and ornamentation (see Simpson, 1900; Johnson, 1947; and Clarke, 1973, for good examples).

In many cases, given the problems discussed above, recognition of modern species of unionaceans is possible only with laboratory evidence on the degree of reproductive isolation or on the basis of chromosome studies. For the distinction of fossil species, the degree of preservation of important skeletal features such as dentition and beak ornamentation may be an additional problem, as it is even with some modern species in which the beaks have become corroded (McMichael and Hiscock, 1958, p. 385). All of the recognized species of unionids described from the Chinle Formation and Dockum Group were established on the basis of one or a few specimens, and hinge line and other internal shell structures have not been reported for many of these species. Geographic, ecological, and sexual variation within these species is largely undetermined.

As mentioned earlier, the great majority of unionids from the upper shale member of the Chinle at Bull Canyon came from two thin, closely spaced beds within a thin channel sandstone (Locality 1). Each assemblage contained hundreds of individuals, in moderate to extremely high densities, and the shells in these assemblages were oriented in the sediment in a way that suggests most individuals were preserved where they died, rather than having been transported significantly after death. All of the unionids in each assemblage lived in a restricted area of a small stream in which the ecological conditions (e.g., sediment grain size, current velocity, depth, temperature, etc.) probably did not vary significantly from one individual in the assemblage to another. The differences in the direction of alignment, density and proportion of disarticulated and ventrally open valves between the unionids of the upper and lower assemblages may indicate that the two assemblages existed in somewhat different current regimes. The isolated shells from these assemblages that were available for study were probably derived mainly from the lower unionid bed. Several morphologically distinct forms of unionids were present in these collections, and each form displays relatively little or no intergradation with the others.

In assessing the systematic status of these groups, two hypotheses were considered: (1) taxonomic (specific) diversity was low, but sexual and/or ecophenotypic variation was high; and (2) the morphologically distinct groups represent true species that occupied similar ecological niches. The latter hypothesis is favored here for the following reasons. First, there is no evidence, from the stream-channel deposits or from the unionids, of significant heterogeneity of environments, aside from the difference in the orientation of the shells in the two assemblages. A large morphological divergence within one or two species would be difficult to understand in a small stream environment with essentially homogeneous sediment characteristics. Large intraspecific ecological variation is certainly not uncommon in modern unionid species, but this develops in response to habitation of a wide variety of substrates and current-flow regimes over a large geographic area.

Secondly, many instances are known within modern fluvial systems where remarkably large numbers of different unionid species live in close proximity at a restricted location under similar ecological conditions. Solem (1974, p. 127) noted that 70 Recent species formerly lived together in the Tennessee River of northern Alabama, and Mozley (1954) reported 46 species and varieties inhabiting Oneida Lake in New York. In another case, Taylor (1980a, b) found as many as 16 and 18 species, respectively, at single stations in two small rivers in Kentucky. At these locations, several genera were represented by two or three species. Parmalee et al. (1980) noted 11 apparently valid species of a single genus in Recent sediments associated with a restricted area of the Middle Cumberland River in Tennessee. The distribution and diversity of unionids within the stream sandstone unit in the Chinle at

Bull Canyon appears to be analogous to unionid occurrences in these modern rivers; namely, several species occurring in a single assemblage at a single locality.

The possibility of sexual dimorphism as a source of variation among the Bull Canyon unionids from Locality 1 is difficult to evaluate. There are no consistent patterns of shell differences between males and females within modern unionid species, and many species show little or no sexual differentiation (Simpson, 1900). Sexual variation has been suggested for two species of Triassic unionids. Simpson (1896, p. 385) believed specimens of *Unio* (now *Antediplodon*) *dockumensis* that were more inflated in the posterior part of the ventral region to be females, presumably by analogy with some modern unionid species. Henderson (1934, p. 259) suggested that differences in the degree of curvature of the ventral shell margin in *U. arizonensis* might be due to sexual dimorphism. Both of these species are represented in the Bull Canyon Chinle by large numbers of specimens; variation in the structures mentioned above is gradational, not bimodal, and therefore is probably not related to sex. There is no real evidence in the various species of Bull Canyon unionids of any significant variations in shell shape or structure that can be attributed definitely to sexual dimorphism.

The taxonomic approach utilized here for the unionids is a conservative one that, of necessity, emphasizes preserved skeletal features. Specimens from the lacustrine unit (Localities 2–5) are generally well preserved, though typically fragmented, and may display both fine external ornamentation such as beak lirae and internal structures such as dentition and muscle scars. The specimens from the fluvial unit (Locality 1), in contrast, are corroded externally so that some shell features are not preserved, and invariably are articulated so that internal shell features cannot be observed. Locality 1 specimens can be assigned to several non-intergrading groups characterized by distinctive shell proportions, structures and ornamentation. Several of these morphotypes are believed to represent undescribed species, but they are not named here because information on these critical structures is lacking. They are, however, discussed and illustrated separately. Better preserved specimens showing internal shell features are required to better assess the taxonomic and biological relationships of these presumed species.

SYSTEMATIC PALEONTOLOGY

Class **Bivalvia** Linne, 1758
Subclass **Palaeoheterodonta** Newell, 1965
Order **Unionoida** Stoliczka, 1871
Superfamily **Unionacea** Fleming, 1828
Family **Unionidae** Fleming, 1828
Subfamily **Unioninae** Fleming, 1828
Genus *Unio* Philippson, 1788

The classification of unionid bivalves utilized in this paper is that of Haas (1969). Nearly all species of Triassic unionids that lack radial ornamentation have been assigned to *Unio* (there is a questionable occurrence of *Lampsilis* in the Triassic: Haas, 1969, p. N450). The concept of the genus *Unio* based on modern species is relatively restricted, and several closely related genera have been established mainly on the basis of soft anatomy. The paleontological concept of *Unio* is necessarily more general than the biological concept, and, in addition, fossil species of *Unio* described from North America have little to do with the original concept of the genus (Haas, 1969, p. N415). The generic name *Unio* will be done away with in the North American fossil record when the unionaceans are more thoroughly analyzed; at present, *Unio* serves as a taxonomic repository for all unionid species that cannot be assigned to one of the other named genera (J. H. Hartman, written comm. 1985).

