Chapter 8
Coprolites

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INTRODUCTION

Coprolites occur in some abundance both within and on the surface of the Ciniza Lake Beds. They are particularly abundant on the surface of the lake beds at locality FW4 in Eastern Wash. About 100 in-place coprolites (mainly from locality FW4) were collected for this project. The hydrocarbon content of six in-place coprolites and one surface coprolite was analyzed by Darrel J. Weber and George C. Lawler. A detailed report of their findings is contained in chapter 9. Portions of these seven coprolites were retained by me for additional study as reported elsewhere in this chapter. Several of the remaining coprolites were sectioned for study (figs. 1a–1f).

Previous Investigations

Coprolites have been known in the Upper Triassic rocks of the southwestern United States for many years, but, as far as I can determine, none have been described in detail. Interestingly, a new species of bacteria was described from an Upper Triassic coprolite in Arizona (Lipman and McLees 1940). It was said to be a sulfur-oxidizing form and was called *Thiobacillus coproliticus.* The coprolite, however, was not described.

GENERAL CHARACTERISTICS

In-place and surface coprolites are generally similar in both external morphology and internal structure. However, in-place coprolites are typically covered with a thin coating of gypsum, and they often contain veins, layers, and small particles of this mineral. In contrast, surface coprolites are not covered with gypsum and contain only small quantities of it. Although the gypsum coating obscures the external features of the in-place coprolites, their gross morphology is clear. The gypsum coating was removed from several of them, and they then showed some of the external characters of the surface coprolites. None of the other units in the area contain coprolites, and there seems to be little question that the surface coprolites were derived from the Ciniza Lake Beds.

The in-place coprolites that contain large quantities of gypsum are more susceptible to weathering than those that do not. Only those that contain small quantities of the mineral can survive for long on the surface of the lake beds, and the majority disintegrate soon after exposure. Consequently the surface coprolites probably represent only a small biased sample of the total population in the lake beds.

External Features

The surface coprolites generally weather gray to brown, and some show small irregular patches and veins of shiny bluish material. They are blue, black, and brown on broken surfaces. The in-place coprolites are usually white to yellow because of the gypsum coating. When the coating is removed, the in-place coprolites are also brown in color. The in-place coprolites are brown to black on unweathered surfaces except for the narrow white veins and small masses of gypsum.

The surface coprolites can be divided into two groups on the basis of their external characteristics. Shapes of the coprolites seem to correlate with this grouping. The coprolites that are smooth are cylindrical to cigar-shaped (fig. 2a). Those that have a rough exterior are typically flattened considerably and are round, oval, or oblong in outline (fig. 2b). The in-place coprolites (fig. 3) show the same range of forms as the surface coprolites, but because of the gypsum coating the nature of the exterior cannot be determined.

Typically the cylindrical coprolites are straight, and they rarely show curvature of the long axis. Usually they have abruptly rounded ends and are nearly circular in cross-section. Only a few appear to have been flattened (fig. 2b). Probably the nonflattening is the result of defecation in water or closer to the ground as Waldman and Hopkins (1970) have suggested. The cylindrical coprolites range from about 5 to 30 mm in diameter and 30 to 39 mm in length. In outline some of them resemble the coprolites found in China in association with Paleocene crocodiles (Young 1964, pls. 1–2). The cigar-shaped coprolites are not common; only six complete specimens were found. They have long tapering ends and are round in cross section (figs. 2h–2k). They range from 8 to 32 mm in diameter and from 30 to 90 mm in length.

The surface coprolites that have an external network of ridges are distinctly flattened and usually have abruptly terminated ends. They range from 1.2 to 9 mm in thickness, from 24 to 49 mm in length, and from 13 to 42 mm in width (fig. 2b). The ridges that form the external network are usually less than 1 mm broad and high and seem to be external features only, not related to internal structure. Perhaps these flattened coprolites were originally soft and were deposited on the ground from some height. Possibly they were dried by the sun prior to burial in the Ciniza Lake Beds although the ridges do not look like wrinkles.

Regular external markings are most clearly defined on the cylindrical and cigar-shaped coprolites that occur on the surface of the lake beds. The markings include longitudinal grooves and striae (fig. 2g), transverse ridges (2h), and spiral grooves (figs. 2e, 2f, 2j, 2k). Presumably these markings were impressed on the feces by muscular pressure.

