Sedimentology and paleontology of Lower Permian fluvial red beds of north-central New Mexico

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Sedimentology and paleontology of Lower Permian fluvial redbeds of north-central New Mexico—preliminary report

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Introduction

Joint application of sedimentological and paleontological principles to research involving terrestrial fluvial units is currently being employed by many workers who desire a more complete understanding of paleoenvironmental and depositional conditions (Dodson, 1971; Dodson and others, 1980; Bown and Kraus, 1981; Behrensmeyer and Tauxe, 1982). The perspective gained from such a union is of unquestionable value to the biostratigrapher and paleoecologist and serves as an additional tool for the sedimentologist investigating local facies variations.

This past summer (1982) a field party representing the Carnegie Museum of Natural History and the University of Toronto initiated a joint research program in the Lower Permian redbed fluvial facies of north-central New Mexico (fig. 1). The excellent exposures in this region have in the past received only sporadic attention from paleontologists and stratigraphers and virtually no attention from sedimentologists. The goals of this project are to: 1) reconstruct the depositional environments of these beds by means of a multivariate basin analysis approach (Miall, 1980); 2) utilize a knowledge of depositional style within facies to locate fossiliferous sediments; 3) gain a comprehensive picture of the vertebrate fauna and insights into environmental factors that may be affecting the distribution patterns of some of its members; and 4) provide an understanding of sandstone-body morphology and geometry as a possible guide to mineral and/or hydrocarbon exploration in this region and in other areas with similar histories of deposition.

Field research was carried out in two phases. The thick, laterally extensive exposures of the Cutler Formation in the Rio Puerco drainage of central Rio Arriba County were the subject of intensive paleontological, sedimentological, and stratigraphic investigation. Similar, but cursory, examinations were also made in the Abo Formation (Lower Permian) in the San Diego Canyon region of Sandoval County and central and northeast Socorro County, and in the Cutler Formation in El Cobre Canyon near Abiquiu, Rio Arriba County. The deposits of these areas also have provided a basis for planning future field research. All specimens have been cataloged into the collections of the Carnegie Museum of Natural History, Section of Vertebrate Fossils; the abbreviation CM is used to refer to that repository.

Sedimentology

Sedimentological inquiry and data collection in the Cutler Formation exposures of the Rio Puerco drainage area resulted in the compilation of 32 vertical sections (totaling 2,892 m) and 17 horizontal sections (documenting three-dimensional sandstone-body morphology). A total of more than 1,100 paleocurrent directions were measured during the course of these investigations. In addition, individual fossil-bearing localities, varying widely in taxa and in quantity of individuals yielded, were mapped and sampled in an effort to address the hydraulic controls on fossil distributions within these fluvial deposits.

Several tentative conclusions can be drawn from the vertical section data of the Rio Puerco drainage area (fig. 2). These conclusions are:

