Tethyan Albian Corals, Cerro de Cristo Rey Uplift, Chihuahua and New Mexico

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Abstract

Solitary and colonial corals range throughout much of the Comanchean Series (Albian-lower Cenomanian) at the classic outcrops on Cerro Cristo Rey that straddle the international border between Chihuahua, Mexico, and Doña Ana County, New Mexico, USA. The stratigraphic units are dominantly clay and quartzose sand interbedded with thin carbonate shell beds. These units were deposited on a shelf between a northern shore and the Chihuahua–Bisbee trough, a major northwest-southeast-trending rift basin on the south.

Nineteen species, four new, in fifteen genera, occur in formations ranging from the middle-upper Albian Finlay Formation at the base to the Lower Cenomanian Buda Limestone at the top. Many of these taxa are distributed widely throughout the Caribbean and Mediterranean provinces of the Tethyan realm. The occurrences at Cerro Cristo Rey extend the known ranges of nine species. Fifteen of the coral species are solitary conical morphotypes that lived on muddy substrates. Four species of colonial corals from the Smeltertown Formation may have been transported from patch reefs.

Introduction

Colonial and solitary corals are locally abundant in Lower Cretaceous and lower Cenomanian carbonates of North America, but generally they are a minor part of the biota in dominantly terrigenous clastic strata. Wells (1932, 1933) published the first comprehensive taxonomic studies of corals from Texas outcrops. Subsequent studies have expanded the geographic and stratigraphic distributions of corals and discussed coral paleoecology (Scott, 1984; Scott and González-León, 1991; Baron-Szabo and González-León, 1999). Corals are common in the stratigraphic section at Cerro de Cristo Rey, New Mexico, and Chihuahua, Mexico. This section is representative of the middle Albian to lower Cenomanian part of the Gulf of Mexico mixed carbonate and clastic succession deposited in the Caribbean Province of the Tethyan realm.

Cerro de Cristo Rey (Cristo Rey) rises 300 m above floor of the Rio Grande valley in New Mexico and lies nine miles (14.4 km) north of the Sierra de Juarez and four miles (6.4 km) west-northwest of the southern terminus of the Franklin Mountains at El Paso, Texas (Fig. 1A). Cristo Rey is named for the 12.2 m Upper Cretaceous Austin Chalk sculpture of the crucifixion of Christ at the crest of the central peak. It has also been referred to as Cerro de la Cruz and formally was called Cerro de Muleros (Mount of the Mule Skinners). The annual pilgrimage to Cristo Rey occurs on the last Sunday in October. Penitents climb a trail from the base of the central peak to the cross at the peak.

The three kilometer circular structure at Cristo Rey is intruded by an andesitic pluton, the Muleros Andesite, which forms its central peak (Lovejoy, 1976). Contact metamorphism and the structural character of the surrounding sediments indicate that a relatively cool, viscous magma was forcibly intruded. This laccolith-like pluton straddles the New Mexico–Chihuahua international border approximately 1.3 miles (2 km) west of the location where Texas, New Mexico, and the Mexican state of Chihuahua meet. The surrounding eroded crests of the outwardly dipping ring of Cretaceous sediments and minor associated felsites form a nearly horizontal plane referred to by Lovejoy (1976) as the "Tableland." Cristo Rey, viewed from above, can best be described as an archery target with the bull's eye being Cristo Rey's central peak.

The age of the Cristo Rey plagioclase-hornblende andesite porphyry intrusion is middle Eocene based on K-Ar radiometric dating (47.1 ± 2.3 Ma) (Lovejoy, 1976). Petrographically related intrusions, normally occurring with related Cretaceous metasediments, are observed at the Campus, Three Sisters, and Vado hill outcrops (Fig. 1B) (LeMone and Simpson, 1983). Additionally, Cretaceous rocks crop out along the western margin of the Franklin Mountains in large part associated with the western boundary fault zone (LeMone and Simpson, 1983).

Petrographically similar intrusions are present to the south in the Sierra de Juarez. These intrusions are critical for establishing the age range of Laramide orogenic movements. In this region, the structural configurations north of Cristo Rey typically are related to Cenozoic basin–and–range style faulting. Conversely, structural styles to the south in the Chihuahua tectonic belt are normally interpreted as Laramide thrusting overprinted by later basin-and-range faulting.

The corals examined in this paper are solely from Cerro de Cristo Rey in Doña Ana County, New Mexico, in Cretaceous units cropping out in sections 8, 9, 15, 16, and 17, T29S. R4E (USGS 7.5 Minute Smeltertown Quadrangle). Corals from the outcrops north of Cristo Rey as well as those to the south in the Sierra de Juarez are not included here. The Cristo Rey stratigraphic succession is present in the autochthon and the overlying allochthonous thrust sheets in the Sierra Juarez (Nodeland, 1980b). Corals, if recoverable from the Sierra de Juarez autochthon, will probably be in a spatially consistent position to that of Cristo Rey. However, the palinspastic reconstruction of the original paleogeographic position of the overlying thrust sheets remains, at best, speculative.

The Cretaceous succession in the Sierra Juarez is thicker (1400 m) and more complete than that exposed at Cristo Rey. It ranges in age from Albian (Nodeland, 1977, 1980a, b; Lovejoy, 1980) to Turonian (Cobban, 1988a,b). The bulk of the Sierra de Juarez exposures consist primarily of the pre-Cristo Rey Cretaceous units in ascending order: Cuchillo, Benigno, Lagrima, and Finlay formations. Nodeland (1977, 1980a, b) documented the variations in thickness of these units between the three thrust sheets.

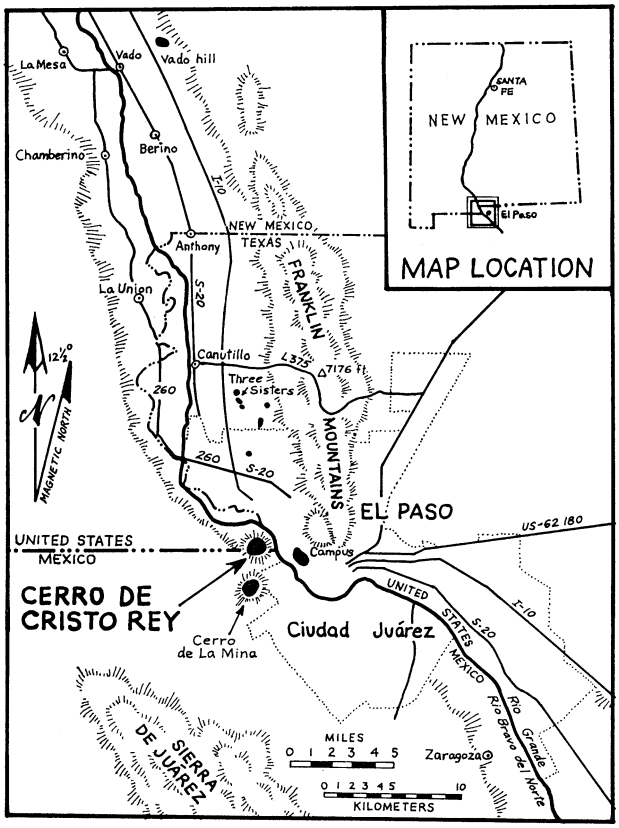

Figure 1A. Location map of Cerro de Cristo Rey, New Mexico and Chihuahua (from Norland, 1986, modified after Lovejoy, 1976). Cristo Rey Peak is located in CW1/2, W1/2, section 16, T. 29 S., R. 4 E., at about 31º26'45"N, 106º32'45").

Figure 1B. Satellite image of Cerro de Cristo Rey.

Stratigraphy of Cerro Cristo Rey

The stratigraphy at Cristo Rey was first defined by Böse (1910), who numbered the units. The modern lithostratigraphic classification at Cristo Rey was defined and correlated by Strain (1976) (Fig. 2).

The middle Albian-lower Cenomanian Cretaceous stratigraphic interval exposed at Cerro Cristo Rey ranges from the Finlay to the Boquillas formations. At Cerro Cristo Rey, the boundary between the Comanchean Series and the Gulfian Series, which have been defined in north-central Texas, is at the contact of the Buda Limestone and the Boquillas Formation. Formations from the Del Norte through the Buda are equivalent to the Washita Group. The boundary between the Fredericksburg and Washita groups is between the Finlay and the Del Norte formations. The boundary between the Trinity and Fredericksburg groups is approximately within the Lagrima Formation at Sierra de Juarez.

Correlation of the Lower/Upper Cretaceous boundary (Albian-Cenomanian) is uncertain; it has been placed above the Anapra Sandstone (LeMone and Kottlowski, 1996), below the Anapra (Strain, 1976), and, more probably, it occurs within the upper strata (two-three meters below the top) of the Anapra. The Aptian-Albian boundary is not exposed at Cristo Rey, but in the Sierra de Juarez it has been placed questionably somewhere near the basal portion of the Cuchillo Formation (*e.g.*, Nodeland, 1980b). If this correlation is accurate, this lithostratigraphic unit should be designated as the Las Vigas Formation. Pre-Cretaceous units are not recognized in the Sierra de Juarez.

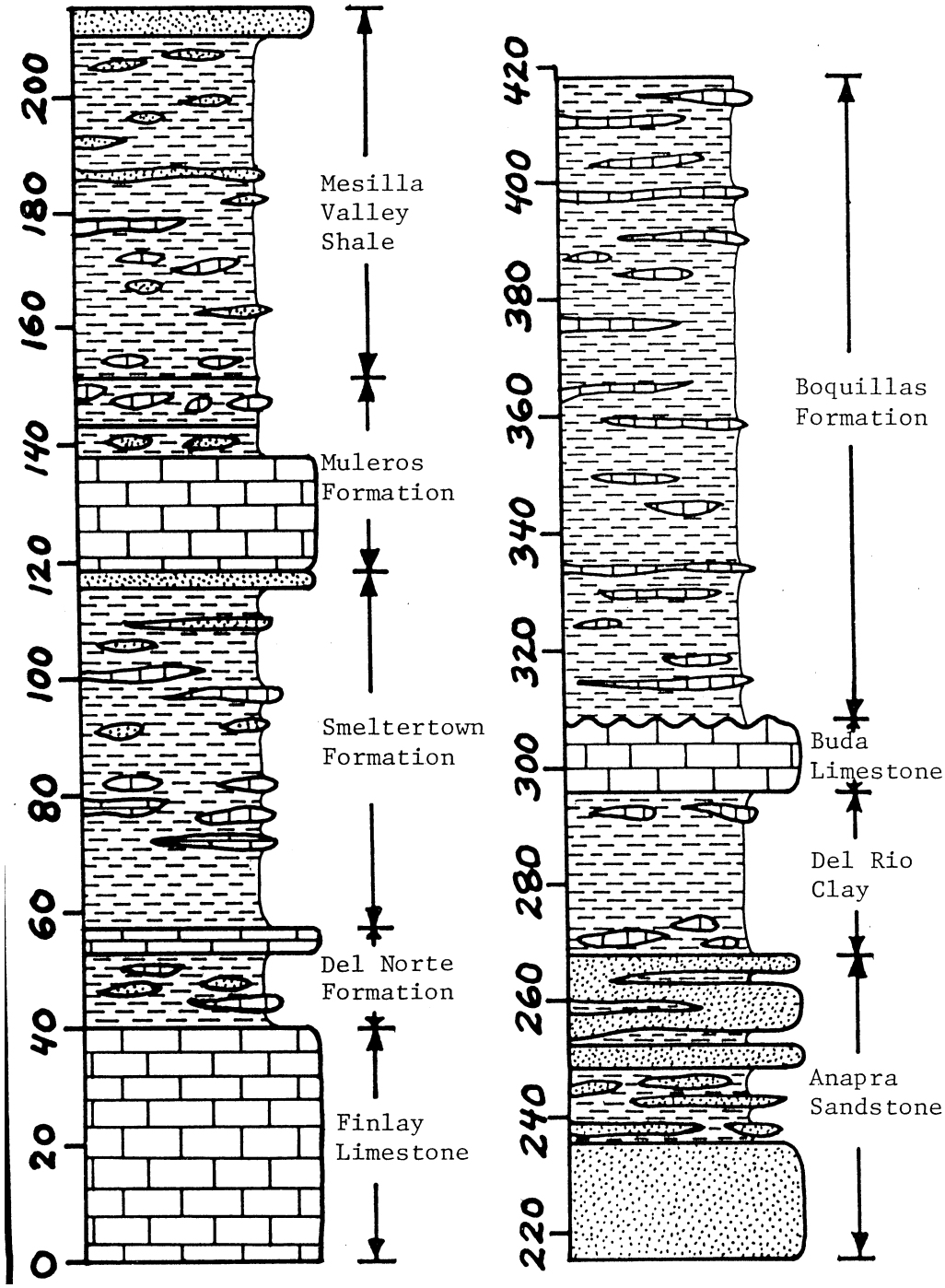

Figure 2. Cretaceous strata exposed at Cerro de Cristo Rey, New Mexico and Chihuahua (from Norland, 1986, modified after Lovejoy, 1976, and Strain, 1976).

Finlay Formation

Only the uppermost 40 m of the middle-upper Albian Finlay Formation are exposed at Cristo Rey. The Finlay crops out along both sides of the Rio Grande at the narrow Paso del Norte (Pass of the North) between Texas and New Mexico. It is equivalent to Böse's (1910) unit 1 (Lovejoy, 1976; Strain, 1976). Massive, nodular, fine-grained, marly limestone is interbedded with thin shales. Bivalves and gastropods are dominant, and ammonoid cephalopods, echinoids, serpulids, and foraminifera (especially *Dictyoconus walnutensis*) are less abundant. Two solitary coral species are described here from the Finlay.

The lower Finlay member overlies the Cox Sandstone, consists of nodular limestone layers interbedded with marls, and represents a ramp deposit. The upper Finlay member consists of biowackestones and biopackstones associated with caprinid rudist banks that have formed on a carbonate shelf. The formation is correlated with the Walnut, Goodland, and Comanche Peak formations of the Fredericksburg Group in north Texas. The middle–upper Albian ammonite boundary is in the upper 10–14 m of the Goodland Formation in central Texas (see Scott *et al.*, in this volume).