The spirally grooved coprolites are particularly interesting. They look like some coprolites described by Buckland (1829, pl. 28; 1841, pl. 15) from the Lower Jurassic of England. Modern dogfish and sharks have spiral valves in their intestines which give the feces a spiral internal structure and an external spiral groove (Zangerl and Richardson 1963). These grooved coprolites from the lake beds indicate that there were vertebrates (fish?) in Lake Ciniza which had a similar spiral valve in their intestines. Internal spiral structure is not evident in the Lake Ciniza coprolites but could have been destroyed during fossilization.

None of the coprolites show evidence of having been attacked by insects or other scatophagous organisms as Bradley (1946) noted in coprolites from the Eocene Bridger Formation of Wyoming. One coprolite from the surface of the Ciniza Lake Beds does appear to be wrinkled (fig. 2c). These wrinkles would probably not have developed had the feces been deposited underwater in the lake and remained covered with water. Perhaps this specimen was deposited on the beach of Lake Ciniza and dried before being covered by sediment. The flattened nature of the coprolite also indicates that it was deposited on the ground and possibly from a low height.

Foreign bodies are visible on the exterior of a few of the coprolites. Two show the remains of clam shrimps (fig. 1c), four show small bones (figs. 1g, 1h), and one contains a piece of wood. There does not appear to be any correlation between the shape of the coprolites and their contents. The piece of wood and some bone fragments, for example, occur in cylindrical coprolites. Other bone fragments occur in flattened coprolites.

Internal Features

Typically the coprolites consist of a broad core and thin (1–2 mm) outer rind composed of dark material that is dense and hard. It generally breaks with an irregular conchoidal fracture. In some of the surface coprolites the rind has been partially removed by weathering, and the core is exposed (fig. 1a; lower left, fig. 1d).