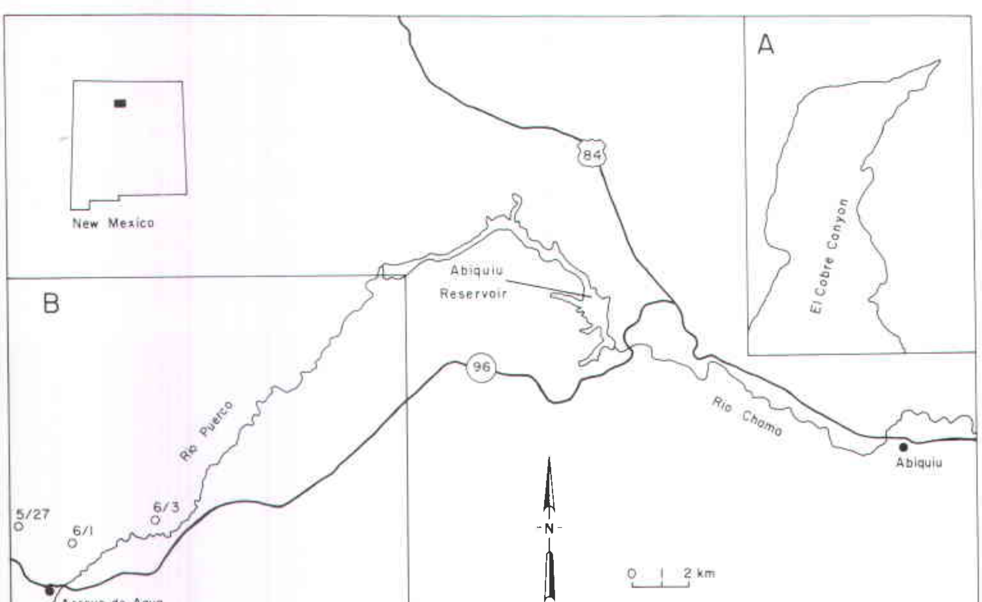

FIGURE 1—LOCATION OF STUDY AREA. **A,** El Cobre Canyon and **B,** Rio Puerco drainage area; open circles in B represent locations of the three vertical sections of fig. 2.

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1) sandstone bodies are concentrated at particular horizons in a given vertical section and lateral continuity of a sandstone horizon is uncommon, suggesting regular avulsion and splay events typical of ephemeral river systems; 2) sandstone to mudstone ratios increase upsection; 3) grain sizes ranging predominantly from medium to coarse in the sandstone bodies, as well as infrequent conglomerates, and abundant channel scouring suggest a midfan fluvial environment; 4) caliche beds of varying maturity and lateral extent are abundant in mudstone deposits throughout all of the vertical sections but become noticeably rare in the highest portions of the thickest sections; 5) local correlations of up to 6–7 km are possible using laterally extensive caliche beds; 6) dark staining of grains, probably because of hematite (not displayed in fig. 2), becomes noticeably reduced upsection, a condition that also was noticed in the San Diego Canyon and Socorro County areas.

Horizontal section data provided the most useful insights into general channel morphology, bedform interrelationships, sinuosity and channel trends, and, to a lesser extent, river geometry. All recorded sections, as well as casual observations, indicate the presence of two distinct types of channel sandstone bodies. One type is U-shaped, of limited lateral extent, and of very low sinuosity. The sands are medium grained and well sorted. Bedforms and biogenic indicators consist primarily of medium to large scale trough crossbedding, abundant dewatering structures, and calcareous tubular nodules. Low width/depth ratios, as well as internal scour surfaces, suggest vertical accretion perhaps similar to that found in modern anastomosing rivers. The second type of sandstone channel fill is laterally extensive and flat based and represents a channel unit that has experienced longer periods of lateral accretion than the U-shaped units. Textural parameters and bedforms of the second type appear comparable to those of the U-shaped units, perhaps exhibiting more large scale trough crossbedding. Paleocurrent measurements of scours suggest low sinuosity.

In addition to the study of the sandstone bodies, U-shaped deposits of reduced mudstones and minor sandstones containing variable concentrations of vertebrate, invertebrate, and plant fossils were sampled, mapped, and measured. Previous reference (Langston, 1953) to these fossil-rich deposits as "pond deposits" can be considered erroneous simply on the basis of their channel-like morphologies and discontinuous lateral extent. Preliminary evaluation of vertical and horizontal sections, as well as taphonomic data recorded from fossils collected by us and by the University of California (Berkeley) nearly a half century ago, strongly suggest that these deposits are the remnants of proximal crevasse splays. The subsequent recognition of lithologically and morphologically similar deposits elsewhere in the section, which are devoid or very sparsely fossiliferous, demonstrates that crevasse-splay deposits are a common feature associated with these sandstone units (as would be expected) and that their fossil content can be highly variable.

Preliminary sedimentological studies of Lower Permian redbed facies in San Diego Canyon, El Cobre Canyon, and northeast and central Socorro County provided us with a means of evaluating some of the stratigraphic data from the Rio Puerco drainage area. These studies also raised questions that will help to direct future field research. Thick (120 m), exclusively fluvial facies in El Cobre Canyon are tentatively considered to be stratigraphically lower than those beds in the Rio Puerco drainage on the basis of their larger grain size and darker color (hematite staining). One other line of evidence suggests this relationship. Within the Rio Puerco drainage area, the Chinle Formation (Triassic) cuts