In the Sierra de Juarez, the Finlay Formation is a major mapping unit. Rudists and *Dictyoconus* are common fossils in the Finlay (Nodeland, 1980b). The thickness of the formation in the thrust sheets is relatively uniform (Table 2). Approximately 100 km southeast of El Paso, in Hudspeth County, excellent exposures of the Finlay Formation crop out on the southwestern margin of the Diablo Plateau (Steinhoff, 1999; Steinhoff and LeMone, 2000; see paper by Steinhoff in this volume).

Del Norte Formation

The Del Norte Formation in its stratotype at Cristo Rey consists of two members, the lower Clay Member (11.9 m) and the upper Calcareous Member (3.8 m) (Strain, 1976). The lower member is calcareous shale interbedded with fine-grained sandstone and nodular limestone. The upper member is fossiliferous limestone interbedded with shale (Strain, 1976). The formation yields ammonites, echinoids, gastropods (*e.g.*, turritellids), bivalves (*e.g.*, ostreids, pectens, texigryphaeids, exogyrids), serpulids, sponges, and five species of solitary corals. The Del Norte comprises Böse's (1910) units 2 and 3, which contain ammonites of the *Adkinsites bravoensis* Zone; thus, the Del Norte correlates with the Kiamichi Formation, Washita Group, in north Texas.

Smeltertown Formation

At its stratotype in Cerro Cristo Rey the Smeltertown Formation is 62-m thick and consists of four units in ascending order: [1] dark gray, fissile shale (13.7 m); [2] silty, calcareous, dark-gray shale with corals and bryozoans in the upper 3 m (14.3 m); [3] silty, olive-gray shale containing interbeds of silty limestone and sandy to silty quartzose siltstone (20.9 m); and [4] ferruginous, sandstone, and silty shale (2.4 m) (Strain, 1976). Ammonites, bivalves, gastropods, crustaceans (crab), ophuroids (Cornell *et al.*, 1991), bryozoans (Nye and LeMone, 1978), echinoids, three solitary and four colonial coral species, and brachiopods have been recovered from this interval.

The Smeltertown Formation has yielded 73 foraminiferal species assignable to 45 genera (Bullock, 1985). Forty-five of these species also occur in the Duck Creek Formation of central and northeastern Texas and southern Oklahoma. Four of these species, (*Textularia duckcreekensis* Tappan, *Citharina duckcreekensis* (Tappan), *Saracenaria duckcreekensis* Tappan, and *Washitella duckcreekensis* Tappan), are limited to the Duck Creek and Smeltertown formations. The Fisher Alpha Index of species diversity divides the Smeltertown at Cristo Rey

into three faunal zones (Bullock, 1985). These zones are, in ascending order: Zone 1 (basal 13 m) marine, inner shelf, maximum depth was 50 m; Zone 2 (13–36 m) marginal marine, hyposaline, lagoonal, maximum depth was 20 m; and Zone 3 (36 m to the top of the formation) hyposaline marsh, maximum depth was 5 m. Other microfossils include ostracodes, bryozoans, and echinoid spines.

Cyclostomate bryozoa occur 12–28 m above the base of the Smeltertown Formation in silty, biostromal, marly to clastic limestones associated with sand and chert pebbles (Nye and LeMone, 1978). Lebenspuren and sole markings are common in the upper strata. The Smeltertown is equivalent to Böse's (1910) unit 4 and is correlated to the Duck Creek Formation of central and northeastern Texas and southern Oklahoma and to the lower part of the Sarten Sandstone of the Cooke Range, New Mexico, based on its ammonites (Cobban, 1987).

The Smeltertown is interpreted as having initiated in distal, restricted circulation, possibly reducing, and marine waters. The succession gradually shallows from offshore marine conditions to a hyposaline lagoonal paleoenvironment. Sedimentation shifts from dark gray shale to clastic turbiditic material and resedimented carbonates. The succession shoals up into the hyposaline marshes containing texigryphaeid biostromes that are capped by ferruginous sandstone and silty shale. The Del Norte and Smeltertown formations, in part, comprise a depositional cycle that represents the first early late Albian seaway connection with the Tucumcari–Purgatoire–Kiowa–Skull Creek formations in New Mexico, Colorado, and Kansas, and the Thermopolis Formation in Wyoming and Montana (Scott *et al.*, 2001).

Muleros Formation

The Muleros Formation at its stratotype on Cerro Cristo Rey is 32.4 m thick and consists of three units in ascending order: [1] gray, irregularly bedded, clayey, richly fossiliferous limestone containing abundant texigryphaeaids (19.8 m); [2] gray to brown siltstone and shale (5 m); and [3] fossiliferous nodular limestone interbedded with shale (Strain, 1976). The Muleros is equivalent to Böse's (1910) unit 5. The lower contact with the underlying Smeltertown is sharp and the contact with the overlying Mesilla Valley Shale is gradational. *Texigryphaea washitaensis* is the most abundant fossil in units 1 and 3. Less abundant fossils are gastropods (turritellids and tylostomids), ammonites, echinoids, foraminifera (*Cribratina texana*), clionid sponge borings, serpulids, bryozoa, and one solitary coral species. The environment of deposition reflects normal to hyposaline, shallow water, carbonate shelf deposition having periodic clastic influx. The Muleros is correlative with the Denton–Fort Worth formations in central and northeastern Texas and southern Oklahoma.

Mesilla Valley Shale

Mesilla Valley Shale is 64 m thick at its stratotype and is divided into two units: a lower olive to dark gray shale, 59.4 m thick, containing a few interbeds of limestone and siltstone and an upper sandstone-shale interval 4.6 m thick (Strain, l976). The upper and lower boundaries are gradational. The base of the Mesilla Valley is the top of the texigryphaeid limestone. The upper contact with the overlying Anapra Sandstone is the base of the lowest 30 cm-thick sandstone bed. The Mesilla Valley is equivalent to Böse's (1910) unit 6. The depositional cycle of the Mesilla Valley Formation appears to correlate into the regional unconformity between the Glencairn and Mesa Rica formations in northeast New Mexico (Scott *et al.*, 2001).

The Muleros Andesite has altered the thermal maturity of the Mesilla Valley Shale according to Thermal Activation Analysis (TAI), based on relative darkening of the palynomorphs on a scale of 1–5 (Norland, 1986). Greatest organic maturation of 5 (black) is present in a narrow zone around the intrusion; the index decreases to 2 (orange brown) to 1 (honey yel-

low color) at the most distant sample points. The mixed organic residues consist of plant tissue, palynomorphs, dinoflagellate cysts, and microforaminiferal linings (Norland, 1986).

Bivalves (pterotrigonids and texigryphaeids) dominate the limestone biostromes and are largely confined to the lower part of unit 1. Additionally, gastropods, cephalopods, echinoids, serpulid worms, brachiopods, and reed-like plant fossils are present. Seven solitary coral species are described here. Upper Albian dinoflagellates occur in the formation (Cornell, 1982). The arenaceous foraminifera, *Cribratina texana,* is recorded throughout the formation, which is correlative with the Weno and Pawpaw formations of central and northeastern Texas and southern Oklahoma.

Anapra Sandstone

The Anapra Sandstone at its stratotype is subdivided into four units: [1] basal thin- to massive-bedded, fine- to medium-grained, ferruginous sandstone (19.8 m); [2] pale yellowish brown arenaceous shale (13.7 m); [3] massive-bedded, medium-grained, quartz sandstone (3.8 m); and [4] interbedded layers of massive-bedded, mottled, ferruginous, medium- to fine-grained quartz sandstone and siliceous shale (15.2 m) (Strain, 1976; Cornell and LeMone, 1987).

Lovejoy (1976) has subdivided the formation into five informal members consisting of three sandstones and two siltstone members; the lower two are approximately equivalent to Strain's (1976) unit 1. The basal sandstone, a tidal and littoral unit, is a massive to thin-bedded, fine- to medium-grained, poorly bedded to cross-bedded sandstone containing plant and marine fossil fragments. The lower transitional unit grades from continental siltstone to bluish-purplish siltstone having lignitic laminae. The middle sandstone unit is massive bedded, medium-grained quartz sandstone that contains a basal lenticular conglomerate composed of pebbles of an aphanitic, intermediate volcanic rock. It is interpreted as a fluvial unit recording a possible northern tectonic pulse. The upper siltstone member is purplish and grades up into the overlying upper sandstone. The uppermost member is a massive, poorly-bedded, clean, medium-grained, quartz sandstone containing marine fossils recorded at the top of the unit. Wacker (1972) has noted lignites in the Anapra in the autochthonous block in the north-central Sierra de Juarez. On the overlying thrust sheet, he recorded an Anapra Sandstone section containing rudists and corals.

Sandstones of transitional (tidal shoals) to continental (fluvial-paludal) environments in the Anapra Sandstone grade down into black shale of the Mesilla Valley Shale. The Anapra contact with the overlying marine Cenomanian Del Rio Clay is also gradational. The marine bivalve *Gyrostrea whitneyi* (formerly *Exogyra*), as well as rare echinoids and arenaceous foraminifera, occur in the upper 3 m of Anapra sandstone and shale; *G. whitneyi* ranges into the Lower Cenomanian Del Rio (Stanton, 1947). Another Lower Cenomanian oyster, *Exogyra clarki*, occurs with *G. whitneyi* in the Del Rio in the El Paso region (Stanton, 1947). The foraminifera *Cribratina texana* (Conrad) is locally abundant in the Anapra, and its range in north Texas is from the Denton Formation to the Grayson Formation. (See data in Scott *et al.* in this volume.) Lovejoy (1976) and Adkins (1928) have correlated the Anapra with the Main Street Limestone of north Texas based on its stratigraphic position below the Del Rio. Consequently, the Albian-Cenomanian boundary may correlate within the uppermost 3 m or so of the Anapra, as it does in the uppermost Main Street.

Del Rio Clay

The Del Rio Clay at Cerro Cristo Rey is primarily 24- to 27-m thick dark-gray shale in which nodular limestone is concentrated in the upper and lower parts of the formation (Lovejoy, 1976). Typically, the Del Rio is a covered slope. This unit is tectonically incompetent and pro-

vides the gliding surface for slippage between the competent Anapra and Buda formations. The base of the lowest massive limestone of the overlying Buda is the top of the Del Rio. It is Böse's (1910) unit 8. Fossils include the dominant bivalve, *Ilmatogyra arietina*, which is common in the lower part of the formation, as well as gastropods, cephalopods, and echinoids. The Del Rio is correlated with the Grayson Formation in north Texas and is lower Cenomanian in age. Throughout west Texas, the Del Rio contains lower Cenomanian ammonites (Young, 1979).

Based on foraminifera, the Del Rio Clay at Cerro Cristo Rey correlates with the Del Rio in the Sierra del Carmen at Big Bend National Park, Brewster County, Texas (Maudlin, 1985). At Big Bend, the Del Rio represents deposition in a low-energy, shallow, epicontinental sea beginning at depths on the order of 60–100 m and passing through a transgressive phase to depths of up to 250 m, before becoming shallower at the top of the unit (Maudlin, 1985).

Buda Limestone

The Buda Limestone forms the top of the Comanchean Series at Cerro Cristo Rey, is about 12 m thick, and consists of massive and nodular limestone interbedded with thin clay (Lovejoy, 1976). Resistant Buda exposures are typically well exposed because they occur between two easily eroded units, the Del Rio Clay and the overlying Boquillas Formation of the Gulfian Series. The Buda is Böse's unit 9 and is lower Cenomanian in age based on its ammonites (Young, 1979). The Buda correlates with the uppermost part of the Sarten Sandstone in north–central New Mexico based on mantellicerid and turrilitid ammonites (Cobban, 1987).

Bivalves are diverse; gastropods (largely turritellids) are the most abundant taxa, and less abundant are echinoids, one coral species, cephalopods, serpulids, crustaceans (crab), and vertebrate fish teeth. Dinoflagellates are diverse (Cornell, 1997). The Buda-Boquillas formational contact is a significant regional unconformity that separates the Comanchean and Gulfian series. For more information on the Buda in west Texas see the paper by Reaser and Robinson in this volume.

Boquillas Formation

The Boquillas Formation is relatively unfossiliferous dark gray shale that contains a few thin-bedded limestone beds. At Cristo Rey, the Boquillas is mostly covered and is 110 m thick. Ammonites and bivalves (inoceramids) are recovered from the unit at Cristo Rey, as well as *Ptychodus* (skate) pavement teeth and shark teeth, but no corals. It is mainly Cenomanian in age, but to the south in the Sierra de Juarez the uppermost part contains Turonian fossils (Cobban 1988a, b). This is Böse's (1910) unit 11. The underlying unit 10 is a felsite sill related to the Loma Plata Felsite, and probably is synchronous with the Middle Eocene Muleros Andesite.

Paleotectonics

The Upper Albian sedimentary rocks at Cerro Cristo Rey were deposited on the northern margin of the Chihuahua–Bisbee trough, a major northwest-southeast-trending rift basin (Mack, 1987) (Fig. 3). Lower Cretaceous sedimentary rocks thicken abruptly into the basin up to 3350 m and change to basinal and evaporitic facies. During the Cenomanian the Western Interior seaway expanded, depositing the Boquillas Formation above the carbonate shelf facies of the Buda (Mack, 1987) (Fig. 4). This contact represents a significant hiatus within the Cenomanian.