The name *Unio* is used here for subcircular to elliptical unionids having beaks relatively close to the anterior end, strongly developed concentric growth lines or folds and no radial ornamentation. Nothing can be said, unfortunately, concerning the dentition or muscle scars of species from Bull Canyon assigned to *Unio*. In addition, because their shells are corroded, it is not certain that the specimens assigned here to *Unio* originally lacked small radial beak lirae, a characteristic of the genus *Antediplodon*.

Unio arizonensis Henderson, 1934

Fig. 8A–D

1934. *Unio arizonensis* Henderson, p. 259, pl. 36, fig. 7a, b.

Material—Ninety-seven articulated specimens, including measured specimens UNM 8403–8448.

Discussion—*Unio arizonensis* was originally described by Henderson (1934) from several articulated, highly recrystallized specimens from the Triassic of Apache County, Arizona. The large number of specimens available from Bull Canyon provides additional information on external morphology and variation, but, because they are preserved in a way very similar to that of the Arizona specimens, nothing can be stated about the dentition or other internal shell structures. *U. arizonensis* is distinctive among Chinle unionids in being very elongate (mean height/width ratio = 0.52), having a relatively pointed and extended posterior margin and conspicuously concave ventral margin, and in possessing beaks that are situated relatively far towards the anterior end, being about 20% of the distance from the anterior to posterior end of a valve (Table 1). The concave ventral margin confers a gently arcuate shape to the shells of some specimens.

The Bull Canyon specimens average about 50 mm in length, somewhat smaller than Henderson's types, and also differ in a minor way by being slightly higher and wider than the specimens illustrated by Henderson. The beaks are the highest part of the valves, in contrast to all of the other species of *Unio* in the Bull Canyon Chinle except *Unio* sp. 1. An elongate, narrow ligament is set into an escutcheon along the hinge line and extends approximately 60% of the distance from the

TABLE 1. Mean measurements (in mm) of unionids from the upper shale member of the Chinle Formation at Bull Canyon. Measurements of individual shells are in the author's files. Abbreviations: N = number of measured specimens; L = maximum length of valves; H = maximum height of valves; W = maximum width of articulated valves; BD = distance of beaks from anterior end of valves; H_b = height of valve at beak; H_l = height of valve at posterior end of ligament; LE = length of ligament relative to distance from beak to posterior end of valve.

Species	N	L	H	W	H/L	W/L	BD	BD/L	H_b/H_l	LE
Unio arizonensis Henderson	45	51.3	26.8	17.7	.52	.35	11.4	.22	1.06	.59
Unio sp. 1	14	45.8	26.5	19.1	.58	.42	9.6	.21	1.07	.58
Unio sp. 2	10	46.9	35.9	23.1	.77	.49	14.1	.31	.88	.72
Unio sp. 3	22	55.3	36.6	24.9	.66	.45	16.3	.29	.92	.69
Unio sp. 4	6	55.5	40.3	25.4	.73	.46	18.4	.33	.86	.71
Unio sp. 5	7	60.9	42.0	22.4	.69	.37	18.4	.30	.89	.67
Unio sp. 6	1	46.6	27.9	20.0	.60	.43	13.1	.28	.92	.63
Antediplodon dockumensis (Simpson)	8	49.1	28.0	-	.57	-	14.9	.30	1.28	-

beaks to the posterior end of the valve. The "broad shallow depression" noted by Henderson is evident on the Bull Canyon specimens as a shallow, oblique, posteriorly inclined sulcus that widens ventrally from the umbo to intersect the ventral margin of a valve about 35 to 40% of the distance from the anterior to posterior end, or about at the position of the ventral indentation.

The valves of *Unio arizonensis* are only slightly inflated, having a mean width/length ratio of 0.35, which is less than that of any other species of *Unio* at Bull Canyon. Some specimens assigned to *U. arizonensis* are unusually long and low (Fig. 8D), and others are somewhat attenuated posteriorly. Poorly preserved specimens of the latter form can be mistaken for *U.* sp. 1, but typical specimens of *U. arizonensis* are readily distinguished from *U.* sp. 1 by their greater length, less inflated and less curved beaks and greater ventral emargination.

None of the four unionid species described by Simpson (1896) from the Dockum Group of north-central Texas appear to have valve proportions that are closely similar to *U. arizonensis*. One of these species, *Antediplodon dockumensis*, is present in the Chinle at Bull Canyon, but is easily distinguished from *U. arizonensis* by its convex, rather than concave, ventral margin and its larger, more elevated beaks. Marshall (1929), however, illustrated a specimen from the Dockum that he assigned to *A. dumblei* that possesses a strongly emarginate ventral margin and resembles *U. arizonensis* in general shape and size. This specimen, and all species of *Antediplodon*, have small radiating lirae on the beak, whereas no radial ornamentation has been reported in *U. arizonensis*. This may not be significant in separating *U. arizonensis* from emarginate and elongate forms of *Antediplodon*, because no specimens of *U. arizonensis* are known that are well enough preserved to adequately demonstrate the presence or absence of radiating beak lirae.

In addition to specimens from the type locality, Henderson (1934) also reported specimens probably representing *Unio arizonensis* from the Triassic near Fort Wingate, New Mexico.

Unio sp. 1

Fig. 8E–G

Material—Twenty-eight articulated shells, including measured specimens UNM 8449–8463.

Description—Shell of medium size, up to about 50 mm in length, rather short and wedge-shaped in lateral profile, with a mean height/length ratio of 0.58 and mean width/length ratio of 0.42; hinge line surmounted in back of beaks by a narrow, low ligament set into a shallow escutcheon that extends about 60% of distance from beaks to posterior valve termination; antero-dorsal margin descending sharply from beaks to form an evenly convex but very blunt anterior margin; postero-dorsal margin very gently convex, sloping gradually posteriorly to a bluntly pointed posterior margin situated just above base of valve; ventral margin straight to slightly emarginate; maximum valve height at beaks, at which point valve height is about 7% greater than at posterior end of ligament; maximum valve width above midheight on posterior slope; maximum valve length just above ventral margin; umbo moderately inflated, with a shallow sulcus that extends oblique-posteriorly across flank and widens towards ventral margin where it meets emargination at about midlength; posterior ridge broadly rounded; anterior ridge less conspicuous, nearly vertical; beaks sharp, prosogyrate, apparently lacking radial ornamentation, strongly curved, elevated significantly above hinge line, situated about 20% of distance from anterior to posterior ends of valve; shell surface with fine growth lines, many of them raised into fairly evenly and relatively widely spaced broad, concentric wrinkles that become obscure towards beaks; internal valve features unknown. Measurements are given in Table 1.