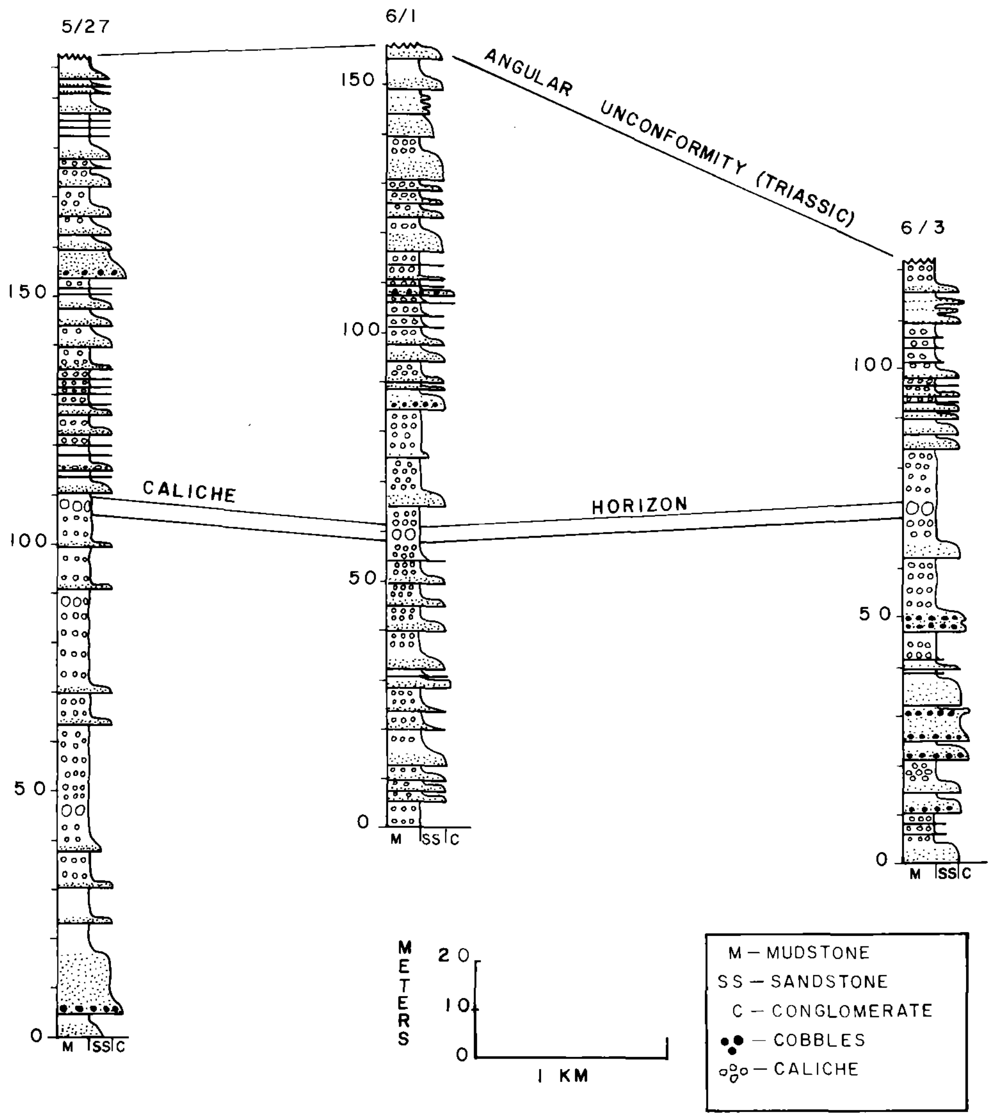

FIGURE 2—Stratigraphic columns from Lower Permian Cutler Formation of Rio Puerco drainage (fig. 1); note lateral continuity of thick caliche horizon (datum marker) and lateral discontinuity of sandstone units.

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down into the underlying Lower Permian beds, thus forming an angular unconformity that dips at a low angle to the east. Assuming continuous eastward downcutting, we may conclude that the Lower Permian beds of El Cobre Canyon are stratigraphically lower than those of the Rio Puerco drainage area.

The redbeds in the San Diego Canyon region are particularly interesting in that they show a continuous transgressive sequence from basal fluvial facies up through eolian and marginal-marine facies. Paleocurrent directions, color changes, bedforms, and channel morphology suggest that at least the lower fluvial facies are roughly contemporaneous with the Rio Puerco beds. Generally finer sediments suggest a more distal fan facies.