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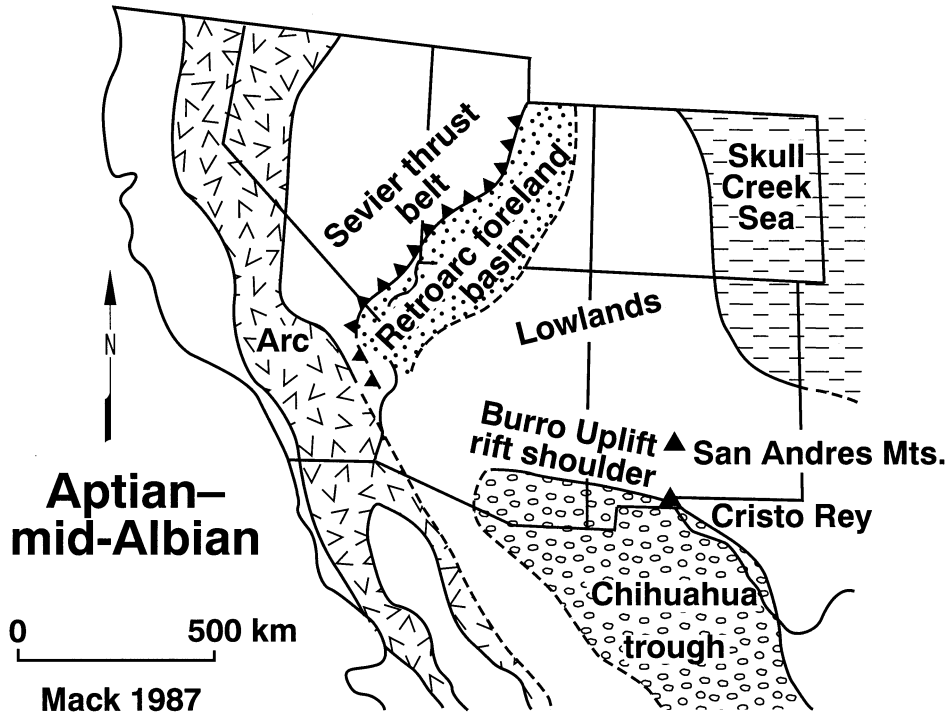

Figure 3. Aptian-mid-Albian paleotectonic map (Mack, 1987).

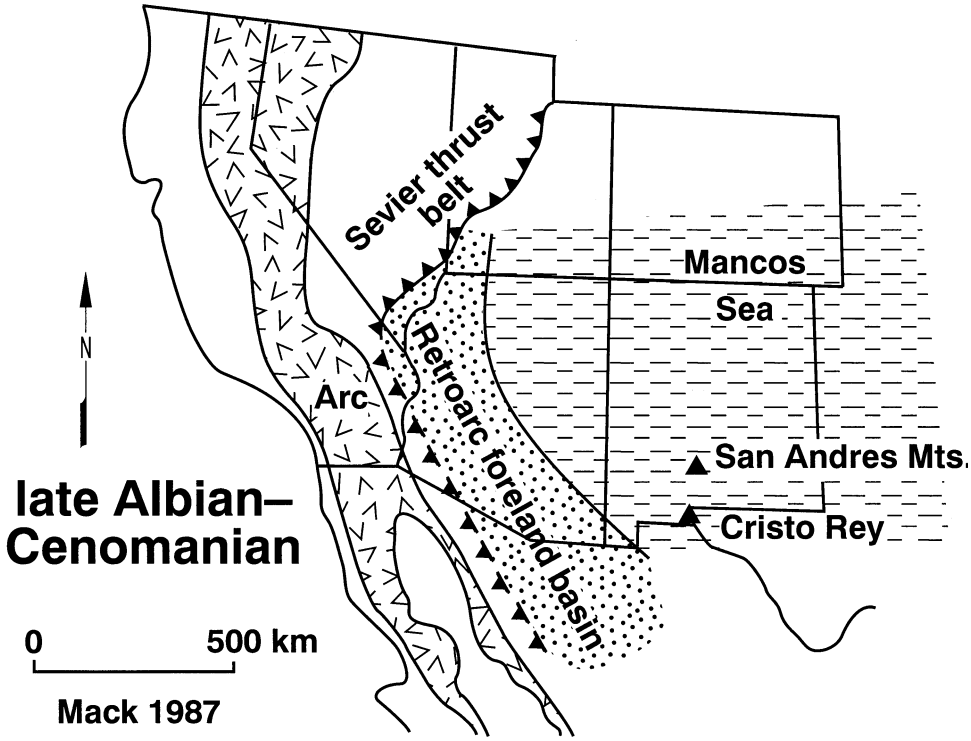

Figure 4. Late Albian-Cenomanian paleotectonic map (Mack, 1987).

Paleoecology

The majority of coral species at Cerro Cristo Rey are solitary, conical, turbinate forms occurring in argillaceous lithologies of the Del Norte, Muleros, and Mesilla Valley formations that were deposited under turbid conditions. These tall, conical forms grew up above the sediment-water interface and kept clean of mud. Two solitary coral species also occur in the Finlay Formation and one in the Buda Formation (Table 1). Three genera at Cristo Rey, *Axosmilia, Conicosmilotrochus,* and *Rennensismilia*, also dwelt in shoal environments of the Late Cretaceous Gosau shelf (Turnšek, 1997).

Table 1. List of coral species described, stratigraphic occurrences, and numbers of specimens at Cerro Cristo Rey. Lithostratigraphic units: FI = Finlay, DN = Del Norte, SM = Smeltertown, MU = Muleros, ME = Mesilla Valley, and BU = Buda.

	Albian					Cen.
	Middle-Late			Late		Early
	FI	DN	SM	MU	ME	BU
Paratrochocyathus crassus Alloiteau, 1958	2	7				
Paratrochocyathus collignoni Alloiteau, 1958	1	5				
Platytrochopsis lashensis Sikharulidze, 1975		3		1		
Coelosmilia texana (Conrad, 1857)		11				
Paratrochocyathus conulus (Phillips, 1829 sensu Michelin, 1841)		3				
Columastraea wintoni (Wells, 1933)			1			
Axosmilia whitneyi (Wells, 1933)			1			
Paratrochocyathus boesei n. sp.			2			
Actinaraea tenuis Morycowa, 1971			1			
Microsolena distefanoi (Prever, 1909)			8			
Dimorpharaea manchacaensis Wells, 1933			2			
Rennensismilia stainbrooki (Wells, 1933)			1		2	
Budaia lovejoyi n. sp.					9	
Parasmiliopsis cenomana (Fromentel, 1863)					3	
Sphenotrochus straini n. sp.					3	
Caryophyllia comanchei Wells, 1933					8	
Diegosmilia complanata (Collignon, 1931)					1	
Conicosmilotrochus mulerosensis n. sp.					4	
Caryophyllia dentonensis Wells, 1947						2

Four species of colonial corals are from the Smeltertown Formation. A nodular limestone about 25 to 28 m above the base of the formation contains coarse sand, chert pebbles, corals, and bryozoans (Lovejoy, 1976; Nye and LeMone, 1978). The corals may be transported together with the other grains, and no coral buildup has been reported. In comparison, *Actinaraea tenuis* lived in patch reefs in the back reef area of the Dinaric carbonate platform, and *Microsolena distefanoi* lived in the reef flat and slope (Turnšek, 1997).

Stratigraphic Significance

Nineteen species of corals from six formations have been identified from the Cerro Cristo Rey locality, Doña Ana County, New Mexico. The formations range in age from Middle Albian to Lower Cenomanian. Four species from this collection are new; the known ranges of nine species are extended.

Four species (*Axosmilia whitneyi*, *Rennensismilia stainbrooki*, *Caryophyllia comanchei*, and *C. dentonensis*) have been reported previously only from the Albian or Cenomanian beds of Texas (Wells, 1933, 1947); three species (*Paratrochocyathus crassus*, *P. collignoni*, and *Diegosmilia complanata*) are known only from the Albian of Madagascar (Alloiteau, 1958) and Maastrichtian of Oman (Baron-Szabo, 2000); *Coelosmilia texana* has been reported at Cerro Cristo Rey by Böse (1910) and in New Mexico (Kues et al., 1985); one species (*Parasmiliopsis cenomana*) is known from the Cenomanian of France (see Alloiteau, 1957); one species (*Platytrochopsis lashensis*) is from the Albian of Georgia (Sikharulidze, 1975); *Columastraea wintoni* is reported from Chili (Prinz, 1991); *Dimorpharaea manchacaensis* occurs in Greece (Löser and Raeder, 1995), in northern Spain (Schöllhorn, 1998), and possibly in Georgia (Bendukidze, 1961); one species (*Paratrochocyathus conulus*) is from the Albian of France, England, and Georgia (see Milne Edwards, and Haime, 1850; Felix, 1914; Alloiteau, 1958; Sikharulidze, 1978); and two colonial species (*Actinastraea tenuis* and *Microsolena distefanoi*) are wide spread and known in the Lower Cretaceous and Cenomanian beds throughout the Tethys; *i.e.*, Caucasus region, southern and middle Europe, and North America (Morycowa, 1964, 1971; Sikharulidze, 1979; Kuzmicheva, 1980; Kuzmicheva and Aliev, 1988; Scott, 1984; Bugrova, 1989; Turnšek, 1992; Baron-Szabo, 1997; Baron-Szabo and González-León, 1999; Löser, 1998a, b; Löser and Raeder 1995; among others).

Stratigraphic comparison of coral species with localities in the world does not permit the construction of a more detailed subdivision of the Albian or Cenomanian, nor discrimination of the Albian-Cenomanian boundary. However, in the locality of Cerro Cristo Rey itself almost all the species are strictly limited to individual lithostratigraphic units. Fifteen of the species investigated occur in only one unit, and four species appear in two units. In this manner, the corals found at Cerro Cristo Rey represent an important contribution to the stratigraphy of Albian corals.

Systematic Paleontology

The coral fauna comprises 116 samples labeled with numbers A1 to A116 and 65 thin sections. The samples come from Cerro Cristo Rey, Doña Ana County, New Mexico, from the following Formations: Buda (A1-A2) (Lower Cenomanian), Mesilla Valley Shale (A82-A116) (Upper Albian), Muleros (A18), Smeltertown (A52-A81), Del Norte (A19-A51), Finlay (A3-A5) (Middle-Upper Albian). The specimens and thin sections are deposited at the Southwest Center for Stratigraphy and Paleontology, University of Texas at El Paso.

Systematics of the coral species described here follows a combination of Alloiteau (1952, 1957) and Wells (1956); more current completions and revisions are by several paleontologists and based mainly on the microstructure (Roniewicz, 1996; Morycowa and

Roniewicz, 1995) and other skeletal features (Baron-Szabo, 1993, 1997; Turnšek, 1997; Löser, 1998a, b; Roniewicz and Stolarski, 2001).

Abbreviations used in descriptions: **d** = corallum diameter; **h** = corallum height; **s** = number of septa; **c–c** = distance between corallite centers.

Classification Scheme

Class Anthozoa Ehrenberg, 1834

Suborder Amphiastraeina Alloiteau, 1952

Family Amphiastraeidae Ogilvie, 1897

Genus: *Budaia* Wells, 1933

Budaia lovejoyi n. sp.

Suborder Faviina Vaughan and Wells, 1943

Family Columastraeidae Alloiteau, 1952

Genus *Columastraea* d'Orbigny, 1849

Columastraea wintoni (Wells, 1933)

Family Axosmiliidae Geyer, 1955

Genus *Axosmilia* Milne Edwards and Haime, 1848

Axosmilia whitneyi (Wells, 1933)

Suborder Meandrina Alloiteau, 1952

Family Meandrinidae Gray, 1847

Genus *Coelosmilia* Milne Edwards and Haime, 1850

Coelosmilia texana (Conrad, 1857)

Genus *Rennensismilia* Alloiteau, 1952

Rennensismilia stainbrooki (Wells, 1933)

Genus *Parasmiliopsis* Alloiteau, 1957

Parasmiliopsis cenomana (Fromentel, 1863)

Suborder Caryophylliina Vaughan and Wells, 1943

Family Caryophylliidae Dana, 1846

Genus *Sphenotrochus* Milne Edwards and Haime, 1848

Sphenotrochus straini n. sp.

Genus *Caryophyllia* Lamarck, 1801

Caryophyllia comanchei Wells, 1933

Caryophyllia dentonensis Wells 1947

Genus *Paratrochocyathus* Alloiteau, 1958
Paratrochocyathus conulus (Phillips, 1829 sensu Michelin, 1841)
Paratrochocyathus crassus Alloiteau, 1958
Paratrochocyathus collignoni Alloiteau, 1958
Paratrochocyathus boesei n. sp.

Genus *Platytrochopsis* Sikharulidze, 1975
Platytrochopsis lashensis Sikharulidze, 1975

Family Parasmiliidae Alloiteau 1952
or Vaughan and Wells, 1943?
(Vaughn and Wells 43 are authors of the subfamily Parasmilinae

Genus *Diegosmilia* Alloiteau, 1958
Diegosmilia complanata (Collignon, 1931)

Genus *Conicosmilotrochus* Turnšek, 1978
Conicosmilotrochus mulerosensis n. sp.

Suborder Fungiina Verrill, 1865
Family Actinacididae Vaughan and Wells, 1943

Genus *Actinaraea* d'Orbigny 1849
Actinaraea tenuis Morycowa, 1971

Suborder Microsolenina Morycowa and Roniewicz, 1995
Family Microsolenidae Koby, 1890

Genus *Microsolena* Lamouroux, 1821
Microsolena distefanoi (Prever, 1909)

Genus *Dimorpharaea* Fromentel, 1861
Dimorpharaea manchacaensis Wells, 1933

Descriptions of Species

Suborder: Amphiastraeina Alloiteau 1952
Family: Amphiastraeidae Ogilvie, 1897

Genus *Budaia* Wells, 1933
Budaia lovejoyi n. sp.
Figs. 5A, B, C, D, E, F

Budaia n. sp., Turnšek *et al.*, 1984, p. 475.

Name: Named for the late Professor Earl M.P. Lovejoy of the University of Texas at El Paso, who wrote the definitive monograph on the Cerro de Cristo Rey uplift of Chihuahua and New Mexico. He died at Cerro de Cristo Rey in May, 1981, while teaching University field camp.

Holotype: A83, with six thin sections.

