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THE SALT MOUNTAIN LIMESTONE OF ALABAMA

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ABSTRACT

The Salt Mountain Limestone of southwestern Alabama is a Late Paleocene (Thanetian) tropical-subtropical, photic-zone reef constructed primarily of sponges, coralline red algae, and lime mud, but with common scleractinian corals (12 species) and abundant bryozoa. Accessory fauna includes larger and smaller benthic foraminfera, echinoderms, endolithic bivalves, and brachiopods. The reef developed on an inner neritic siliciclastic shelf, probably over a local diapiric shoal, at an approximate paleolatitude of 31°-32° North. The final demise of the reef was evidently caused by siliciclastic influx from the prograding Holly Springs Delta System of the Mississippi Embayment. This massive carbonate underwent several episodes of diagenetic alteration, including early marine micritic cementation.

Smaller benthic foraminifera assemblages suggest depositional water depths of 15-30 meters for forereef sediments, to less than 5 meters for the reef core. The dominant alga is *Archaeolithothamnium*, which occurs as both thick and thin crusts, and rhodoliths, suggesting water depths between 5-20 meters. At least 15 distinct sponge morphotypes are consistently identified, ranging from small, 2 -10 cm oblong buds to large, vase- or barrel-shaped forms that may have reached 1 meter in length. Echinoderms are extremely abundant, as indicated by ossicles and plates, but only six species of regular echinoids have been identified. Conspicuously absent are any remains of irregular echinoids, which may not have occupied reef niches at that time as they clearly did by the Late Eocene and Early Oligocene.

The constructional dominance of coralline algae and sponges in the Salt Mountain could be an indication that scleractinians had not yet fully established their post-Cretaceous role as primary reef framestone builders in the Gulf of Mexico Basin. The abundance of hexactinellid sponges, however, may be especially significant. The siliceous hexactinellids are exclusive K-strategists, requiring stable environments, but are bathymetrically tolerant. They reached their greatest diversity in the Late Cretaceous and were common reef/mound constructors in the Jurassic. Their presence in the Salt Mountain suggests a temporary role as early post-Cretaceous photic-zone reef constructors prior to the full recovery of scleractinian-dominated reefs in the later Paleogene.

PART I
INTRODUCTION TO THE SALT MOUNTAIN LIMESTONE

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I. OVERVIEW

In the 57 years since the publication of Lyman Toulmin's monograph, "The Salt Mountain Limestone of Alabama" (*Geological Survey of Alabama Bulletin 46*), there has been surprisingly little research on this fossiliferous Gulf Coast formation. Perhaps this is because the formation is locally restricted in outcrop and, therefore, considered to be of minimal stratigraphic importance (it is entirely omitted in many regional stratigraphic surveys–*e.g.* Gibson *et al.*, 1982; Mancini, 1984; Mancini and Tew, 1991). Or possibly because this carbonate buildup appears to be recrystallized and largely non-fossiliferous.

But thin-section analysis and careful collecting along the outcrop have uncovered a diverse, undescribed biota of coralline red algae, siliceous sponges, and corals. The collection of papers in this volume deals with various aspects of the Salt Mountain Limestone, and is intended as a resource for continuing research. It reviews past research and summarizes current investigations on the stratigraphy, paleontology, and paleoecology of the Salt Mountain. These papers are not exhaustive. In particular, systematic treatment of the diverse sponge fauna is still in progress. Coralline algae and bryozoa are also largely unstudied. But the broader paleobiological significance of the Salt Mountain biota is clear. The age and reefal character of the Salt Mountain give it a unique significance with regard to the post-Cretaceous evolution of reef communities.

The publication of these articles coincides with a fieldtrip scheduled for March 26, 1997, in conjunction with the 46th annual meeting of the Southeastern Section of the Geological Society of America at Auburn, Alabama, and is sponsored by the Southeastern Section of the Paleontological Society. Special thanks go to Emily Vokes for her cooperation and guidance in the preparation of this special collection of articles.

II. GENERAL DESCRIPTION

The Salt Mountain Limestone is a muddy, soft to well-indurated, reefal carbonate of Late Paleocene age, located in southwestern Alabama. It is composed of several lithologies, including bioclastic packstones/floatstones, algal and sponge-algal boundstones, sponge bafflestones, and coral framestones. Toulmin (1940b, p.30) described the Salt Mountain in outcrop as "hard white crystalline limestone forming irregular ledges 2 to 8 feet thick, and beds or lenses of soft white limestone." The extreme hardness of most of the rock gives it a cherty appearance and texture. But silica makes up only a small fraction of the composition of both soft and hard lithologies (Toulmin, 1940b). The "cherty" texture results from the abundance of micritic cements.

The Salt Mountain is densely fossiliferous, although this is not immediately evident on the outcrop. There is a rich microfauna in the less indurated beds, including foraminifera, ostracods, bryozoa, and brachiopods. Framebuilding coralline algae, sponges, and corals are most evident in thin-section, but are also common in outcrop. *In situ* corals may reach over 1 meter in diameter. Sponges range in size from 1-2 cm to large fragments of barrel-shaped sponges that may have approached 1 meter in length. Most solitary sponges range from 2-10 cm in size. Extensive, anasthomosing sponge networks can be seen in several areas along the top of the outcrop. The sponges are generally preserved as micritic casts.

The Salt Mountain has been unanimously recognized as a reefal limestone because of the presence of fairly large colonial corals. Smith and Johnson (1887, p.21) mentioned "great masses of corals" which "make up a very considerable portion of the hill". Langdon (1891) described the Salt Mountain as "an atoll built up in Tertiary seas." And according to Toulmin (1967, p.88), "The limestone hill called Salt Mountain once had a coral reef along the top. The reef has been removed by zealous collectors." Large coral colonies are now fairly rare, but can still be collected along the top of the outcrop.

The scleractinian corals, however, are not the primary reef constructors. Although not recognized by these early geologists, coralline red algae and sponges are by far the volumetrically dominant contributors to the buildup. The massive nature of the limestone, and its micritic composition, obscure this fact when making outcrop observations. Furthermore, the sponges are primarily the siliceous hexactinellids, a group that today is largely restricted to deep and/or cold waters. Yet the Salt Mountain clearly developed in photic-zone, tropical-subtropical Late Paleocene waters–a time when scleractinian-dominated reefs had still not yet recovered from the effects of the terminal Cretaceous extinction event. The unique organic construction of the Salt Mountain reef makes it especially deserving of paleoecologic research, particularly with respect to its importance for our understanding of the evolution of post-Cretaceous reef communities.

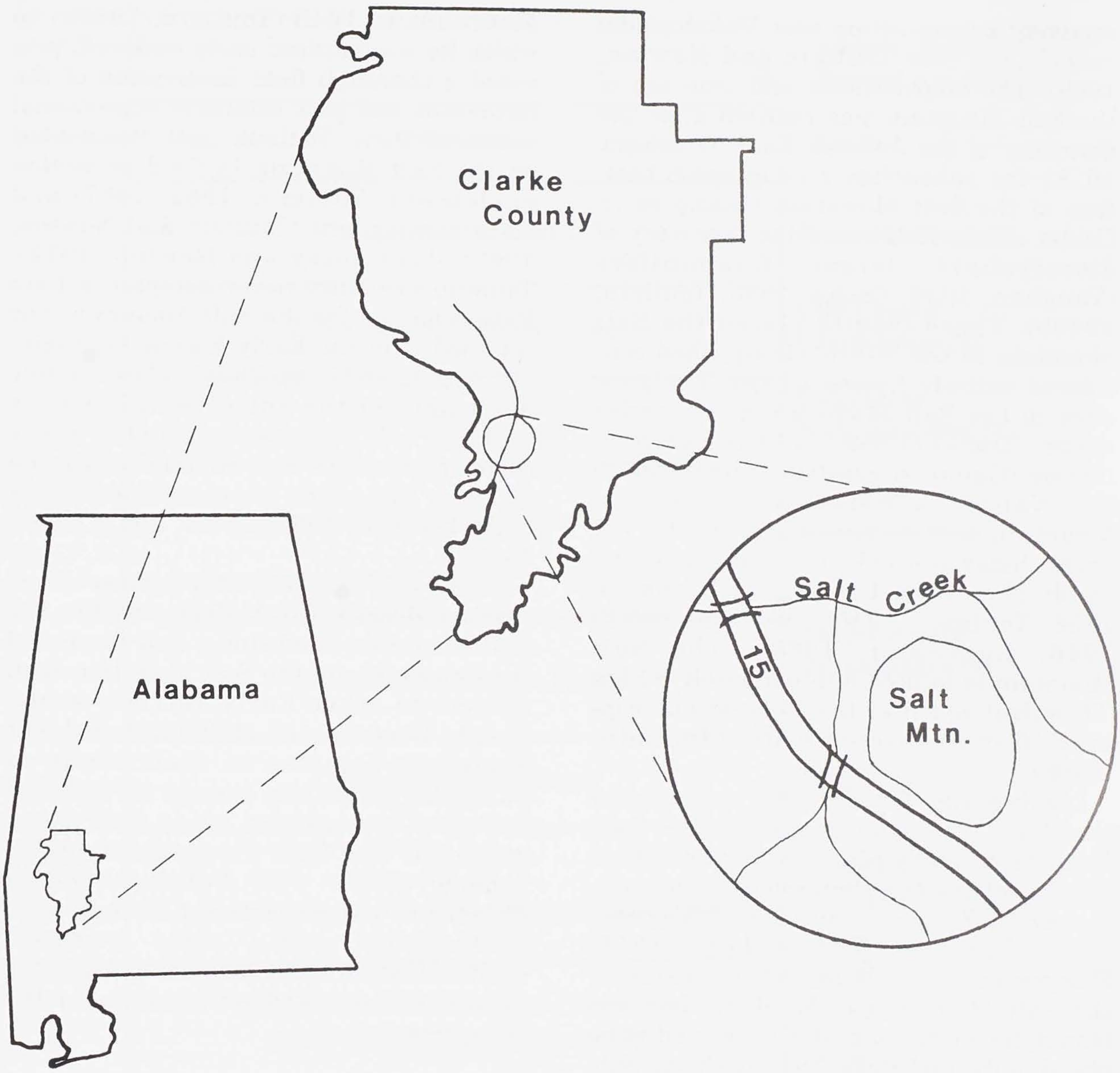
III. TYPE AREA AND REGIONAL OCCURRENCE

The type locality and only significant exposure of the Salt Mountain Limestone is located about 9.6 km (6 miles) south of Jackson, Clarke Co., Alabama, on County Highway 15 (sec. 33, T6N, R2E; Text-figure 1)(see Causey and Newton, 1972). The approximately 40 meters (130 feet) of limestone exposed here was brought to the surface on the upthrown block of the Jackson Fault (with a minimum displacement of over 400 meters [1,312 feet]; Toulmin, 1940b). The strata dip to the east from 8 to 10 degrees. This uplift was associated with the growth of the Klepac Salt Dome (Louann Salt, Jurassic in age), which is one of the easternmost surficial expressions of salt dome intrusion in the Gulf of Mexico Basin. Organic construction of the reef was probably facilitated by local shoaling resulting from dome development. Both Upper Cretaceous and Tertiary sediments thin across the Klepac Dome (Joiner and Moore, 1966; Moore, 1971).

The Salt Mountain Limestone has been reported from the subsurface of southeastern Mississippi, southwestern Alabama and the Florida panhandle (Toulmin, 1955; Murray, 1961; Rainwater, 1964; Maher and Applin, 1968; Bryan, 1991, fig.3). Reported thicknesses are variable and the formation may be discontinuous. There appears to be an increase in thickness in northern Florida near what was the flanks of the Suwannee Channel, a current-swept strait that flowed across north Florida and south Georgia from the Cretaceous through the Oligocene (Popenoe *et al.*, 1987). The Salt Mountain is 21 to 27 meters (70 to 90 feet) thick in Walton and Bay Counties, Florida, but is absent near the coast in Gulf County and in the Tallahassee area (*i.e.*, the axis of the Suwannee Channel) (Toulmin, 1955).

The flanks of Suwannee Channel were frequently the location of organic and reefal buildups (Chen, 1965; Manker and Carter, 1987; Pinet and Popenoe, 1985), although it is unknown if the Salt Mountain here or in other subsurface areas represents the reef facies. The subsurface Salt Mountain is usually recognized by its foraminiferal fauna, and published lithologic descriptions are of limited use. It seems probable that the subsurface Salt Mountain may at best resemble Biofacies 1 as seen at the type section. Cole (1944, pl.12) illustrates a thin section from samples of the Salt Mountain taken from a core in Jackson County, Florida. The lithology appears to be a grainstone, and is rich in *Discocyclina* and bryozoa, but seems to lack algae.

According to Toulmin (1955) the Salt Mountain becomes conformable with the Early Paleocene (Danian) Clayton Formation in the subsurface of southeastern Alabama. This is significant from the standpoint of facies development in that the upper Clayton in this region (as seen along the Chattahoochee River near Fort Gaines, Georgia, and at Rutledge, Alabama) is a rhodolith limestone very reminiscent of the Salt Mountain, and contains a smaller foraminiferal and brachiopod fauna with strong affinities to that of the type Salt Mountain (Toulmin, 1941; Bryan, 1993). This time-transgressive aspect of the Salt Mountain and upper Clayton formations was evidently the source of much early confusion and miscorrelation (MacNeil, 1946).



Text-figure 1. Type locality of the Salt Mountain Limestone, located approximately 10 km south of Jackson, Clarke County, Alabama (sec. 33, T6N, R2E). Trace of Jackson Fault is illustrated on Clarke County outline (from Bryan, 1991).

IV. EARLY INVESTIGATIONS AND BIOSTRATIGRAPHY

The Salt Mountain was first described by Smith and Johnson (1887) as the "Coral Limestone," the uppermost division of their single formation, the "White Limestone," which included the lower "Jackson" and middle "Vicksburg (orbitoidal)" divisions. Smith and Johnson (p.20) described 46 meters (150 feet) of "Coral Limestone" at Salt Mountain–"The rock here, is a hard, white limestone, composed in great measure of masses of coral partly silicified. Near the base of this rock there occur great numbers of the spines and plates of echinoderms." The formation was first referred to as the "Salt Mountain limestone" by Langdon (1891).

Working before the discovery of the Jackson Fault, and prior to the full recognition and correlation of the Paleocene and Oligocene systems, these early workers thought that the Salt Mountain overlay what are now known to be Oligocene (Vicksburgian) carbonates, and was Eocene in age. Indeed, faulting has juxtaposed the Salt Mountain into a position of apparent superposition over Vicksburgian carbonates (see Toulmin and Newton, 1963). The displacement and true age of the Salt Mountain was realized after the discovery of the Jackson Fault (Hopkins, 1918), the subsurface stratigraphic position of the Salt Mountain (Blanpied *in* Crider *et al.*, 1932), and the discovery of discocyclinid larger foraminifera (Vaughan, 1936; Cooke, 1935; Toulmin, 1940b). These studies placed the Salt Mountain in the Wilcox Group, then considered entirely Eocene in age. The presence in the Salt Mountain of the index oyster, "*Ostrea thirsae*" [= *Odontogryphea thirsae* (Gabb)] suggested equivalence to the Nanafalia Formation. The Salt Mountain was understood to be the offshore, limey equivalent of the nearshore, sandy Nanafalia Formation (Blanpied, 1938; Toulmin, 1940b, 1967; MacNeil, 1946; Rainwater, 1964). The Salt Mountain is located approximately 80 km (50 miles) south of the nearest outcropping "*Ostrea thirsae* beds" (Toulmin, 1940b).

Loeblich and Tappan (1957) established the Late Paleocene age of the Salt Mountain using planktic foraminifera (assignable to the *Planorotalites pseudomenardii* Zone, = Zone P4; Berggren, 1963, Berggren and Aubert, 1975, Fluegeman, this volume). They considered the Salt Mountain to be older than the Nanafalia Formation and suggested it be placed in the underlying Midway Group. Subsequent work by Wind (1974) and Siesser (1983) on calcareous nannoplankton confirms the Late Paleocene age. Wind and Siesser have both assigned the Salt Mountain to nannoplankton zone NP7 (Text-figure 2), although slightly older than the Nanafalia Formation (Wind, 1974).

Toulmin published his Alabama Geological Survey monograph on the Salt Mountain in 1940 (Toulmin, 1940b) in which he summarized early research, provided a thorough field description of the formation, and gave extensive microfaunal taxonomic lists. Toulmin later commented on the Salt Mountain in field excursion guidebooks (Toulmin, 1962, 1967) and state publications (Toulmin and Newton, 1963; also Causey and Newton, 1972). Toulmin evidently never accepted a Late Paleocene age for the Salt Mountain, but retained it in the Early Eocene (Toulmin, 1962, p.3; 1977, pp.28,90). The earlier placement of the entire Wilcox Group within the Eocene has resulted in many correlations of the Salt Mountain with the Oldsmar Limestone of subsurface Florida (*e.g.*, Toulmin, 1955; Levin, 1957; Chen, 1965).

Bryan (1991), using thin section observations, described 4 biofacies within the Salt Mountain Limestone, and discussed the importance of the Salt Mountain with respect to other Early Tertiary reefs. Finally, Denison *et al.* (1993) included Salt Mountain samples in their study of Paleogene strontium isotope (87Sr/86Sr) variation in seawater, using Gulf Coast material. The Salt Mountain samples proved to be well below expected Paleocene values, but consistent with Cretaceous and older values. Contamination from migrating Mesozoic brines is undoubtedly the cause for the low ratios.

V. GENERAL PALEONTOLOGY

The Salt Mountain Limestone contains a rich, but only partially documented biota. Salt Mountain taxa that have been investigated include calcareous nannoplankton (Wind, 1974; Siesser, 1983), planktonic foraminifera (Toulmin, 1940b; Loeblich and Tappan, 1957), smaller benthic foraminfera (Toulmin, 1940b, 1941; Berggren, 1974; Berggren and Aubert,

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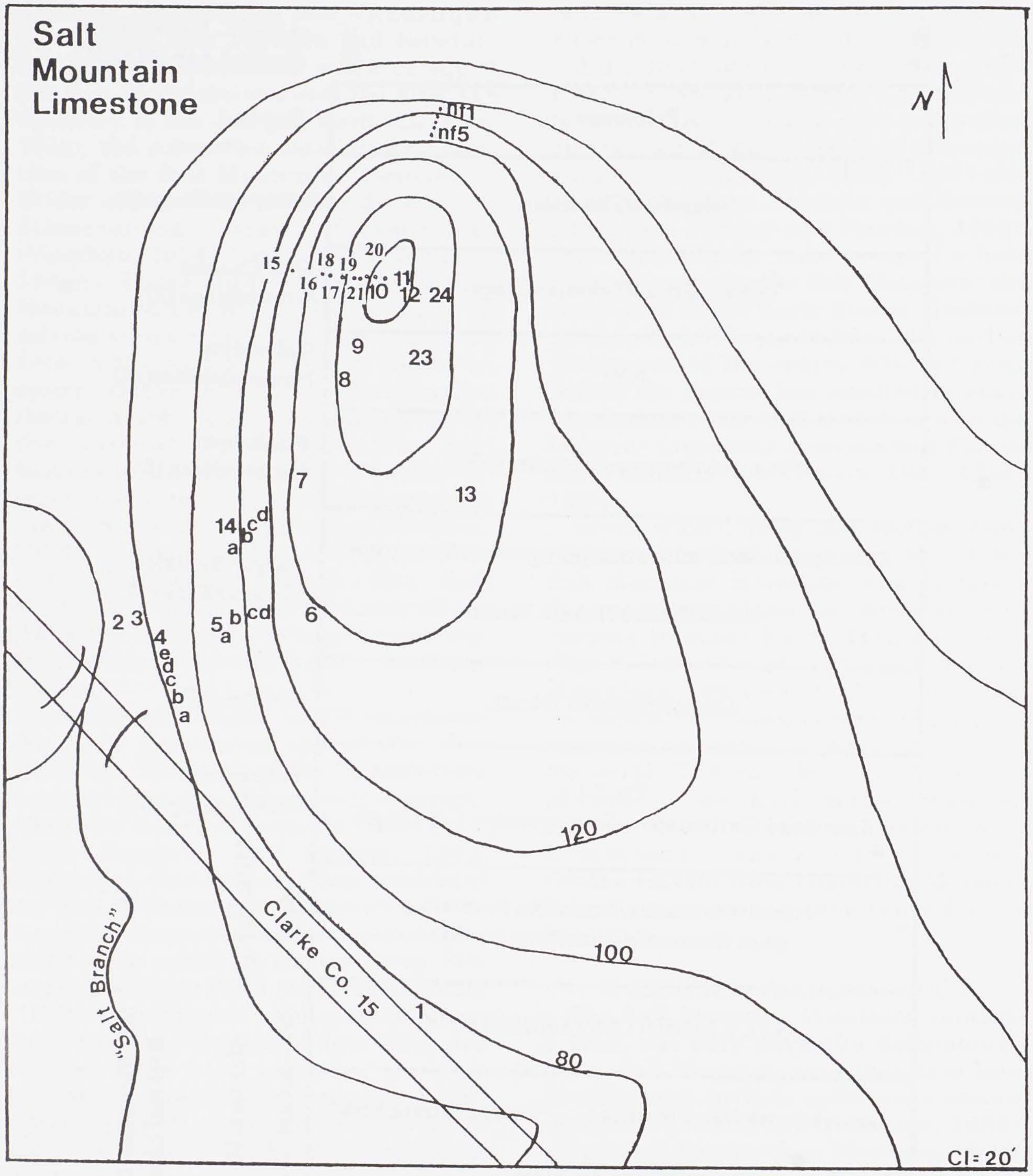
Text-figure 2. Generalized stratigraphy of the Salt Mountain Limestone and regional lithocorrelates. Sources: 1, Haq *et al.*, 1988; 2, Harland *et al.*, 1989; 3, Murray, 1961; 4, Wind, 1974, Siesser, 1983; 5, Loeblich and Tappan, 1957, Berggren, 1963, Berggren and Aubert, 1975; 6, Gravell and Hanna, 1938, Cole, 1959, 1969; 7, Toulmin, 1977; 8, Haq *et al.*, 1988, and this paper; 9, Lindberg, 1988, and others; 10, Toulmin, 1940b, 1977; 11, Chen, 1965, Cole, 1938, Lindberg, 1988; Winston, 1978, 1994.