All of the beds in the Rio Arriba and Sandoval Counties are thought to have been derived from a common source area, the Uncompahgre positive area, during the Late Pennsylvanian and Early Permian (Baars, 1962). In this light, considering these discontinuously exposed beds as deposits in a single, three-dimensional system representing a progradational terrestrial phase is important. Characterization of the system on a regional scale will involve the additional sampling and compilation of vertical and horizontal sections in the El Cobre Canyon and San Diego Canyon areas.

Preliminary investigations of the Abo Formation exposures in Socorro County provided an opportunity to study distal-fan, lagoonal, and marginal-marine facies (together considered as a deltaic environment by some authors). Although these beds are not all derived from the same primary source area as the northern beds, similarities in timing of deposition, lithological content, and fauna and flora suggest strong parallels. Thus, these beds may be considered a model for a reasonable extension of the northern facies to the southwest. Such assumptions, while not entirely useful in a strict sedimentological sense, will hopefully help explain existing vertebrate-fossil distribution gradients in the northern beds.

Discussion

Although limited published lithostratigraphic data are available from these strictly fluvial exposures (Williston and Case, 1912; Fracasso, 1980), Baars (1962) has shown that accurate correlations between Permo–Carboniferous redbeds of the Colorado Plateau at the stage level are convincing only when interbedded marine deposits are present. Similarly, the biostratigraphic data, discussed extensively in the literature (Langston, 1953; Romer, 1960; Vaughn, 1963; Fracasso, 1980), have been found equivocal at the stage level (see Fracasso, 1980, for a synopsis of arguments). Preliminary results from this past season, however, suggest the validity of using laterally extensive caliche horizons as intrabasinal marker beds at a local level. The basin-wide, upsection decrease in dark staining of sandstone grains is an intriguing phenomenon and may eventually prove to be useful as a regional stratigraphic tool. However, the relationship between this upsection decrease in staining and facies changes is not presently understood and must be evaluated before attempting to apply such a trend as a chronostratigraphic tool.

A recent development in fluvial sedimentology has been toward elucidating and defining channel morphologies and geometries with a commensurate de-emphasis on genetic modeling (Friend, in press). A basin-analysis approach to the problems concerning the controls on the geometries and morphology is attaining widespread acceptance (Miall, 1980). The need for such an approach to the Lower Permian redbed deposits of New Mexico is indicated because none of the existing fluvial models is entirely appropriate to explain the full range of sandstone parameters displayed in these exposures. In addition, recent work on the regional Late Paleozoic tectonic history of this area (Kluth and Coney, 1981) has demonstrated the fairly unique nature of the intracratonic orogenic events responsible for alluvial deposition. Thus, our concentration will be on characterizing extra-basinal, as well as basinal, controls on fluvial style.

Of further interest is the fact that many of the recent examples of applied fluvial sedimentological research involve delineating distributional patterns of economic minerals and hydrocarbons within fluvial systems. Implicit in these studies is a need to understand sandstone geometry and morphology as well as lithostratigraphic cycles (Collinson, 1980).

Paleontology

Intensive prospecting for vertebrate fossils in the Rio Puerco drainage has resulted in the collection of many partial to complete skeletons of either new or incompletely to poorly known animals. Re-examination of a site discovered by D. S. Berman (approximately 1.5 km northwest of Arroyo de Agua) in 1979, which at that time produced a partial skull and disarticulated but associated remains of a dissorophid amphibian probably belonging to *Broiliellus*, has yielded important new finds. Most notable among these are: 1) four complete paleoniscoid fish and patches of scales of others; 2) several partial skulls and partially articulated and associated postcranial materials also probably referable to *Broiliellus;* and 3) a partial skull, numerous vertebrae, and some limb elements belonging to a captorhinid reptile. The paleoniscoid fish are fusiform in shape, measure approximately 10 cm in length, and obviously belong to a single species. Previously known occurrences of paleoniscoid fish from the Lower Permian of New Mexico are limited to isolated scales in coprolites and one very fragmentary specimen that was tentatively identified (Langston, 1953) as *Progyrolepis* sp., known otherwise only from the Lower Permian of Texas. The latter specimen has not been described or figured. To date, only two imperfect skulls probably referable to the dissorophid amphibian *Broiliellus* have been described from the Lower Permian of New Mexico, both from the Cutler Formation of the Rio Puerco drainage. There is some doubt that these specimens pertain to *Broiliellus,* which is based on good materials from the Lower Permian of Texas. The specimens collected by us and an excellently preserved skull and partial postcranial skeleton discovered by one of us (D. S. Berman; about 1.6 km southeast of Arroyo de Agua) in 1979, should not only resolve this confusion but greatly increase our knowledge of the cranial anatomy of the dissorophids. The skulls are very much like that illustrated here in fig. 5 for the dissorophid *Ecolsonia cutlerensis* (see below), differing most noticeably in having a normal size external narial opening (not expanded posteriorly), a posteriorly open otic notch, and approximately one-half smaller overall size. The discovery of a captorhinid reptile is also of great interest because they are very poorly represented in Lower Permian collections from New Mexico. The captorhinids, which in life had an appearance much like the small iguanid lizards living today, are a very diverse, commonly encountered member of the Lower Permian of Texas and Oklahoma.

