

The Cretaceous corals of Mexico: occurrences and history of research

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ABSTRACT

An extensive, detailed compilation of the known occurrences and described species of Cretaceous scleractinian corals in the country of Mexico, based almost entirely on published scientific literature, is presented for the first time. Cretaceous corals have been reported from more than 170 localities in more than 200 published studies dating from at least as early as 1839. Unfortunately, relatively few of these 200 publications actually described coral species: the entire research history on Mexican Cretaceous coral systematic paleontology is contained in only 16 studies. A total of 116 coral species have been described from these occurrences, inclusive of unnamed coral species and with previously suggested synonymies taken into consideration. Overall the coral occurrences span nearly the entire Cretaceous Period, from the Berriasian through the Maastrichtian, but at least 60 percent of them are from the Early Cretaceous. Furthermore, the vast majority (about 90 percent) of the total number of Mexican Cretaceous coral species are known from the Early Cretaceous. Based on these data, it seems likely that many of the Cretaceous corals of Mexico are still unknown. The detailed review of the literature on Mexican Cretaceous corals presented in this study establishes a modern foundation for future investigations of the paleobiogeography and systematic paleontology of the members of this significant group of reef-building organisms.

Key words: corals, Cretaceous, Mexico, research history.

RESUMEN

Con base en la revisión de literatura científica, se presenta por primera ocasión una compilación extensiva de la ocurrencia de especies descritas de corales escleractinios del Cretácico de México. A partir de 1839, más de 200 publicaciones reportan corales del Cretácico para más de 170 localidades. Desafortunadamente, muy pocas de estas 200 investigaciones publican descripciones de especies de corales: la historia de la investigación acerca de corales fósiles de México está contenida en tan solo 16 artículos. Un total de 116 especies han sido descritas en estos trabajos, incluyendo especies que no fueron determinadas y especies con sinónimos previamente descritas. Los reportes de estos corales fósiles abarcan prácticamente todo el Periodo Cretácico, del Berriasiano al Maastrichtiano. De estos reportes, el 60 % corresponde al Cretácico Inferior. En relación a las especies formalmente descritas, el 90 % fueron reportadas para el Cretácico Inferior. Con base en estos datos, es muy probable que existan especies cretácicas aún sin describir. Este informe establece la base para futuras investigaciones sobre la paleontología sistemática y paleobiogeografía de los miembros de este importante grupo de constructores de arrecife.

Palabras clave: Corales, Cretácico, México, revisión histórica.

INTRODUCTION

The earliest reported discovery of Cretaceous corals in Mexico was made more than 160 years ago. Since that time, many studies have noted occurrences of fossil corals in the Cretaceous System of Mexico, but relatively few of these works actually provided detailed taxonomic descriptions of the coral species. Furthermore, despite the numerous studies of many other Cretaceous invertebrate groups over the past century and a half, the corals of the entire Mexican Cretaceous System were rarely studied and they remain largely unknown. Therefore, the ultimate purpose of this report is to provide a detailed review of literature and previously described coral species that will serve as a modern foundation for future work on the Cretaceous corals of Mexico.

The Cretaceous corals of Mexico are important with regard to studies of global paleoceanographic and paleobiogeographic conditions because most of continental Mexico was centrally positioned in the path of western Tethyan surface currents through the tropics during most if not all of the Cretaceous. Therefore, when utilized as a proxy for paleoecologic conditions and paleoceanographic surface currents, the biogeographic distributions of Cretaceous coral species from Mexico and adjacent regions are key indicators of Tethyan surface current flow patterns between the European realm, the equatorial Caribbean realm and the ancestral Pacific realm during Cretaceous time. Regional and global comparisons of coral species identified from these regions also will help facilitate reconstructions of their paleobiogeographic histories and evolution. However, due to a general lack of knowledge about the distribution and taxonomy of Mexican Cretaceous corals and coral reefs, the potential significance and implications of these organisms have yet to be realized fully. Ideally, the information presented in this report will help to further work on the Cretaceous corals of the New World.

The objectives of this study are: to review the published literature concerning the Cretaceous scleractinian corals of Mexico; to state the locations and ages of Cretaceous coral occurrences reported in this literature; to compile a list of coral species that have been described from Cretaceous occurrences in Mexico; and, if known, to list the institution in which each of the collections of studied coral specimens is deposited. This information will be of great significance in future studies of Cretaceous paleoecology, paleobiogeography and paleoceanography, both regionally within North America and globally. Furthermore, for completeness and to provide taxonomic documentation, the references for the original authors of all coral species listed herein have been included in the bibliographic references.

Over the past century the knowledge on the taxonomic diversity of Mexican Cretaceous corals has increased gradually, but the additions have been sporadic

(see Table 1) and many discovered faunas remain to be described. The fauna of 34 coral species described more than a century ago from the Lower Cretaceous of southeastern Mexico (Felix, 1891) is still the most diverse occurrence of corals known from that region. This seems unusual because a few studies which concentrated solely on Cretaceous corals have subsequently been made in that same region of Mexico. Corals frequently are abundant and often diverse whenever they occur, but the skeletal features necessary for accurate taxonomy, even at the family and genus level, typically are poorly preserved or entirely obliterated by recrystallization. The unfortunate mineralogic instability of the aragonitic scleractinian skeleton has no doubt been one of the major hindrances to the development of knowledge about the fossil record of this fascinating group of marine animals.