<58.5 — >55	Approx. Radiometric-Derived Age (Ma)(1)		
Paleocene	**Epoch**		
Selandian/Thanetian	**European Stage (2)**		
Wilcox Group/Sabinian Stage	**Gulf Coastal Group/Stage (3)**		
NP7	**Calcareous Nannoplankton (4)**		
***Planorotalites pseudomenardii* (P4)**	**Planktonic Foraminifera (5)**		
Discocyclina weaveri--Pseudophragmina stephensoni ***Ranikothalia catenula* Fauna**	**Larger Benthic Foraminifera (6)**		
Odontogryphaea thirsae	**Molluscs (7)**		
TA 2.1 **Lowstand Carbonate Transgressive Carbonate**	**Sequence Stratigraphy (8)**		
Wilcox Formation/Nanafalia Formation (Salt Mountain Limestone locally)	**W/E**	**Mississippi(9)**	**Salt Mountain Limestone and Regional Lithocorrelates**
SALT MOUNTAIN LIMESTONE	**SW**	**Alabama(10)**	
Gravel Creek Sand Member “Ostrea thirsae beds” **Nanafalia Formation**	**S.Cent–E.**		
Wilcox Group Undifferentiated (Salt Mountain Limestone locally)	**Panhandle**	**Florida(11)**	
Cedar Keys Formation	**Peninsula**		
Rebecca Shoal Dolomite	**Southern**		



Text-figure 3. Sampling locations at Salt Mountain plotted on the topographic map of Toulmin (1940b).

1975; Brisken and Fluegeman, 1990; Fluegeman this volume), larger benthic foraminifera (Vaughan, 1936; Cole, 1959,1969; Bryan this volume), coralline algae (Bryan, 1991; not described), sponges (Bryan, 1991; not described), scleractinian corals (Vaughan, 1900; Stemann this volume), ostracods (Toulmin, 1940b), bryozoa (Toulmin, 1940b; not described), brachiopods (Toulmin, 1940a,b; Stenzel, 1942), echinoids (Cooke, 1959; Carter this volume), and miscellaneous fauna (*viz*, annelids, molluscs, crinoids, vertebrates; Toulmin, 1940b; Bryan, 1991).

VI. DIAGENESIS

The unique organic composition of the Salt Mountain Limestone make its syn- and post-depositional history an especially promising subject for research. The following are only preliminary observations. As already noted, the "cherty" texture of the rock derives from the abundance of micritic cements. In fact, all indurated lithologies have a predominant microspar matrix (probably a neomorphic alteration of original micrite cement). Micrite is sometimes found as thin laminae and frequently fills large cavities, such as spongocoel and the areas surrounding branching corals. The microspar matrix sometimes has a vuggy porosity, with sparse and incompletely developed calcite spar within the vugs. Although the matrix contains most of this secondary porosity, some biochems are also eroded by vugs and many are especially affected along their margins (*e.g.*, coralline algal plates). Subhedral to euhedral Fe-oxides stains are common. Original aragonitic molluscs (especially endolithic bivalves) are preserved as sparry molds with micrite envelopes or as micritic internal molds.

Sponges are preserved as micritic replacements (casts). Spicules within the sponges are completely dissolved, but are nonetheless remarkably preserved as sparry calcite casts (within the micritic body fossil casts). Large coral colonies are also preserved as micritic casts, but details of the septal patterns are often lost (with spar filling corallite voids). Some corals do retain their septa as spar replacements, surrounded by micritic molds (mud infill of interseptal spaces). In outcrop, massive colonies of *Stylophora ponderosa* may quickly grade into otherwise nondescript mudstone, showing how secondary alteration has largely destroyed much of the original reef fabric.

Several syn-depositional and post-depositional diagenetic events are recognizable. There is abundant evidence for early marine, micritic cementation. Most thin sections show regular fracturing of microspar matrix. These fractures are filled with additional micrite/microspar, micritic intraclasts, or a combination of these with calcite spar. Fine laminated micrite may be observed in abrupt, truncated contact with coarse debris (forming small "angular unconformities"), then covered by additional mud, with an iron-oxide contact between the two layers. Also, large, bored lithoclasts sometimes compose the core of algal boundstones and rhodoliths, indicating earlier phases of syn-depositional cementation. Geopetal structures are common and meteoric influence (perhaps more than one phase) is also evident.

VII. REGIONAL PALEOENVIRONMENTAL SETTING

The Late Paleocene was a period of increased warming in an ice-free global ocean. This warming culminated in the Early Eocene, probably the warmest interval in the Cenozoic (Kennett, 1982; Crowley and North, 1991). There were rapid and short-lived temperature increases of 10°C or more in global deep water and high latitude surface waters, resulting in severe extinctions in deep water microfaunas (the "Late Paleocene Thermal Maximum", Zachos *et al.*, 1993; Kennett and Stott, 1991). But low latitude surface waters were evidently unaffected by these temperature excursions, and may not have been significantly different than the present (Adams *et al.*, 1990; Bralower *et al.*, 1995).

In the Gulf Coastal Plain of the southeastern United States, tropical to subtropical conditions are indicated. According to Wolfe (1978), Late Paleocene (lower Wilcox Group) leaf assemblages of the Mississippi Embayment (35°N) represent megathermal (paratropical) Tropical Rain Forest conditions in terrestrial environments of the northern Gulf Coast. In the marine environment, Palmer (1967) considered most Paleocene and Eocene molluscan assemblages of the Gulf Coast to be tropical or subtropical forms. The Salt Mountain reef clearly indicates tropical to subtropical marine conditions, although probably representing the northern extent of such environments.

The Salt Mountain reef developed on an otherwise siliciclastic shelf setting. According to the paleogeographic maps of Stephenson (1928, fig.4), Chen (1965, fig. 42), Rainwater (1964, fig. 9), Gallaway *et al.* (1991, fig. 15), Mancini and Tew (1993, fig. 1), Huddlestun (1993, fig. 50), and Smith *et al.* (1994), the Salt Mountain must have developed within an inner neritic shelf setting, not far from the influence of the Wilcox deltaic sedimentation, and at an approximate paleolatitude of 31°-32° North. During the Late Paleocene, the extensive Holly Springs Delta System covered some 160,930 square km (100,000 square miles) of Louisiana and Mississippi and prograded basinward in three phases with four lobal complexes, developing growth faults, mobilizing salt, and depositing up to 1500 meters of siliciclastics (Gallaway, 1968; Gallaway *et al.*, 1991). The Salt Mountain developed contemporaneously, just to the east of the Holly Springs delta complex, at the eastern extreme of the Mississippi Salt Basin (Martin, 1978, figs. 4,5; Ewing, 1991, fig. 8, pl. 2).

It is likely that the Salt Mountain reef developed on a local shoal, resulting from Klepac Salt Dome development. The Salt Mountain rests on the siliciclastic Naheola Formation. The base of the Salt Mountain is a thin (3-10 cm), glauconitic, calcareous, fossiliferous sand. This sand sharply overlies massive, gray carbonaceous clays and sands of the Naheola Formation (Toulmin, 1962). So the Salt Mountain reef did not develop over an antecedent carbonate (as do many reefs), but appears to have been a carbonate cap–a small bank–which grew over a siliciclastic shoal. Reefal buildups of Cretaceous and Tertiary age are reported from several topographic highs in the Gulf Coast, such as the Sabine Arch of Louisiana and Mississippi, the Jackson Dome of central Mississippi, the Wiggins Uplift of southern Mississippi and Alabama, and numerous salt domes in Louisiana and Texas (Murray, 1961, figs. 6.33, 6.34, 6.36, 6.43, p.107, 361, 386, 392; Frost and Schafersman, 1978; Forman and Schlanger, 1957; Coleman, 1983).

Bryan (1991) compared the Salt Mountain reef to the modern Flower Garden Banks of the northwestern Gulf of Mexico. Both the Salt Mountain and the Flower Garden reefs developed over salt diapirs on siliciclastic-dominated shelves. On the modern Texas-Louisiana shelf, these prominences rise above turbid bottom waters of seasonally variable salinity and temperature (influenced by runoff from the Mississippi River and winter mixing), into clear subtropical to tropical waters originating from the Caribbean with winter temperature minima of only 19° to 20° C (the water column remains stratified and little influenced by winter mixing). Such conditions are suitable for coral-algal reef growth, although because these reefs are near the northern limit for tropical reefs (at 27°N), hermatypic coral diversity is much lower than typical Western Atlantic reefs (Rezak *et al.*, 1985, 1990).

To the south and southeast of the Salt Mountain type area, glauconitic and calcareous shales and sands (Wilcox Group, undifferentiated) formed in much of the Florida panhandle (Chen, 1965) while a large carbonate platform (Cedar Keys Formation, largely an evaporitic dolostone) developed over peninsular Florida. Winston (1978, 1994) reports a dolomitized barrier and atoll reef around much of southern peninsular Florida (Rebecca Shoal Dolomite), equivalent, in-part, with the Cedar Keys Formation. The organic structure of formation is not known.

PLATE 1

Coralline algal bindstone/floatstone, from Biofacies 1. Specimens deposited at Okaloosa-Walton Community College.

Figures

1. Large rhodolith, encrusting over sponge (not seen). Size: 15 cm (long dimension). OW 00113.
2. Floatstone composed of thin, broken algal plates. Size: 19 cm (long dimension). OW 00114.
3. Thick-crusted algal boundstone with lithophagid bivalve boring (l). Size: 5.8 cm (long dimension).
4. Thin section of algal boundstone. Size: 5.5 mm (long dimension).

1

2

3

4

PLATE 1

VIII. SALT MOUNTAIN LIMESTONE BIOFACIES

Bryan (1991) recognized four biofacies on the basis of thin section examination and field relationships. Recent re-sampling of additional outcrops (Text-figure 3) along the mountain has confirmed the consistent presence of these biofacies, but has also shown that lithologic variability is greater that originally reported. Biofacies boundaries are not distinct or consistent, and facies grade laterally as well as vertically. Although some bedding is evident in the outcrop (usually between soft and harder limestone), the formation is essentially massive. The four biofacies of Bryan (1991) are briefly summarized below. The original biofacies names have been modified to reflect the classification of reefal limestones as summarized by James (1983, 1984).

Biofacies 1: Foram-Bryozoan-Algal Bindstone/Floatstone.

Laminar, thin-to-thick encrusting calcareous red algae (mostly *Archaeolithothamnium*) and bryozoans with larger foraminifera (discocyclinids) within micritic matrix. Accessory fossils include planktonic foraminifera, small and large sponges, branching corals, molluscs, echinoderms, and small corals. Biofacies 1 is the volumetrically dominant rock type in the Salt Mountain. Thick-crusted (up to 0.5 cm for individual layers) algal bindstone and rhodoliths are common, but the corallines predominantly occur as very thin, usually fragmented crusts (Plate 1). Thin laminae may extend laterally for several centimeters over micritic substrate.

Biofacies 2: Coral Bafflestone.

Small, delicate, branching corals in micritic matrix. Other allochems include smaller foraminifera, bryozoans, small sponges, and common regular echinoid spines. Coralline algae are rare in this facies, but are found encrusting the branching corals. Larger foraminifera are also uncommon. This biofacies is very similar to Biofacies 4, but appears to have less echinoderm, algal, and (miliolid) foraminifera biochems.

Biofacies 3: Sponge-Coral Bafflestone/Framestone.

Sponges in micritic matrix with massive corals. Coralline red algae are rare to common. Planktonic foraminifera are regularly seen in the micrite. At Stations 13, 21, and 24 (Text-figure 3; and Krumm, this volume), large patches dominated by the coral *Stylophora ponderosa* can be seen *in situ*. The massive coral *Actinacis alabamensis* is less dominant, but still common (Plate 2).

Biofacies 4: Coral-Echinoderm Bafflestone/Floatstone.

Coarse echinoderm debris (spines and ossicles) and branching corals in micrite. Bryozoans and red algae are also common, the algae frequently encrusting echinoderm biochems. Larger foraminifera are rare but miliolid foraminifera are present. Laminated micrite is common and is often seen in abrupt contact with coarse echinoderm debris, suggesting early marine cementation. Biofacies 4 is compositionally similar to Biofacies 2. It is found only at the highest peak of the outcrop.

Additional Biofabrics.

There are additional biofabrics within the Salt Mountain which, although not abundant, are common. There are micritic laminites, for example, possibly of stromatolitic origin, and several samples of white mudstones with "mesoclotted" fabric may be thrombolites. There are also regular occurrences of rhodoliths (Plate 1). These rhodoliths seem to always have large fossils or lithoclasts as cores, with comparatively thin coatings of coralline algae. These round algal boundstones, however, are usually not completely, concentrically encrusted by coralline algae. So there would appear to have been minimal movement on the substrate caused either by

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PLATE 2

Dominant scleractinian corals of the Salt Mountain Limestone, from Biofacies 3. Specimens deposited at Okaloosa-Walton Community College.

Figures
1. Colony of *Stylophora ponderosa*. Size: 18 cm by 12 cm. OW 00115.
2. Colony of *Actinacis alabamensis*. Size: 19 cm by 10 cm. OW 00116.

1

2

PLATE 2

currents or bioturbators. But the overall rarity of rhodoliths, the incomplete development of existing rhodoliths, and the thinness of most algal crusts, indicate that the bulk of the Salt Mountain reef developed predominantly below wave base.

At sampling Station 21 a very large, well-preserved, *in situ* colony of *Stylophora ponderosa* was recently discovered (Text-figure 4). This area was more extensively sampled using a meter-grid system (similar to that used by Krumm, this volume) in order to document the organic construction of the reef at a finer scale of analysis. The 5 x 2.5 meter grid with sample locations is shown in Text-figure 5. Table 1 provides lithologic descriptions.

The lithologies within the grid at Station 21 are like those across the rest of the outcrop, and can be easily classified as either Biofacies 1 or 3 as described above. The dominant lithology is an algal and sponge-algal boundstone (mostly Biofacies 3), with abundant bryozoan- and bryozoan-algal rich biomicrite (Biofacies 1). Rare but large coral growth occurs only in one area and coral diversity is lower than in the grid described by D. Krumm (this volume).

IX. CORALLINE ALGAE AND SPONGES

Two groups that are of special interest with regard to reef construction are the coralline red algae and sponges, which, along with micritic cements, comprise the bulk volume of the reef. The most abundant alga and primary reef constructor is *Archaeolithothamnium*. Also present are *Lithoporella, Mesophyllum,* and possibly *Lithothamnium, Tenarea,* and *Lithophyllum* (E. Praeger, pers. comm., 1991).

Crustose coralline red algae are common inhabitants of reef and forereef environments in both Tertiary and Recent buildups (Adey and MacIntyre, 1973; Wray, 1977; Ghose, 1977). In the Salt Mountain, they occur as both thick (5 mm), but primarily thin (1-2 mm) crusts. According to Steneck (1986) thin crusts are indicative of comparatively greater water depths and slower growth rates relative to thicker coralline crusts. The depth range of overlap of thin and thick crustose corallines in modern reefs ranges from 5-20m (Steneck, 1986, fig. 4).

The dominant Salt Mountain red alga, *Archaeolithothamnium*, is today a tropical to subtropical genus that is most abundant in relatively deep waters (60-80 meters; Minnery, 1990), although it has a broad bathymetric distribution and certainly reached into shallower water during the Paleogene. The genus, for example, constructed rock-forming abundances of rhodoliths around Early Oligocene fringing coral reefs in Georgia and Florida (Manker and Carter, 1987; Carter *et al.*, 1995).

The Salt Mountain sponge fauna should prove to be especially informative when it

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PLATE 3

Some common sponge body fossils of the Salt Mountain Limestone, from Biofacies 3. Specimens deposited at Okaloosa-Walton Community College.

Figures
1. OW 00103. Size: 8.5 cm by 5.6 cm.
2. OW 00107. Size: 2.7 cm by 2.9 cm.
3. OW 00108. Size: 5.4 cm by 4.4 cm.
4. OW 00109. Size: 3.2 cm (width) by 2.6 cm (height).
5. OW 00106. Two, narrow tubular sponges. Size: 11.7 cm by 3.2 cm (top).
6. OW 00101. Polished cross-section of large, tubular sponge. Size: 6.8cm by 5.3 cm.
7. OW 00105. Size: 7.4 cm by 6.0 cm.
8. OW 00110. Size: 11.7 cm by 4.2 cm.
9. OW 00111. Size: 5.4 cm by 2.9 cm.
10. OW 00112. Size: 5.9 cm by 2.9 cm.
11. OW 00104. Size: 9.8 cm by 5.7 cm.
12. OW 00102. Laminar, encrusting sponge. Size: 13.6 cm by 5.9 cm.


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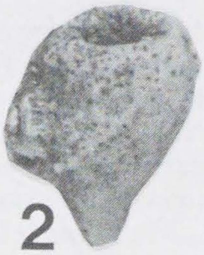
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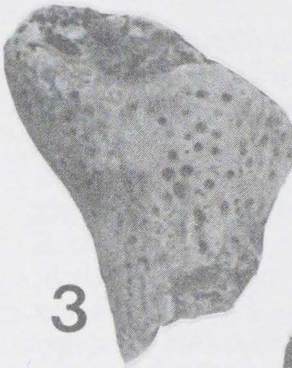
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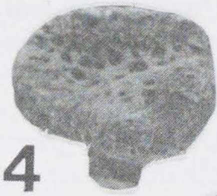
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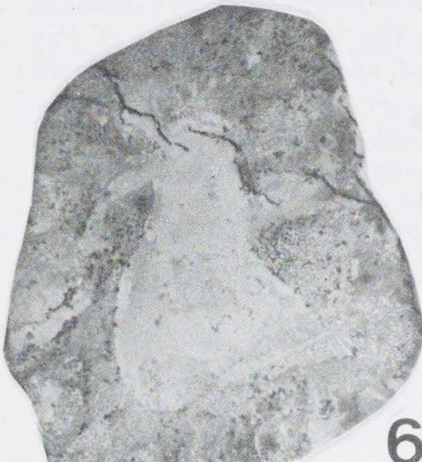
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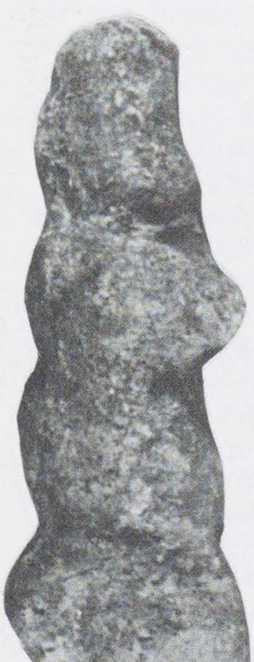
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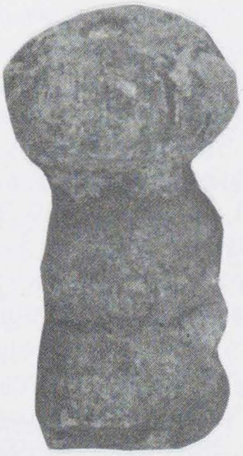
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PLATE 3

is described. At least 15 distinct morphotypes can be consistently identified among the larger sponge body fossils (Plate 3). The size of sponge body fossils ranges from small, 2 cm oblong buds to large, vase- or barrel-shaped forms reaching uncertain size (perhaps from 50 cm to 1 meter in length). Most are 2 to 10 cm in length, with a variety of growth forms (conical, tubular, anasthomosing, laminar-encrusting, etc.). J. Keith Rigby (pers. comm., 1990) recognized two species of hexactinellid in the Salt Mountain: one dictyid or lychniskid, with a cylindrical body and net-like skeleton; and one lyssakid, with a more irregular skeleton and spicules irregularly oriented and spaced within the skeleton.