Discussion—*Unio* sp. 1 is most similar to *U. arizonensis;* comparison of the two species is given in the discussion of *U. arizonensis*. The two species seem to be closely related, and some poorly preserved specimens are distinguished only with difficulty. *Antediplodon dockumensis*, which superficially resembles *Unio* sp. 1, is more elongate, has more anteriorly extended valves, possesses small radial lirae on the beaks and has a convex rather than straight to emarginate ventral margin. Of the unionids present in the Chinle of Bull Canyon, only the three species mentioned above have a shallow sulcus on the umbo and valve flanks.

Unio sp. 2

Fig. 8Q–S

Material—Thirteen articulated specimens, including measured specimens UNM 8360–8370.

Description—Shell medium-sized, up to about 50 mm in length, bluntly subrectangular in shape, with a mean height/length ratio of 0.77, moderately inflated (mean width/length ratio 0.49); hinge line moderately convex, surmounted in back of beaks by a relatively wide ligament set into a shallow escutcheon that extends about two-thirds of distance from beaks to posterior end of valve; dorsal and ventral margins diverging posteriorly at a low angle so that valve height near posterior end of ligament is about 14% greater than height at beaks; posterior margin bluntly rounded, projecting slightly further above midheight than below it; antero-dorsal margin gently convex; ventral margin gently convex; maximum valve width just above midheight and just posterior to beaks; maximum valve length at or above midheight; umbo moderately inflated, lacking sulcus; anterior and posterior ridges not significantly set off from general curvature of valve; beaks sharp, prosogyrate, apparently lacking radial ornamentation, elevated slightly above hinge line, situated about one-third of distance from anterior to posterior ends of valve; shell surface with irregular, fine growth lines and larger, raised concentric wrinkles; internal shell features unknown. Measurement are given in Table 1.

Discussion—*Unio* sp. 2 is distinguished from most other species of Triassic unios by its short, high shape reflected in an unusually high height/width ratio, and by its truncated posterior end. In some respects it approaches shorter specimens of *Unio* sp. 3, but is much less elongate than typical representatives of that species and differs also in having a more symmetrically convex posterior margin that has it greatest extension at or above midheight of the valve rather than sloping posteriorly to a rounded point immediately above the base. *Unio* sp. 2 is most similar in general proportions to *Unio thomasi* described by Henderson (1934) from the Triassic of Arizona. Henderson gave a length of 30 mm and a height of 34.5 mm for the holotype, but this must be in error as his illustrations show specimens that are somewhat longer than high (estimated height/length ratio, measured from illustrations of *U. thomasi*, is about 0.75). Although *U. thomasi* is also an unusually short species, it differs from *Unio* sp. 2 in being much wider and more inflated and having an estimated width/length ratio of 0.75, compared to a mean of 0.49 for *Unio* sp. 2. Also, the beaks of *U. thomasi* are described as being nearly terminal and raised well above the hinge line, whereas those of *Unio* sp. 2 are situated about one-third of the distance from the anterior to posterior ends of the valves and are but slightly elevated above the hinge line.