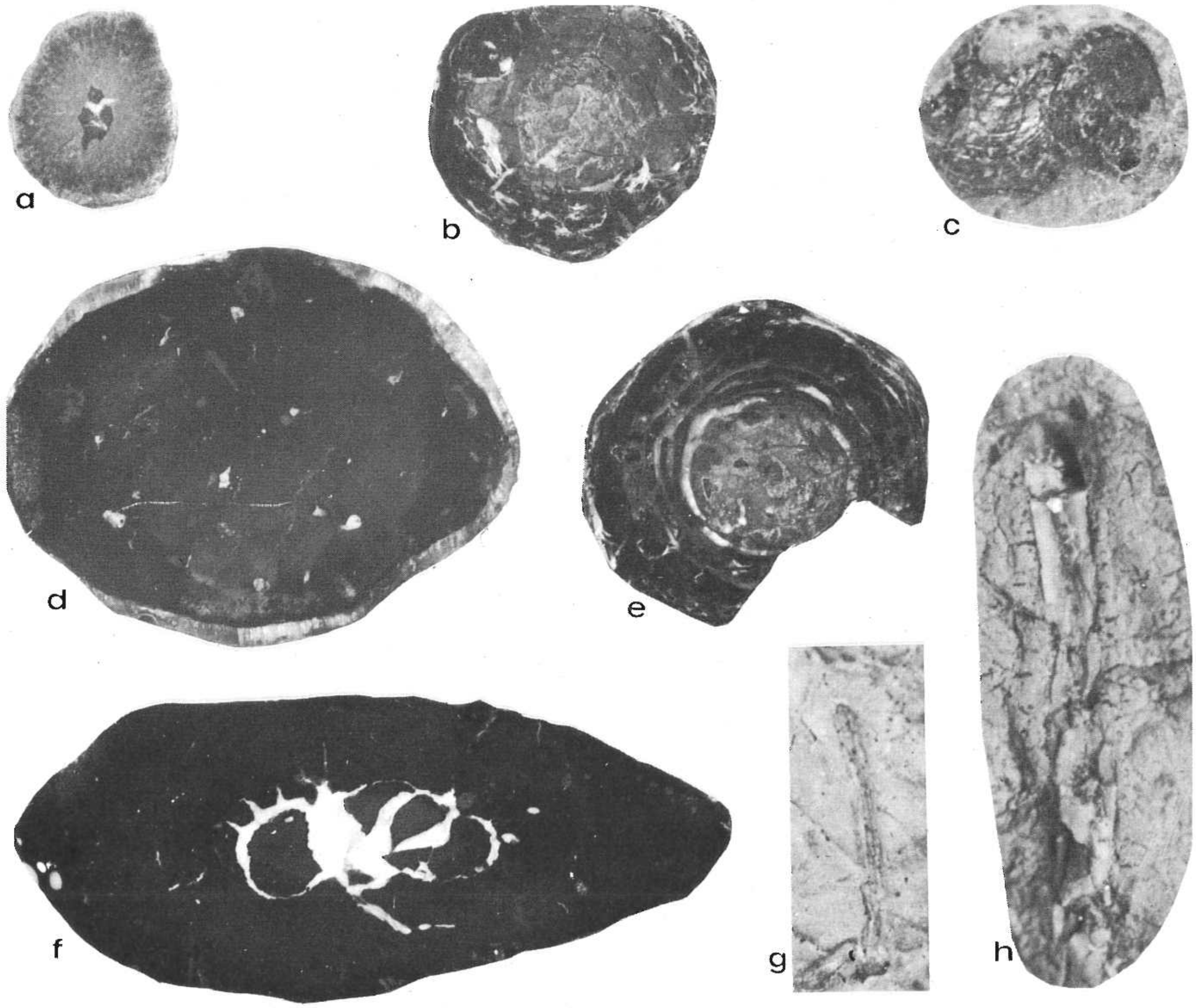

FIGURE 1.–Coprolites from Ciniza Lake Beds and from surface of lake beds. a, f.–Coprolites containing a central body of gypsum. Both fossils from surface of lake beds. X½. b, e.–Coprolites containing concentric layers of gypsum. Note that central part of core in these coprolites is lighter colored than outer part. Both fossils are from lake beds. X2. c.–Clam shrimps in a coprolite. Fossil comes from surface of lake beds. X2. d.–Coprolite containing small cavities filled with gypsum. Fossil is from lake beds. Note layer of gypsum which covers exterior of coprolite. X2. g, h.–Bone fragments in two coprolites. Both are from surface of lake beds. X5.

The dark material in the core of the coprolites is not always homogeneous. It may consist of two or more masses of slightly different shades of brown or black that are sharply defined (figs. 1e, 1f). In this feature they compare with Pennsylvanian coprolites described from Indiana by Zangerl and Richardson (1963). However, some masses in those coprolites commonly contained recognizable bone fragments. The masses in the Lake Ciniza coprolites probably indicate that feces accumulated in the intestine of the producing animal for some time before being expelled as in the Pennsylvanian coprolites (Zangerl and Richardson 1963).

Many of the Lake Ciniza coprolites contain small rounded cavities or small rounded particles of gypsum which evidently fill cavities (fig. 1d). The cavities resemble those reported in Eocene coprolites from North Dakota by Jepsen (1963), who attributed them to small pockets of gas in the