During the course of collecting stratigraphic data at widely scattered points, we encountered and explored new and potentially fossiliferous areas. At one such area (approximately 13 km northeast of Arroyo de Agua), a large block was excavated that has so far produced four skulls with postcranial skeletons of *Seymouria,* a modest-sized (maximum length of over 70 cm), reptilelike amphibian (fig. 3). The skulls of all four specimens are similar in being small and of identical size (about 8.5 cm in length compared to known maximums of over 11 cm) and in exhibiting an incomplete state of ossification. This suggests that they are juveniles and probably members of the same brood. Until now *Seymouria* was known only from contemporaneous beds in southeast Utah (Vaughn, 1966) and north-central Texas (White, 1939).

Of particular interest was the discovery of 14 small (1.35–2.50-cm-long) skulls (fig. 4), many with partial, articulated postcranial skeletons, of a microsaur amphibian. These were found while investigating the richly fossiliferous crevasse-splay deposits approximately 1 km southeast of Arroyo de Agua. Most of the specimens occurred weathering out of caliche nodules or a fine-grained sandstone and littering a 2 m^2 surface of a small siltstone hillock some 80 m from the well-known Camp quarry (see Langston, 1953). Other specimens were found in the immediately adjacent area. Microsaurs constitute a very diverse group of small amphibians that range from the Lower Pennsylvanian to the Lower Permian of North America and Europe. Their wide range of body forms and probably of habitat preferences were seemingly not unlike those of living salamanders, apodans, lizards, and snakes. Those collected by us were probably fossorial in habit and much like the apodans in appearance. Until now microsaurs were represented in ☞

FIGURE 3—DORSAL VIEW OF THREE SKULLS AND PARTIAL VERTEBRAL COLUMN (CM 38022) OF AMPHIBIAN *SEYMOURIA* FROM CUTLER FORMATION (LOWER PERMIAN) OF RIO PUERCO DRAINAGE; scale in centimeters.

the Lower Permian of New Mexico by only a single jaw, tentatively assigned to the Lower Permian Texas genus *Pantylus*, from the well-known Anderson quarry about 1 km south of Arroyo de Agua (Langston, 1953). Preliminary examination of the new specimens strongly suggests assignment to a new species and possibly a new genus and definitely excludes assignment to *Pantylus*. Though the presence of a new taxon is quite important, equally exciting is the occurrence of a population of microsaurs showing marked variation in growth stages. Such a wide range in sizes may allow for detailed ontogenetic, as well as phylogenetic, studies. Investigation of other nearby crevasse-splay deposits, known to contain the disarticulated and hydraulically sorted remains of microvertebrates, resulted in the discovery of associated limb and axial elements of an araeoscelid reptile; tentative diagnosis allies it most closely with *Araeoscelis* from the Lower Permian of Texas and Oklahoma. Except for its elongated neck and limbs, the small, lightly built *Araeoscelis* had a typical lizardlike appearance, reaching over a third of a meter in length (Vaughn, 1955); the Cutler araeoscelid is, however, considerably smaller.