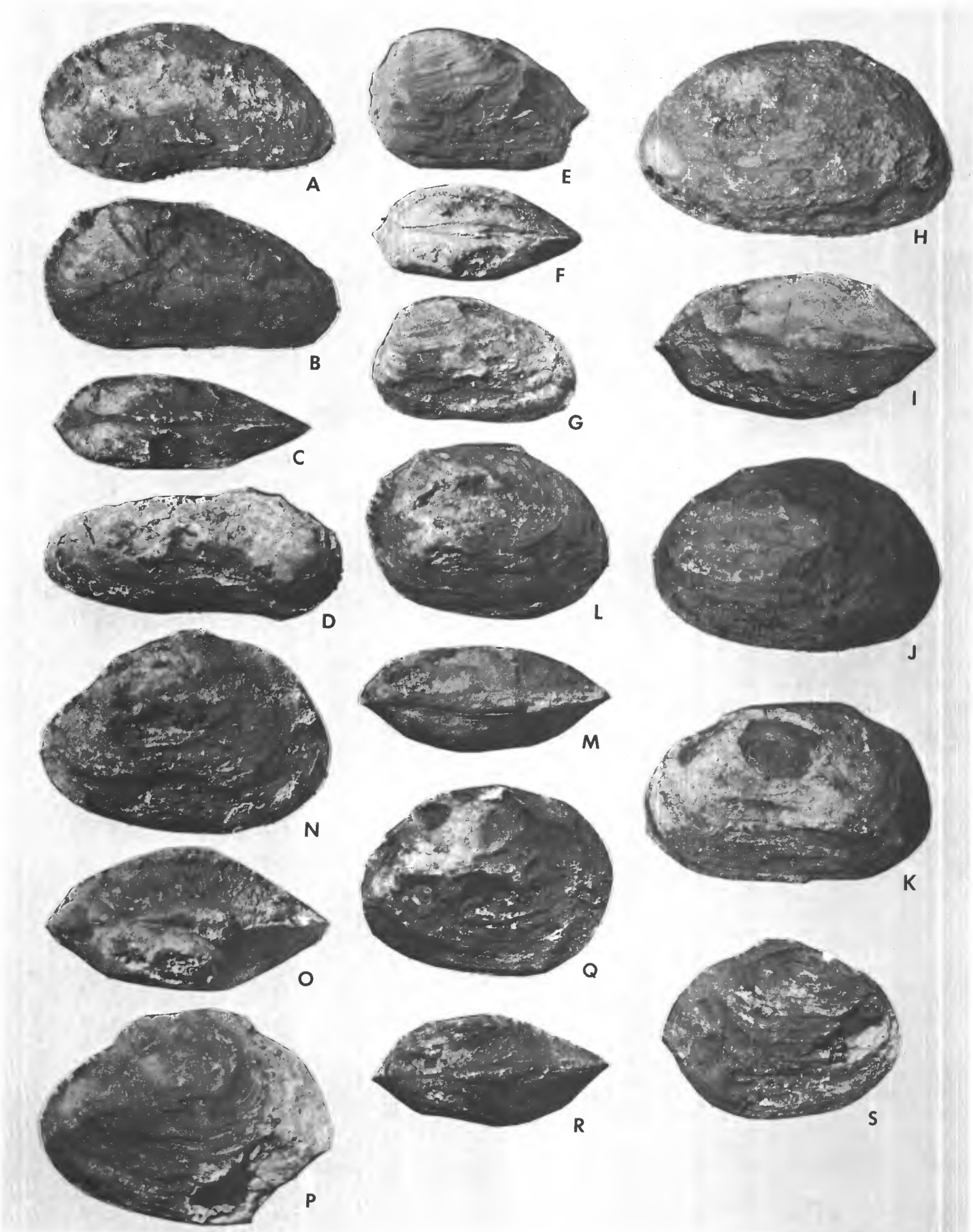
Unio sp. 3

Fig. 8H–K

Material—Twenty complete articulated specimens and about 30 fragmentary shells, including measured specimens UNM 8371–8387.

Description—Shell medium-sized, up to about 70 mm in length, elongate, with a mean height/length ratio of 0.66, somewhat tumid along flanks and dorsal part of posterior ridge, with a mean width/length ratio of 0.45; hinge line moderately convex, surmounted in back

FIGURE 8. Unionids from the upper shale member of the Chinle, Bull Canyon, all ×1. A–D, *Unio arizonensis* Henderson: A, UNM 8403, left valve; B, UNM 8414, left valve; C, UNM 8405, dorsal view; D, UNM 8447, right valve of an unusually lanceolate specimen. E–G, *Unio* sp. 1: E, UNM 8449, left valve; F, G, UNM 8450, dorsal view and left valve. H–K, *Unio* sp. 3: H, UNM 8371, left valve; I, J, UNM 8372, dorsal view and left valve; K, UNM 8376, left valve. L–M, *Unio* sp. 6, UNM 8402, left valve and dorsal view. N–P, *Unio* sp. 4: N, O, UNM 8398, left valve and dorsal view; P, UNM 8399, left valve. Q–S, *Unio* sp. 2: Q, UNM 8360, left valve; R, S, UNM 8361, dorsal view and right valve.


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of beaks by a conspicuous high, narrow ligament set into a shallow escutcheon that extends about two-thirds to three-fourths of distance from beaks to posterior end of valves; dorsal and ventral margins diverging at a low angle so that maximum valve height is near posterior end of ligament and is about 9% greater than height at beaks; antero-dorsal margin gently convex, rounding smoothly into strongly convex anterior margin; postero-dorsal margin gently convex, sloping after a slight angulation at posterior end of ligament rather sharply down to an evenly rounded, somewhat pointed posterior margin situated near base of valve; ventral margin gently convex; maximum valve width about midheight or slightly above, along posterior part of flanks and posterior slope; maximum valve length about midway between midheight and ventral margin; umbo moderately inflated, lacking sulcus; posterior ridge broadly rounded and somewhat tumid; anterior ridge inconspicuous; beaks relatively sharp, prosogyrate, apparently lacking radial ornamentation, elevated slightly above hinge line, situated about 30% of distance from anterior to posterior end of valves; shell surface with fine growth lines and much larger raised, irregularly spaced concentric wrinkles that fade to obscurity near beaks; internal valve features unknown. Measurements are given in Table 1.

Discussion—*Unio* sp. 3 is distinguished by its relatively elongate shape, basally displaced and relatively pointed posterior termination, tumid shell and convex ventral margin. Variation among specimens assigned to *Unio* sp. 3 is pronounced. Some specimens are shorter than normal, with a correspondingly higher height/length ratio, but still maintain the same general shape, which separates them immediately from the short, subrectangular *Unio* sp. 2. Other specimens are elongate, but possess a rather truncated and more evenly rounded posterior margin. Although extreme examples of each of these variants may appear to depart significantly from typical representatives of *Unio* sp. 3, a full range of intergrading specimens is present in the collection. Some individuals having the typical shape are more laterally compressed than is usual for the species.

Unio sp. 3 is most similar to *Unio* sp. 4; the discussion of the latter species includes considerations of their relationships. *Unio* sp. 5 is much narrower and more evenly oval than *Unio* sp. 3. *Unio arizonensis* and *Unio* sp. 1 differ from *Unio* sp. 3 in being narrower, having higher beaks and in possessing a concave rather than convex ventral margin.

Unio sp. 4
Fig. 8N–P

Material—Six articulated specimens, including measured specimens UNM 8388–8389, 8398–8401.

Description—Shell medium-sized, up to about 60 mm in length, broadly expanded posteriorly, with a mean height/length ratio of 0.72, moderately inflated especially along posterior slope, with mean width/length ratio of 0.47; dorsal margin moderately convex and diverging posteriorly from ventral margin at about a 40° angle, so that maximum valve height occurs near posterior end of ligament and is about 20% greater than height of valves at beaks; anterior margin evenly convex; postero-dorsal margin sloping from a moderate angulation at end of ligament to form a broadly rounded posterior margin situated below midheight of valve; ventral margin moderately convex; hinge line with a relatively wide, high ligament set into a shallow escutcheon extending about three-fourths of distance between beaks and posterior end of valve; maximum valve width above midheight and below midpoint of ligament; maximum valve length slightly below midheight; umbo moderately inflated, lacking sulcus; posterior ridge tumid dorsally; anterior ridge inconspicuous; beaks of moderate size, relatively sharp, prosogyrate, apparently lacking radial ornamentation, slightly elevated above hinge line, situated about one-third of distance from anterior to posterior ends of valve; shell surface with fine growth lines and relatively regularly spaced large concentric wrinkles; internal valve features unknown. Measurements are given in Table 1.