Very little is currently known of Tertiary sponge faunas, but those described usually consist of several Cretaceous "holdover" species (Weidenmayer, 1980, p.84; Finks, 1986). It is expected that many of the Salt Mountain taxa will also have strong Mesozoic affinities. In the southeastern United States, Tertiary sponges have rarely been reported. Rigby and Smith (1992) describe microscleres from choristic demosponge *Geodia* from the Paleocene (Danian) Porters Creek Formation of southwestern Alabama, and undescribed hexactinellids have recently been discovered in the Eocene Shubuta Marl near Perdue Hill, Alabama. But the largest fauna known to date is the Middle Eocene Castle Hayne Limestone of North Carolina. The Castle Hayne has a large sponge fauna (17 species) occurring in two facies: one dominated by hexactinellids and lithonine Calcarea, and a shallower facies with dominant demosponges (choristids and plinthosellid lithistids) and fewer hexactinellids (Finks, 1986; Rigby, 1981). These sponges, however, did not construct a reef, nor are they associated with larger foraminifera, coralline algae, or corals. The Castle Hayne was evidently a temperate water carbonate.

X. SEQUENCE STRATIGRAPHY AND REEF GROWTH

As pointed out by Fluegeman (this volume), only the mid- to upper portion of the Salt Mountain may correlate with the lower portion of the "*Ostrea thirsae* beds" member of the Nanafalia Formation (a transgressive systems tract). The lower 20 meters or so of the Salt Mountain may correlate with the non-marine, incised-valley fill, Gravel Creek Sand Member (the lowest member) of the Nanafalia Formation (a lowstand systems tract).

This correlation is important with regard to the depositional environment of the Salt Mountain. It would imply that the Salt Mountain began as a low-stand carbonate during Gravel Creek time–early TP2.1 cycle (Mancini and Tew, 1991; Baum and Vail, 1988, fig. 13), and confirm a shallow neritic origin for the Salt Mountain. The reef core of the Salt Mountain would then have been deposited as a transgressive carbonate, probably equivalent to the lower portion of the "*Ostrea thirsae* beds" of the Nanafalia Formation.

If this correlation is correct, the Salt Mountain could represent no more than 2 million years of deposition (*i.e.*, from the beginning of cycle TA2.1 at 58.5 Ma, to the development of the condensed section at 56.5 MA; Haq *et al.*, 1988), and probably much less–particularly if the Salt Mountain is entirely younger than the Gravel Creek Sand. Eustatic sea level rise during the TA2.1 third order cycle (late Thanetian) was large–perhaps up to 125 meters or more (Haq *et al.*, 1988, fig. 14). A conservative estimate of 100 meters rise in 2 million years is equivalent to an average rate of rise of 50 mm per 1000 years, or 50 Bubnoffs (1 Bubnoff = 1mm/1000 years; Kendall and Schlager, 1981). This is well within the range of typical third order sea level cycles (10-100 Bubnoffs; Kendall and Schlager, 1981). Assuming a maximum duration of the reef of 2 million years, constant deposition throughout the TA2.1 cycle, and given a thickness of approximately 40 meters (130 feet) at the type section, a minimum accumulation rate for the Salt Mountain would be 20 mm per 1000 years, or 20 Bubnoffs.

What, then, was the fate of the Salt Mountain reef? From these estimates, the reef would not have been able to keep up with sea level rise. But according to Schlager (1991), typical third-order sea level cycles are too slow to drown most healthy reefs (accretion rates of most Holocene reefs range from approx.1000-10,000 Bubnoffs, depending on depth;

Schlager, 1992). The actual growth rate of the Salt Mountain was certainly much greater than 20 Bubnoffs. There are no evident unconformities at the type section (Toulmin, 1955), nor mineralized hardgrounds. There are perhaps two shallowing-upwards depositional cycles (Bryan, 1991) and massive corals are found at the top of the formation. The reef appears to have easily kept pace with sea level rise.

Schlager (1992) mentions the common occurrence of echinoderm-rich grainstone facies with drowning events, and the fact that many drowning "unconformities" do not represent significant stratigraphic hiatuses. The Salt Mountain does have an echinoid-rich (but muddy) facies at the top of the type section, but why such facies should be associated with drowning is unclear (perhaps incipient drowning and hardground development favor an increased recruitment of the epifaunal regular echinoids). While the reef may have drowned from an abrupt deepening, it is more likely that the Salt Mountain coral-algal-sponge reef was simply overwhelmed by siliciclastic influx.

Although difficult to see in outcrop, the Salt Mountain is overlain by over 21 meters (70 feet) of "Wilcox clay" (possibly of the Nanafalia Formation; Causey and Newton, 1972). Toulmin (1962, 1967) describes this lithology as: "Clay, light gray to medium light gray, weathers pale

TABLE 1. Sample Descriptions from Grid 21, Salt Mountain Limestone. Listed are the volumetrically dominant components. Other biochems are common. All "algae" in descriptions refer to coralline red algae, predominantly but not exclusively *Archaeolithothamnium*.

Sample	*Description*
1a	Sponge-algal boundstone. 55 mm x 15/30 mm hexactinellid encrusted by coralline red algae.
1b	Algal boundstone (possibly with encrusting sponge or stromatolites) overlain by echinoderm-bryozoan-algal biomicrite; some coral. The biomicritic matrix appears to fill cavities or borings within the algal boundstone.
1c	Bryozoan-algal biomicrite. Some coral, echinoid spines.
2a	Bryozoan-algal biomicrite. Some encrusting foraminifera with algae; minor sponge, coral, echinoid spines.
2b	Sponge-algal boundstone/bryozoan biomicrite. Rare coral, discocyclinids.
2c	Coral framestone (*Stylophora ponderosa*, partially overlying bryozoan biomicrite).
3a	Algal boundstone, overlying bryozoan-algal biomicrite.
4a	Sponge-algal boundstone. Some echinoid spines.
4b	Sponge-algal boundstone, with bryozoan-algal biomicrite.
4c	Coral-algal-sponge boundstone, with bivalve boring (*Lithophaga*) and bryozoan-algal biomicrite matrix. Some echinoderm spines.
5a	Sponge-algal boundstone.
6a	Coral-sponge-algal boundstone, with bryozoan biomicrite matrix.
6b	Sponge-algal boundstone. Rare discocyclinids.
7a	Sponge-algal boundstone.
7b	Sponge-algal boundstone, with bryozoan biomicrite matrix. Encrusting foraminifera, mollusc and/or brachiopod fragments.
8a	Sponge-algal boundstone.
8b	Sponge boundstone.
9a	Sponge-algal boundstone, with *Lithophaga* borings.
10a	Bryozoan biomicrite. Possible algal boundstone, sponge.
12a	Bryozoan biomicrite.
14a	Sponge-algal boundstone.
15a	Algal boundstone, with bryozoan biomicrite.

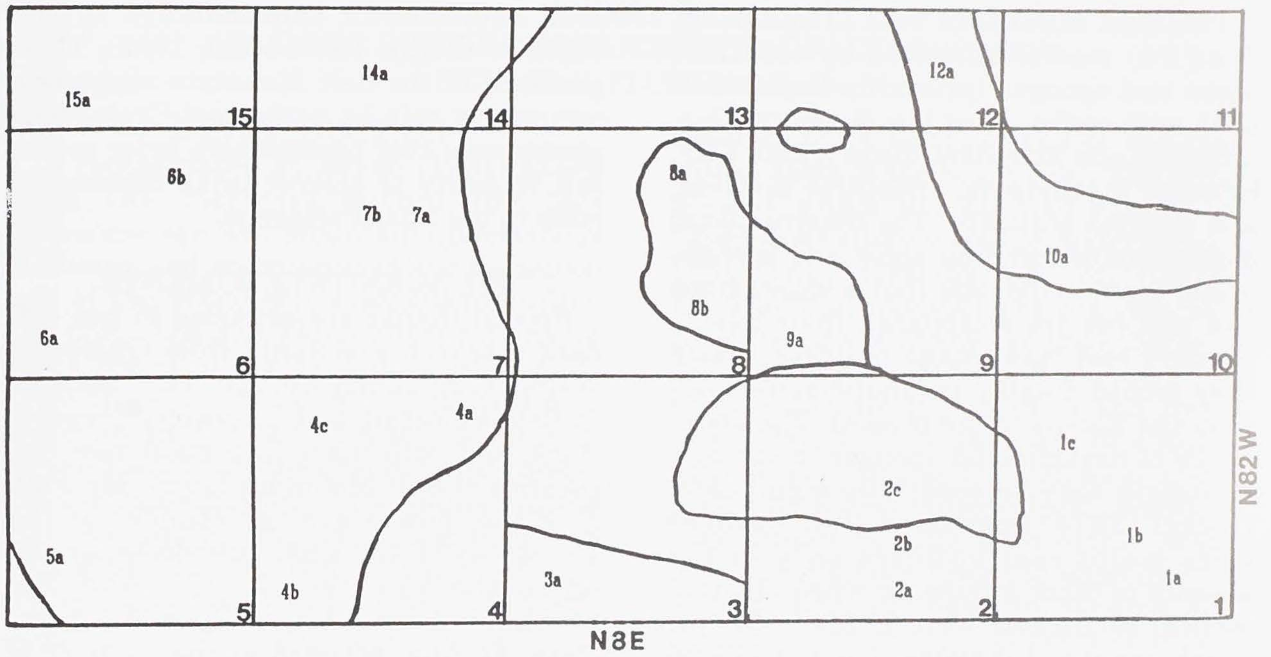
Text-figure 4. *In situ* colony of *Stylophora ponderosa* at sampling station number 21 (see Text- figures 3, 5).

to dark yellowish-orange, thin-bedded to massive, very finely sandy, glauconitic, micaceous, subconchoidal fracture; contains some thin partings of fine-grained sand from which flakes of limonite weather; includes in the lower part a 1-foot layer of fine- to coarse-grained very glauconitic sand. The lower part of the bed near the contact with the Salt Mountain Limestone is pale yellowish brown massive blocky clay. The change from limestone to clay is abrupt, but the contact is apparently conformable." Toulmin (1955, p.219) also indicates that, "Downdip in southwestern Alabama near the coast the undifferentiated Wilcox above the Salt Mountain limestone consists of dark gray micaceous carbonaceous shale with some lignite steaks and some beds of gray and brown hard marl and brown claystone."

It is assumed then that the demise of the reef was caused by siliciclastic influx from the prograding Holly Springs Delta System. These Wilcox Group siliciclastics overwhelmed carbonate production and buried the reef.

XII. THE SALT MOUNTAIN LIMESTONE AND THE POST-CRETACEOUS RECOVERY OF PHOTIC-ZONE REEFS

There is a growing literature on the recovery of reef communities following Phanerozoic mass extinction events (*e.g.*, Newell, 1971; Heckel, 1974; Sheehan, 1985; Talent, 1988; Copper, 1988, 1989, 1994; Kuznetsov, 1990; Flugel and Flugel-Kahler, 1992; Kauffman and Fagerstrom, 1993; Wood, 1993, 1995). And there is a general consensus that during mass extinctions, shallow-water tropical reef communities suffer disproportionately relative to other benthic communities. Reefs typically are the first benthic communities to suffer from the extinction event, experience the greatest diversity loss relative to other marine benthos, and delay recovery for 2 to 10 m.y. or more after the extinction (temperate water benthic communities may rebound within 1-2 m.y.). But



Text-figure 5. Meter sampling grid with subsamples taken at sample station number 21 (see Text-figure 3). See Table 1 and text for discussion.

questions remain over the recovery phase: Are the initial post-extinction reefs trophically similar to pre-extinction reef communities? Does community recovery show any ecological succession? Do stress-tolerant, eurytopic taxa initiate reef recovery (perhaps in an offshore to onshore move or as Lazarus immigrants), creating novel (temporary or permanent) post-extinction reefs?

Despite this interest, however, there is perhaps the least documentation of reefs immediately following the best-studied mass-extinction, the Cretaceous-Tertiary (K-T) event (Copper, 1994a). After the terminal Cretaceous loss of rudist-coral reefs, diverse scleractinian-dominated reefs were not widespread until the mid-late Eocene. Paleocene photic-zone reefs are indeed rare and insufficiently documented, prompting Copper (1989) to ask, "Why did it take nearly 10 million years for reefs to begin even a modest recovery to patch reef size following the...end-Cretaceous (extinction)...when corals, sponges, and other metazoans were available as the pioneers for new reef ecosystems?" During the Danian Stage of the Paleocene, there were evidently no significant oligotrophic adaptations nor photic-zone reef development anywhere. Photic-zone carbonates were instead dominated by coralline red algae, bryozoa, brachiopods, and oyster bioherms. Conspicuously absent at this time are the larger benthic foraminifera (LBF), which were common inhabitants of both Late Cretaceous and Late Paleocene to Recent reef facies.

Oligotrophic adaptations are evident, however, by the Thanetian Stage of the Paleocene (plankton Zone P4, 8 m.y. after the K-T boundary) in the form of photosymbiont-hosting, K-strategist planktonic and LBF (Hallock *et al.*, 1991; Hottinger, 1987). Limited hermatypic coral associations developed in the Late Paleocene, but these reefs were generally small, low-diversity coral-algal patch reefs. Most Thanetian carbonate platforms such as those of Libya (Terry and Williams, 1969), Oman (Racz, 1979), Egypt (Kuss and Leppig, 1989), India (Ghose, 1976,1977), and offshore Brazil (Carozzi, 1989) were large foram- and/or coralline algal-dominated ramps (Mresah, 1993). True reef-rimmed shelf margins may have been entirely absent at this time (J. Kuss, 1990, pers. comm.). Mresah (1993) suggests that larger foraminifera, particularly nummulitids, temporarily occupied the vacant ecologic niches left by scleractinian corals after the K-T event.

The Salt Mountain reef (Thanetian, Zone P4) was constructed by coralline algae and sponges (primarily hexactinellids), with common but low diversity scleractinians and abundant discocyclinid LBF, bryozoa, brachiopods, endolithic bivalves, and cidaroid echinoids. The constructional dominance of coralline algae and sponges would seem to indicate that scleractinians had still not yet established their role as primary reef framestone builders, which they would display in photic-zone reefs from the Eocene to the present. The abundance of hexactinellid sponges in the Salt Mountain may be especially significant. Heckel (1974) suggested that sponges were major reef builders only in the absence of other groups, or when environmental conditions were unfavorable for these groups. Likewise, Copper (1989) noted the persistence of algae and sponges in Phanerozoic reef development, with corals only present during optimal conditions. The siliceous hexactinellids are exclusive K-strategists, requiring stable environments, but are bathymetrically tolerant. They reached their greatest diversity in the Late Cretaceous and were common reef/mound constructors in the Jurassic (Rigby, 1987; Mehl, 1992). Their presence in the Salt Mountain suggests a temporary role as early post-Cretaceous photic-zone reef constructors prior to the full recovery of scleractinian-dominated reefs in the later Paleogene.

XII. ACKNOWLEDGMENTS

Special thanks are extended to two student research assistants from Okaloosa-Walton Community College. They assisted in field collecting and laboratory preparations, and both made important new discoveries of Salt Mountain fauna. Mr. Paul S. Kline, now a geology student at the University of Alabama, Tuscaloosa, assisted in the summer of 1995. And Ms. Stephanie Schroeder, of Eglin Air Force Base, Florida, assisted in the summer of 1996. Roger Portell (Florida Museum of Natural History) loaned topotypes of Salt Mountain larger foraminifera collected by Lyman Toulmin.

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PART II
SMALLER BENTHIC FORAMINIFERAL PALEOECOLOGY

RICHARD H. FLUEGEMAN, JR.

I. INTRODUCTION

A recent paper by Bryan (1991) examined the biofacies within the late Paleocene age Salt Mountain Limestone of Alabama and reconstructed the paleoecology of the megafossil assemblages within the unit. The Salt Mountain is a 37 meter thick reefal limestone known principally from the subsurface and from its single outcrop in Clarke County, Alabama. Bryan's work was the first detailed paleoecologic examination of the faunas of the Salt Mountain. Especially significant in this study was the recognition of sponges as an important constituent of the Salt Mountain reef communities. This association is considered unique among the poorly known Paleocene reefs worldwide. Considering the limited knowledge of Paleocene reefs, Bryan (1991) has provided valuable insight into the survival and recovery of reef communities following the Cretaceous-Paleogene extinction.

Placing these results within a proper sequence stratigraphic framework would further enhance the understanding of early Paleogene reefs and their relationship to fluctuating sea-level. Although sequence stratigraphy of outcropping Paleogene sediments has been studied in the eastern Gulf Coastal Plain of the United States (Baum and Vail, 1988; Mancini and Tew, 1991) the Salt Mountain Limestone was not included. Carbonate depositional systems respond differently to fluctuating sea-level than do siliciclastic systems (Sarg, 1988; Schlager, 1992) and a simple comparison of the Salt Mountain section to those siliciclastic sections previously studied updip may be misleading.

Studies of benthic foraminiferal paleoecology provides a tool to help place the Salt Mountain Limestone within a sequence stratigraphic framework by reconstructing the sea-level history of the unit. Briskin and Fluegeman (1990) studied benthic foraminiferal assemblages from the Paleocene of the eastern Gulf Coastal Plain and were able to place paleoecologic and paleobathymetric estimates on identified sequences. Additionally, their study of assemblages identified some smaller scale fluctuations of sea-level within some of the sequences. The principles on which Briskin and Fluegeman based their study were the understanding that the distribution of benthic foraminiferal assemblages are controlled by water mass characteristics (Streeter, 1973; Lohmann, 1978) and are not affected by substrate type (Culver and Buzas, 1982). While not a measure of absolute bathymetry, benthic foraminiferal assemblages do reflect paleoecologic conditions, which may change with either water depth or distance from the shoreline. In either case, changes in assemblages through time should reflect a change in relative sea-level. The independence from substrate type enables a comparison from carbonate to siliciclastic depositional settings where the respective sedimentological responses to fluctuations in relative sea-level are likely to be quite different.

II. AGE AND CORRELATION

Tappan and Loeblich (1957) studied planktonic foraminifera from the Salt Mountain and identified it as a Paleocene unit assignable to the *Planorotalites pseudomenardii* Zone (Zone P4). The work of Wind (1974) and Siesser (1983) identified calcareous nannofossils from the middle and upper portion of the Salt Mountain and assigned the formation to the *Discoaster muehleri* Zone (Zone NP7). Both of the biostratigraphic assignments are consistent with a late Paleocene age and suggest a correlation with the "*Ostrea thirsae* beds" of the Nanafalia Formation of the Paleocene outcrop belt.

This correlation may be an oversimplification. While both units contain calcareous nannofossils of zone NP7, the bulk of the "*Ostrea thirsae* beds" are actually within zone NP8 (Gibson *et al.*, 1982). Additionally, the zone NP7 nannofossils from the Salt Mountain are from near the middle and top of the section suggesting that the Salt Mountain may be at least in part correlative with the non-marine Gravel Creek Member of the Nanafalia Formation. No nannofossils have been identified from the lower 20 m of the Salt

Mountain.