Type locality: West margin of the northeast sector of Cerro de Cristo Rey, in outcrops along Bowen Gulch, Doña Ana County, New Mexico (S1/2, SW section 9, T. 29 S., R. 4 E.; 31º47'31"N, 106º32'30").

Type stratum: Mesilla Valley Shale, upper Albian.

Material: Holotype A83, 8 paratypes (A82, A85, A86, A87, A89, A96, A100, A108), and seven thin sections.

Diagnosis: *Budaia* which has a trochoidal corallum and thick smooth septa; all cycles nearly the same thickness; rare, long vesicular dissepiments; and microstructure of small to medium-sized trabeculae, which have a midseptal line.

Dimensions: **d** = 13–15 mm; **h** = 20–35 mm; **s** = 24 (6+6+12).

Description: Trochoidal corallum has a slightly enveloped, narrow (not pointed) base. The epitheca is completely preserved in its lower part but only as sparse rings above the lower part. Where the epitheca is absent, septa and endotheca can be observed. The calyx is circular to oval, somewhat inclined, and nearly bilaterally symmetrical. The septa are thick, straight, smooth, and have only rare, sparse lateral granulae. The first two cycles of 12 septa are almost equal in length. The third cycle is less than half as long as the first two cycles, but the septa are of equal width; septa do not thin toward the center. In the upper part of the corallum the septa terminate freely in the vicinity of the center. The septa reach the center in the lower part of the corallum and fill it entirely. The columella is absent. The wall is a septoparatheca with epitheca and is commonly strongly leached on the surface. Endotheca consists of large, long vesicular dissepiments, which are sparsely distributed over the entire lower part of the corallum. The microstructure consists of small- to medium-sized trabeculae with midseptal lines surrounded by a layer of additional fibers.

Comparisons: The new species differs from *B. travisensis* Wells, 1933 (p. 66-67) by its broader calyx and larger number of thick septa, which extend to the very center of the corallum, and by fewer dissepiments (see also Baron-Szabo, 1993, p.157-158). Similar thick septa also occur in the genera *Tiarasmilia*, *Blothrocyathus* and *Adkinsella*, but they are distinguished from the new species by the following characteristics: *Tiarasmilia* Wells, 1932 (p. 227-230) from the Glen Rose Formation of Texas has no endotheca or epitheca. *Blothrocyathus* Wells, 1932 (p. 241-243) from the Glen Rose of Texas has a high, cylindrical corallum and better-developed endotheca. Löser (1998a) revised this genus as a junior synonym of *Aulastraeopora* Prever (1909). *Adkinsella* Wells, 1932 (p. 39-40) from the Edwards Formation of Texas has no endotheca and is laterally symmetrical.

Discussion: Wells (1933) attributed the genus *Budaia* to the Family Trochosmilidae, Suborder Faviina. Baron-Szabo (1993) attributed the genus *Budaia* to the Family Amphiastraeidae, Suborder Amphiastraeina; Roniewicz and Stolarski (2001) attributed the Family Amphiastraeidae to the Suborder Pachythecaliina. We follow Baron-Szabo because of priority.

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Author
Subject
Taxa
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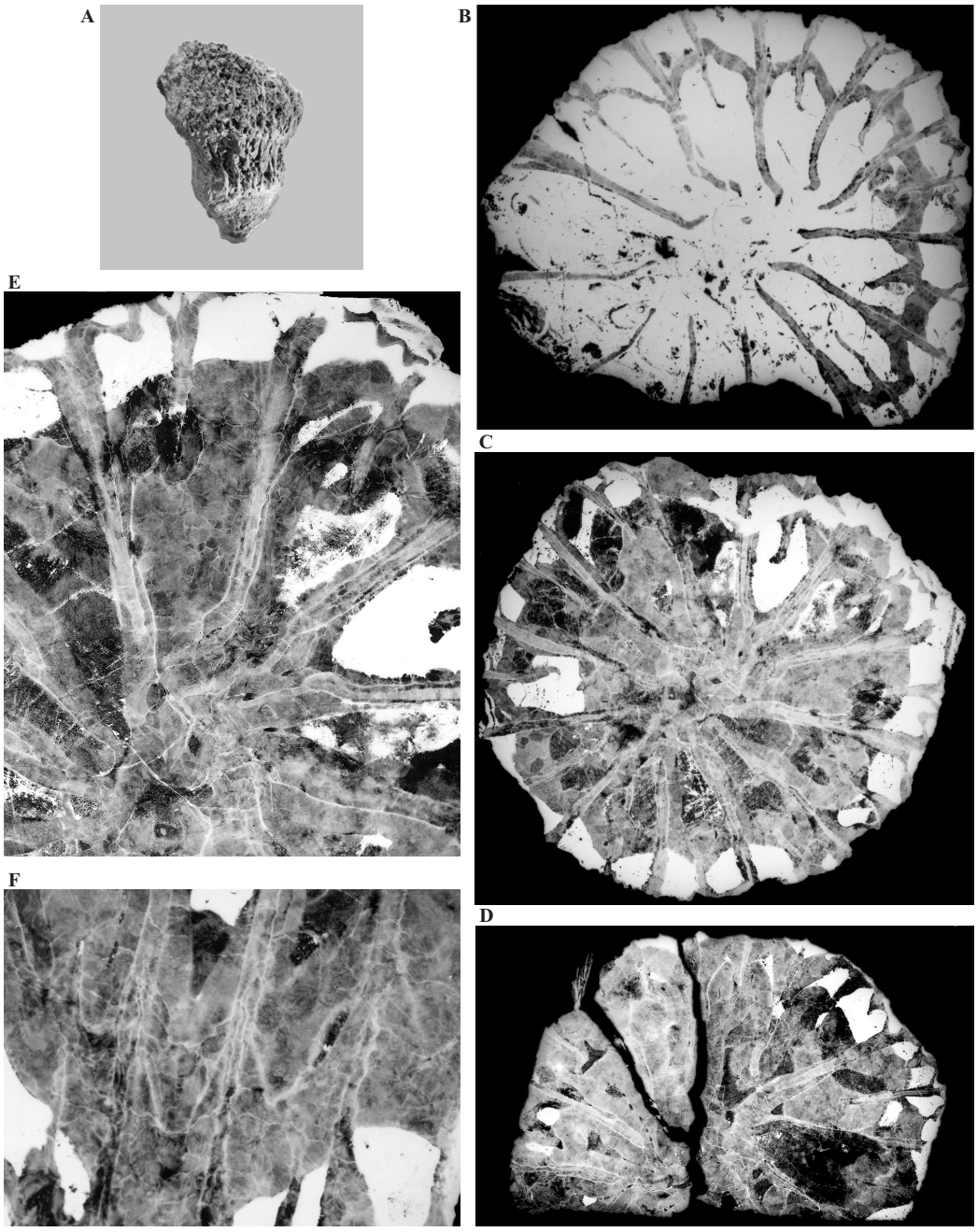

Figure 5. A, B, C, D, E, F: *Budaia lovejoyi* n.sp.; A: the surface of the corallum from side, A82, x1; B, C, D: transverse thin sections of holotype in order from near calyx to near apex, A83a, b, c, x4; E: detail from Fig. 5C, x8; F: longitudinal thin section, A83f, x8; Mesilla Valley Shale, upper Albian.

Suborder: Faviina Vaughan and Wells, 1943

Family: Columastraeidae Alloiteau, 1952

Genus: *Columastraea* d'Orbigny, 1849

Columastraea wintoni (Wells, 1933)

Figs. 6A, B, C

Stephanocoenia? *wintoni* Wells, 1933, p.69, pl.5, Fig. 9; Löser, 1994, p. 74.

Columnocoenia sp. Turnšek and LeMone, 1981, p. 14.

Columastraea wintoni (Wells), Turnšek et al., 1984, p. 475.

Stylina wintoni (Wells), Prinz, 1991, p. 195, text-fig. 29, pl. 8, Fig. 5; Löser, 2000, p. 76.

Description: Wells described the anatomy fully (1933). The microstructure consists of medium-sized trabeculae.

Dimensions: **d** of calice = 1.9–2.5 mm; **c–c** = 2.5–3 mm; **s** = 24; colony = 25 x 27 x 29 mm.

Comparison: The peritheca of the colony examined is somewhat wider than Well's holotype. The species *Columastraea paucipaliformis* Baron-Szabo and González-León (1999, p.472-473) from the Cerro de Oro area, northern Mexico in the Cerro de Oro Formation (upper Barremian–lower Aptian) has only two complete cycles of septa (=12+s). Alloiteau has discussed the revision of the genus *Stephanocoenia* (1952, p. 626-627; 1957, p. 56-58). The genus *Columnocoenia* Alloiteau has a more lamellar columella and a better-developed endotheca. Scott and González-León (1991, p. 62) have compared *S. wintoni* to *Columnocoenia ksiazkiewiczi* Morycowa, which they have found in the middle Albian Espinazo del Diablo Formation, northern Mexico. *Stylina* has no pali.

Distribution: Recorded from the middle-upper Albian Goodland Formation, Fort Worth, Tarrant County, Texas. The new material extends the range into the upper Albian.

Material: Sample A56 from Cerro de Cristo Rey, Doña Ana County, New Mexico. Recovered from the upper Albian Smeltertown Formation.

Family: Axosmiliidae Geyer, 1955

Genus: *Axosmilia* Milne Edwards and Haime, 1848

Axosmilia whitneyi (Wells, 1933)

Fig. 6D

Pleurosmilia whitneyi Wells, 1933, p. 62, pl. 2, Fig. 20; pl. 5, Fig. 5.

?*Pleurosmilia quaylei* Wells, 1933, p. 63-64, pl. 2, Fig. 16, pl. 5, Figs. 3-4.

Axosmilia whitneyi (Wells), Turnšek *et al.*, 1984, p. 475; Löser, 2000, p. 14.

Description: Wells (1933) has described adequately the species. In addition, the microstructure consists of small- to medium-sized trabeculae. The fibers are on the periphery of the corallum in several series with midseptal line.

Dimensions: **d** of calice = 25 x 28 mm; **h** = 60 mm; **s** = 48 + s5.

Comparison: The dimensions of the specimen examined are similar to two of Wells' species (*P. whitneyi* and *P. quaylei*) (Wells, 1933, p. 62-63), but it is narrower and higher. Wells notes that both species differ by preservation of the epitheca and

the lengths of the columella. The epithecal character depends on the vagaries of the surface preservation, which may be profoundly affected by leaching. The length of the columella depends on the depth of the section of the corallum (see Turnšek and Mihajlovic, 1981). Therefore it is reasonable to combine both species. The name *whitneyi* is preserved because it appears first in Wells (1933). The species *Axosmilia villersensis* (Koby) (see also Baron-Szabo, 1993, p. 160-161) is significantly smaller (d = 12 x 20 mm).

For the details concerning the revision of the genus *Pleurosmilia* Fromentel, which is the more recent synonym of the genus *Axosmilia* Milne Edwards and Haime, see Wells (1956) and Turnšek and Mihajlovic (1981).

Distribution: Recorded from the lower part of the lower Cenomanian Buda Formation in Texas. The new material extends the range into the upper Albian.

Material: Specimen A55 was collected from the upper Albian Smeltertown Formation at Cerro de Cristo Rey, Doña Ana County, New Mexico.

Suborder: Meandriina Alloiteau, 1952
Family: Meandrinidae Gray, 1847

Genus: *Coelosmilia* Milne Edwards and Haime, 1850
Coelosmilia texana (Conrad, 1857)
Figs. 6E, F, G

Turbinolia texana Conrad, 1857, p. 144, pl. 2, Figs. 3a-b.

Trochosmilia texana (Conrad), Felix, 1914, p. 83.

Coelosmilia texana (Conrad), Wells, 1933, p. 52-56, pl. 4, Figs. 17-22 (contains older synonymy). Turnšek and LeMone, 1981, p.14; Turnšek *et al.*, 1984, p. 475; Kues and Lucas, 2000, p. 234; Löser, 2000, p. 20.

Desmophyllum? texanum (Conrad, 1857), Kues *et al.*, 1985, p. 268.

Dungulia texana (Conrad), Shimer and Shrock, 1944, p. 122, pl. 45, Figs. 33-37.

Description: Wells has given an accurate description (1933).

Dimensions: **d** of calice = 7–10 x 8–15 mm; **h** = 15–25; **s** = 48.

Distribution: Recorded from the Walnut, upper Goodland and Kiamichi formations (Fredericksburg and Washita Groups), middle to basal upper Albian) in several localities in Texas; it has also been reported from the Tucumcari Shale, New Mexico (Kues *et al.*, 1985).

Material: Recovered from the Del Norte Formation (upper Albian) at Cerro de Cristo Rey, Doña Ana County, New Mexico (samples A19, A20, A21, A22, A25, A26, A43, A45, A46, A47, and A50).

Genus: *Rennensismilia* Alloiteau, 1952
Rennensismilia stainbrooki (Wells, 1933)
Figs. 6H, I, J, K

Trochosmilia stainbrooki Wells, 1933, p. 51-52, pl. 4, Figs. 1-8.

Rennensismilia sp. Turnšek and LeMone, 1981, p. 14.

Rennensismilia steinbrooki (Wells), Turnšek *et al.*, 1984, p. 475; Löser, 2000, p. 70.

Description: Corallum is trochoid and has an open, large calice, which has a bent edge on one side. Lateral outside is ribbed. The septa are developed in 5 to 6 cycles. Younger cycles have shorter septa and are of the same thickness as older septa. Septal margins have sharp granulae. In the deeper parts of the corallum, the septa thicken towards the axial part. The columella is absent. The wall is septoparathecal having a thin epitheca. The endotheca consists of rare peripheral dissepiments. The microstructure is of small trabeculae, some with a median line and poorly preserved fibers.

Dimensions: **d** = 18–23 x 24–28 mm; **h** = 23–27 mm; **s** = ca. 100.

Remarks: The lack of a columella excludes the species from *Trochosmilia*. This fact and the structure of septa and endotheca approach it to *Rennensismilia*. Alloiteau has discussed in detail the relationship of the genus *Rennensismilia* to *Trochosmilia* (1952, p. 637; 1957, p. 86-87), and Turnšek (1978, p. 77); the microstructure of *Rennensismilia* has been described by Sorauf (1999).