Discussion—The shape of *Unio* sp. 4 is distinguished by an ascending hinge line that diverges at a relatively large angle from the ventral margin, resulting in a low anterior area and a conspicuous expansion of the shell posteriorly. The posterior end of the shell is typically very broadly rounded, almost truncate, but some specimens show a more pointed posterior margin. *Unio* sp. 4 is most closely related to *Unio* sp. 3; the shape of the flanks of the valves, the inflated posterior ridge and the ventrally displaced posterior termination of the shell are similar in both species. *Unio* sp. 4 differs, however, in having higher, more truncated valves and a much greater divergence of the dorsal and ventral margins across the anterior two-thirds of the shell. The two species are distinguished without difficulty in the collections, and significant intergradation does not appear to occur.

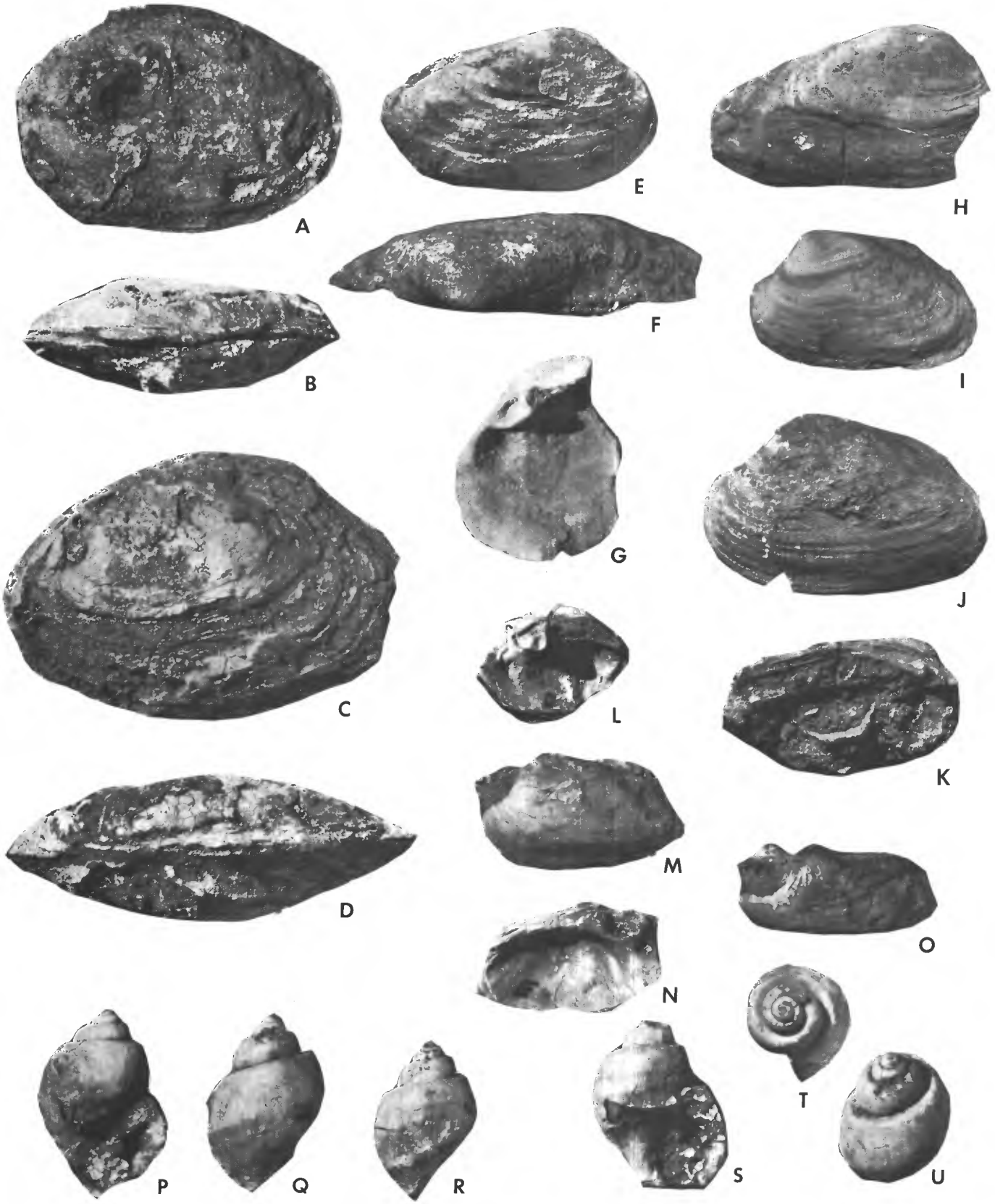
The possibility exists that *Unio* sp. 3 and *Unio* sp. 4 represent the males and females, respectively, of a single species. Clarke (1973, p. 111) noted that in the modern unionid *Lampsilis ovata* the female shells are typically less elongate than male shells, and that females are much higher near the posterior end of the ligament than at the beaks, whereas males are about equally high at both points. These sexual differences in shell shape are similar to the main distinguishing characteristics of *Unio* sp. 3 and *Unio* sp. 4. If these two were sexual morphs rather than separate species, one would expect to find approximately equal numbers of both forms within an assemblage. However, *Unio* sp. 3 is about ten times more abundant than *Unio* sp. 4 in the stream sandstone at Locality 1. Also, the validity of using sexual dimorphism in a modern species of *Lampsilis* as a model for dimorphism in a Triassic species of *Unio* is open to question. Although the analogies with the sexual dimorphism of *L. ovata* may be suggestive, in the absence of better evidence supporting the interpretation as sexual morphs the two Triassic forms discussed here are considered to be separate, closely related species.

Unio sp. 5
Fig. 9A–D

Material—Ten articulated specimens, including measured specimens UNM 8391–8397.