Other biostratigraphic work has been done on the Salt Mountain and the "*Ostrea thirsae* beds." Both units are in planktonic foraminiferal zone P4 but this is a broad zone representing more than 3 million years (Berggren *et al.*, 1995). A revised planktonic foraminiferal biozonation presented in Berggren *et al.*(1995) divides Zone P4 into three subzones. The "*Ostrea thirsae* beds" are placed in subzone P4c based on the presence of both *Globanomalina pseudomenardii* and *Acarinina soldadoensis*. Planktonic foraminifera have only been collected from the lower part of the Salt Mountain and *G. pseudomenardii* is the only biostratigraphically important species present. The presence of *Globoanomalina pseudomenardii* and the absence of *Acarinina soldadoensis* suggests that the lower part of the Salt Mountain should be assigned to subzone P4b. Also absent from the Salt Mountain Limestone is the distinctive benthic foraminifer *Discorbis washburni*. This fossil is a characteristic element of the benthic foraminiferal fauna of the "*Ostrea thirsae* beds" and defines the *Discorbis washburni* total range zone of Fluegeman *et al.* (1990).

The above biostratigraphic data suggest that the Salt Mountain Limestone may correlate in part with the "*Ostrea thirsae* beds" of the Nanafalia Formation but that a significant portion (as much as 20 meters) of the Salt Mountain Limestone may correlate with the underlying Gravel Creek Member of the Nanafalia Formation.

III. BENTHIC FORAMINIFERA

Benthic foraminifera were first described from the Salt Mountain Limestone by Vaughan (1936). He described the larger foraminifera *Discocyclina weaveri* and *Pseudophragmina stephensoni* from the Salt Mountain. Toulmin (1941) described and illustrated the entire foraminiferal fauna collected from the base of the Salt Mountain. In addition to the larger foraminifera already described, he identified a diverse assemblage of smaller foraminifera.

The presence of species of *Discocyclina* and *Pseudophragmina* suggests an affinity with the Tethyan fauna described by Berggren (1974) from the Sirte Basin of Libya and Mali. After evaluating the entire fauna reported by Toulmin (1941) however, Berggren and Aubert (1975) concluded that the Salt Mountain benthic foraminiferal fauna was a typical assemblage of the cosmopolitan "Midway Fauna." Briskin and Fluegeman (1990) did use Salt Mountain benthic foraminiferal data in their study of assemblages and they did identify a *Discocyclina-Pseudophragmina* assemblage as characteristic of reef environments. They recognized this assemblage as an "overprinted" assemblage occurring in the same samples with a typical Midway association. Because of the isolated occurrence of the Salt Mountain assemblages and the uncertainty of their correlation, Briskin and Fluegeman (1990) did not use the Salt Mountain data in constructing their paleontologic sea-level curve.

IV. METHODS OF STUDY

Samples were collected at 1 m intervals through the 37 meters of Salt Mountain Limestone at the type locality. In the laboratory, thin sections were made of all samples and examined to determine rock type and foraminiferal constituents. Samples were assigned to one of the four biofacies identified by Bryan (1991). Disaggregation was attempted on a portion of each sample. The samples were dried for 24 hours at 100 degrees Celsius. They were then soaked in de-ionized water for 24 hours. The samples were then wet sieved and dried for an additional 24 hours. The resulting washed material was then examined under a binocular microscope and individual foraminifera were identified. Because of the degree of lithification, the washing procedure did not produce complete disaggregation in any of the samples. Some washed material was obtained from all samples with the exception of the boundstones. Foraminifera were picked and identified using the taxonomy of Toulmin (1941), as modified by Berggren and Aubert (1975). The obtained foraminifera were censused and each sample was assigned to one of the paleoecologic assemblages identified by Briskin and Fluegeman (1990).

V. BENTHIC FORAMINIFERAL PALEOECOLOGY

Foraminifera were identified from throughout the Salt Mountain Limestone. Most of the faunas could be assigned to one of the assemblages identified by Briskin and Fluegeman (1990). In the case of the boundstones, an insignificant wash necessitated thin section study of the foraminifera. In these samples, the most conspicuous components of the fauna were identified. Examination of the literature on benthic foraminifera enabled assignment of these samples to paleoecologic assemblages.

The lower 3 meters of the Salt Mountain Limestone consists of a foraminiferal-bryozoan-algal biomicrite (Biofacies 1 of Bryan, 1991). It is from this unit that Toulmin (1941) collected his foraminiferal fauna. Samples collected from this interval in this study had the most complete disaggregation and thus the best foraminiferal assemblages were collected here. Benthic foraminifera collected from the lower meter of this unit are assignable to the *Pulsiphonina-Anomalinoides* assemblage of Briskin and Fluegeman (1990). This assemblage is characterized by an abundance of the species *Pulsiphonina prima* and *Anomalinoides acuta*. Other abundant species associated with this assemblage in the Salt Mountain Limestone include *Marsonella oxycona, Discocyclina weaveri, Pseudophragmina stephensoni, Alabamina westraliensis,* and *Nonionella insecta*. This assemblage has been identified from a number of localities worldwide (Berggren and Aubert, 1975) and it has been assigned to a variety of bathymetric ranges. Briskin and Fluegeman (1990) considered this assemblage to represent those paleoecologic conditions found at from 15-30 meters of depth.

The next meter contains benthic foraminifera assignable to the *Cibicidoides-Anomalinoides* assemblage of Briskin and Fluegeman (1990). This assemblage is characterized by an abundance of *Cibicidoides alleni* and *Anomalinoides midwayensis* associated with a diverse foraminiferal fauna including, in the Salt Mountain Limestone, *Discocyclina weaveri* and *Pseudophragmina stephensoni*. This assemblage is a common association within the Midway fauna throughout the world (Berggren and Aubert, 1975) and is generally considered to represent water depth of 5 - 10 meters. Briskin and Fluegeman (1990) concurred and considered this assemblage to represent inner neritic conditions. The occurrence of this assemblage in the Salt Mountain Limestone represents a relative fall in sea-level from the conditions of the lower part of this unit.

The upper part of the lower unit of the Salt Mountain contains an assemblage assignable to the *Lenticulina-Anomalinoides* assemblage of Briskin and Fluegeman (1990). This assemblage is characterized by the abundance of *Lenticulina midwayensis* and *Anomalinoides umbonifera* and a general low diversity of benthic foraminifera. *Discocyclina weaveri* and *Pseudophragmina stephensoni* are present in this assemblage in the Salt Mountain. The *Lenticulina-Anomalinoides* assemblage was first recognized in the Aquia Formation of Maryland and Virginia by Nogan (1964). He interpreted this assemblage to represent water depth of less than 5 meters. Briskin and Fluegeman (1990) considered the *Lenticulina-Anomalinoides* assemblage to indicate littoral, subtidal conditions. This interpretation is accepted here for the upper part of this unit of the Salt Mountain Limestone.

The next 7 meters of the Salt Mountain Limestone consist of a sponge-coral biomicrite. This is biofacies 3 of Bryan (1991). The lithified nature of the rocks in this interval prevented the collection of foraminiferal assemblages by washing. Thin section studies reveal numerous individuals of *Discocyclina weaveri* and *Pseudophragmina stephensoni*. This interval is assigned to the *Discocylclina-Pseudophragmina* assemblage of Briskin and Fluegeman (1990). They considered this assemblage to be associated with reef environments. In the case of the Salt Mountain Limestone, the *Discocylina-Pseudophragmina* assemblage is restricted in use to the main body of the reef. The few foraminifera obtained from washings from this interval are mostly individuals of *Lenticulina toddae*. This association of the *Lenticulina-Anomalinoides* assemblage suggests water depth of less than 5 meters for the *Discocylina-Pseudophragmina* assemblage. This is consistent with the bathymetric estimates of the lower unit and indicates a stabilization of reef development.

In the next 10 meters of the Salt Mountain Limestone, the lithology is again assignable to Biofacies 1 of Bryan (1991). Benthic foraminifera collected from washings are assignable to the *Pulsiphonina-Anomalinoides* assemblage. *Discocyclina weaveri* and P*seudophragmina stephensoni* are also common constituents of the fauna. Both the lithology and the benthic foraminifera indicate a rise in relative sea-level.

Overlying this unit is a coral biomicrite. This unit is identified by Bryan (1991) as Biofacies 2. The unit as measured in this study is 8 meters thick. Foraminifera obtained from washings of this interval are robust individuals of *Anomalinoides umbonifera, Lenticulina midwayensis*, and *Lenticulina toddae*. Numerous individuals of *Lenticulina* sp. are also visible in thin section. Specimens of D*iscocyclina weaveri* and *Pseudophragmina stephensoni* are rare in this interval with only two isolated tests seen in thin section. The above association suggests assignment of this interval to the *Lenticulina-Anomalinoides* assemblage. The paleoecologic conditions implied by this assemblage are consistent with the interpretation of this biofacies as a low energy thicket near the main reef buildup (Bryan, 1991) and indicates a fall in relative sea-level.

Overlying this interval is a recurrence of Biofacies 3. The unit is 7 meters thick and is assigned to the *Discocyclina-Pseudophragmina* assemblage. This indicates the development of reef conditions and a further fall in relative sea-level.

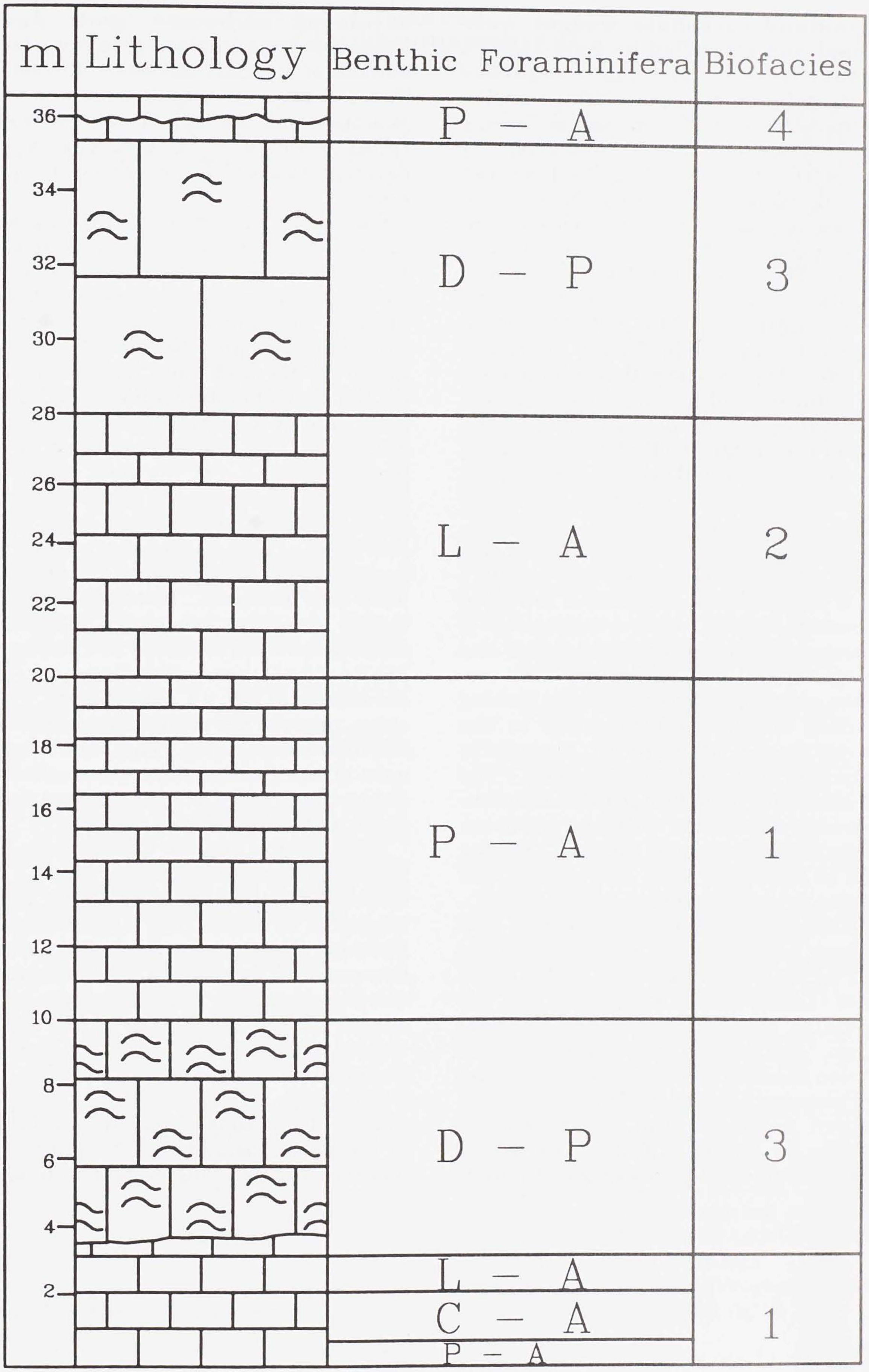
The upper 2 meters of the Salt Mountain Limestone consists of a coral-echinoderm biomicrite. This is Biofacies 4 of Bryan (1991). The foraminifera collected from this interval indicate assignment to the *Pulsiphonina-Anomalinoides* assemblage. The paleoecologic conditions implied by the presence of this assemblage represent a rise in relative sea-level, and thus deeper water conditions than either Biofacies 2 or 3. This interpretation differs from that of Bryan (1991) who interpreted the coral-echinoderm facies to be a shallow water backreef deposit. The distribution of the benthic foraminiferal assemblages and the biofacies of Bryan (1991) are shown in Text-figure 1.

VI. DISCUSSION: FORAMINFERAL PALEOECOLOGY AND SEQUENCE STRATIGRAPHY OF THE SALT MOUNTAIN LIMESTONE

As discussed previously, the Salt Mountain Limestone does not fit into most of the sequence stratigraphic interpretations of the Paleogene of the eastern Gulf Coastal Plain. The fact that the sequence models developed for the region deal mostly with clastics is certainly a part of this difficulty but the greatest problem has been the lack of a precise correlation with the sections of the Paleocene outcrop belt to the North. The published planktonic foraminiferal age (P4) for the entire Salt Mountain Limestone and calcareous nannofossil age (NP7) for the upper half of the formation suggest an age no younger than the lower part of the "*Ostrea thirsae* beds" of the Nanafalia Formation. When the revised planktonic foraminiferal biostratigraphy of Berggren *et al*. (1995) is considered, the lower part of the Salt Mountain may be older than the entire "*Ostrea thirsae* beds." These plus the presence of the benthic foraminiferan *Alabamina westraliensis* and the absence of both *Discorbis washburni* and *Nonion graniferum* make a strong argument that the Salt Mountain is older than the *Discorbis washburni* benthic foraminifera zone. If this is the case, the Salt Mountain Limestone is a correlative of the Gravel Creek Member of the Nanafalia Formation, the lowstand deposits of Cycle TA 2.1 of Haq *et al*.(1987).

>

Text-figure 1. Section of the Salt Mountain Limestone showing the distribution of benthic foraminiferal assemblages and their relationship to biofacies of Bryan (1991). Abbreviations: L-A = *Lenticulina-Anomalinoides* assemblage, C-A = *Cibicidoides-Anomalinoides* assemblage, P-A = *Pulsiphonina-Anomalinoides* assemblage, D-P = *Discocyclina-Pseudophragmina* assemblage.


m
Lithology
Benthic Foraminifera
Biofacies
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
P – A
4
D – P
3
L – A
2
P – A
1
D – P
3
L – A
C – A
P – A
1

Lowstand carbonate wedges were defined and classified by Sarg (1988). Further work on carbonate sequence stratigraphy by Schlager (1992) clarified the characteristics of carbonate sediments deposited during lowstand conditions. Of particular interest here is the lowstand wedge developed during long (durations in millions of years) sea-level cycles and in conjunction with gentle depositional slopes. The depositional setting of Salt Mountain Limestone is consistent with these conditions. The Salt Mountain formed during Cycle TA 2.1 of Haq *et al.*(1987). They consider this cycle to have had a duration of 3.5 ma. The long sea level cycle plus the broad nature of the shelf in the eastern Gulf of Mexico during Paleocene time would both be conducive to the development of a lowstand carbonate wedge provided the physical, chemical, and biological conditions necessary for carbonate sediment development are met.

Is it reasonable to associate a lowstand carbonate wedge with a siliciclastic sequence? The models of Sarg (1988) and Schlager (1992) deal exclusively with carbonate platforms and genetically linking the Salt Mountain Limestone to the Gravel Creek Member of Nanafalia Formation may not be appropriate. The Salt Mountain could be a lowstand carbonate wedge associated with the northern margin of the Suwannee Channel. During much of Paleogene time, this margin was the site of reef buildups (Chen, 1965). Additionally, both the Cedar Key and Oldsmar Limestones of Paleocene age in the Florida subsurface are reefal limestones (Levin, 1957; Chen, 1965) and are associated with the Suwannee Channel margin. Similarities have also been noted between the Salt Mountain Limestone and the Paleocene Clayton Formation of southeastern Alabama and southwestern Georgia by Bryan (1993). The above works document the presence of a well developed carbonate shelf during Paleocene time in close proximity to the outcrop of the Salt Mountain Limestone. The actual connection between the Salt Mountain and the carbonate shelf is a bit tenuous however, due to the lack of detailed subsurface information in the area.

Can lowstand carbonates develop without a carbonate shelf in close proximity? Rezak *et al.*(1985) document several carbonate banks in the northwestern Gulf of Mexico. These banks developed on top of salt diapirs on an otherwise clastic shelf. Bryan (1991) used these reefs as a model for the Salt Mountain Limestone. These reefs were at their maximum development during the last glacial maximum, a sea-level lowstand. If the Salt Mountain developed at lowstand, there should be some evidence of drowning with rising sea-level. The succession of benthic foraminiferal assemblages is consistent with this pattern. Further, Schlager (1992) identifies "encrinite" lithologies capping drowned lowstand reef sequences. While the upper lithology at Salt Mountain is not an echinoderm grainstone, many of the grains are rounded and the rock is well sorted. This with the presence of the *Pulsiphonina-Anomalinoides* assemblage indicate increasing water depth and rising relative sea-level.

In summary, benthic foraminifera from the Salt Mountain Limestone record a pattern of fluctuating sea-level similar to that suggested by Bryan (1991) in his study of biofacies. Further, the fluctuation in relative sea-level recorded in the lower part of the Salt Mountain Limestone may be the sea-level cycle equivalent to the Gravel Creek Member of the Nanafalia Formation suggested by Briskin and Fluegeman (1990). This cycle was inferred by a study of sea-level periodicity in the Paleocene and was thought to have occurred during a long lowstand phase.

PART III
LARGER FORAMINIFERA
JONATHAN R. BRYAN

I. INTRODUCTION

Only two species of larger benthic foraminifera (LBF) have been recognized from the Salt Mountain Limestone, but the stratigraphic, biogeographic, and ecologic significance of these taxa make them worthy of some discussion.

II. SYSTEMATIC PALEONTOLOGY

The frequent nomenclatorial changes that plague LBF generally have affected the Salt Mountain species as well. Vaughan (1936) first described two species of *Discocyclina* from the Salt Mountain, *D. blanpiedi* and *D. cookei*, distinguished by test size, test shape, size of the embryonic chambers, and features of the equatorial chambers. Cole (1959, 1969) later synonymized these two species as follows:

Discocyclina (Discocyclina) weaveri Vaughan, 1929
(= *Discocyclina blanpiedi* Vaughan, 1936)
Pseudophragmina (Athecocyclina) stephensoni (Vaughan), 1929
(= *Discocyclina cookei* Vaughan, 1936)

Classifications of the discocyclinids vary. I have followed Cole (1964, 1969) and Loeblich and Tappan (1988). Synonymies are not complete, but list original and other important or recent references.

Order FORAMINIFERIDA Eichwald, 1830
Suborder ROTALIINA Delage and Herouard, 1896
Family DISCOCYCLINIDAE Galloway, 1928
Genus DISCOCYCLINA Gumbel, 1870
DISCOCYCLINA (DISCOCYCLINA) WEAVERI Vaughan, 1929
Plate 1, figure 1

Discocyclina (Discocyclina) weaveri VAUGHAN, 1929, pl. 1, figs.1,2.
Discocyclina blanpiedi VAUGHAN, 1936, pl.41, figs.1-7 (Salt Mountain Limestone).
Discocyclina (Discocyclina) weaveri Vaughan. COLE, 1959, pl.33, figs.3-5 (full synonymy p. 384).