Comparison: The species *Trochosmilia stainbrooki* has all the main characteristics of the genus *Rennensismilia*. The relationship of the genus *Rennensismilia* to *Trochosmilia* has been discussed in detail by Alloiteau (1952, p. 637; 1957, p. 86-87), and Turnšek (1978, p. 77); the microstructure of *Rennensismilia* is described by Sorauf (1999). We must add that the wall of *Rennensismilia* is septoparathecal and not only parathecal as mentioned by Alloiteau (1957), which is clearly visible on his Pl. 1, Fig. 9. Our specimens of *R. stainbrooki* differ from other species of *Rennensismilia* in having more weakly developed endotheca. Wells (1933) notes 100-133 septa in his description of the species, and our specimens are within the low end of the range of the type.

Distribution: Recorded from the zone of *Texigryphaea tucumcari* of the Kiamichi Formation from Three Lakes, Texas (upper Albian).

Material: Recovered from the Smeltertown Formation (upper Albian) (Sample A64) and the Mesilla Valley Shale (upper Albian) (Samples A84, A91) at Cerro de Cristo Rey, Doña Ana County, New Mexico. The coral has not yet been recovered from the intermediate Muleros Formation.

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Subject
Taxa
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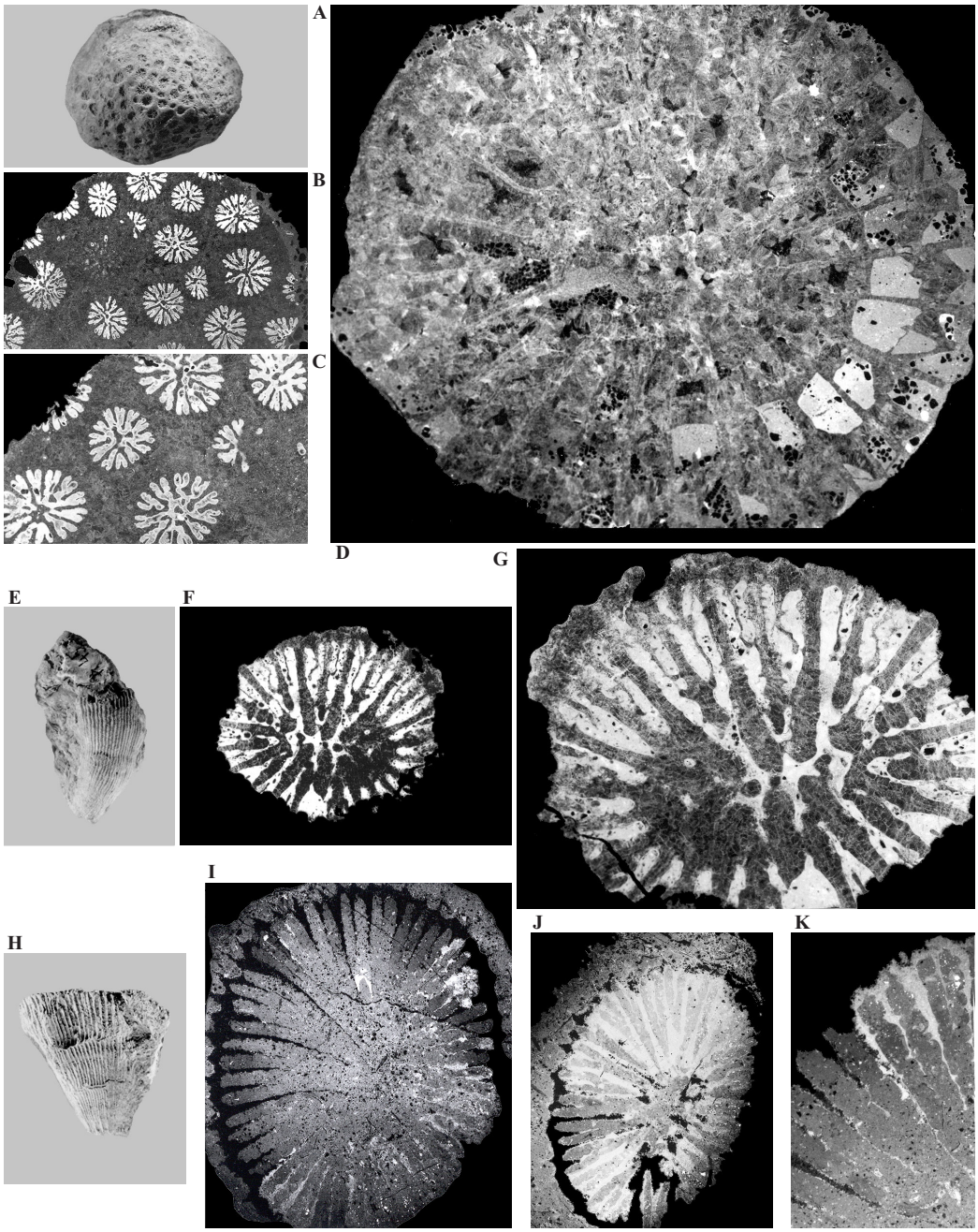

Figure 6. A, B, C: *Columastraea wintoni* (Wells, 1933); A: the surface of the colony, A56, x1; B: transverse thin section, A56a, x4; C: detail from Fig. 6B, x8; Smeltertown Formation, upper Albian. D: *Axosmilia whitneyi* (Wells, 1933); transverse thin section, A55a, x4; Smeltertown Formation, upper Albian; E, F, G: *Coelosmilia texana* (Conrad, 1857); E: the surface of the corallum, A45, x1; F: transverse thin section, A46a, x4; G: the same as Fig. 6F, x8; Del Norte Formation, upper Albian; H, I, J, K: *Rennensismilia stainbrooki* (Wells, 1933); H: the surface of the corallum, A84, x1; I, J: transverse thin sections near calyx and near apex, respectively, A91a, b, x4; K: detail from Fig. 6I, x8; Mesilla Valley Shale, upper Albian.

Genus: *Parasmiliopsis* Alloiteau 1957

Parasmiliopsis cenomana (Fromentel, 1863)

Figs. 7A, B, C, D

Trochosmilia cenomana Fromentel, 1863, p. 261, pl. 64, Figs. 1, 1a-c, non Figs. 1d-e.

Parasmiliopsis cenomana (Fromentel) Alloiteau, 1957, p. 87-88, pl. 8, Fig. 13; Turnšek *et al.*, 1984, p. 475; Löser, 2000, p. 60.

Description: The description follows that of Alloiteau. The corallum is trochoid, and the calice is subcircular. The lateral side of the entire corallum is ribbed. The costosepta are distally and laterally granulated. The wall is parathecal or septothecal; the endotheca is poorly preserved; the columella is spongy, formed by septal axial prolongations. The microstructure is not preserved.

Dimensions: **d** = 11–16 mm; **h** = 20–22 mm; **s** = 48.

Comparison: Examined specimens match Alloiteau's description in all structures except that the septa are slightly more winding.

Distribution: Recorded from the Cenomanian of La Mans (Sarthe), France. The new material extends the range into the upper Albian.

Material: Recovered from the Mesilla Valley Shale (upper Albian) at Cerro de Cristo Rey, Doña Ana County, New Mexico (Samples A90, A99, A105).

Suborder: Caryophylliina Vaughan and Wells, 1943

Family: Caryophylliidae Dana, 1846

Genus: *Sphenotrochus* Milne Edwards and Haime, 1848

Sphenotrochus straini n. sp.

Figs. 7E, F, G, H, I, J

Sphaenotrochus n. sp., Turnšek *et al.*, 1984, p. 475.

Name: Named for William S. Strain, Professor Emeritus of the University of Texas at El Paso, who studied the Cretaceous geology of the southwest for four decades. He defined the lithostratigraphic units Del Norte Formation, Smeltertown Formation, Muleros Formation, Mesilla Valley Shale, and Anapra Sandstone of Albian age at Cerro de Cristo Rey.

Holotype: Sample A101 with 3 thin sections.

Type locality: Cerro de Cristo Rey, Doña Anna County, New Mexico.

Type stratum: Mesilla Valley Shale of upper Albian age.

Material: Holotype (A101) and paratypes: (A110, A112).

Diagnosis: Corallum turbinate, epitheca, septa thick, the columella lamellar and thick, microstructure of mini-trabeculae have wide lateral perpendicular fibers.

Dimensions: **d** = 9–10 mm; **h** = 15 mm; **s** = 24 + s4.

Description: The turbinate corallum has a sharp base; it is straight to slightly curved above the base; and partially ribbed. The calyx is circular to slightly oval. The septa are very thick, smooth, and only locally have very small, lateral granulae. The

septa are developed in three cycles in an uneven irregular hexameral system. The first six septa extend to the center, two of which are extremely long and connect with the columella. The second septal cycle is somewhat shorter. The third cycle is only one-third the length of the first two cycles. All cycles are of the same thickness. The wall is septothecal. The columella is lamellar. The endotheca is absent. Microstructure consists of mini-trabeculae which have a large perpendicular layer tissue that gives it a lamellar appearance, similar to amphiastraeins.

Comparison: The corallum shape is more pointed in the base than other species of this genus (see Wells, 1956, p. 425, Figs. 326.3a-b, 327.4a-b). From the most similar Tertiary species, *S. crispus* (Lamarck), it differs in having smooth, thick axial septa. The genus, *Sphenotrochus*, is similar to *Axosmilia* in its smooth, thick septa and lamellar columella; *Axosmilia*, however, has endotheca.

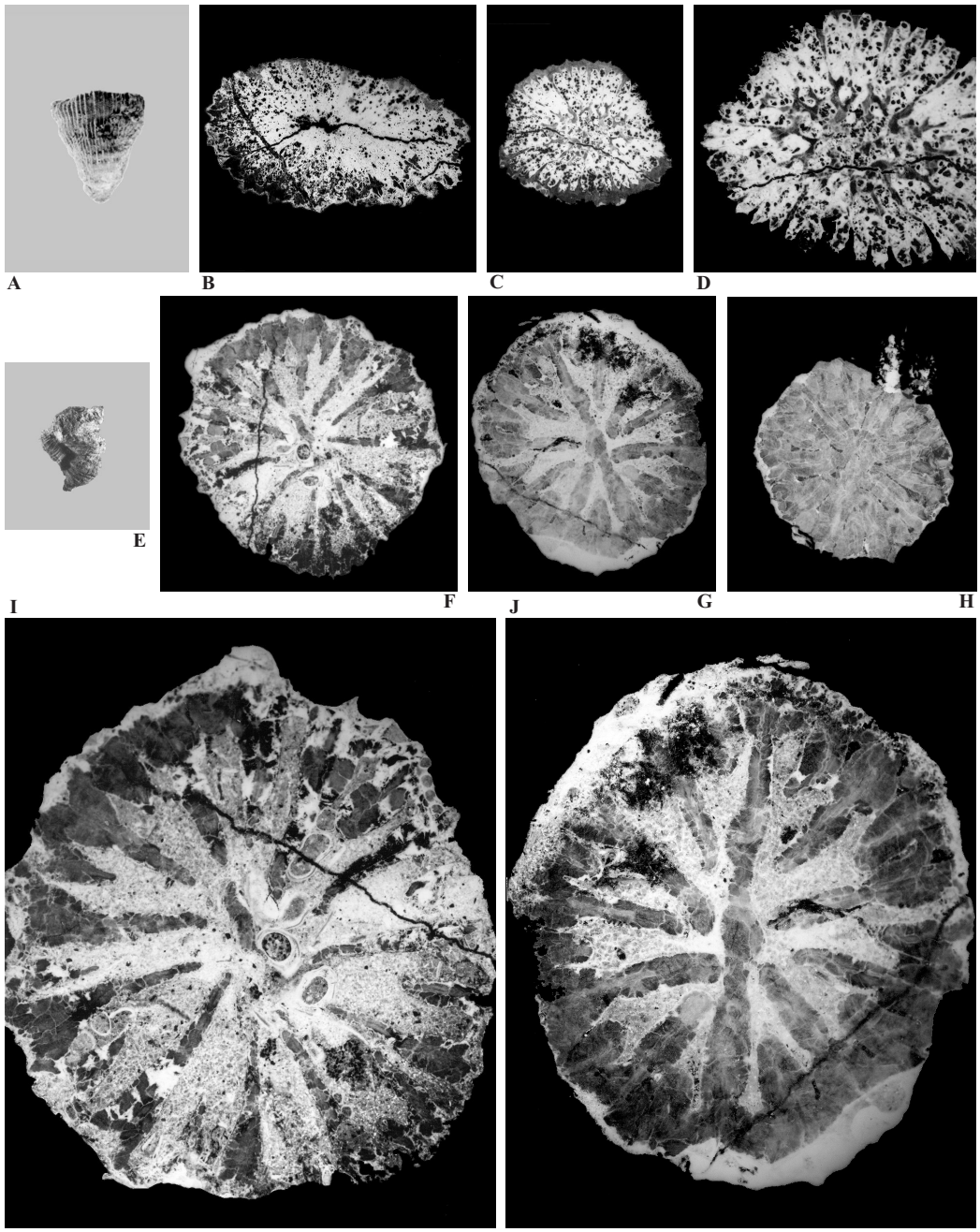

Figure 7. A, B, C, D: *Parasmiliopsis cenomana* (Fromentel, 1862); A: the surface of the corallum, A105, x1; B, C: transverse thin sections from near calyx to near apex, A99a, b, x4; D: part of the Fig. 7C, x8; Mesilla Valley Shale, Upper Albian; E, F, G, H, I, J: *Sphaenotrochus straini* n. sp.; E: the surface of the corallum, A110, x1; F, G, H: transverse thin sections of holotype from near calyx to near apex, A101a, b, c, x4; I, J: the same as Figs. 7F, G, x8; Mesilla Valley Shale, upper Albian.