Description—Shell medium-sized to large, up to 80 mm or more in length, nearly symmetrically oval in shape, with a mean height/length ratio of 0.69, laterally compressed, with a mean width/length ratio of 0.37; dorsal and ventral margins evenly and nearly symmetrically convex, diverging posteriorly at a slight angle to about midlength so that maximum valve height occurs near posterior end of ligament and is about 12% greater than height at beaks; anterior and posterior margins evenly and rather sharply rounded, the anterior end slightly more so than the posterior end; hinge line surmounted behind beaks by a narrow, raised ligament set into a shallow escutcheon that extends about two-thirds of the distance from beaks to posterior end of valve; maximum valve width above midheight and posterior to beaks; maximum valve length at or slightly below midheight; umbo gently convex, with slight hint of a sulcus in some specimens; posterior and anterior ridges very low and not set off significantly from general curvature of valve flanks; beaks relatively sharp, prosogyrate, lacking radial ornamentation, slightly elevated above hinge line, situated about 30% of distance from anterior

FIGURE 9. Unionids and gastropods from the upper shale member of the Chinle Formation, Bull Canyon. A–D, *Unio* sp. 5: A–B, UNM 8393, right valve showing possible phytosaur tooth mark, and dorsal view, ×1; C–D, UNM 8391, left valve and dorsal view, ×1. E–K, *Antediplodon dockumensis* (Simpson): E, UNM 8344, right valve, ×1; F, UNM 8352, dorsal view of right valve, showing beak lirae, ×1.5; G, UNM 8340, interior view of anterior part of right valve, showing dentition and adductor-muscle scar, ×1.5; H, UNM 8349, right valve, ×1; I, UNM 8311, left valve of a relatively small specimen, ×1; J, UNM 8356, left valve with posterior margin broken off, ×1; K, UNM 8358, hinge line and dentition of left valve, ×1. L–O, *Antediplodon* sp.: L, UNM 8301, dentition of right valve, ×1.5; M, UNM 8302, exterior of left-valve fragment, ×2; N, UNM 8302, interior of left-valve fragment showing dentition, ×2; O, UNM 8302, oblique dorsal view of left valve showing beak lirae, ×2. P–U, *Triasamnicola pilsbryi* Yen and Reeside: P–Q, UNM 8468, apertural and adapertural views (note dark stripes on lower half of body whorl), ×2; R, UNM 8465, adapertural view, ×2; S, UNM 8469, apertural view showing two dark stripes on penultimate whorl, ×2; T, U, UNM 8468, apical and oblique apical views, ×2.


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to posterior end of shell; shell surface with fine growth lines and irregularly spaced large, raised concentric folds; internal valve features unknown. Measurements are given in Table 1.

Discussion—*Unio* sp. 5 is distinguished by its nearly symmetrical oval shape and compressed form. It could be confused only with unusually narrow or post-depositionally compressed specimens of *Unio* sp. 3, but normal specimens of that species are far more inflated and have a ventrally placed posterior point that is sharper than the anterior margin.

Most specimens of *Unio* sp. 5 were obtained from Locality 1, but a few large examples were collected from the lacustrine facies (Localities 2 and 3). One specimen (UNM 8393, Fig. 9A) from Locality 1 had a circular puncture on its left valve, in which the shell was fractured inwardly as if by compression from a conical object. The size of this hole is the same as that of an average phytosaur tooth and, as the remains of at least two phytosaur skulls were present in the same sandstone unit as the unionid specimen, the shell puncture may have been caused by a bite from one of these large aquatic reptiles. The rarity of possible tooth marks on the large number of unionids examined suggests that these bivalves were either not utilized as food by phytosaurs, or were swallowed whole.

Unio sp. 6

Fig. 8L–M

Material—Three articulated specimens, only one of which (UNM 8402) is reasonably well preserved.

Description—Shell medium-sized, about 45 mm in length, elongately oval in shape, with a mean height/length ratio of 0.60 and mean width/length ratio of about 0.43; hinge line convex, with a wide, high ligament set into an escutcheon that extends about 60% of distance from beaks to posterior end of shell; maximum valve height about midlength, posterior to beaks; antero-dorsal margin rounding smoothly into evenly and bluntly convex anterior margin; postero-dorsal margin evenly and gently convex, sloping gradually to a bluntly pointed posterior end that is situated slightly below midheight; ventral margin very gently convex; beaks small, sharp, prosogyrate, apparently lacking radial ornamentation, slightly elevated above hinge line, and situated about 30% of distance from anterior to posterior end of valve; umbo moderately expanded, with slight hint of a sulcus; posterior ridge rounded, somewhat inflated so that greatest width of shell occurs along it about two-thirds of the distance from beaks to posterior margin; shell surface with fine to irregularly folded concentric growth lines; internal valve features unknown. Measurements are given in Table 1.

Discussion—*Unio* sp. 6 is relatively small and most closely resembles *Unio* sp. 3. However, it differs from that species in being somewhat more elongate and in having a shorter, more truncated anterior margin and a slightly sharper posterior margin. It is more laterally compressed than *Unio* sp. 2, *Unio* sp. 3 and *Unio* sp. 4. Because only one reasonably well preserved specimen is available, the variability of this species cannot be determined; but, on the basis of its shape and proportions, it seems to be distinct from the other species described here.

Subfamily **Hyriinae** Ortmann, 1911

Genus ***Antediplodon*** Marshall, 1929

As noted previously, this genus was established by Marshall (1929) for unionids of elongate form that possess several fine radiating riblets or lirae on the beaks. The type species is *Antediplodon dumblei* from the Dockum Group of Texas; Marshall also assigned *Unio graciliratus* and *U. dockumensis* from the Dockum, as well as a Pliocene species, *A. dewittensis,* to *Antediplodon*. Perhaps because the genus was established in a paper otherwise dealing with Pliocene unionids, the range of *Antediplodon* is given only as Pliocene in the Treatise (Haas, 1969). Because the internal shell structures, including the dentition, were not described or figured for the Pliocene species, and there are numerous unionacean genera with radial beak ornamentation, there is no certainty that the Triassic and Pliocene species belong within the same genus. Silberling (quoted in Stewart et al., 1972, p. 78) used *Antediplodon* as a subgenus of *Unio* in an identification of *U.* (A.) cf. *dockumensis* from the Chinle of Arizona, which by implication shifts *Antediplodon* from the Hyriinae, where it was placed by Haas (1969), to the Unioninae. There is some merit in this approach, as no generically significant differences in dentition pattern or shell form between Triassic species of *Unio* and *Antediplodon* have been documented. However, *Antediplodon* is treated as a genus here, with the understanding that more study is needed in order to determine its actual relationship to taxa here referred to *Unio*.

Antediplodon dockumensis (Simpson, 1896)

Fig. 9E–K

1896. *Unio dockumensis* Simpson, p. 384–385, fig. 5.
1929. *Antediplodon dockumensis* Marshall, p. 5.

Material—Fifty-five disarticulated, incomplete valves, including measured specimens UNM 8341–8359.