Remarks: According to Vaughan's original description, *D. weaveri* "possesses an embryonic apparatus in which the second chamber almost entirely surrounds the first and the first two chambers are nearly surrounded by a ring of chambers larger than the succeeding equatorial chambers." In the 1936 description of "*D. blanpiedi*" from the Salt Mountain, Vaughan notes that the deuteroconch only partly embraces the protoconch. Cole (1959) points out that the original specimen illustrated by Vaughan (1929) was obliquely oriented, giving only the appearance of a eulepidine embryonic apparatus. The deuteroconch is distinctly reiniform. The equatorial chambers are distinct, each with well-defined walls, yet arranged in annuli, and appear subrounded to oblong, but usually retaining the hexagonal shape.

Family ASTEROCYCLINIDAE Bronnimann, 1951
Genus PSEUDOPHRAGMINA H.Douville, 1923
PSEUDOPHRAGMINA (ATHECOCYCLINA) STEPHENSONI (Vaughan, 1929)
Plate 1, figure 2

Discocyclina stephensoni VAUGHAN, 1929, pl. 6, figs. 1-4.
Discocyclina cookei VAUGHAN, 1936, pl. 42, figs. 1-6 (Salt Mountain Limestone).
Pseudophragmina (Athecocyclina) stephensoni (Vaughan).COLE,1953, pl.2, figs.4-11 (subsurface of Georgia).
Pseudophragmina (Athecocyclina) stephensoni (Vaughan).COLE, 1959, pl.32, figs.1-4 (full synonymy p.386).
Pseudophragmina (Athecocyclina) cookei (Vaughan). COLE, 1964, fig. 588,3.
Pseudophragmina (Athecocyclina) stephensoni (Vaughan). COLE, 1969, pl.6, figs.1,2.
Pseudophragmina (Athecocyclina) stephensoni (Vaughan). FROST and LANGENHEIM, 1974, pl.22, figs.1-9, pl.23, fig.5.
Athecocyclina stephensoni (Vaughan). ROBINSON AND WRIGHT, 1993, fig. 31.1,2,6.

Remarks: This species can be recognized by the subcircular protoconch embraced by a much larger, distinctly reniform, deuteroconch. Radial chamber walls are incomplete or indistinct (Cole, 1964, p.C715-717). This gives the appearance of layers of concentric rings around the nucleoconch. Vaughan (1936) indicates that the test of this species is usually undulate and may be selliform (saddle-shaped). Selliform tests are common in larger foraminifera living in agitated waters.

III. BIOSTRATIGRAPHIC AND BIOGEOGRAPHIC SIGNIFICANCE

Gravell and Hanna (1938) defined the "*Discocyclina Blanpiedi–Discocylina Cookei* Zone" larger foraminiferal biozone as essentially equivalent to the Salt Mountain Limestone. The geographic extent of this zone was not clearly defined, but was recorded from the subsurface of southwestern Alabama and Jackson County, Florida. Cole (1959, 1969) indicates that these same two orbitoid foraminifera are part of his *Operculina* (= *Ranikothalia*, Robinson and Wright, 1993) *catenula* Fauna, an upper Paleocene to (?)lowermost Eocene LBF assemblage found in Haiti, Trinidad, Mexico, Venezuela, Barbados, Cuba, and the southeastern United States (Cole, 1959, 1969). Species of the *Operculina catenula* Fauna include (Cole, 1959):

Ranikothalia catenula (Cushman and Jarvis)
Actinosiphon semmesi Vaughan
Discocyclina (Discocyclina) barkeri Vaughan and Cole
Discocyclina (Discocyclina) cristensis (Vaughan)
Discocyclina (Discocyclina) weaveri Vaughan
Pseudophragmina (Athecocyclina) stephensoni (Vaughan).

Of the six regional locations of the fauna mentioned by Cole, only at the Salt Mountain Limestone is the primary zonal species, *Ranikothalia catenula*, absent. But both *Ranikothalia catenula* and *Pseudophragmina stephensoni* have been reported from the Porters Creek Formation in the subsurface of Georgia (Cole and Herrick, 1953; Cole, 1959). If this lithostratigraphic correlation is correct, it would extend the range of these foraminifera into the Danian, although Fluegeman (pers. comm.) indicates that this interval is probably Late Paleocene in age (Zone P4c). Both *Pseudophragmina (Athecocyclina) stephensoni* and *Discocyclina (Discocyclina) weaveri* are widespread across the Gulf of Mexico basin and Caribbean in rocks of Late Paleocene to Early Eocene age (Cole, 1969; Frost and Langenheim, 1974).

The genera *Discocylcina* and *Ranikothalia* were among the earliest Tertiary LBF genera, and appear to have a near worldwide distribution at their usual first appearance in the Late Paleocene. They are found in each of the major LBF faunal provinces: American, Tethyan, Indo-Pacific, and both genera were primarily open shelf dwellers (Adams, 1972; Hottinger, 1972). *Discocyclina*, however, has the widest paleolatitudinal range of any Cenozoic large foraminiferan. During the mid-late Eocene, when LBF diversity was at its highest, *Discocyclina* reached Alaska, New Zealand, and southern Australia. Evidently, either some species were tolerant of cool waters, or subtropical conditions extended into much higher latitudes (Adams *et al.*, 1990).

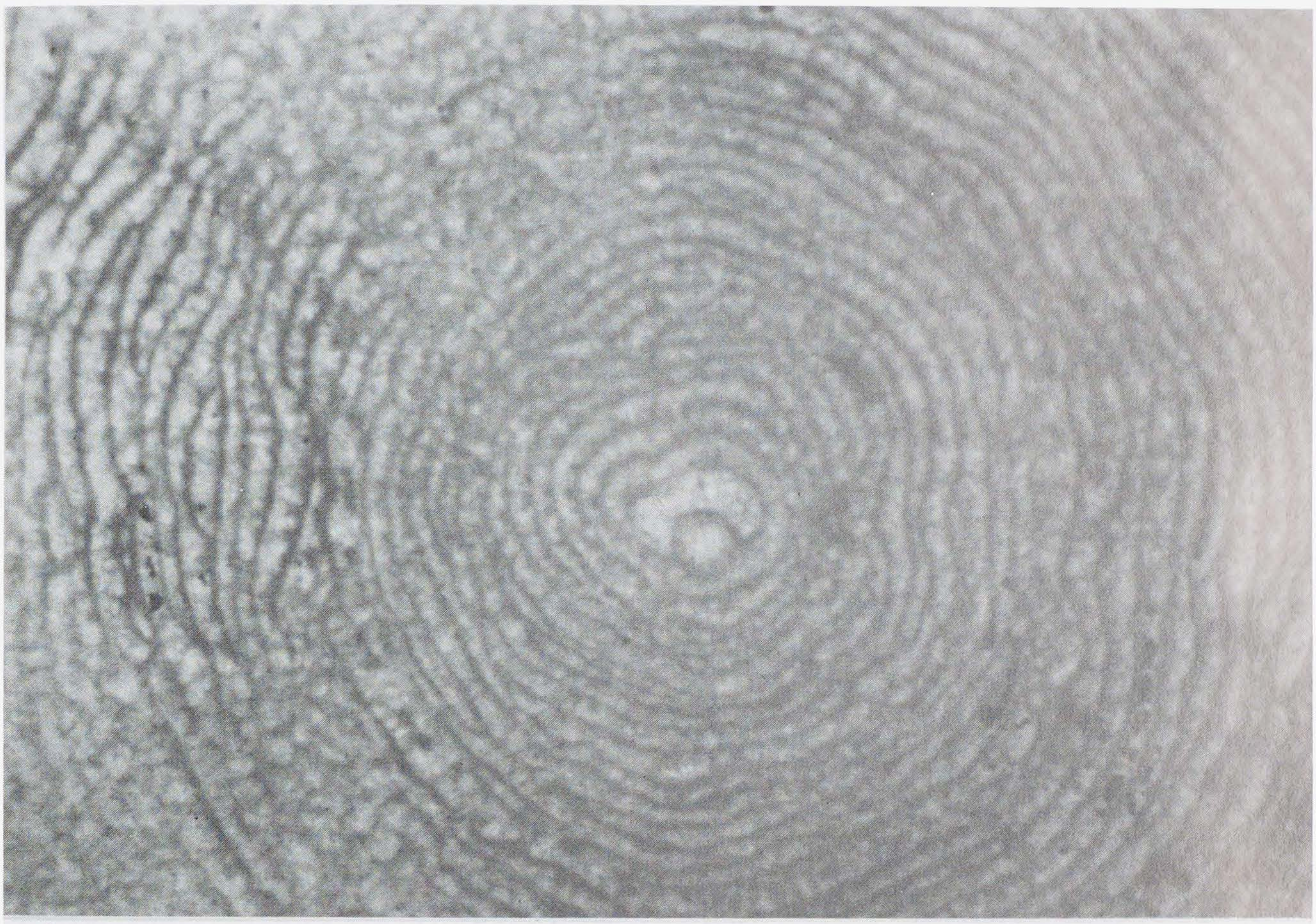
Using smaller benthic foraminfera,

PLATE 1

Figures

1. Equatorial view (4x) of *Pseudophragmina (Athecocyclina) stephensoni* (Vaughan, 1929) (formerly *Discocyclina cookei*), from Station 2 of Toulmin (1940b). Florida Museum of Natural History specimen UF 69497.

2. Equatorial view (4x) of *Discocyclina (Discocyclina) weaveri* Vaughan, 1929 (formerly *Discocyclina blanpiedi*), from Station 1 of Toulmin (1940b). Florida Museum of Natural History specimen UF 69496.



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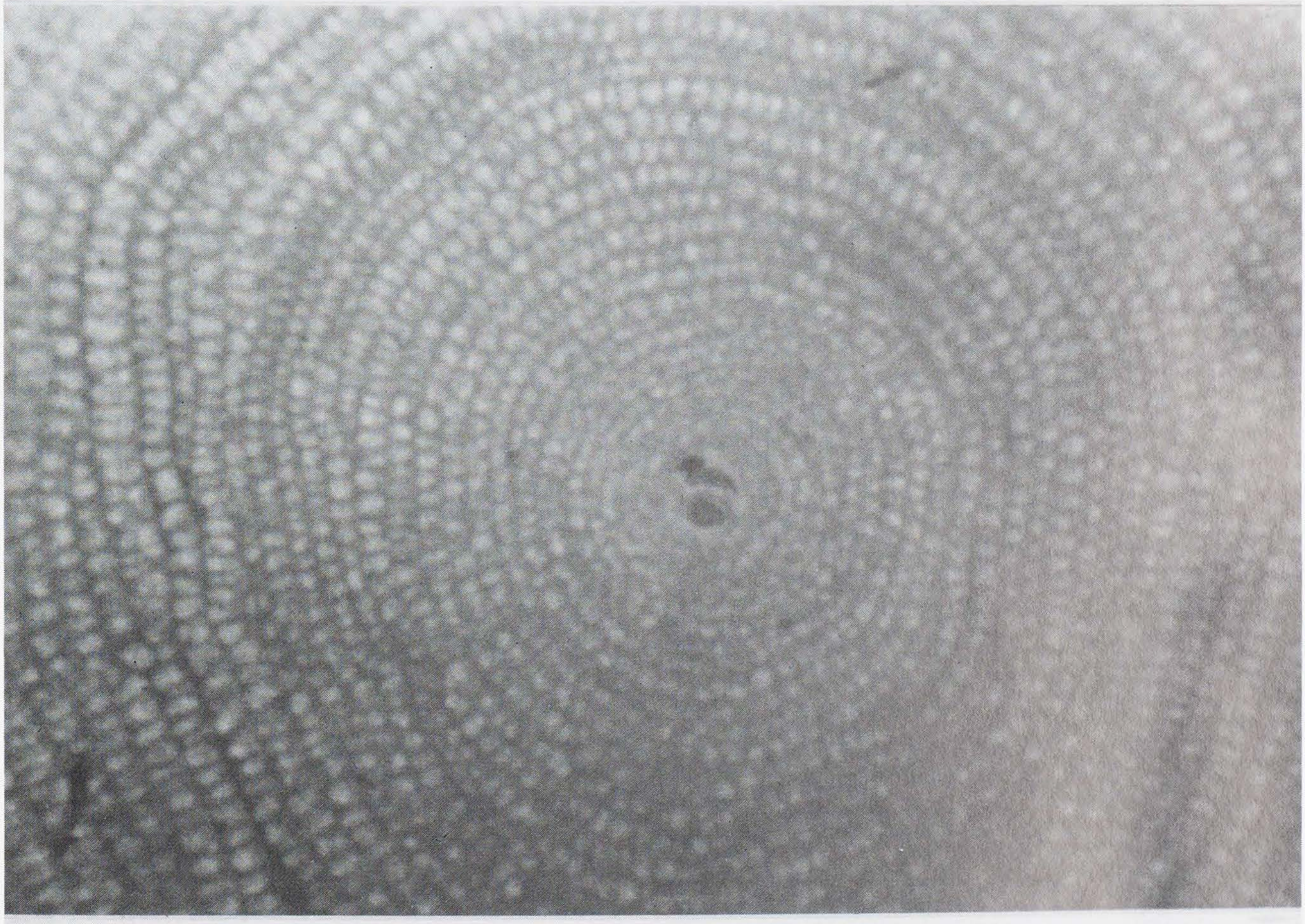

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PLATE 1

Berggren and Aubert (1975) identified three circum-Atlantic/Tethyan foraminferal assemblages during the Paleocene. The first is the "Tethys Carbonate Fauna" (see Berggren, 1974), which was deposited in inner to middle neritic waters (<30-50 meters depth). The second is the "Midway-type-fauna", representing middle to outer neritic water depths (50-200 meters depth). And the third is the "Velasco-type fauna", indicating slope-rise and deeper conditions (>200 meters depth). They consider the Salt Mountain fauna to represent, "essentially, an extension of the Midway (fauna)", but the presence of discocyclinid larger foraminfera indicates strong affinities with their Tethys Carbonate Fauna.

IV. PALEOECOLOGY

Today, larger foraminifera are found almost exclusively in tropical to subtropical, oligotrophic to mesotrophic environments, such as in reefs and related facies. Nearly all harbor algal photosymbionts within their cytoplasm and their complex, compartmentalized tests are thought to be, at least in part, adapted for this purpose. Most extinct LBF are associated with similar paleoenvironments, and are inferred to have also hosted photosymbionts. When present, LBF are frequently found in great abundance and may rival corals and algae in carbonate sediment production.

According to Vaughan (1945) nearly all American discocyclinids are found in "tropical to subtropical, and south temperate latitudes," and are associated with other larger foraminifera and coralline algae. He estimates that discocyclinids ranged from "slightly below tide level to perhaps 100 meters" and probably could not tolerate temperatures below 16°C. According to Ghose (1977), large, flat discocylcinids (such as those found in the Salt Mountain) are characteristic of shallow fore-reef environments (smaller, more robust forms may be found in backreef areas near the reef core). Breard *et al.* (1994) also suggest inner neritic depths (0-30 meters) for discocylclinids of the Gulf Coast Paleocene and Eocene, as did Eva (1976) for *Pseudophragmina* in the Jamaican Middle Eocene. Fermont (1982) reports *Discocyclina* in upper to lower foreslope enviroments in the Eocene of Ein Avedat (Israel). Frost and Langenheim (1974) record *Pseudophragmina (Athecocyclina) stephensoni* in sandy, high-energy, nearshore sandy limestones of Late Paleocene age in the Chiapas, Mexico. In the Salt Mountain Limestone, the discocyclinids are primarily found in Biofacies 1, interpeted as a forereef deposit (Bryan, 1991), and according to Fluegeman (this volume), deposited in water depths of 15 to 30 meters.

PART IV
CORALS

THOMAS A. STEMANN

I. INTRODUCTION

Although the Salt Mountain Limestone has long been known as a "coral limestone," only two coral species have been formally recognized from this formation (Bryan, 1991). Vaughan (1900) described the massive corals *Stylophora ponderosa* and *?Turbinoseris alabamensis* (now considered *Actinacis alabamensis*), and noted other forms were also present but were unidentifiable due to their poor preservation. The relatively poor preservation of the Salt Mountain corals is one reason this fauna has been largely overlooked in studies of Paleogene reefs. More detailed, recent studies, however, have revealed a considerable diversity of corals (Bryan, 1991; Krumm and Santos, 1993). Recognition of the fauna as a unique Paleocene Caribbean reef community has also been hampered by earlier confusion about the age of the formation among some workers (cited in Bryan, 1991).

The Salt Mountain coral fauna is significant for two reasons. First, as the only known Paleocene coral-algal build up in the Western Hemisphere, it is an important key to our understanding of how reef communities became reestablished after the coral extinctions of the end-Cretaceous (Wells, 1956; Rosen and Turnsek, 1989; Veron, 1995). Second, at a paleolatitude of about 31-32°N (Bryan, this volume), the Salt Mountain coral community represents one of the highest latitude Tertiary age coral build-ups in the Western Hemisphere. Thus, it is also important to our understanding of latitudinal variation and geographic control of reef growth and coral communities.

The present report provides a brief description of the Salt Mountain coral fauna, its ecology and its relationship with other known Tertiary through Recent reef communities. This study is based on the collections of Jonathan Bryan and his students and by Debra Krumm. All specimens figured here will be reposited at the Florida Museum of Natural History. A complete, systematic description of the fauna will be published separately.

II. THE FAUNA

The Salt Mountain coral fauna includes 12 species, two of which were previously described from the formation by Vaughan (1900) (Table 1). Besides these 12 coral species, a single sclerite of the octocoral *?Parisis* has also been collected. Among the corals, three species are also recorded from the Paleogene of the Caribbean and Gulf Coast regions (*Madracis herricki, Cyathoseris eocenica* and *Actinacis alabamensis*). One species, *Cyathoseris ?valmondasiaca*, appears close to a species known from the European Eocene. Four species recognized here are apparently new (Table 1). Two others, *?Trochoseris* sp. and *Antillia* sp., cannot be referred to any described species and are only known from single specimens. These species are therefore left in open nomenclature. Finally, one form could only be identified to the family level, Caryophylliid sp. Table 2 presents a short diagnostic key for the Salt Mountain fauna.

Massive and explanate-laminar corals are the most diverse and volumetrically important part of the Salt Mountain scleractinian community. Corals are highly recrystallized, though considerable skeletal detail is preserved (Text-figure 1). Moldic preservation is also common, especially among platy forms. *Stylophora ponderosa* is by far the most abundant and largest (up to 1 meter in diameter) coral in the fauna. *Actinacis alabamensis* is also common and may reach 0.2 m in breadth and thickness. Locally, however, some small thickets of the thinly branched, dendroid corals, *Oculina* new sp. and *Dendrophyllia* new sp., (Text-figure 2) may be volumetrically important, especially in Biofacies 2 and 4 (Bryan, this volume). The massive, encrusting and explanate species are largely confined to the Sponge-Coral Bafflestone/Framestone Biofacies 3 of Bryan (this volume), though smaller, isolated coral heads may be found elsewhere throughout the section. To date, no robust branching forms similar to those that dominate later Tertiary reefs, such as *Acropora, Pocillopora* or branching *Stylophora* (Veron, 1986; Budd *et al.*, 1994), have been collected from the Salt Mountain Limestone.

Other than the Salt Mountain, there is only one other important Paleocene coral fauna from the Gulf Coast region (Vaughan, 1900), the corals from the Lower Paleocene Midway Group of Alabama (Table 3). Comparisons between Midway and Salt Mountain faunas are interesting because there are, in fact, no species or genera in common between the two. This is unusual because all the Midway Group species (except *Mesomorpha duncani*) belong to genera that are common in Eocene and, in some cases, younger Caribbean coral faunas (Budd *et al.*, 1992; Wells, 1956). Frost and Langenheim (1974) found *Siderastrea hexagonalis* in the Lower Eocene of Mexico, while during the Eocene *Haimesastrea conferta* and closely related congeners are a conspicuous part of Caribbean and eastern Pacific reef communities (Vaughan, 1922; Frost and Langenheim, 1974). It is highly likely that further collection from the Salt Mountain Limestone will yield some corals closely related to those found in the Midway Group.