Genus *Caryophyllia* Lamarck, 1801

Caryophyllia comanchei Wells, 1933

Figs. 8A, B, C, D, E, F

Caryophyllia comanchei Wells, 1933, p. 45-46, pl. 1, Fig. 14, pl. 3, Figs. 26-28; Turnšek *et al.*, 1984, p. 475; Löser, 2000, p. 17.

Description: Morphology has been described by Wells (1933).

Dimensions: **d** = 7–9 x 12–17 mm; **h** = 11–28 mm; **s** = 48.

Comparison: The specimens examined are somewhat smaller (d = 14 x 21 mm; h = 27–30 mm), than those described by Wells, but they fit his morphological description.

Distribution: Recorded from the Buda Limestone at Shoal Creek, Travis County, Texas (lower Cenomanian). The new material extends the range into the upper Albian.

Material: Recovered from the Mesilla Valley Shale, upper Albian at Cerro de Cristo Rey, Doña Ana County, New Mexico (Specimens A92, A94, A98, A102, A104, A106, A111, A113).

Caryophyllia dentonensis Wells 1947

Figs. 8G, H, I, J, K, L, M

Caryophyllia dentonensis Wells, 1947, p. 4-5, pl. 1, Figs. 12-14; Turnšek and LeMone, 1981, p. 14; Turnšek *et al.*, 1984, p. 475; Löser, 2000, p. 17.

Description: The species is described by Wells (1947).

Dimensions: **d** = 8 x 10 mm; **h** = 15–20 mm; **s** = 48.

Comparison: This species seems to have more crowns of pali, which indicates an affinity to the Trochocyathidae.

Distribution: Recorded from the Weno or Pawpaw (upper Albian) west of Roanoke, Denton County, Texas. The new material extends the range into the lower Cenomanian.

Material: Recovered from the Buda Limestone (Cenomanian) at Cerro de Cristo Rey, Doña Ana County, New Mexico (Samples A1 and A2).

Genus: *Paratrochocyathus* Alloiteau, 1958

Remarks: Baron-Szabo (2000, p. 126) treats the genus *Paratrochocyathus* Alloiteau as a synonym of *Trochocyathus* Milne Edwards and Haime, because "the type of the columella and pali are not generic-level characters." We, nevertheless, always observe in our specimens a clear papillose columella in which there is no fusion between pali or between septal trabeculae. We, therefore, follow Alloiteau and recognize *Paratrochocyathus* as a valid genus.

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Search
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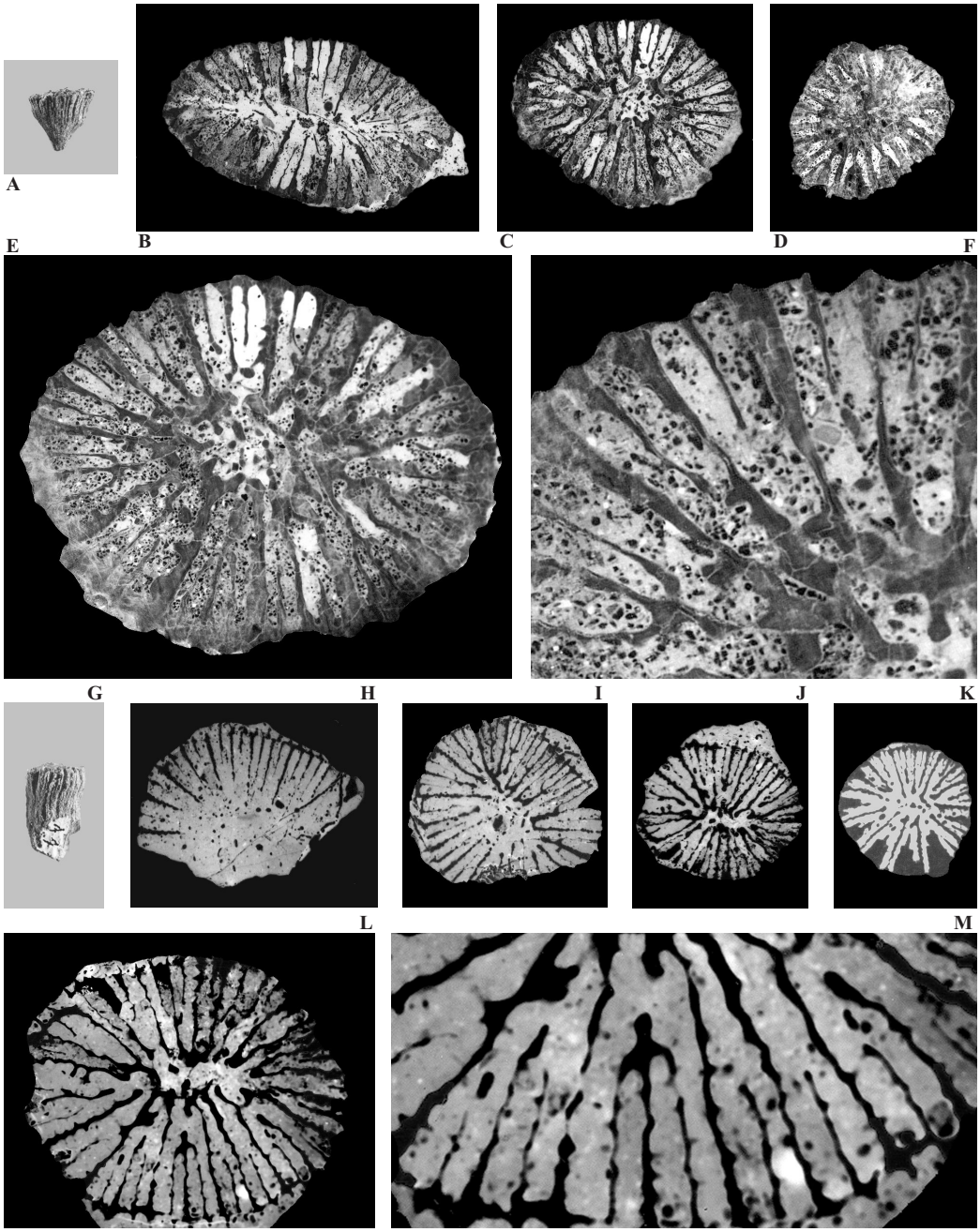

Figure 8. A, B, C, D, E, F: *Caryophyllia comanchei* Wells, 1933; A: the surface of the corallum, A102, x1; B, C, D: transverse thin sections from near calyx to near apex, A104a, b, c, x4; E: the same as Fig. 8C, x8; F: detail from Fig. 8C, x20; Mesilla Valley Shale, upper Albian; G, H, I, J, K, L, M: *Caryophyllia dentonensis* Wells, 1947; G: the surface of the corallum, A1, x1; H, I, J, K: transverse thin sections from near calyx to near apex, A2a, b, c, d, x4; L: the same as Fig. 8J, x8; M: detail from Fig. 8J, x20; Buda Limestone, lower Cenomanian.

Paratrochocyathus conulus (Phillips, 1829 sensu Michelin, 1841)
Figs. 9A, B, C, D, E

Caryophyllia conulus: Phillips, 1829, p. 121, pl. 2, Fig.1.

Turbinolia conulus: Michelin, 1841, p. 1, pl. 1, Fig. 12.

Trochocyathus conulus: Milne Edwards and Haime, 1850, p. 63-64, pl. 11, Fig. 5 (older synonymy discussed).

Trochocyathus conulus (Michelin), Felix, 1914, p. 79-80 (with older synonymy).

Trochocyathus conulus (Phillips), sensu Michelin, Löser, 2000, p. 81.

Paratrochocyathus conulus (Phillips), Alloiteau, 1958, p. 123, 135, Text-fig. 20; Sikharulidze, 1975, p. 54-55, pl. 1, Figs. 2a-z; 1978, p. 222; Turnšek *et al.*, 1984, p. 475.

Remarks: Two authors are credited with this species, Phillips (1829) and Michelin (1841). Milne Edwards and Haime (1850, p. 63) explain that Phillips (1829) published the species name with rough figures only and no description. Michelin (1841) has first described the species.

Description: Descriptions provided by Alloiteau (1958) and Sikharulidze (1975). The type is unknown.

Dimensions: **d** of calice = 6–12 mm; **h** = 9–20 mm; **s** = 48+s5.

Comparison: Alloiteau (1958, p. 123, p. 135) is sure that *Trochocyathus conulus* shows the structure of septa and pali characteristic of his new genus *Paratrochocyathus*. A similar species, *Paratrochocyathus crassus,* has a more oval calyx. *P. androiavensis* Alloiteau has a thicker wall. The genus *Protrochocyathus* differs in the structure of columella and costae (Alloiteau, 1958, p. 135; Baron-Szabo, 1998, p. 152). The species is also discussed by Löser and Stolarski (1997).

Distribution: Recorded from the Albian of France, England, and Madagascar as well as the lower Albian of western Georgia, Caucasus region.

Material: Recovered from the Del Norte Formation (upper Albian) from Cerro de Cristo Rey, Doña Ana County, New Mexico (Samples: A28, A48, A33).

Paratrochocyathus crassus Alloiteau, 1958
Figs. 9F, G, H

Paratrochocyathus crassus Alloiteau, 1958, p. 138-139, pl. 2, Figs. 12-13; Turnšek and LeMone, 1981, p. 14; Turnšek *et al.*, 1984, p. 475; Löser, 2000, p.60.

Description: Alloiteau (1958) has described the species. The septal microstructure consists of mini-trabeculae having lateral perpendicular fibers and midseptal lines.

Dimensions: **d** = 7–9 x 9–11 mm; **h** = 10–17 mm; **s** = 48.

Comparison: The axial part of each septa is slightly thicker than described by Alloiteau because the specimens examined are partly recrystallized. The other structures match the holotype. This species differs from other species of the genus by its rougher ribs.

Distribution: Recorded from the Albian-Cenomanian of Madagascar.

Material: Specimens were recovered from the middle–upper Albian Finlay Formation (A3, A4) and the Del Norte Formation (A27, A29, A30, A32, A37, A38, A40) at Cerro de Cristo Rey, Doña Ana County, New Mexico.

Paratrochocyathus collignoni Alloiteau, 1958
Figs. 9I, J, K

Paratrochocyathus collignoni Alloiteau, 1958, p. 135-136, pl. 31, Figs. 3-4;
Turnšek *et al.*, 1984, p. 475; Löser, 2000, p. 60.

Description: Morphology is as described by Alloiteau (1958). The microstructure consists of mini-trabeculae having perpendicular fibers.

Dimensions: **d** = 7–10 x 10–15 mm; **h** = 15–28 mm; **s** = 48+s5.

Comparison: Alloiteau's holotype has 48 septa. The specimens examined have more than 48 septa and match more closely the paratype. These new specimens differ from *P. conulus* by their more oval calyx and higher corallum. Externally, *P. collignoni* resembles *Parasmilia austinensis* Wells (1932, p. 56-58, pl. 4, Figs. 9-11), but the latter has endotheca.

Distribution: Recorded from the Albian of Madagascar.

Material: Recovered from the middle–upper Albian Finlay (A5, A51) and Del Norte (A35, A36, A41, A43, A51) formations from Cerro de Cristo Rey, Doña Ana County, New Mexico.

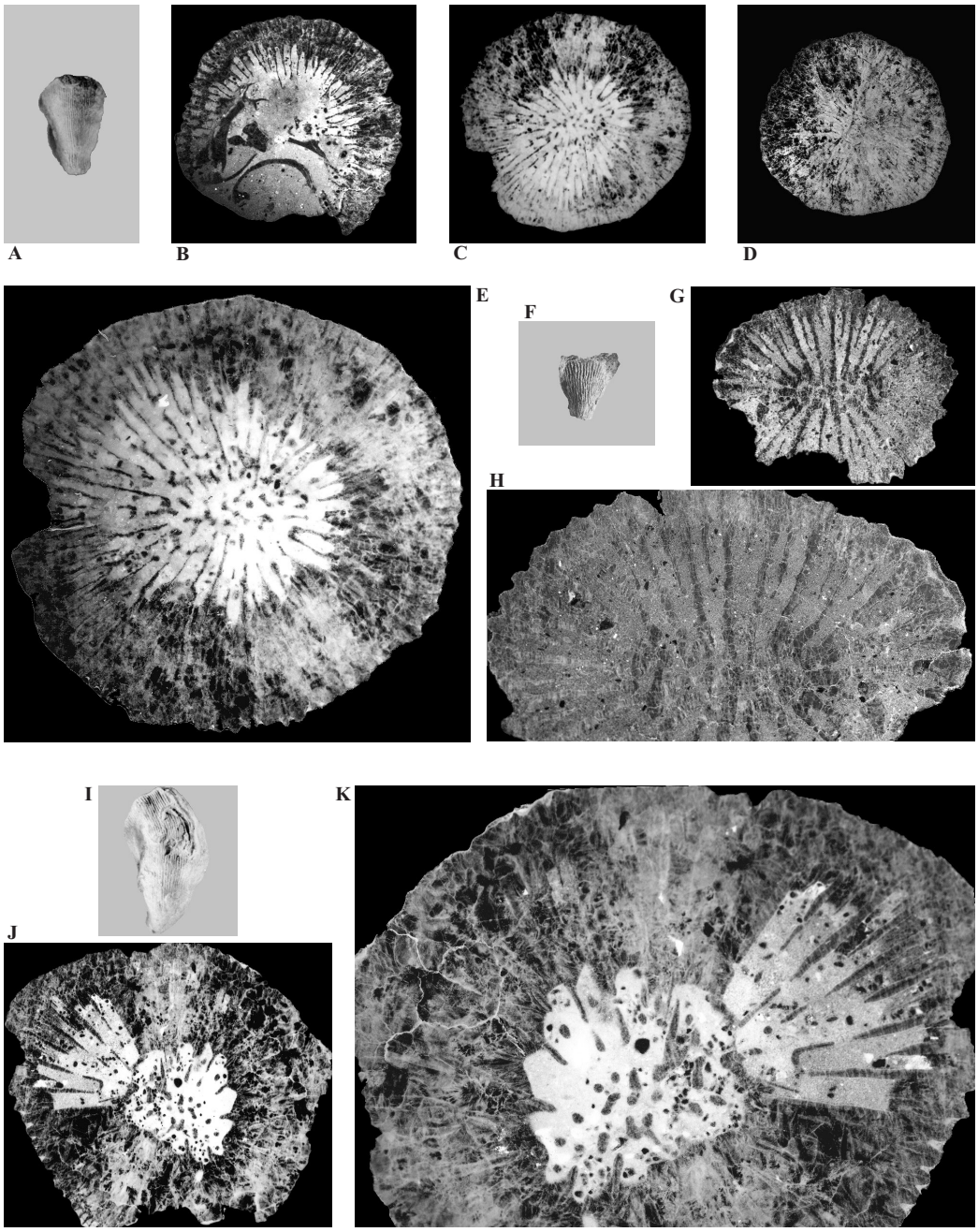

Figure 9. A, B, C, D, E: *Paratrochocyathus conulus* (Phillips, 1829 sensu Michelin, 1840); A: the surface of the corallum, A28, x1; B, C, D: transverse thin sections from near calyx to near apex, A48a, b, c, x4; E: the same as Fig. 9C, x8; Del Norte Formation, Upper Albian. F, G, H: *Paratrochocyathus crassus* Alloiteau, 1958; F: the surface of the corallum, A32, x1; G: transverse thin section, A27a, x4; H: detail from Fig. 9G, x8; Del Norte Formation, Upper Albian; I, J, K: *Paratrochocyathus collignoni* Alloiteau, 1958; I: the surface of the corallum, A43, x1; J: transverse thin section, A5, x4; K: detail from Fig. 9J, x8; Finlay (A5) and Del Norte (A43) formations, middle-upper Albian.