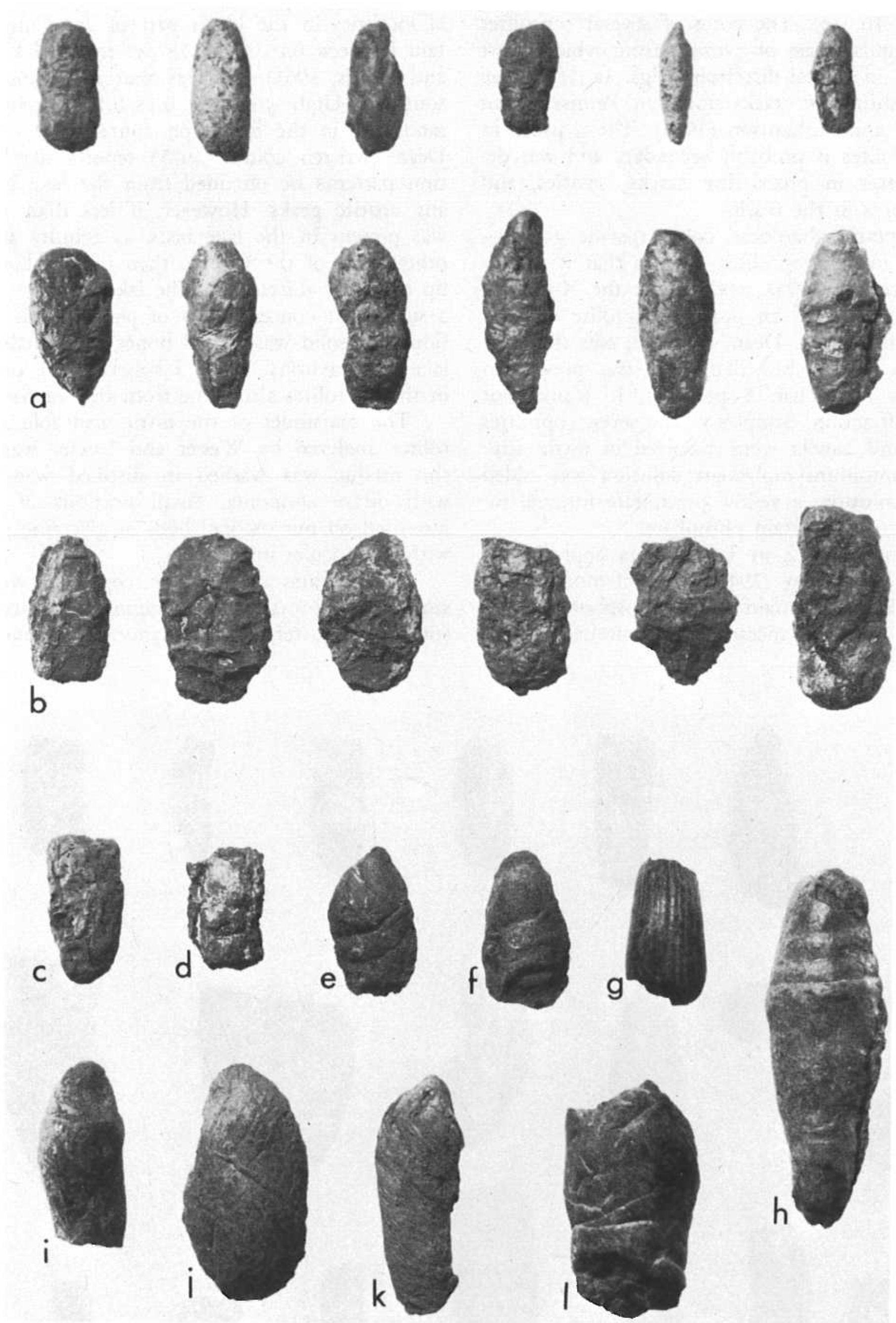

FIGURE 2.–Coprolites from surface of Ciniza Lake Beds. a.–Cylindrical and cigar-shaped coprolites. Compare smooth exteriors with those in figure 2b. X½. b.–Flattened coprolites. Note network of narrow ridges on exteriors. X½. c, j.–Wrinkled? coprolites. d, e, f, i, k, l.–Spirally grooved coprolites. X½. g.–Longitudinally grooved coprolite. X½. h.–Transversely grooved coprolite. X½.

original feces. Such an explanation appears to be reasonable for cavities in the Lake Ciniza coprolites.

The coprolites, especially those found in place in the lake beds, commonly contain gypsum (figs. 1a, 1b, 1d–1f). Dean (written comm. 1975) reports that the X-ray diffraction pattern he obtained from an in-place coprolite showed lines for only a large amount of gypsum and a small amount of crystalline clay. A layer of gypsum occurs between the core and rind of many coprolites, and veins of gypsum may cut across both core and rind. Some coprolites contain concentric layers of the mineral (figs. 1b, 1e). The cores of several coprolites contain a central irregular mass of gypsum from which short veins radiate outward in several directions (figs. 1a, 1f). Some veins look like the shrinkage cracks noted in Pennsylvanian coprolites by Zangerl and Richardson (1963). The gypsum in the Lake Ciniza coprolites is probably secondary and was deposited by groundwater in preexisting cracks, cavities, and along zones of weakness in the fossils.

The physical properties—hardness, color, specific gravity—of the dark material in the coprolites suggest that it is apatite. Dean (written comm. 1975) reports that the X-ray diffraction pattern obtained from an in-place coprolite did not show any indication of apatite. Dean, however, says that apatite could have been present but that, if it was present in very small quantities (less than 5 percent), it would not show up on X-ray diffraction. Samples of the seven coprolites analyzed by Weber and Lawler were dissolved in nitric acid. When a drop of ammonium molybdate solution was added to a portion of the solution, a yellow precipitate formed, indicating that the coprolites contain phosphate.