III. PALEOECOLOGY

The massive morphology of the most common corals may suggest that the Salt Mountain Limestone was deposited at shallow to moderate water depths. Conversely, the dominance of delicately branched corals in some facies could suggest either much deeper water below effective wave base or shallow protected environments. Indeed, fossil (Alvarez *et al.*, 1991) and modern congeners of the *Dendrophyllia* sp. are often found in very deep water settings (>250 m) (Cairns, 1979; Wells, 1956). Still, the abundant crustose algae associated with and in many cases encrusting the Salt Mountain corals indicates the fauna was deposited in fairly shallow water.

A chief question concerning the fauna is whether the corals were predominately zooxanthellate (and thus similar to reefal assemblages of the later Cenozoic) or azooxanthellate. Because all the species and at least half the genera represented in the Salt Mountain collections are extinct it is difficult to precisely determine whether

TABLE 1. Corals of the Salt Mountain Limestone. Zooxanthellate and Azooxanthellate determinations based on colony morphology and systematic relationships to modern coral groups. Additional stratigraphic occurrences taken from Bryan and Huddleston (1991), Budd *et al.* (1992), Vaughan (1900) and Wells (1934).

Coral Species	**Colony Morphology**	**Zooxanthellate-Azooxanthellate?**	**Other Occurrences**
Stylophora ponderosa Vaughan, 1900	massive	Z	--
Madracis new sp.	encrusting	A/Z	--
Madracis herricki Wells, 1934	encrusting	A/Z	Mid. Eocene, Texas
?Trochoseris sp.	solitary	Z	--
Cyathoseris ?valmondasiaca (Michelin, 1843)	explanate	Z	Mid.Eoc., Paris Basin
Cyathoseris eocenica (Stemann *in* Budd *et al.*, 1992)	explanate	Z	Upper Eoc., Panama
Sideroseris new sp.	phaceloid-solitary	A	--
Actinacis alabamensis (Vaughan, 1900)	massive	Z	Eoc., Jamaica,Panama Lower Olig., Georgia
Oculina new sp.	dendroid	A/Z	--
Antillia sp.	solitary	Z	--
Caryophylliid sp.	solitary	A	--
Dendrophyllia new sp.	dendroid	A	--

or not any bore algal symbionts. In this study, colony morphology and species' systematic relationships with modern corals were used to make estimates about the presence or absence of zooxanthellae in the Salt Mountain fauna (Table 1). Using these criteria, three groups of species were recognized: zooxanthellate (Z), azooxanthellate (A) and those species (A/Z) that may have been zooxanthellate, azooxanthellate or facultatively both (*i.e.*, apozooxanthellate).

Zooxanthellate Corals

Six of the 12 Salt Mountain species were probably true zooxanthellate corals. All are most closely related to modern species that bear algal symbionts. Although *Actinacis alabamensis* belongs to an extinct family, the Actinacidae, most workers consider it to be closest systematically and ecologically to members of the reef coral family Poritidae (Bosellini and

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TABLE 2. A field key to the Scleractinian corals of the Salt Mountain Limestone. Additional diagnostic information for each species is listed in parentheses. Abbreviations are cd - corallite diameter; cs - spacing of corallite centers; ns - number of septa per corallite.

I. Solitary
  A. Diameter 30-50 mm . . . . *Antillia* sp.
    (trochoid; elliptical; 12 septa/cm at wall)
  B. Diameter 20-30 mm . . . . ?*Trochoseris* sp.
    (>30 septa/cm at wall)
  C. Diameter 10-15 mm . . . . Caryophylliid sp.
    (cylindrical; ns: 40-50)
II. Colonial
  A. Branched
    1. Branch diameter 7-8.5 mm . . . . *Sideroseris* new sp.*
      (ns:55-65; thin rods connecting septa)
    2. Branch diameter 3.0-4.5 mm . . . . *Dendrophyllia* new sp.
      (ns: 24-48; wall porous)
    3. Branch diameter <3.0 mm . . . . *Oculina* new sp.
      (ns:12-24; major septa w/pali; wall solid)
  B. Massive-laminar
    1. Corallites in series
      a. Series parallel edge . . . . *Cyathoseris eocenica*
        (platey; cd:5-12 mm; cs:2.5-10 mm)
      b. Series radiate . . . . *Cyathoseris ?valmondasiaca*
        (cup-shaped; cd:<7.5 mm; cs:1.5-5 mm)
    2. Corallites not in series
      a. Solid coenosteum
        i. Septa in cycles of 6 . . . . *Stylophora ponderosa*
          (massive; cd: 1.0-0.5 mm; cs:1.0-1.3 mm)
        ii. Septa in cycles of 10
          aa. cd: 1.3-1.8 mm . . . . *Madracis* new sp.
            (encrusting-?branched; cs: 2.0-3.0 mm)
          bb. cd: 2.3-3.5 mm . . . . *Madracis herricki*
            (encrusting-nodular; cs: 2.0-3.0 mm)
      b. Porous coenosteum . . . . *Actinacis alabamensis***
        (cd: 0.8-1.5 mm; cs: 2.0-3.0 mm)

Notes:
* *Sideroseris* new sp. may also be found as a solitary coral.
***Actinacis alabamensis* colonies are rarely preserved well enough to exhibit clear coral- CD in sectioned colonies is often significantly less than the 1.5 mm found on the holotype.

Russo, 1995). Also, *A. alabamensis* and *Stylophora ponderosa*, both grew as large, massive colonies with small (<1.5 mm) corallites, a combination of characteristics that is rare in known modern azooxanthellate corals (Coates and Jackson, 1985). Similarly, the explanate or platy corals, *Cyathoseris ?valmondasiaca* and *C. eocenica*, were almost certainly zooxanthellate because this growth form is unknown among modern Pacific or Caribbean azooxanthellate corals (Veron, 1986; Budd *et al.*, 1994). Among the solitary corals, only *Antillia* sp. is considered a near-certain zooxanthellate species because it is a member of an entirely zooxanthellate family, Mussidae, and because of its large diameter (Coates and Jackson, 1985). A single, poorly preserved specimen here attributed to *?Trochoseris* sp. may also be a zooxanthellate coral based on its possible relationship to the reef coral family Agariciidae.

Azooxanthellate Corals

Three species in the Salt Mountain probably did not bear algal symbionts (Table 1). The most common of these belongs to the genus *Dendrophyllia,* a group composed entirely of azooxanthellate corals. The solitary coral fragment assigned to the family Caryophylliidae is also almost certainly an ahermatypic coral since solitary corals belonging to this family all lack symbiotic algae. Based on its small solitary or phaceloid morphology, the specimens of *Sideroseris* sp. probably represent an azooxanthellate coral species. It is, however, a member of the important reef coral family, the Siderastreidae, and congeneric species of this extinct genus are known to co-occur with other Paleogene 'hermatypic' species (Wells, 1945; Frost and Langenheim, 1974).

A/Z Corals

Three species in the Salt Mountain fauna (M*adracis herricki, Madracis* new sp. and *Oculina* new sp.) may have been either zooxanthellate or azooxanthellate and are designated A/Z in Table 1. Given their morphology and relationship to modern species they were quite possibly apozooxanthellate corals, that is, they could survive indefinitely with or without symbiotic algae. Modern representatives of the genera *Madracis* and *Oculina* range from the Caribbean-Western Atlantic tropics north to the Mediterranean (Rezak *et al.*, 1985; Wells, 1973; Wells, 1956) and include species with or without zooxanthellae as well as apozooxanthellate species. Among modern corals, *Madracis* is the best known genus to include facultatively zooxanthellate species (Veron, 1995), but both *Madracis* and *Oculina* that are important in faunas from higher latitudes (Rezak *et al.*, 1985). Fossil occurrences from regions at the northern limit of reefal development clearly suggest that many extinct species of both of these genera were also apozooxanthellate (Allmon *et al.*, 1996; Vaughan, 1900). For instance, *Madracis herricki* of the Salt Mountain Limestone is also present in the Eocene of Bastrop County, Texas (about 30°N) where it co-occurs with a low diversity fauna of exclusively azooxanthellate corals (Wells, 1934) suggesting that it, too, is azooxanthellate or at most apozooxanthellate.

IV. COMPARISONS WITH OTHER FAUNAS

The Salt Mountain fauna is five times or more less diverse than many Neogene through Recent coral communities in the Caribbean (Budd *et al.*, 1994) and also far less species-rich than Eocene (Budd *et al.*, 1992) and Oligocene (Vaughan, 1919) reef faunas. Admittedly, the relatively small outcrop area of the Salt Mountain Limestone, its generally poor coral preservation and the comparatively few coralline facies represented all serve to decrease the number of species recorded from this formation. Still, two other important factors restricting species richness in the Salt Mountain fauna are the after effects of the end-Cretaceous extinctions (Wells, 1956; Veron, 1995) and the high latitude posi-

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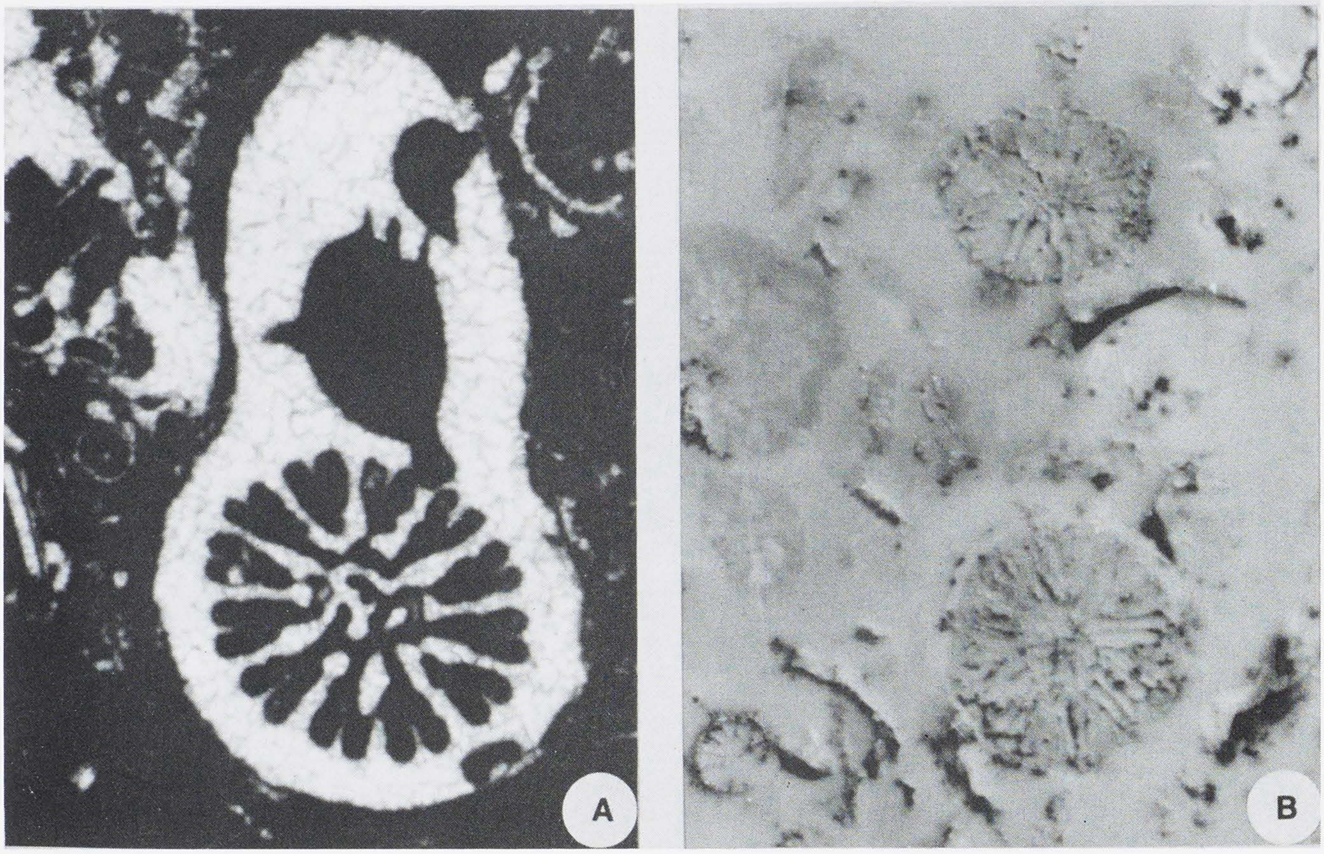
Text-figure 1. Massive and laminar corals of the Salt Mountain Limestone. A. Side view of *Actinacis alabamensis* colony, 0.8x. B. Oral view of *Stylophora ponderosa* colony, 1.25x. C. Moldic impression of *Cyathoseris eocenica* colony, 0.8x. D. Moldic impression of *Madracis* new sp., 1.0x.


A
B
C
D



Text-figure 2. Branched corals of the Salt Mountain Limestone. A. Thin-section photo of *Oculina* new sp. corallite and oblique section of branch. Note solid corallite wall and lobate ends of septa (pali), 20x. B. Polished slab photo of two *Dendrophyllia* new sp. branches. Note porous corallite walls and algal coating on larger of two branch sections, 7x.

tion of the Salt Mountain build up.

Late Cretaceous coral faunas of the Caribbean and North American region are in need of revision, but it can be said that at the generic level they are more diverse than any communities of the Gulf Coast Paleocene (Wells, 1956; Rosen and Turnsek, 1989). None of the species and only five genera of the Salt Mountain fauna, *Madracis, Trochoseris, Cyathoseris, Actinacis* and *Oculina*, can be traced back into the Cretaceous (Wells, 1956). While the K-T extinction event significantly affected scleractinians in general and zooxanthellate corals specifically (Rosen and Turnsek, 1989), this can only partially explain the low diversity in the Salt Mountain fauna.

Globally, Paleocene coral faunas are generally depauperate compared to those of the later Tertiary (Rosen and Turnsek, 1989). However, some earliest Tertiary reef coral communities may be fairly diverse. For instance, the Paleocene of northern Somalia contains 33 species and 20 genera (A. Russo cited in Rosen and Turnsek, 1989) and the Paleocene reef fauna of northcentral Pakistan includes 37 recorded species and 28 genera (Gregory, 1930). Approximately 20 genera of reef (*i.e.*, zooxanthellate-like) corals are present both in Cretaceous and in Eocene or younger Caribbean sediments but are absent in the Salt Mountain (compiled from Vaughan, 1919; Wells, 1956; Budd *et al.*, 1992). Thus, the nine coral genera recognized in the fauna (Table 1), while a higher number than in any other reported Paleocene fauna from the Western Hemisphere, actually represent less than a third of the probable standing diversity in the Caribbean and North American region.

In terms of coral species richness, the Salt Mountain fauna is broadly similar to other Tertiary subtropical coral communities (*e.g.*, Vaughan, 1919). Among the best described of these is the Upper Oligocene Damon Mound reef of the Anahuac Formation, Texas (Frost and Schafersman, 1978). Like the Salt Mountain build-up, the Damon Mound reef also developed at relatively high paleolatitude on a local topographic high amidst a siliciclastic dominated shelf. With only about 14 species, the Damon Mound coral fauna is also a comparatively low diversity community, presumably representing a depauperate, high latitude fauna (Frost and Schafersman, 1978). Coral species richness is, therefore, comparable with that of the Salt Mountain, but, coral abundance is considerably greater in the Damon Mound reef. Also, unlike the Salt Mountain coral fauna, the Damon Mound reef community does not include a significant number of azooxanthellate or apozooxanthellate species.

The co-occurence and co-dominance of hermatypic and non-hermatypic corals in the Salt Mountain are typical of many communities at the northern limit of zooxanthellate coral growth such as in the Pliocene of Florida (Allmon *et al.*, 1996) or in the modern Gulf of Mexico or Atlantic coast of Florida (Rezak *et al.*, 1985). Among Recent reef communities, those of the Flower Garden Banks, the northernmost reefs in the Gulf of Mexico (Rezak *et al.*, 1985), are probably most similar to the Salt Mountain fauna. Like the Salt Mountain fauna, the scleractinians of the Flower Garden Banks include relatively few species, less than a third of modern Caribbean reef coral diversity. Also, the community includes several probable apozooxanthellate species of *Madracis* (Rezak *et al.*, 1985). While coral abundance in the Salt Mountain Limestone is not as high as seen in the Flower Garden Banks, the two faunas are similar in that they are both dominated by massive to laminar corals rather than rapidly growing, robust branching zooxanthellate species that dominate most later Tertiary through Recent Caribbean reefs.

V. CONCLUSIONS

The Salt Mountain coral fauna is a mixture of true reefal and non-reefal elements. It probably represents a community near the northern limit of zooxanthellate coral growth. As such, the low diversity of corals may be chiefly attributable to environmental conditions present at these high latitudes rather than the result of a delayed recovery from the K-T extinctions on tropical reefs.

Although more than 50% of the genera represented in the Salt Mountain can be traced back into the Cretaceous, the fauna does exhibit some distinctly Cenozoic aspects. For the most part, the genera that cross the K-T boundary and are pre-

TABLE 3. Vaughan's (1900) colonial scleractinians of the Midway Group, Lower Paleocene, Alabama. All are species named by Vaughan (1900). None of these species are yet known from the Salt Mountain, although congeners of all species are known from younger deposits. Only *Mesomorpha* is unknown in younger Caribbean reef coral assemblages. Zooxanthellate and azooxanthellate determinations are determined as in Table 1.

Coral	**Species Azooxanthellate**
Siderastrea hexagonalis	Z
S. (Stephanomorpha) monticuliformis	Z
Mesomorpha duncani	?Z
Oculina ?smithi	A/Z
Astrangia wilcoxensis	A/Z
Dichocoenia alabamensis	Z
Haimesiastrea conferta	A/Z

sent in the Salt Mountain Limestone (*e.g.*, *Madracis, Trochoseris*) are not significant players on Cretaceous reefs (Wells, 1956). The most dominant, massive corals in the late Paleocene of Alabama, *Stylophora, Actinacis*, and *Cyathoseris*, remain important on Eocene and Oligocene reefs worldwide (Budd *et al.*, 1992; Bosselini and Russo, 1995). Thus, the Salt Mountain fauna shows that many important Tertiary reef coral clades were already significant parts of coral communities by the late Paleocene.

Two significant absences from the Salt Mountain are corals from the families Acroporidae and Faviidae, the two most dominant scleractinian families on modern reefs (Veron, 1995; Wells, 1956). There is no clear explanation for the absence of faviids, such as the genus *Montastraea*, since these corals are generally found wherever zooxanthellate corals occur. The absence of acroporids is more understandable because their importance on the early Tertiary was not nearly so great as in the Neogene through Recent (Wells, 1956) and in the Caribbean-Western Atlantic region they apparently have always been restricted to low latitude reefs (*e.g.*, Frost and Schafersman, 1978; Logan, 1988; Rezak *et al.*, 1985).

Finally, it should be stated that at a paleolatitude of 30-31º N, the Salt Mountain fauna is a "high latitude" community only in relation to the Gulf of Mexico and Caribbean region. There is probably more luxuriant reef coral growth today on the Bermuda Platform at >32° N than anywhere in the northern Gulf of Mexico since at least the Cretaceous (Logan, 1988). Similarly, modern Japanese coral faunas at >30°N are orders of magnitude more species rich than any northern Gulf communities (Veron, 1992). In the European Tethys region, significant coral reef growth occurred at >40°N until the Late Miocene (Wells, 1956). Thus on a global scale, reef coral growth in the Gulf of Mexico-Western Atlantic region is unusually restricted. The existence of a low diversity, marginal reef fauna in the Salt Mountain Limestone suggests that this restriction of reef growth in the Gulf of Mexico and the environmental conditions contributing to it have been in place for at least 55 million years.

PART V

SALT MOUNTAIN PATCH REEF SURVEY

DEBRA K. KRUMM

I. INTRODUCTION

A survey of a coral-algal-sponge patch reef from Bryan's (1991) Biofacies 3 was conducted using a three-square-meter by two-square-meter grid system. The objective was to map a portion of the Paleocene reef to determine whether the exposure was a true framework or a non-structured buildup and to identify the corals and associated bioeroding bivalves. Paleocene frameworks are rare, particularly those containing hermatypic corals (Fagerstrom, 1987; Bryan, 1991). The relationship between borers and host corals dates back to the appearance of scleractinian corals in the Triassic (Kleemann, 1990). Endolithic bivalves tend to emerge relatively unscathed from mass extinction events, while their hosts can suffer significant losses (Kauffman, 1988; Kleemann, 1990). The presence in the Salt Mountain Limestone of Paleocene coral patch reefs offers the opportunity to look at scleractinian and endolithic bivalve diversity at a point during the recovery stage following the end-Cretaceous worldwide mass extinction event.