Description—Valves of medium size, up to about 60 mm in length, moderately elongate, with a height/length ratio of about 0.60, relatively narrow (width/length ratio less than 0.50); hinge line gently convex, with a long, narrow escutcheon; ligament unknown; antero-dorsal margin slightly concave, sloping ventrally at a higher angle than straight postero-dorsal margin; anterior margin evenly convex beneath a rounded angulation at base of antero-dorsal margin; posterior margin evenly and bluntly rounded; ventral margin gently convex to nearly straight; maximum valve height at beaks; maximum valve length just below midheight; maximum valve width below or a little behind beaks on flanks at about midheight; umbo prominent, gently convex in profile, with a slight to obscure sulcus beginning near beaks and widening obliquely posteriorly towards ventral margin; posterior ridge broadly rounded below relatively flat posterior area; anterior ridge scarcely differentiated from general valve curvature; beaks high, sharp, prosogyrate, elevated conspicuously above hinge line, situated about one-third of distance between anterior and posterior ends of shell, ornamented with 12 to 18 short, narrow, sharply rounded radiating lirae; these lirae increasing slightly in size from sides to central area of beaks, but not extending far ventrally across umbo; valve surface with fine, irregularly spaced concentric growth lines and larger concentric wrinkles of irregular spacing and size that bend sharply anteriorly as they cross posterior slope towards hinge line; thickness of a mature shell decreasing from about 3 mm near hinge line to less than 1 mm round periphery of valve; hinge plate thick and relatively massive; dentition of left valve consisting of two elongate posterior lateral teeth separated by a narrow groove that extend to a point just behind posterior end of escutcheon, and two prominent cardinal teeth; posterior cardinal tooth large, roughly pyramidal in shape, with several narrow furrows across blunt apex, and situated directly below beak; anterior cardinal tooth smaller, more flange-like, situated anterior to beak; teeth separated by a deep triangular socket; dentition of right valve consisting of a single long posterior lateral tooth and a single flange-like cardinal tooth, with a wide triangular anterior socket above tooth and nearer to hinge line, and a more depressed triangular socket behind tooth; anterior adductor-muscle scar (right valve) a large, subcircular, relatively shallow depression situated below and mostly anterior to dentition, bounded posteriorly by a broad, low ridge projecting ventrally from hinge plate; posterior adductor-muscle scar unknown.

Measurements are given in Table 1. Because few of the isolated valves were complete, and the posterior ends were broken off most specimens, complete sets of measurements could be made on only a few specimens.

Discussion—These specimens from Bull Canyon agree in their significant features with Simpson's (1896) description of *Unio dockumensis*. Specimens ranging in length from about 25 to 60 mm were present in one assemblage, and significant intraspecific variation occurs in some characteristics. Smaller specimens have a more pronounced umbonal sulcus than large individuals, and this sulcus is sometimes manifested on the ventral margin by a slight emargination that is absent in larger specimens. The degree to which the radial beak ornamentation is expressed also varies; in many specimens the beaks had been eroded to the extent that the fine radiating lirae are absent. One well-preserved specimen, however, not only has lirae on the beaks, but also fine lirae on the posterior area. Although the shell proportions of small and large

individuals are generally similar, a few large specimens are significantly more elongate posteriorly than normal. *Antediplodon dockumensis* is easily distinguished from other unionids at Bull Canyon by its radial beak ornamentation, high beak, concave antero-dorsal margin and subtriagular shape. *Unio* sp. 1 is somewhat similar in having an elevated beak and somewhat triangular shape, but it differs from *A. dockumensis* in having a more inflated umbo, a more pronounced sulcus that generally produces a distinct emargination at the ventral margin, beaks that are closer to the anterior end of the shell and in lacking radial ornamentation.

A. dockumensis was originally reported from the Dockum Group of Texas, but is also present in the Chinle of Utah and Arizona (Stewart et al., 1972). This is the first report of its presence in New Mexico.

Antediplodon sp.
Fig. 9L–O

Discussion—Several fragmentary valves displaying dentition cannot be definitely assigned to *A. dockumensis*. Most have some indication of beak lirae, and the valve lengths indicated by the fragments are no more than 30 mm. The antero-dorsal margin of these valves is nearly straight and extends virtually horizontally in front of the beaks rather than being gently concave and sloping antero-ventrally at about a 30° angle, as in *A. dockumensis*. The best preserved fragment (UNM 8302, Figure 9M–O) assigned to *A.* sp. has lirae that extend from the beak area to cover, faintly, the central and anterior areas of the valve. The dentition of the left valve is similar to that of *A. dockumensis*, but the posterior cardinal tooth is somewhat longer, the socket is larger, and the anterior cardinal tooth is narrower than in that species. A well-preserved anterior adductor-muscle scar is also preserved on several left valves of *A.* sp.; it is a small, deep, circular pit below and slightly forward of the socket. On the right valves, the single tooth is wider than the relatively narrow tooth of *A. dockumensis*, and its outer surface is marked by a shallow depression that is not well developed in that species. The anterior socket in these valves is a relatively narrow groove above the tooth, as opposed to a large triangular anterior socket set more forward of the tooth in *A. dockumensis*.

These differences suggest the presence of a second species of *Antediplodon* in the Bull Canyon Chinle, one that is too incompletely preserved to adequately characterize at present. Both *U. terrae-rubrae* and *U.* sp. indet., briefly described by Meek (1875) and illustrated by Cope (1877) from the Gallina area of northern New Mexico, resemble *A.* sp. in having lirae on the beaks as well as on other parts of the valves. Judging from Cope's illustrations, the beaks of the fragmented specimens are more anteriorly placed and their hinge lines more convex than is the case on *A.* sp., but the significance of these differences and the exact relationships of the Gallina forms to species described from the Dockum Group is impossible to assess without more complete specimens.

Class **Gastropoda** Cuvier, 1797
Subclass **Prosobranchia** Milne-Edwards, 1848
Order **Mesogastropoda** Thiele, 1925
Superfamily **Rissoacea** Adams and Adams, 1854
Family **Hydrobiidae** Stimpson, 1865

The gastropod classification used here is that of the Treatise on Invertebrate Paleontology (Knight et al., 1960), except that the term Mesogastropoda is substituted for Caenogastropoda, following the usage of most recent gastropod workers. Yen and Reeside (1946) assigned *Triasamnicola* to the family Amnicolidae. Taylor (1960) noted that Americans have generally used Amnicolidae, while European workers have preferred Hydrobiidae, and that the latter name has priority. Modern hydrobiids are rarely more than 10 mm high (Taylor, 1966, p. 118), whereas *Triasamnicola pilsbryi* may reach a considerably larger size.