Paratrochocyathus boesei n. sp.
Figs. 10A, B, C, D

Paratrochocyathus n. sp., Turnšek *et al.*, 1984, p. 475.

Name: Named for Emil Böse, whose 1910 monograph of Cerro de Muleros (Cerro de Cristo Rey) has been the standard work on the paleontology of the area for over fifty years.

Holotype: Sample A54 with a thin section.

Type locality: Cerro Cristo Rey, Doña Ana County, New Mexico.

Type stratum: Smeltertown Formation, lower part of the upper Albian.

Material: Holotype (A54) and paratype (A65), two thin sections.

Diagnosis: *Paratrochocyathus* having a broad, turbinated corallum. The species has a wide, circular calyx.

Dimensions: **d** = 20 mm; **h** = 25 mm; **s** = 96 to 140.

Description: The corallum is turbinate, widens rapidly from below, and has a general, disk-like shape. The calyx is circular. The external side is finely ribbed. Septa are straight, laterally sparsely granulated. The septa are developed in five complete cycles and the beginning of a sixth. The first three cycles reach to the center of the corallum. The last cycles are much shorter, appearing only in the periphery, where they all fuse into a broad septotheca. Pali appear in two crowns, columella is papillose. Endotheca is absent. The microstructure consists of mini-trabeculae with midseptal line and perpendicular fibers.

Comparison: Of the known species of the genus, the new species most closely resembles *Paratrochocyathus collignoni* Alloiteau. It differs from *P. collignoni* by possessing a wider corallum and a larger number of septa (**d** = 8–13; **s** = 48–62 in *P. collignoni*). All other species are smaller. The external appearance of *P. boesei* n. sp. is similar to the species *Parasmilia bullardi* (Wells, 1932, p. 232-233, pl. 30, Fig. 8; pl. 31, Fig. 5), which has dissepiments but not pali.

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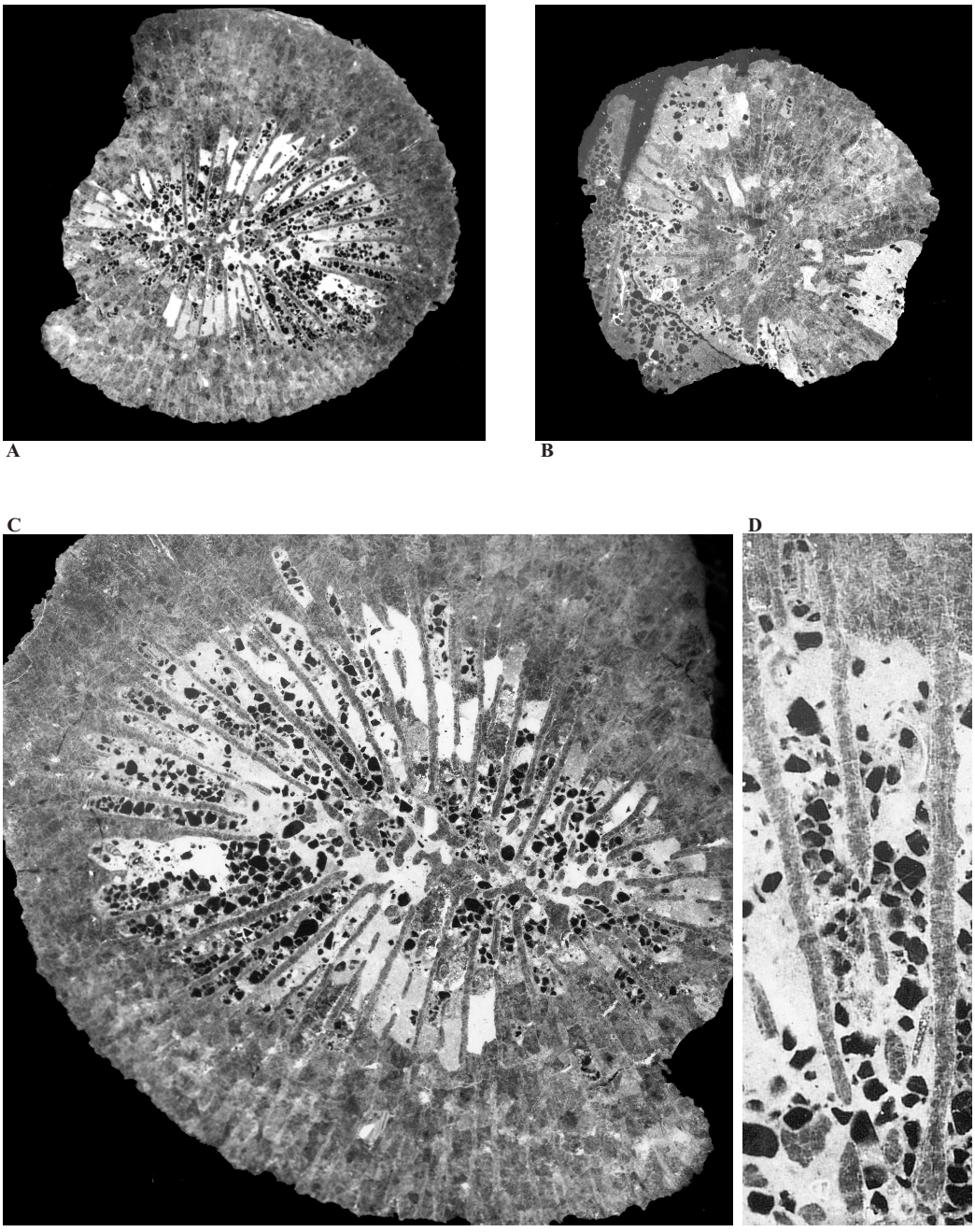

Figure 10. A, B, C, D: *Paratrochocyathus boesei* n. sp.; A: transverse thin section of holotype, A54a, x4; B: transverse thin section, A65a, x4; C: the same as Fig. 10A, x8; D: detail from Fig. 10A showing microstructure, x20; Smeltertown Formation, upper Albian.

Genus: *Platytrochopsis* Sikharulidze, 1975

Platytrochopsis lashensis Sikharulidze, 1975

Figs. 11A, B, C, D

Platytrochopsis lashensis Sikharulidze, 1975, p. 53-54, pl. 1, Figs. 4a-z, text-figs. 1a,b,v; 1978, p. 224-225; Turnšek and LeMone, 1981, p. 14; Turnšek *et al.*, 1984, p. 475; Löser, 2000, p. 65.

Description: The Cerro Cristo Rey specimens are similar to those described by Sikharulidze (1975). Solitary turbinate cuneiform which has a wide base and ribs on side; calyx is oval; septa are compact in periphery and porous in axial part, laterally granulated; and cycles differ in length, but less in width. The wall is septothecal, the spongy columella is made of pali and axial septal prolongations. The microstructure consists of mini-trabeculae having midseptal lines and lateral perpendicular fibers.

Dimensions: **d** = 9–10 x 10–14 mm; **h** = 12–15 mm; **s** = 48.

Comparison: The examined specimens are somewhat higher than the paratypes described by Sikharulidze (**h** = 6.5–11 mm), but they fit the holotype (**h** = 12 mm).

Distribution: Recorded from the lower Albian of Lashe, the zone of *Leymeriella tardefurcata*, western Georgia (Caucasus region). The new material extends the range into the upper Albian.

Material: Recovered from the middle Albian Del Norte Formation (A42, A44, A49) and the Upper Albian Muleros Formation (A18). Not recovered from the intervening Smeltertown Formation.

Family: Parasmiliidae Alloiteau 1952

Genus: *Diegosmilia* Alloiteau 1958

Diegosmilia complanata (Collignon, 1931)

Figs. 11E, F, G

Microseris complanata Collignon, 1931, p. 48, pl. 5(1), Figs. 4-5.

Diegosmilia complanata (Collignon): Alloiteau, 1958, p. 153-154, text-fig. 25; Besairie and Collignon, 1959, p. 139; Turnšek and LeMone, 1981, p. 14; Turnšek et al., 1984, p. 475; Löser, 2000, p. 28; Baron-Szabo, 2000, p. 126, pl. 12, Fig. 1.

Description: Only a fragment of the corallum has been preserved, from which a thin section has been made. The shape of the corallum is, therefore, indeterminate. The structures of all elements in thin section are the same as in specimens described by Alloiteau (1958). The 48 septa are arranged in two orders of twelve and a third order of twenty-four.

Dimensions: **d** = 8 x 9 mm; **s** = 48. The corallite diameter of the type material, in which the wall is almost completely missing, is about 11–12 mm (Baron-Szabo, 2001, personal communication). The corallum diameter of the Cerro Cristo Rey specimen is slightly smaller than that of the Maastrichtian specimens in Oman, which have a more complete exterior wall preserved than our material.

Distribution: Recorded from the Cenomanian of Madagascar and the Maastrichtian of the United Arab Emirates-Oman area. The new material extends the range into the upper Albian.

Material: Recovered from the upper part of the late Albian Mesilla Valley Shale (A95) at Cerro de Cristo Rey, Doña Ana County, New Mexico.

Genus: *Conicosmilotrochus* Turnšek, 1978

Conicosmilotrochus mulerosensis n. sp.

Figs. 11H, I, J, K, L

Conicosmilotrochus n. sp., Turnšek *et al.*, 1984, p. 475.

Name: Named for the old designation for the Cristo de Rey, Cerro de Muleros (Mount of the Mule Skinners).

Holotype: Sample A114 with one thin section.

Type stratum: Upper Albian Mesilla Valley Shale.

Material: Holotype A114, and samples A97, A115, A116.

Diagnosis: A species of *Conicosmilotrochus* which has a very slightly oval calyx; septa have thick lateral thorny granulae.

Dimensions: **d** = 6–6.5 x 6–7.5 mm; **h** = 15 mm; **s** = 44–48.

Description: The corallum is ceratoid, has a slightly oval to almost round calyx, and a narrow base. The septa are developed in four cycles, which gradually become shorter and thinner. The septa of the first two cycles become thicker in the axial area. The septa have lateral thorny granulae; no other endotheca is developed. The wall is septothecal. Columella and pali are absent. The poorly preserved microstructure is of mini-trabeculae with midseptal lines.

Comparison: This new species is most similar to *Conicosmilotrochus dentatus* (Turnšek 1978, 1997), but the new species differs by having a more circular and smaller corallum (in *C. dentatus*, **d** = 7–9 x 10–13; **h** = 20–22 mm).