The source of phosphorous in Lake Ciniza coprolites is unknown. According to Bradley (1946), feces of modern reptiles and mammals do not contain much phosphorous, and presumably the feces of their ancestors were similar in this regard. Bradley (1946) speculates that some phosphorous in the Bridger coprolites was derived from shards of volcanic glass in the Bridger Formation, but that most came from decomposition of the fluid and solid wastes of the Bridger animals and their bones. I believe that some of the phosphorous in the Lake Ciniza coprolites originated from the clays in the Chinle Formation which, in turn, were derived from the volcanic materials in the unit. Several workers have determined that the Chinle Formation contains small amounts of P_2O_5. Schultz (1963, p. C6), for example, found that clays at several localities in the lower part of the Chinle Formation contain between 0.26 and 0.78 percent of P_2O_5. Huff (in Smith and others, 1963) indicates that mudstone in the Chinle in southern Utah contains 0.14–0.19 percent P_2O_5 and that sandstone in the formation contains 0.13–0.22 percent P_2O_5. Dean (written comm. 1975) reports that the X-ray diffraction patterns he obtained from the lake beds did not show any apatite peaks. However, if less than 1 percent of P_2O_5 was present in the lake beds, as Schultz and Huff found in other parts of the Chinle, then it probably would not show up on X-ray diffraction. The lake waters may have contained a significant concentration of phosphorous which came from fluid and solid wastes and bones of animals that lived in the lake and environs. Thus, I believe some of the phosphorous in the coprolites also came from the waters of Lake Ciniza.

The remainder of the nitric acid solution from the coprolites analyzed by Weber and Lawler was centrifuged, and the residue was washed in distilled water and neutralized with dilute ammonia. Small portions of the residue were mounted on microscope slides in glycerine jelly and examined with a binocular microscope.

The residues of all seven coprolites were essentially the same. They contain many fragments of structureless, brown (organic?) matter, a few palynomorphs, and a small number

FIGURE 3.—Coprolites from Ciniza Lake Beds. Their exteriors are covered with a thin coating of gypsum. Fossil at left end of middle row consists of one coprolite overlapping another. All are from lake beds. X½.

of tiny bits (1 mm^2) of plant cuticle. The palynomorphs and the cuticles are slightly corroded, but they are recognizable. Many of the palynomorphs described by Stone in chapter 5 were observed on these slides. A fragment of a flat coprolite containing a bone was macerated in nitric acid as above. Its content is similar to that of the other coprolites.

J. F. Stone made a palynomorph analysis of a cylindrical coprolite from the lake beds. He determined that it contained the following palynomorphs:

Palynomorph	Percentage
Brodispora striata	0.8
Cycadopites fragilis	4.8
Minutosaccus schizeatus	0.4
Klausipollenites sp.	19.8
Platysaccus sp.	0.4
Alisporites gottesfeldi n. sp.	1.2
A. opii	6.3
Pityspontes chinleana	36.5
Gramosaccus sulcatus	11.9
Patinasporites sp.	7.5
unidentified	10.3
Total (rounded)	100.0

All these grains occur in the Ciniza Lake Beds. However, nine of the Lake Ciniza forms were not found in this residue. Stone points out that the percentages of palynomorphs in the coprolite correspond roughly to the percentages of palynomorphs in the lake beds in the middle of section FW1.

It appears from the recently published bibliography of coprolites (Hantzschel, El-Baz, and Amstutz 1968) that palynomorphs have never previously been reported from Upper Triassic coprolites. Spores have been described from Permian coprolites of France by Renault (1900) and from Upper Cretaceous coprolites of Canada by Waldman and Hopkins (1970).

DISCUSSION

When this investigation began, it was hoped that the contents of the coprolites might allow correlation of a particular shape of coprolite with either carnivorous or herbivorous animals in the lake and even suggest a particular family or genus. So far, this hope has not been realized. Bones and clam shrimps occur in both cylindrical and flattened coprolites in conjunction with palynomorphs and plant fragments. One coprolite contains only plant material, and it is cylindrical. One explanation for the occurrence of both plant and animal fragments in the same coprolites is that there were several sizes or groups of omnivorous animals in and near the lake. Alternatively, palynomorphs and plant fragments may have been ingested accidentaly from lake waters by carnivorous animals. Another explanation is that the plant material was in the digestive track of the prey of the carnivorous animals that produced the plant- and animal-bearing coprolites.

Possibly the clam-shrimp-bearing coprolites were produced by fish near the base of the food pyramid in Lake Ciniza. Otherwise, it seems that about all that can be concluded is that the coprolites described here were probably produced by several different groups and sizes of animals.

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