Two skulls (fig. 5) and considerable amounts of disarticulated but closely associated postcranial materials of the large amphibian *Ecolsonia cutlerensis* were recovered from a highly fossiliferous crevasse-splay deposit known as the Miller bonebed (see Langston, 1953) approximately 1 km north of Arroyo de Agua. *E. cutlerensis* was described by Vaughn (1969) as a new genus and species of the family Trematopsidae on the basis of a partial skull from the crevasse-splay deposits 1 km southeast of Arroyo de Agua. Until this time no other materials of this animal had been found. *E. cutlerensis* was described as possessing an unusual combination of dissorophid and trematopsid features, thus reinforcing an earlier concept of a close relationship between the two families. Assignment to the Trematopsidae was based mainly on the weight of the highly typical and unusual trematopsid feature of an extremely long external narial opening. The new specimens of *E. cutlerensis* will not only allow a more complete description of its anatomy but a more precise assessment of its familial assignment. At present only the skulls are sufficiently prepared for close study. They exhibit all the hallmark features of the Dissorophidae, the elongated narial opening being the only apparent link to the Trematopsidae. At least one dissorophid, *Longiscitula* DeMar (1966) from the Lower Permian of Texas, has been described as possessing an elongated external narial opening.

Discussion

Prospects for continued success in expanding our knowledge of the Lower Permian vertebrate fauna of the Rio Puerco drainage and the nearby areas of El Cobre Canyon and San Diego Canyon appear excellent. Of course, further prospecting will probably result in not only new species of morphological and phylogenetic interest, but more complete specimens of those already identified on fragmentary remains. Most importantly, however, we hope that a paleontological-sedimentological approach to the Lower Permian redbeds of New Mexico will resolve enigmatic distributional patterns exhibited by many members of the vertebrate faunas.

The Lower Permian redbeds of the Rio Puerco drainage, El Cobre Canyon, and San Diego Canyon areas, though not continuous in outcrop, were derived almost entirely from the same source, the Uncompahgre positive area to the north, and their fossiliferous levels are essentially contemporaneous. Though no obvious physical barriers separated these spatially close areas, they exhibit numerous, marked faunal differences. Presently, two genera of amphibians, *Limnoscelis* and *Diasparactus*, and three genera of reptiles, *Chamasaurus*, *Baldwinonus*, and *Nitosaurus*, are recognized as unique to El Cobre Canyon. However, the two amphibians have close counterparts, *Limnosceloides* and *Diadectes*, in the Rio Puerco area, whereas the three reptiles are based on very fragmentary specimens and their determinations are questionable. Genuine faunal differences most probably exist between these two areas, but they are not as striking as those between the Rio Puerco and San Diego Canyon areas. Though both areas contain many faunal elements in common, several notable examples of animals are known from the San Diego Canyon area that are conspicuously absent from the Rio Puerco and, for the most part, El Cobre Canyon areas. These include the lungfish *Gnathorhiza* (recently discovered by D. S. Berman from El Cobre Canyon but not reported), the amphibians *Diplocaulus*, *Trimerorhachis*, and an embolomere, and the reptile *Dimetrodon*. On the other hand, one can also list numerous fossil genera found in the Rio Puerco area but not the San Diego

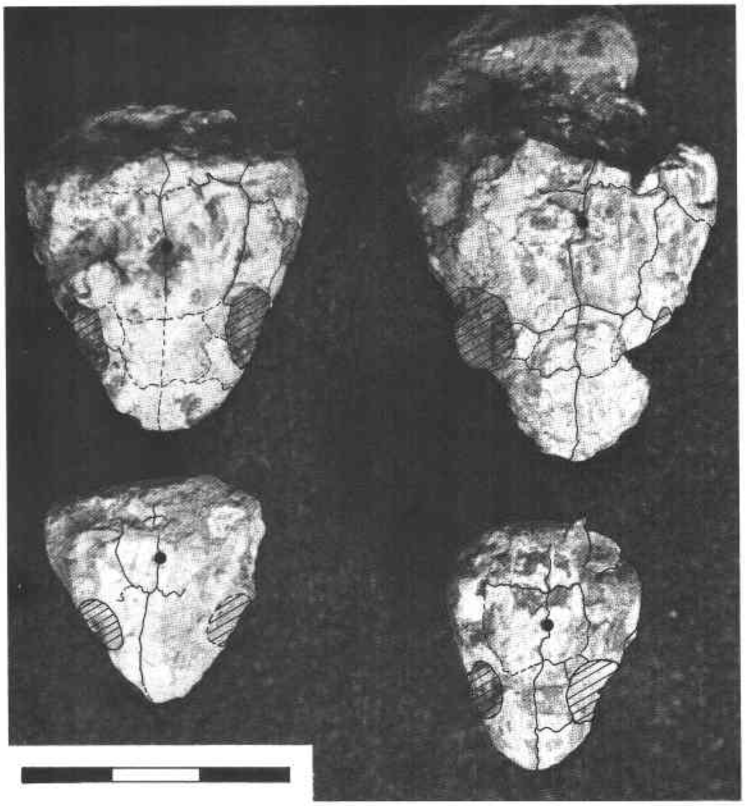

FIGURE 4—DORSAL VIEW OF FOUR MICROSAUR AMPHIBIAN SKULLS (CM 38023) FROM CUTLER FORMATION (LOWER PERMIAN) OF RIO PUERCO DRAINAGE; scale equals 1.5 cm.