Genus *Triasamnicola* Yen and Reeside, 1946

Triasamnicola pilsbryi Yen and Reeside, 1946
Fig. 9P–U

1946. *Triasamnicola pilsbri* Yen and Reeside, pp. 50–51, pl. 1, fig. 9a–d.

Material—More than 400 specimens, mainly from Locality 2.

Discussion—Yen and Reeside (1946) adequately described the distinctive features of *T. pilsbryi*, but some additional descriptive comments are included here to further characterize the species. *T. pilsbryi* is easily distinguished from other members of the genus by the presence of a prominent flat to slightly concave subsutural shoulder that is separated from the outer-whorl surface by a sharp angulation at a low ridge on the outer margin of the shoulder. The shoulder is obscurely developed on the earliest two whorls, but becomes much more conspicuous on the later whorls. Some of the Bull Canyon specimens are significantly larger than those reported by Yen and Reeside (1946) from the Chinle of southeastern Utah. The maximum height of some Bull Canyon specimens, based on incomplete individuals, is about 18 mm, compared to 11+ mm of the largest Utah specimens. The general proportions of individuals within the two collections, however, are very similar. Mature specimens from Bull Canyon have four to five whorls; the largest Utah specimen has 4.5 whorls. The average width/height ratio of the Bull Canyon specimens is 0.67, compared to 0.69 for the Utah specimens. Yen and Reeside (1946) provided no measurements of the pleural angle, but judging from their illustrations it was about 71°, very close to the 73° average for the Bull Canyon collection. The growth lines are fine, locally raised into minor crenulations, and sharply prosocline across the shoulder, becoming more gently so on the outer whorl surface before bending gradually back towards the aperture on the lower third of a whorl.

Most of the specimens from Bull Canyon are heavily encrusted with matrix and lack intact apertural margins, but some are extremely well preserved and possess remnants of their original color patterns. In the fossils these are manifested as a variable number of dark stripes arranged spirally along the whorls (Fig. 9Q, S). On early whorls, a single narrow stripe existed low on the side of a whorl just above the suture. With growth, additional stripes of equal size were added both above and below the initial one, producing a maximum of four on the body whorls of some individuals. These stripes are distributed fairly evenly from immediately below the whorl shoulder to the base of the whorl. More commonly only two stripes are present on the body whorl, and these are restricted to the basal half of the whorl. Some specimens lack stripes, though there is no apparent difference in the quality or type of preservation between these and the striped specimens.

Triasamnicola pilsbryi has previously been reported only from what is probably the Owl Rock Member of the Chinle (Stewart et al., 1972) in southeastern Utah (Yen and Reeside, 1946), and tentatively (as *T.* cf. *T. pilsbryi*) from northern Arizona (Yen, 1951). The Owl Rock Member is in the upper part of the Chinle (Stewart et al., 1972) and is roughly correlative with the upper shale member of the Chinle in eastern New Mexico. The genus *Triasamnicola* has also been reported from the Upper Triassic of southwest China (Nanking Institute of Geology and Paleontology, 1974).

DISCUSSION

The distribution of mollusc taxa in the studied interval of the upper shale member of the Chinle at Bull Canyon is correlated to some extent with depositional environment. All specimens of *Unio arizonensis*, *U.* sp. 2, *U.* sp. 4 and *U.* sp. 6 were obtained from the stream-channel-sandstone unit at Locality 1, and more than 80% of the specimens of *U.* sp. 1, *U.* sp. 3 and *U.* sp. 5 were likewise found in the channel sandstone, with only a few of each of these species being present in the lacustrine facies. On the other hand, a large majority of *Antediplodon dockumensis* and *Triasamnicola pilsbryi* specimens came from the lacustrine facies at Localities 2 and 3, and all specimens of *A.* sp. were from this facies. Thus, the Bull Canyon unionids reached a greater diversity in fluvial environments than in lacustrine environments. Whether this was generally the case in the Upper Triassic of the southwestern United States is not known, as most reports of Chinle unionid species have not included details concerning the lithologies or depositional environments of the units from which they were collected. Stewart et al. (1972) reported *Unio* from siltstones, sandstones, limestones and limestone-pebble conglomerates representing a variety of nonmarine environments in the upper part of the Chinle on the Colorado Plateau. From the information given by Yen (1951) and Stewart et al. (1972), Chinle gastropods appear to have preferred lacustrine environments, as is the case at Bull Canyon.

Some nonmarine mollusc species had a widespread geographic distribution during the time of Chinle deposition. *Antediplodon dockumensis* was present from Arizona to Texas, and *Unio arizonensis* and *Triasamnicola pilsbryi* from Arizona and Utah, respectively, to eastern New Mexico. Although each of the other species of *Unio* described in this paper is known at present only from Bull Canyon, they will likely be found in other areas having Chinle exposures. Although a few species of unionids have been reported from the Upper Triassic of the Atlantic Coast area (e.g., Pilsbry in Wanner, 1921, 1926), none are conspecific with any of the Chinle taxa.

Stewart et al. (1972) reported that the lower part of the Chinle in the Colorado Plateau region contains an abundant vertebrate and invertebrate fauna, whereas the fauna of the upper part of the Chinle in that area is scanty and consists mostly of lacustrine molluscs. Gregory's (1972) summary of Triassic paleontology in eastern New Mexico, however, suggests that the most fossiliferous part of the Dockum Group is in the upper part of the Chinle and overlying Redonda Formation. Observations of the fauna in Bull Canyon support Gregory's observations. However, given the sporadic distribution (or at least the reported distribution) of nonmarine molluscs in Chinle outcrops, the distribution reported by both Gregory and Stewart et al. may well be correct in their study areas. Detailed comparisons of the western and eastern Chinle faunas in terms of diversity, taxonomic composition, environments and stratigraphic distribution must await completion of more detailed paleontological studies of both areas.

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