II. METHODS OF STUDY

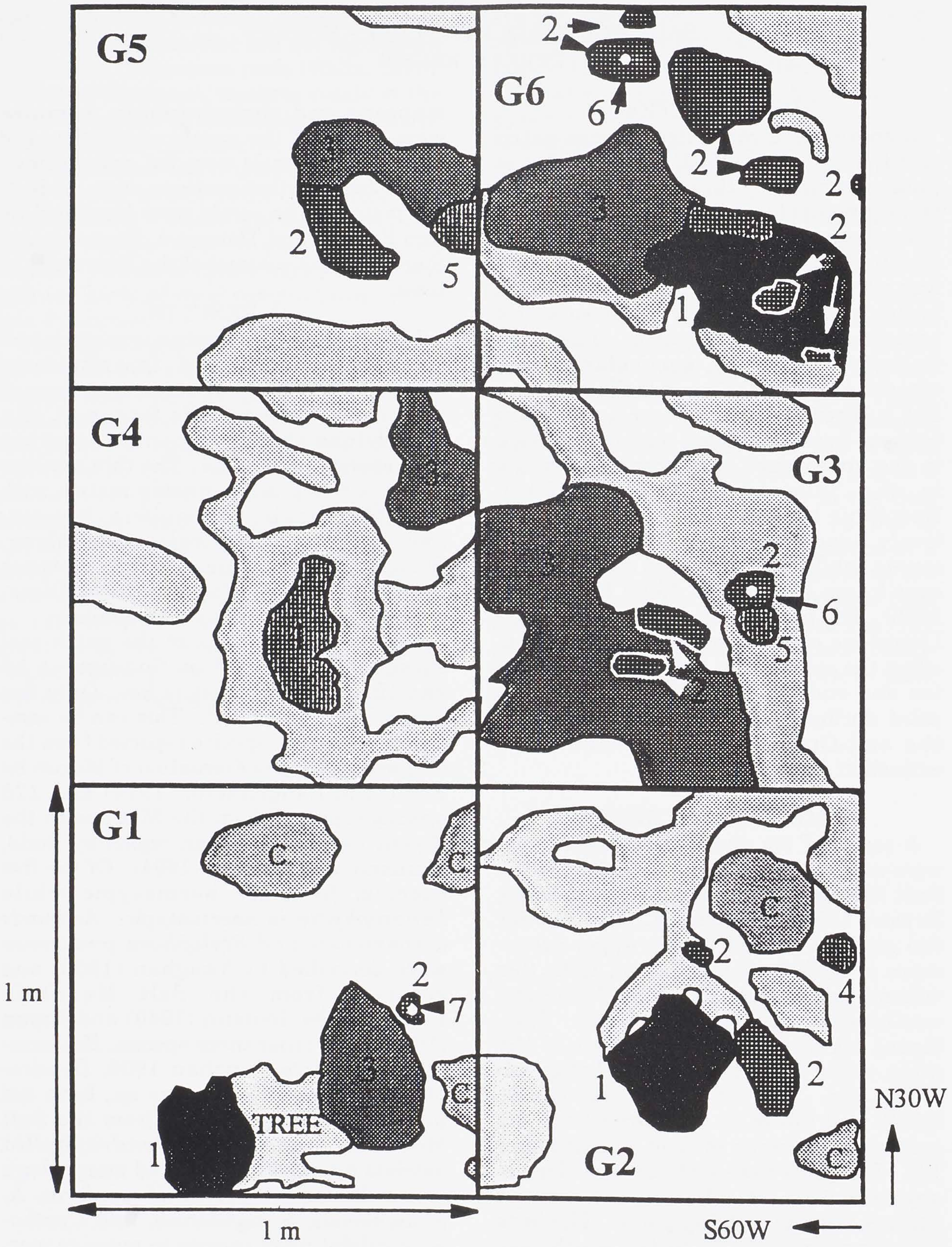
A series of six one-meter-square grids were mapped on an exposed portion of the Salt Mountain Limestone containing Bryan's (1991) Biofacies 3. The site for the grids is located in the upper occurrence of Biofacies 3 (see Bryan, 1991, this volume, and Fluegeman, this volume) and was based on amount of exposure. Text-figure 1A illustrates the layout of the grids, while Text-figure 2 is a photograph of the site. The set of six grids trends N30W and S60W as measured from the southeastern corner of Grid 2 (Text-figure 1A). The grids were laid out on a slope of approximately 20° following the exposed surface, not the bedding plane. The beds dip approximately 7° to the south (see Bryan, 1991, p. 428). The corals exposed on the hillside within the grids were mapped to scale. The locations of mollusks were noted on the maps. No other macrofossils were observed. Microfossils were not examined in this study. After mapping and photographing, samples were taken of the corals, mollusks, and matrix. The corals were cut and polished in the lab and thin sections were made of the matrix. The corals were identified by Ann F. Budd and Thomas A. Stemann (see Stemann, this volume) of the University of Iowa.

III. RESULTS

Lithologies. The matrix is micritic and contains bioclasts of foraminifera, sponges, and algae. It surrounds some of the corals. Other corals form part of a boundstone that is cemented together with sponges and algae. The thin sections reveal a fine-grained muddy matrix with branching corals, foraminifera, bryozoa, and with very little calcareous algae. Fluegeman (this volume) places Biofacies 3 into the benthic foraminiferal *Discocyclina-Pseudophragmina* assemblage.

Corals. The results of the patch reef survey are presented in Text-figures 1A and 1B. Coral diversity is low. Only five species were identified. This can be compared to 65 coral species reported from the Oligocene Chiapas Formation of Mexico by Frost and Langenheim (1974) and 175 species reported from the Miocene to the Recent for the Caribbean region by Budd, Stemann, and Johnson (1994). Of the five species, four are hermatypic while *Dendrophyllia* is ahermatypic. *Actinacis alabamensis* and *Stylophora ponderosa* were described by Vaughan (1900) and reported from the Salt Mountain Limestone by Toulmin (1940) and Bryan (1991). The other three species, *Haimesastraea conferta* Vaughan 1900, *Dendrophyllia* sp., and *Cyathoseris* sp., have not previously been reported from the Salt Mountain Limestone. *Dendrophyllia* exhibits a branching dendroid morphology, while the other species, *H. conferta, A. alabamensis, S. ponderosa,* and *Cyathoseris* exhibit more ramose to massive morphologies.

Endolithic Bivalves. Bryan (1991) reports specimens of the chemically-boring bivalve genus *Lithophaga* boring into a laminated algal boundstone from Biofacies 1. The specimens are confidently assigned



Text-figure 1A. Field map of an exposed section of a Salt Mountain Limestone patch reef from Bryan's (1991) Biofacies 3. Grid maps how the relationships of the corals, associated molluscs, and matrix (G=GRID). Each grid map is a square meter. Text-figure 1B contains the keys to numbers, letters, and symbols.

FAUNAL LIST FOR SALT MOUNTAIN GRIDS 1-6

NUMERICAL KEY:

Scleractinia:

1. *Actinacis alabamensis* Vaughan, 1900
2. *Dendrophyllia* sp.
3. *Stylophora ponderosa* Vaughan, 1900
4. *Haimesastraea conferta* Vaughan, 1900
5. *Cyathoseris* sp.

Mollusca:

6. Gastropod
7. *Lithophaga* aff. *nigra*

SYMBOL KEY:

▩ - *Actinacis alabamensis*

▦ - *Dendrophyllia* sp.

▒ - *Stylophora ponderosa*

▥ - *Haimesastraea conferta*

▥ - *Cyathoseris* sp.

C - Unidentified coral

░ - Matrix

□ - Cover

Text-figure 1B. Faunal list for Grids 1-6 of the Salt Mountain patch reef represented in Text-figure 1A. Keys to numbers, symbols, and letters from the grid maps.

to the genus based on shell morphology. Also, the borehole cuts across the layers of algae rather than conforming to them or causing the layers to grow around the bivalve as would be the case for a nestler or a burrower. The borehole was not lined. Bryan (1991) also illustrates a boring from Biofacies 2 that bears a strong resemblance to *Gastrochaena (Rocellaria) ovata* Sowerby, 1834. The outline of the shell is consistent with gastrochaenids, as is the thick lining around the siphons and thinner lining around the bivalve (Carter, 1978). The specimen is very small, however, so identification to species level is tentative.

Only one specimen of *Lithophaga* was found in the grids mapped for this project. It was associated with *Dendrophyllia* sp. in Grid 1 (see Text-figure 1A), although Bryan (1991) mentions other bivalve borers from Biofacies 3. Because of the

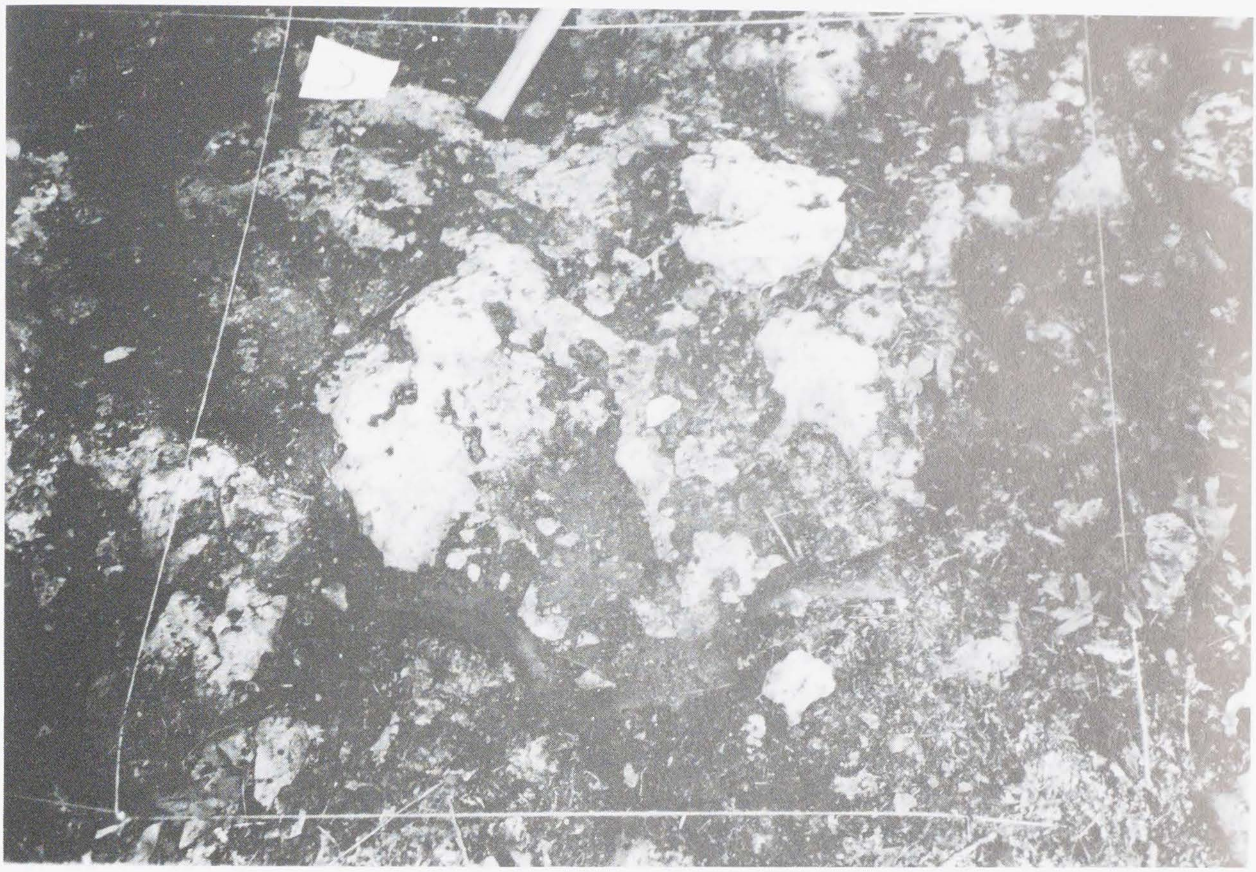
Text-figure 2A. Field position of Grids 1-6 laid out on exposed patch reef (Text-figure 1A). Grid 1 is in the lower right corner. Grids 5 and 6 are in the upper left corner of the photo. Each grid is a square meter in size. The hammer between Grids 2 and 3 is for scale.

nature of the preservation, it was not possible to determine whether the bivalve was boring into branches of *Dendrophyllia* or into associated encrusting or laminated substrata or both. The shell morphology clearly resembles *Lithophaga*. No borehole linings were visible. The specimen bears a strong resemblance to Bryan's (1991) specimen from Biofacies 3. The outlines of the shells and the lack of linings place the specimens in the subgenus *Lithophaga* with similarities to *L. (L.) nigra*, but are small for the species (Abbott, 1974; Dudley, 1986).

IV. SUMMARY AND CONCLUSIONS

The coral-algal-sponge boundstone of Bryan's (1991) Biofacies 3 represents a series of patch reefs in the sense of Fagerstrom (1987). The frameworks are cemented together to form independent topographically raised structures. However, the high diversity normally associated with scleractinian reefs is absent.

Several factors may have affected coral diversity. Bryan (1991) points out that the Salt Mountain reefs may have been growing at the northern limits of the coral species' temperature ranges. Another major factor may have been the slow recovery rate of coral species after the mass extinction of the end of the Cretaceous. Water depth was apparently not a factor. Fluegeman (this volume) places the water depth over the patch reefs at less than five meters based on the presence of the *Discocyclina-Pseudophragmina* assemblage. He describes Biofacies 3 as representing the stabilization of reef



Text-figure 2B. Close-up of Grid 2 illustrating exposures of coral and matrix, along with portions covered by vegetation.

development in the Salt Mountain Limestone. Although few endolithic bivalves were found, those present in the patch reef exhibit typical morphologies and modes of life similar to modern western Atlantic species. The Salt Mountain represents an initial, post-Cretaceous reestablishment of scleractinian corals (with their endolithic bioeroders) as reef framework constructors.

PART VI
ECHINOIDS

BURCHARD D. CARTER

I . CHARACTERISTICS OF THE SALT MOUNTAIN ECHINOID FAUNA

Echinoids, it seems, were volumetrically a major part of the living fauna of at least some facies of the Salt Mountain Limestone. Smith and Johnson (1887, p. 20) commented on the "...great numbers of the spines and plates of echinoderms..." in the lower beds of the sole outcrop, and again (p. 21) that ..."the only recognizable fossils are the spines and plates of echinoderms and great masses of corals". Langdon (1891, p. 599) spoke of the "...characters of the Salt Mountain Limestone - i.e. corals and spines of echinoids...". Vaughan (1900, p. 31) also mentioned echinoid spines as an obvious component in the lower 6 meters (20 feet) of his measured section. Bryan (1991, p. 428-430) indicated the presence, and even prevalence, of echinoderm fragments in three of his four biofacies.

This obvious numerical abundance, however, belies a remarkably low apparent diversity. Toulmin (1940, p. 109) reported five recognizable echinoderm taxa from the Salt Mountain. Of these, one is a crinoid (*Rhizocrinus cylindricus*? Weller) and one is a seastar (*?Goniaster mammilata* Gabb). The other three are regular echinoids, which he assigned to *Dorocidaris, Salenia,* and *Loriolia*. Toulmin also recorded additional fragmentary material, including "...three or four kinds of spines..." suggesting that additional, unrecognizable echinoid taxa might have been present.

Cooke (1959) also records low echinoid diversity from the Salt Mountain Limestone, reporting only two or three genera of regular echinoids. Two of these, certainly from the Salt Mountain, are cidaroids, assigned by Cooke to *Cidaris* sp. aff. *splendens* (Morton, 1841), and *Tylocidaris salina* Cooke, 1959. The third, also a regular echinoid, is *Gagaria salis* (Cooke, 1941). This latter is based upon a single "badly corroded" specimen from the locality of Salt Mountain, but uncertain stratigraphic position. It may have come from the Oligocene Marianna Limestone.

Table I records the known echinoid species from the Salt Mountain Limestone. It is constructed so as to be as inclusive of reported occurrences as possible, though critical of prior taxonomic assignment. The systematic paleontology upon which the table is based is presented in a separate section of the paper.

The age of the Salt Mountain Limestone falls within the earlier part of the Late Paleocene (Bryan, this volume). Correlative units in the Gulf Coastal Plain have no reported echinoid fauna, though I have collected *Linthia* sp. cf. *alabamensis* from the base of the Nanafalia Formation in southeastern Alabama. However, the Vincentown Sand of New Jersey, which is probably partially correlative with the Salt Mountain, has a rich echinoid fauna. Cooke (1959) reports 10 species from the Vincentown, including the following relevant species: *Cidaris splendens, Tylocidaris walcotti, Salenia tumidula,* and *Echinopsis diatreta*. Each of these has, or may have, a congeneric counterpart in the Salt Mountain.

II. ECOLOGICAL IMPLICATIONS OF THE FAUNA

The most striking aspect of the known echinoid fauna of the Salt Mountain Limestone is the lack of irregular echinoids. Even among the reported debris – pedicillariae, spines, test fragments, and lantern fragments according to Toulmin (1940, p. 109) – the probability is that it derives from regular echinoids. First, fragments of irregular tests would be immediately recognizable. Second, irregular echinoids typically do not have large, robust spines which would be an obvious component of rocks. Third, excepting the Orders Clypeasteroida (whose only Paleocene representative is a rare African species) and the Oligopygoida (whose record begins in the Eocene) most irregular echinoids lack lanterns in the adult stage. Only the relatively uncommon Holectypoida might be expected to have contributed irregular lanterns to a Paleocene deposit in North America. (However, it should be noted that holectypoids, for example *Echinoneus*, do inhabit Recent reef environments.) Finally, any environment with little enough water agi-

TABLE I. Echinoid species known from the Salt Mountain Limestone.

Taxon recognized herein	Previously named	Source
"*Cidaris*" sp.	*Dorocidaris; Cidaris* sp. cf. *splendens*	Toulmin, 1940; Cooke, 1959
cidaroid indet.	*Tylocidaris salina*	Cooke, 1959
Stereocidaris? sp.	none	J. Bryan, pers. comm.
Salenia? sp.	*Salenia*	Toulmin, 1940
Gagaria? salis	*Gagaria salis*	Cooke, 1959
Echinopsis? sp.	*Loriolia*	Toulmin, 1940

tation to preserve complete tests, or even fairly complete, recognizable regular echinoid fragments, should also allow preservation of irregular species, were they present (Kier, 1977a).

The most obvious explanation for the lack of irregular echinoids in the Salt Mountain Limestone is that the mixed cobbly/muddy substratum provided an unburrowable habitat for a mobile deposit feeder. Echinoid species which burrow in muddy bottoms often have test structures that are highly adapted to maintaining a steady supply of fresh seawater through a dorsal tunnel, and funnelling waste water into a posterior one. Echinoids that inhabit coarser bottoms are not faced with similar hydrologic problems and lack these highly specialized adaptations (Smith, 1984; Carter *et al.*, 1989). Thus, though one irregular echinoid species might be able to burrow into muddy sediment, or another into gravel, the mixture of the two textures might exclude either species.

Alternately, the ability to burrow into gravel-rich sediments simply might not have existed in the Paleocene, either because taxa so adapted had not yet evolved, or because the niche had not yet been refilled after the Late Cretaceous extinction. As discussed below, far too little is known about the echinoid faunas of Mesozoic reefs (and early Cenozoic ones as well, for that matter) to decide if this is a problem of "recovery" or of the appropriate traits not having evolved at all by the early Cenozoic.

Modern reefs do have a small complement of burrowing irregular echinoid species. Kier and Grant (1965) report a fauna from rock bottoms on and near Recent reefs in the Florida Keys including the regular echinoids *Eucidaris tribuloides, Diadema antillarum, Arbacia punctulata, Echinometra lucunter, Echinometra viridis*, and the irregular echinoids *Echinoneus cyclostomus* and *Brissus unicolor*. I have seen or collected several of the same species, including both the irregulars, from the shore adjacent to a rocky bottom with scattered patch reefs off the coast of Kingston, Jamaica. Prager and Ginsburg (1989) demonstrated that the spatangoid *Meoma ventricosa* burrows among large rhodoliths on the fore-reef slope of southern Florida.