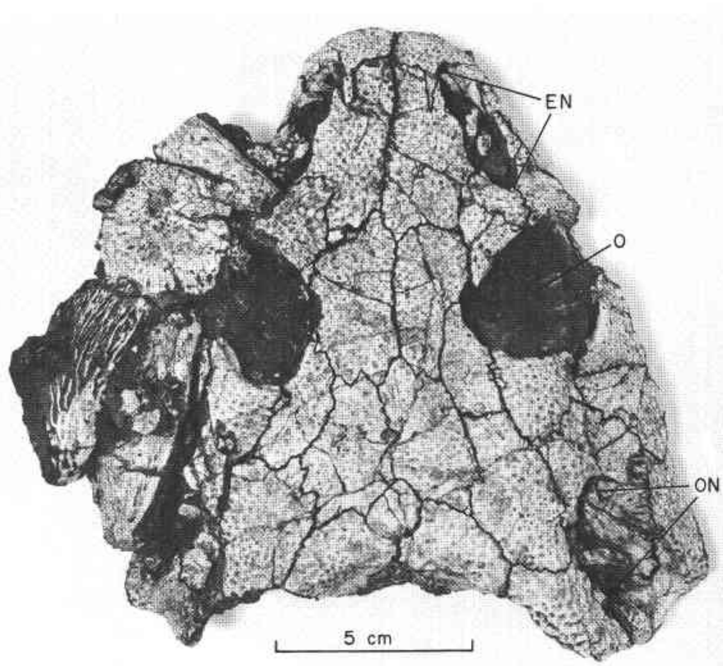

FIGURE 5—DORSAL VIEW OF SKULL (CM 41703) OF DISSOROPHID AMPHIBIAN *ECOLSONIA CUTLERENSIS* FROM CUTLER FORMATION (LOWER PERMIAN) OF RIO PUERCO DRAINAGE. Portions of lower jaw and shoulder girdle adhering to left side of skull; external naris **(EN)**, orbit **(O)**, and otic notch **(ON)** indicated.

Canyon area or other Abo Formation exposures farther to the south: the amphibians *Pantylus*, the microsaurs described here, *Zatrachys*, *Chenoprosopus*, *Ecolsonia*, *Tseaiaia*, *Seymouria*, and *Limnosceloides*, and the reptiles *Aerosaurus* and *Oedaleops*. Attempts to explain distributional patterns of the Lower Permian redbed faunas of New Mexico on the basis of broad, paleogeographic features ("truly deltaic" or "coastal plain" versus "somewhat more upland" faunas) have been inadequate (Berman and Reisz, 1980). A realistic approach to this problem must clearly be based, at least in great part, on a thorough sedimentological study that allows recognition of the various physical habitats.

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Geographic names

U.S. Board on Geographic Names

Manzanita Mountains—mountains, 29 km (18 mi) long, extend south from Tijeras Canyon to Cañon de los Seis at the north end of the Manzano Mountains 24 km (15 mi) southeast of Albuquerque; Bernalillo, Torrance, and Valencia Counties, New Mexico; Tps. 6–10 N., Rgs. 4–6 E., New Mexico Principal Meridian; 35°04'40" N., 106°24'15" W. (north end), 34°50'00" N., 106°23'25" W. (south end); *not*: Manzano Mountains.

Manzano Mountains—mountains, 48 km (30 mi) long, extend south from Cañon de los Seis at the south end of the Manzanita Mountains to Abo Canyon 32 km (20 mi) east of Belen; Torrance and Valencia Counties, New Mexico; Tps. 3–7 N., Rgs. 4 and 5 E., New Mexico Principal Meridian; 34°51'25" N., 106°19'45" W. (north end), 34°27'05" N., 106°29'15" W. (south end).

—Dave Love,
NMBMMR Correspondent