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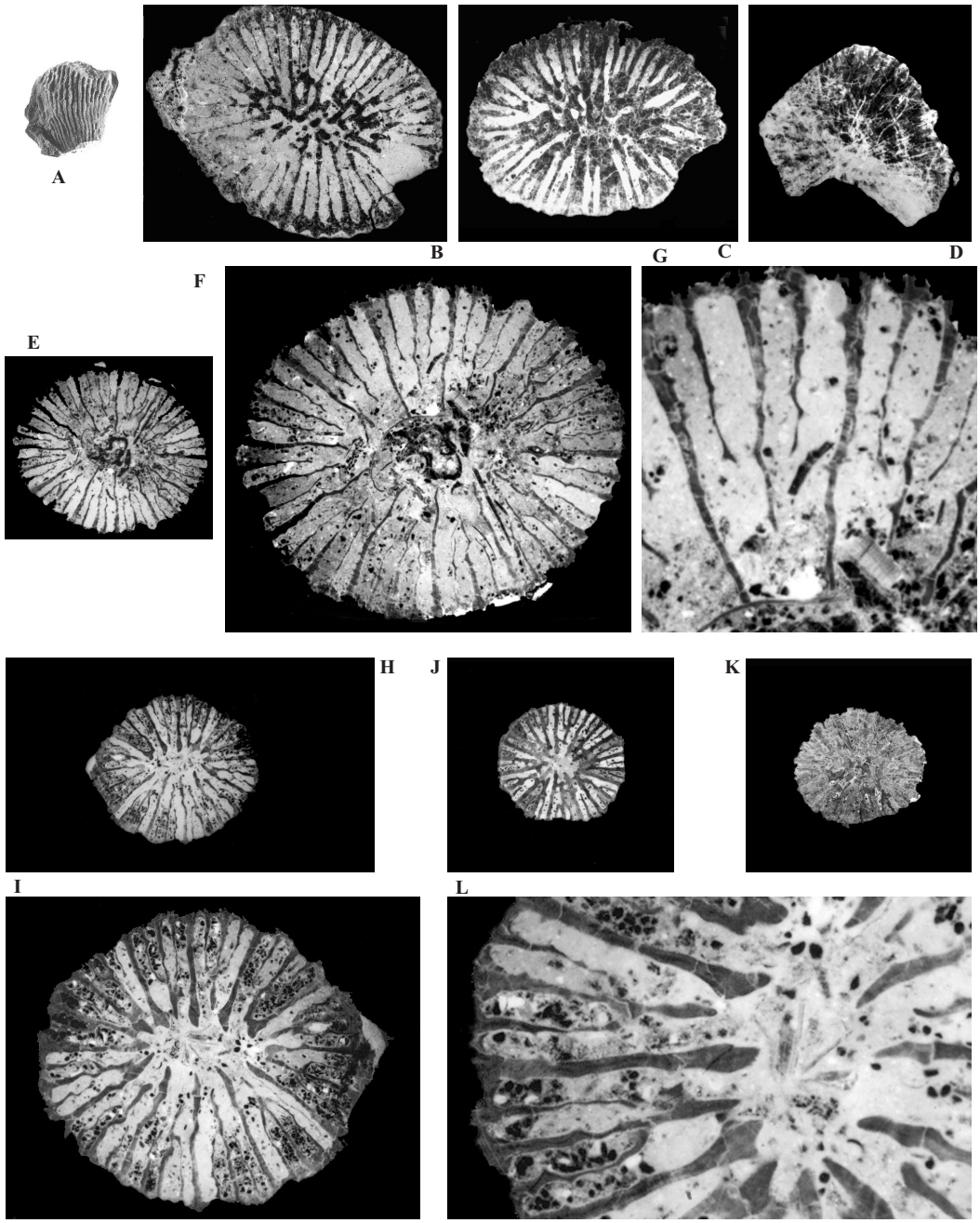

Figure 11. A, B, C, D: *Platytrochopsis lashensis* Sikharulidze, 1975; A: the surface of the corallum, A49, x1; B, C, D: transverse thin sections from near calyx to near apex, A44a, b, c, x4; Del Norte Formation, Upper Albian; E, F, G: *Diegosmilia complanata* (Collignon, 1931); E: transverse thin section, A95a, x4; F: the same as Fig. 11E, x8; G: detail from Fig. 11E, x20; Mesilla Valley Shale, upper Albian; H, I, J, K, L: *Conicosmilotrochus mulerosensis* n. sp.; H: transverse thin section of holotype, A114a, x4; I: the same as Fig. 11H, x8; J, K: thin sections from near calyx to near apex, A116ab, x4; L: detail from Fig. 11H, x20; Mesilla Valley Shale, upper Albian.

Suborder: Fungiina Verrill, 1865
Family: Actinacididae Vaughan and Wells, 1943

Genus: *Actinaraea* d'Orbigny 1849
Actinaraea tenuis Morycowa, 1971
Figs. 12A, B

Actinaraea tenuis. Morycowa, 1971, p. 128-129, pl. 35, Fig. l, pl. 36, Fig. 1, text-fig. 37; Kusmicheva, 1980, p. 106-107, pl. 39, Figs. 4ab; Turnšek and Mihajlovic, 1981, pl. 45, Figs. 1-4; Turnšek and LeMone, 1981, p. 14; Scott, 1984, p. 344, pl. 2, Figs. 12-13; Turnšek et al., 1984, p. 475; 1992, p. 217-218, pl. 5, Figs. 7-8; Sikharulidze, 1985, p. 61-62, pl. 28, Figs. 1a, b; Kuzmicheva and Aliev, 1988, p. 175-176, pl. 8, Figs. 2a, b; Bugrova, 1989, p. 28-29, pl. 4, Figs. 1a, b.; Czászár and Turnšek, 1996, p. 434, Fig. 7/6; Baron-Szabo, 1997, p. 79, pl. 12, Figs. 1-2; Löser, 1998b, p. 178; 2000, p. 6.

Description: Morycowa (1971) provides a modern description.

Dimensions: Colony = 21 x 20 x 20 mm; **c–c** = 4–5 mm; **s** = 24–34 (8–10/2 mm).

Comparison: The examined part of the colony has the same structures as the types but differs in that the distance between the corallites is smaller (d = 1.5 mm compared to Morycowa's specimens, in which d = 3–5 mm)

Distribution: Recorded from numerous Lower to Upper Cretaceous localities in the Tethys: the Berriasian of Georgia (Caucasus region); the Barremian-Aptian of Turkestan, Azerbaidjan, Ukraine, East Serbia, Romania, Slovenia, Hungary, and Germany; the Albian of Texas; the Cenomanian of Germany; and the Turonian Allgäuer Schrattenkalk of Brandenberger Gosau, Austria.

Material: Recovered from the upper Albian Smeltertown Formation (Sample A53) at Cristo Rey, Doña Ana County, New Mexico.

Suborder: Microsolenina Morycowa and Roniewicz, 1995
Family: Microsolenidae Koby, 1890

Genus: *Microsolena* Lamouroux, 1821
Microsolena distefanoi (Prever, 1909)
Figs. 12C, D, E, F

Microsaraea distefanoi. Prever, 1909, p. 71, pl. 2, Figs. 6-6a.

Microsolena distefanoi. Morycowa, 1964, p. 86-87, pl. 25, Fig. 2, pl. 26, Figs. 1-2; Turnšek and Buser, 1974, p. 101-102, pl. 11, Fig. 2; 1976, p. 59, pl. 17, Figs. 1-2; Kuzmicheva, 1980, p. 103, pl. 38, Figs. 1ab; Turnšek and LeMone, 1981, p. 14; Scott, 1984, p. 342, pl. 2, Figs. 9-10; Kuzmicheva and Aliev, 1988, p. 171-172, pl. 6, Figs. 3ab; Turnšek et al., 1984, p. 475; 1992, p. 217, pl. 6, Figs. 4-6; Löser, 2000, p. 52; Löser and Raeder, 1995, p. 52; Császár and Turnšek, 1996, p. 434, pl. 8, Fig. 11; Baron-Szabo and Steuber, 1996, p. 24, pl. 14, Fig. 6; Baron-Szabo, 1997, p. 82-83, pl. 13, Fig. 5; Turnšek, 1997, p. 128, Figs. 128a-g; Baron-Szabo and González-León, 1999, p. 486-487, Fig. 5f.

Description: Morycowa (1964) provides a modern description. The examined specimens are encrusting fragments of colonies.

Dimensions: Colony 3–20 mm thick; **c–c** = 4–6 mm; **s** = 36–48, 7–11 septa/2mm.

Comparison: Wells's (1932, p. 252) species of *Microsolena texana* is similar to *M. distefanoi* differing only by its greater calycal diameter and more numerous septa. In Well's material the distance between corallites ranges from 9 to 12 mm and averages 7.5 mm, and each corallite has from 40 to 50 septa. Morycowa's (1964) material from the Cenomanian of Poland is somewhat smaller, the distance between corallites ranging from 3.5 to 8.0 mm, the number of septa from 30 to 42, and the density of septa from 6–8 per 2 mm. The species *Microsolena guttata* Koby has more regularly porous septa.

Distribution: The species in known from the Lower Cretaceous and Cenomanian of the whole Tethys. *M. texana* is known from the lower Glen Rose Formation (lower Albian) of Blanco, Hays and Comal Counties, Texas (60 m above the base of the Glen Rose).

Material: Recovered from the Smeltertown Formation (early late Albian) (Samples A58, A59, A60, A62, A63, A73, A76, A77) at Cerro de Cristo Rey, Doña Ana County, New Mexico.

Genus: Dimorpharaea Fromentel, 1861

Dimorpharaea manchacaensis Wells, 1933

Fig. 12G

Dimorpharaea manchacaensis Wells, 1933, p. 118-119, pl. 11, Figs. 5-9; Turnšek and LeMone, 1981, p. 14; Turnšek *et al.*, 1984, p. 475; Löser, 1994, p. 46; 2000, p. 29; Löser and Raeder, 1995, p. 51-52; Schöllhorn, 1998, p. 99.

Description: Morphology is similar to that described by Wells (1933). The microstructure consists of medium-sized trabeculae.

Dimensions: Colony = ca. 25 x 25 x 20 mm; **c–c** in series = 4–5 mm; **c–c** of rows = 4–6 mm; **s** = 22–30; density of septa = 4–5/2mm.

Comparison: The corallites of the examined specimen are among the smallest of this species. Wells (1933) has reported **c–c** 6–8 mm, and Löser and Raeder (1995) report **c–c** 5–9 mm. The density of septa is the same in all known representatives of the species (4–5 / 2mm). The species *Dimorpharaea deikei* Bölsche, (see Löser 1994, p. 47-49) has only somewhat smaller corallites (**c–c** = 2–5 mm), but the density of septa is considerably greater (8/2mm).

Distribution: Recorded from the lower beds of the Buda Limestone in the first creek of Manchaca, Travis County, Texas (lower Cenomanian). The new material extends the range into the upper Albian.

Material: Recovered from the upper Albian Smeltertown Formation (Samples A75, A78) at Cerro de Cristo Rey, Doña Ana County, New Mexico.

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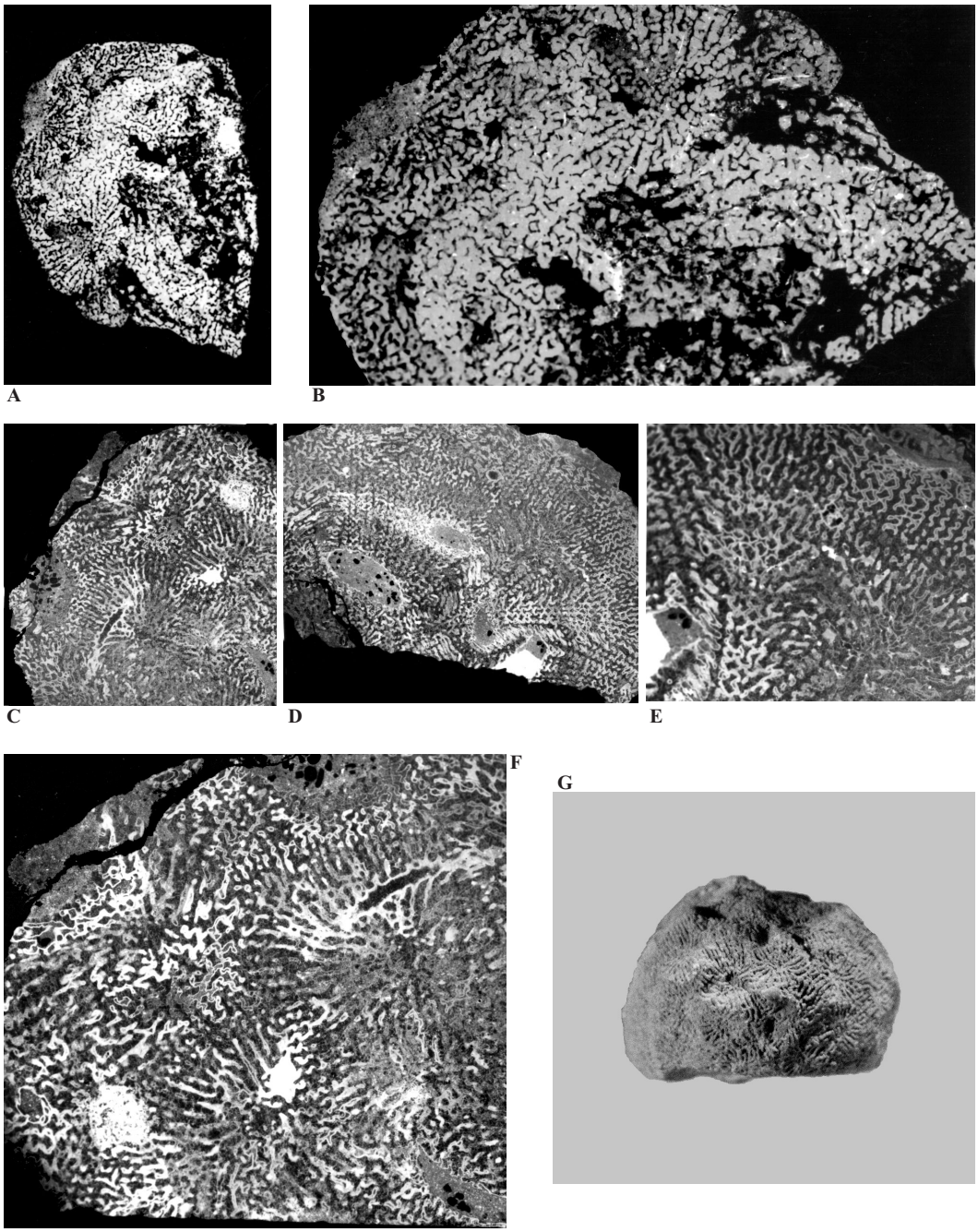

Figure 12. A, B: *Actinaraea tenuis* Morycowa, 1971; A: transverse thin section of the colony, A53a, x4; B: a part of Fig. 12A, x8; Smeltertown Formation, Upper Albian; C, D, E, F: *Microsolena distefanoi* (Prever, 1909); C: transverse thin section, A59a, x4; D: longitudinal thin section, A59b, x4; E: detail from Fig. 12D, x8; F: detail from Fig. 12C, x8; Smeltertown Formation, upper Albian; G: *Dimorpharaea manchacaensis* Wells, 1933; exterior surface of the colony, A78, x4; Smeltertown Formation, upper Albian.

Acknowledgments

We are grateful for the careful and constructive reviews by Dr. Rosemarie Baron-Szabo and Dr. Hannes Löser. The Slovenian Academy of Sciences and Arts has provided financial support of the coral study by the senior author, who appreciates the technical help of her colleagues from the Ivan Rakovec Institute of Paleontology ZRC SAZU.

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