Dollfus and Roman (1981) give the life habits of numerous species of Red Sea echinoids. The following summary of that work is augmented by Nebelsick (1992). Reef and rock dwelling regular echinoids include *Eucidaris metularia, Phyllacanthus imperialis, Diadema setosum, Temnopleurus toreumaticus, Microcyphus rousseaui, Nudechinus scotiopremnus, Tripneustes gratilla, Parasalenia poehli, Echinostrephus molaris, Echinometra mathaei, Heterocentrotus mamillatus, H. trigonaris, Echinothrix calamaris* and the echinothuriid *Asthenosoma varium*. These 14 species explicitly cited as reef-dwellers by Dollfus and Roman represent approximately 54% of the regular echinoids (total of 26 species) they recorded. The authors did not provide any ecological information for several of the remaining species, so the proportion may be higher or lower than 54%. Reef-dwelling irregular echinoids in the region include only two species of a total of 28 (7%). *Clypeaster reticulatus* apparently lives epifaunally and *Brissus latecarinatus* infaunally. Seven additional irregular species were not attributed to any environment, but all can be inferred not to have inhabited gravel bottoms based on their test forms.

The association of irregular echinoids, often species of the Recent reef-dwelling genera, with reef and reef-like deposits are known back through the Neogene and into the Oligocene. The algal buildups of the Lower Oligocene Bridgeboro and Florala Limestones of the eastern Gulf Coast (Manker and Carter, 1987; Bryan, 1993) have a fauna including not only cidaroids and other regular echinoids, but also irregular echinoids of the genera *Clypeaster* (probably epifaunal), *Brissus* (probably infaunal), *Macropneustes* (an infaunal species similar in morphology to Recent *Meoma ventricosa*), and possibly *Plagiobrissus*(?). Donovan and Veale (1996) document the persistence of the *Echinoneus* - *Brissus* association with reef-related facies in the Caribbean from the Late Oligocene to the present. I am not familiar with any studies of Eocene framework reefs in the Western Hemisphere that include information on the echinoid faunas, but a small Upper Eocene probable patch reef at Gebel Mokattam, near Cairo, Egypt, interestingly has eight or nine echinoid species in its calcarenitic flanking beds, of which seven (including species of *Sismondia, Fibularia, Agassizia, Schizaster, Eupatagus,* and *Echinolampas*) are irregulars (Roman and Strougo, 1988; Carter and Hamza, 1994). The genus *Brissus*, including species very similar in form to, if not identical with, *B. unicolor*, is known from the Eocene of the Caribbean (Kier, 1984; Donovan and Veale, 1996). *Echinoneus* apparently ranges back only to the Oligocene. Thus, if the Salt Mountain Limestone is typical of Paleocene reefs, their echinoid faunas were completely dominated by regular echinoids, and irregular echinoids may have begun moving into reef habitats, or back into reef habitats, only in the Eocene, being certainly well established there by the Oligocene.

Pre-Paleocene reef echinoids are even less well documented. Prior to the mid-Jurassic there were no irregular echinoids at all, but all the orders of irregulars had appeared by the end of the Jurassic, excepting the Clypeasteroida (Kier, 1977b; Smith, 1989). The Late Jurassic (Oxfordian) of Europe includes extensive reef deposits. The reefal facies were all originally included in the Rauracian local stage (Wilson, 1975). In their tabulation of echinoid species described through 1924, Lambert and Thiery (1909-1925) list about 130 nominal species of echinoids specifically from the Rauracian. Of these, about 29 (22%) are irregulars: all holectypoids and cassiduloids. (At the generic level the percentage of irregulars is 34%, a fact to keep in mind in light of Mr. Lambert's tendency to create and accept thoroughly oversplit taxa). Interestingly, the list includes the earliest members of the Suborder Echinoneina, whose Recent relatives are common reef-dwelling irregulars.

Of course, not all Rauracian rocks were reef framework facies, and so it is not possible to know how many of these irregular echinoids lived on a reef proper. Smith (1984) records 19 echinoid species from various subfacies of "rubbly algal gravels" and "patchy development of corals, interpreted as a lagoonal patch reef ..." in the English Jurassic. Of these, only two (~10%) are irregular echinoids; both are cassiduloids. One of these is very rare, and is known only from fragments in an oosparite associated with the reef. The other is fairly common, even as whole tests, in this same facies and in another oolitic sand, but is also known from a relatively small number of whole tests and fragments in the reefal facies, particularly the algal rubble. Whether the species actually inhabited the reef rubble or not is debatable, but its more common occurrence in the oolitic flanking beds argues against it.

Cretaceous reefs are widely distributed in North America, particularly in the subsurface (*e.g.*, the Stuart City trend of the Edwards Limestone of Texas, and the equivalent "Golden Lane" Mexican Cretaceous reefs). Surface exposures of Cretaceous reefs do exist, for example the Edwards includes patch reefs in surface exposure, but I have not located any specific studies which allow relating echinoid species to any particular lithofacies. Cooke (1946; 1955) lists a number of species from the Edwards Limestone and equivalents (the Fredricksburg Group) of the southern mid-continent region. He identifies only one species (the saleniid regular *Goniopygus zitteli*) from the Edwards itself, but lists an additional four species from unspecified Fredricksburg Group strata. Of these, three are regulars and the fourth (the spatangoid *Heteraster texanus*) is irregular. Test morphology of the latter, and its common occurrence in the fine grained facies of the Goodland Limestone, suggests a preference for burrowing into consistently fine substrata, so it probably does not occur in the reef facies of the Edwards. Obviously, the Edwards has an overall depauperate echinoid fauna in outcrop, and no data are available to tell how many of the few echinoid species occur in the reefal sediments. In whichever facies they do occur, it is obvious that the fauna is dominated by regular echinoids. It remains a source of frustration that characterization of reefal echinoid faunas is so difficult in one of the most reef-rich time intervals, particularly the one immediately preceding a major mass extinction.

III. SYSTEMATIC PALEONTOLOGY

Class ECHINOIDEA Leske, 1778
Subclass PERISCHOECHINOIDEA M'Coy, 1849
Order CIDAROIDA Claus, 1880
?Family CIDARIDAE Gray, 1825
?Subfamily CIDARINAE Gray, 1825
?Genus CIDARIS Leske, 1778

"Cidaris" sp.

Plate 1, figures 1a,b,c,2

Dorocidaris TOULMIN, 1940, p. 109.
Cidaris splendens (Morton) (part). COOKE, 1941, p. 5, pl. 1, fig. 12.
Cidaris sp. aff. *C. splendens* (Morton). COOKE, 1959, p. 10, pl. 1, fig. 11.

MATERIAL: Three test fragments from Toulmin's collections in the FMNH (UF 69500); unspecified number of fragments, including a figured specimen, from Cooke, 1959 (USNM 498879a); one complete test (the first known complete test of the species) collected by Stephanie Schroeder, now in the FMNH (UF 77000), one complete test, collected by Jonathan Bryan and probably of this species, at the Geological Survey of Alabama. I have not seen this last specimen.

REMARKS: Toulmin (1940) listed three generic names of echinoids from the Salt Mountain. In the material from his collections at the FMNH are three lots of specimens each labelled with one of these names, and it is likely that these are the basis for his generic list. One of the lots (UF 69500) is labelled "*Dorocidaris* sp. cf. *D. splendens*. Cidaroid genera are, unfortunately, based upon characteristics that are very unlikely to be preserved in fossil material, and *Dorocidaris* is now considered a synonym of *Cidaris*, a genus for which "...no valid fossil species has yet been described..." (Fell, 1966). Thus, Toulmin's assignment cannot be retained. I have not seen Cooke's material in the USNM, but his figured specimen is decidedly similar to Toulmin's material.

DESCRIPTION: There are three test fragments in Toulmin's lot (UF 69500), each very small, and each containing both partial ambulacra and interambulacra. The largest fragment (figured in Plate 1, figure 2) measures 2.9 mm wide, and includes a full interambulacrum and both adjacent half interambulacra. It is also only 2.7 mm high and reaches nearly, if not completely, from the peristome to the periproct. Thus, it is from an exceptionally small individual, roughly 5 mm total diameter as a gross estimate. The other two fragments are less complete, and probably come from slightly larger individuals, but still on the order of 10 mm total diameter or less. The ambulacra include nonconjugate (separated, in fact, by a distinct ridge) pore pairs, distinctly inclined to the axis of the ambulacral column. Each interambulacral plate bears a single, proportionally large, perforate, noncrenulate tubercle, surrounded by a single circle of coarse scrobicular tubercles. On the smaller two individuals, this scrobicular ring is in immediate contact with that of the adjacent plate, but on the largest, the plate corners bear additional coarse tubercles beyond the scrobicular ring. These are almost, but not quite, as large as the scrobicular tubercles. Toulmin's specific assignment is consistent with one made (apparently) independently by Cooke for different material (see below). Based upon the material available to Toulmin it is only possible to conclude that they come from a cidaroid, and probably a cidarid, echinoid. Standard practice is now to label such taxa "*Cidaris*" sp. As discussed below, the assignment of this species to "*Cidaris*" *splendens* is probably incorrect, so it is herein treated as "*Cidaris*" sp.

Cooke (1941, 1959) records a cidaroid from the Salt Mountain that he states is similar to *Cidaris splendens* of the Vincentown Sand of New Jersey, only smaller. His single fragment is about 15 mm wide by 15 mm high, and includes much of an entire interambulacral column with both adjacent half-ambulacra. It is decidedly similar to the fragments in Toulmin's collection, and I do not doubt they are conspecific. The only difference is that there are more granular secondaries in the material figured by Cooke, but this is probably because it comes from a larger specimen, with more area on the extrascrobicular part of the plate. The structure of Cooke's fragment is, as was Toulmin's, consistent with a member of the Cidaridae, but since genera are virtually impossible to distinguish without pedicellariae, current practice would be to call the species "*Cidaris*" sp. cf. *splendens*. Incidentally, Cooke suggests that because this specimen is so much smaller than those from the Vincentown Sand, it probably represents a distinct, unnamed species. Size notwithstanding, the tuberculation of the two is distinct enough that he is probably right about this, so his material is herein distinguished from *C. splendens* (Morton), and joins Toulmin's specimens in "*Cidaris*" sp. in this report.

The specimen found by Stephanie Schroeder (figured in Plate 1, figures 1a,b,c) and the one found by Bryan are essentially identical to the material of Toulmin and Cooke. These are the only complete tests of the species known.

?Subfamily STEREOCIDARINAE
Lambert, 1900
?Genus STEREOCIDARIS Pomel, 1883

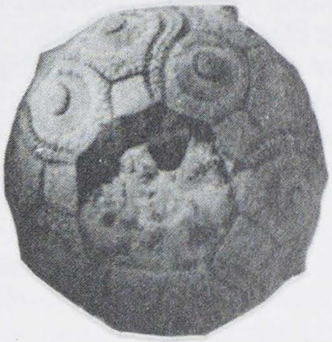
STEREOCIDARIS? sp.
Plate 1, figure 3

MATERIAL: Three matrix encrusted fragments which each include part of a single interambulacrum and one adjacent half ambulacrum, found loose on the Salt Mountain Limestone outcrop by Bryan. Two of the three specimens (UF 76998) are very poorly preserved, and include fewer plates, but are clearly identical with the third (UF 76999), upon which the following description is based.

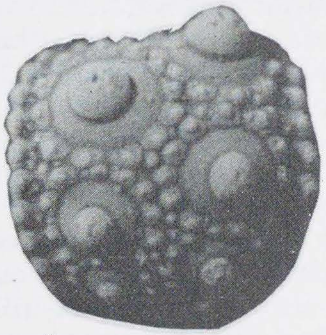
PLATE 1

Figures
1a-1c. "*Cidaris*" sp. UF 77000.
  1a. Lateral view, x2.
  1b. Apical view, x1.5. Standard orientation is not certain, but the specimen may be oriented with ambulacrum I toward top of page.
  1c. Oral view, x1.5. If ambulacra are properly identified, specimen is in standard orientation.
2. "*Cidaris*" sp. UF 69500. Interambulacral fragment with adjacent half-ambulacra, x12.
3. *Stereocidaris?* sp. UF 76999. Interambulacral fragment with one attached half-ambulacrum, x1.
4. *Salenia?* sp. UF 69498.
  4a-c. Isolated ambulacral fragments, x10.
5. *Echinopsis?* sp. UF 69499.
  5a-b. Isolated ambulacral fragments, x10.
  5c. Isolated interambulacral fragment, x10.
  5d. Enlargement of 5b, x20.
(All specimens are darkened with red dye and lightly coated with ammonium chloride.)


1a


1b


1c


2


3

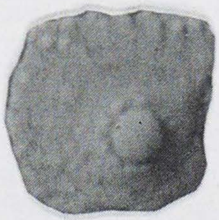

4a


5d


5a


4b


5b


4c


5c

PLATE 1

DESCRIPTION: The exposed portion of the best test measures about 30 mm in height and width. There is some etching and/or abrasion of the surface, but surface detail is visible in some places. The primary interambulacral tubercles are perforate and subcrenulate, and the scrobicular tubercles surrounding the depressed scrobicle are small and sparse. In the extrascobicular areas, the secondary tubercles are aligned in distinct rows, on pronounced ridges, radiating away from the primary. The most apical preserved primary tubercles are still at least a plate distance away from the apical system. They are somewhat reduced, but none is entirely atrophied. The ambulacral pores lie in a distinct, slightly sinuous groove, and are nonconjugate. Though an exact generic, or even subfamilial, assignment is not possible, the subcrenulate tubercles and nonconjugate pores suggest the Family Cidaridae, and either the stereocidarine or cidarine subfamily. The somewhat sinuous ambulacra tend to favor the former, so I herein refer to this species as *Stereocidaris?* sp., even though it is not certain that any of the adapical primary tubercles are atrophied.

Family and Subfamily INCERTAE SEDIS

INDETERMINATE CIDAROID

Cidaris splendens (Morton) (part). COOKE, 1941, p. 5, pl. 1, figs. 13-15.
Tylocidaris? salina COOKE, 1959, p. 12, pl. 1, figs. 12-14.

MATERIAL: Three detached spines, figured in Cooke, 1959 (USNM 498879b).

DESCRIPTION: Cooke (1959) based *Tylocidaris salina* upon slightly fusiform spines and no test material. The generic assignment was probably predicated upon the fusiform shape of the spines, Cooke is not explicit on this point. However, though spine morphology can be characteristic of *Tylocidaris*, the diagnostic spines are typically much more clavate than fusiform in the genus. (Compare the *T. macneili* spine in Cooke's plate 1, fig. 4, with his figures of *T. salina*). Small, slightly fusiform spines such as the latter are not diagnostic, and the generic assignment, though reasonable, is far from certain. I refer to these spines as "indeterminate cidaroid" herein.

Subclass EUECHINOIDEA Bronn, 1860
Superorder ECHINACEA Claus, 1876
Order SALENOIDA Delage and Hérouard, 1903
Family SALENIIDAE L. Agassiz, 1838
Subfamily INCERTAE SEDIS

SALENIA? sp.

Plate 1, figures 4a,b,c

Salenia TOULMIN, 1940, p. 109.

MATERIAL: Toulmin's material identified as *Salenia* sp. (UF 69498), comprises three very small test fragments, each of which is a single interambulacral plate.

REMARKS: Because no ambulacral, apical, or peristomal characters are known, generic assignment must be uncertain. The tubercle morphology is certainly consistent with the genus *Salenia*, and the genus is a fairly common, easily recognized, often reef-dwelling regular echinoid. Toulmin's generic identification is quite likely correct, but in order to emphasize the uncertainty, I herein refer to his species as *Salenia?* sp.

DESCRIPTION: Interambulacral plates small, the largest measuring about 1.9 mm in height and 2.2 mm in width. The tubercles are very large, prominent, imperforate and crenulate. Their diameter is impossible to relate to the total plate size, because they blend smoothly into the scrobicle, which is not at all depressed. The tubercle and scrobicle together, however, take up nearly 70% of the plate height. There are two or three rows of secondary tubercles restricted to one edge of the plate, probably the adoral, flexing slightly onto the interradial suture.

Order TEMNOPLEUROIDA Mortensen, 1942
Family GLYPHOCYPHIDAE Duncan, 1889

ECHINOPSIS? sp.

Plate 1, figures 5a,b,c,d

Loriolia TOULMIN, 1940, p. 109.

MATERIAL: Toumin's lot at the FMNH (UF69499) includes three test fragments, two of which are single ambulacral plates and the third a single interambulacral plate.

REMARKS: The genus *Loriolia* is restricted to the Lower Cretaceous, and belongs to an order (Hemicidaroida) restricted to the Mesozoic, so Toulmin's generic assignment of this specimen is highly unlikely.

DESCRIPTION: The ambulacral plates (figured in Plate 1, figures 5a,b,d) are trigeminate, apparently with simple diadematoid compounding. The pores are quite large, and the pores within one pair are separated by a high ridge. The large, prominent tubercles are crenulate and perforate. On one of the plates, the primary tubercle is flanked by a pair of smaller secondaries (Plate 1, figures 5a,d). The one on the adapical side of the plate is nearer the perradial suture than the one on the abapical. On the other ambulacral fragment (Plate 1, figure 5b) the secondaries are apparently not preserved, but a distinct bump on the corner at the perradial suture and the abapical edge, if it is the remains of a tubercle, indicates that the position of the secondaries is not consistent from plate to plate. No scrobicular tubercles are preserved on either fragment. The interambulacral plate (Plate 1, figure 5c) is distinctly wider than high, and has three large perforate, crenulate tubercles. One lies near the adradial suture, closer to the adapical(?) suture than the abapical, and is slightly larger than the other two. These lie at the opposite end of the plate, with the more adapical(?) of the two a little closer to the interradial suture than the other. They are approximately equal in size. Assignment of this material to a genus is essentially impossible. The ambulacral compounding and tubercle morphology place them in either the Order Hemicidaroida (where Toulmin put them) or the Family Glyphocyphidae of the Order Temnopleuroida. There are not any obvious sutural pits on the plate edges, as would be expected of most glyphocyphids, but the fragmentary nature of the specimen would make indistinct sutural sculpture easy to miss. It is interesting to note, in this light, that the glyphocyphid genus *Echinopsis*, which has virtually no test sculpturing, is reported from the age-equivalent Vincentown Sand by Cooke (1959), who assigns *Cidaris diatretum* Morton to the genus. This species is known only from the holotype, which unfortunately is lost. Comparison, then, must be with the drawings of Clark (1915). In these drawings the ambulacral structure of *E. diatreta* are very much like that of the Salt Mountain species, but the interambulacral structure is clearly different. This indicates that the two are not conspecific. The type species of *Echinopsis* (*E. elegans* Agassiz from the Eocene of France) has proportionally much smaller tubercles than either of these species, and assignment of the American material to that genus should be considered tentative. Thus, I herein treat Toulmin's species as *Echinopsis?* sp.

Family INCERTAE SEDIS

GAGARIA? SALIS (Cooke)

Thylechinus (Gagaria) salis COOKE, 1941, p. 13, pl 2, figs. 12-14.

Gagaria salis (Cooke). COOKE, 1959, p. 17, pl. 3, figs 7-9.

MATERIAL: Cooke's third Salt Mountain species, *Gagaria salis* (Cooke, 1941) is based upon a single "badly corroded" specimen (USNM 166497).

REMARKS: The holotype of the species comes from the locality of Salt Mountain, but uncertain stratigraphic position. Thus, the suspicion must be entertained that the specimen is actually from the Oligocene Marianna Limestone, which outcrops just to the north of the Salt Mountain Limestone. Cooke suggests that the tuberculation and peristome serve to distinguish this species from the common Oligocene *G. mossomi*, but the poor nature of the specimen does not rule out the possibility of the specimen belonging to the Oligocene species. Assuming that the specimen did actually come from the Salt Mountain, it is interesting that *Gagaria* is otherwise unknown from the Paleocene anywhere in the world, and unknown from any other pre-Oligocene rocks in North

America. This fact, along with the poor nature of the material, leads me to treat this specimen as *Gagaria? salis*. Until additional material is located, there is nothing to add to Cooke's description.

IV. ACKNOWLEDGMENTS

Toulmin's Salt Mountain echinoid material has recently been acquired by the Florida Museum of Natural History, and I have been able to re-examine it thanks to Roger Portell, who went above and beyond the call of duty to locate and catalogue it. Yonnie Williams read the manuscript and cleaned up my verbal messes.

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