Despite the importance of these Cretaceous coral faunas, there have been relatively few reviews of the occurrences or coral species that are known from Mexico. Compilations or reviews of Cretaceous Mexican coral occurrences, either fairly complete or regionally specific in scope, were included in articles by Aguilera (1897b, 1906, 1907), Freudenberg (1921), Burckhardt (1930), Wells (1933), Müllerried (1933b, 1934, 1941, 1942a), Schuchert (1935), Imlay (1944a, 1944b), Maldonado-Koerdell (1950, 1953), Chubb (1959), and Barceló-Duarte (1978). Some of the occurrence information presented in this report was derived from these sources.

The previous studies of Cretaceous corals in Mexico are reviewed in the following discussion. The discussion encompasses works that include taxonomic treatments of Cretaceous corals as well as other works that contain relevant information on the occurrences and the stratigraphic and geographic distributions of Cretaceous corals in Mexico. These studies are presented in chronologic order based on year of publication, with some exceptions, through the 1980s. The discussion for the studies published during the 1990s and later is arranged by geographic region in order to provide a more cohesive review of numerous coral occurrences that otherwise would have been difficult to synthesize. The coral species from Mexico that are described in the articles cited below are listed in Table 1. Although the literature cited may seem extensive, it probably is not exhaustive and undoubtedly many Cretaceous coral occurrences may have been missed. Nonetheless, the following review of the literature certainly presents the essential work on Mexican Cretaceous coral taxonomy along with much of the necessary occurrence information that is required for future investigations of this subject. The positions of many of the Cretaceous coral occurrences discussed in this report are plotted on the map shown in Figure 1.

Any omissions are solely the responsibility of the author. Comments, additions and corrections pertaining to the subject of this report are welcomed and

Table 1. List of the coral species described from the Cretaceous of Mexico. The author of each study, the formation name and age of each occurrence if known, the Mexican state, and the coral species described are listed in chronologic order based on year of publication. Refer to the text for discussion.

Author	Formation/Age	State	Described species
Conrad (1857)	Lower Cretaceous	Chihuahua	<i>Turbinolia texana</i> Conrad, 1857
Urquiza (1883)	Probably middle Cretaceous	Michoacán	<i>Trochoseris sinuosa</i> Fromentel, 1857 <i>Thamnastraea pediculata</i> Fromentel, 1857
Felix (1891)	Probably Zapotitlán Fm.; Barremian - Aptian	Puebla	<i>Porites</i> sp. <i>Thamnaraea holmoides</i> Felix, 1891 <i>Polyphyloseris polymorpha</i> Felix, 1891 <i>Thamnastraea xipei</i> Felix, 1891 <i>Thamnastraea barcenai</i> Felix, 1891 <i>Thamnastraea</i> cf. <i>T. stricta</i> Fromentel, 1857 <i>Thamnastraea tenochi</i> Felix, 1891 <i>Thamnastraea crespoides</i> Felix, 1891 <i>Mastophyllia conophora</i> Felix, 1891 <i>Latimaeandra steini</i> Felix, 1891 <i>Latimaeandra sauteri</i> Felix, 1891 <i>Latimaeandra montezumae</i> Felix, 1891 <i>Latimaeandra tulae</i> Felix, 1891 <i>Latimaeandra</i> (?) sp. <i>Cyathoseris petalophyes</i> Felix, 1891 <i>Siderofungia zitteli</i> Felix, 1891 <i>Siderofungia irregularis</i> Felix, 1891 <i>Thamnoseres arborescens</i> Felix, 1891 <i>Calamophyllia sandbergeri</i> Felix, 1891 <i>Cladophyllia miroi</i> Felix, 1891 <i>Hydnophyllia wollheimi</i> Felix, 1891 <i>Cryptocoenia neocomiensis</i> d'Orbigny, 1850a <i>Cryptocoenia micrommatos</i> Felix, 1891 <i>Cyathophora atempa</i> Felix, 1891 <i>Phyllocoenia cyclops</i> Felix, 1891 <i>Phyllocoenia nannodes</i> Felix, 1891 <i>Astrocoenia globosa</i> (Fromentel, 1887) <i>Latusastraea</i> cf. <i>L. polygonalis</i> (Fromentel, 1862) <i>Latusastraea provincialis</i> (d'Orbigny, 1850a) <i>Eugyra neocomiensis</i> Fromentel, 1857 <i>Eugyra cotteaudi</i> Fromentel, 1857 <i>Dendrogyra mariscali</i> Felix, 1891 <i>Stylophora tehuacanensis</i> Felix, 1891 <i>Prohelia anomalos</i> Felix, 1891
Gregory (1899)	From a Neocomian limestone	San Luis Potosí	<i>Stylina collinsi</i> Gregory, 1899
Aguilera, in Böse (1910)	Lower Cretaceous	Chihuahua	<i>Trochosmia</i> (<i>Coelosmia</i>) <i>texana</i> (Conrad, 1857) <i>Trochosmia</i> (<i>Coelosmia</i>) <i>chihuahuensis</i> Aguilera, in Böse, 1910 <i>Placosmia bravoensis</i> Aguilera, in Böse, 1910 <i>Placosmia mexicana</i> Aguilera, in Böse, 1910
Wells (1933)	From an Aptian limestone	Durango	<i>Orbicella whitneyi</i> Wells, 1932, n. var.
Imlay (1940)	Carbonera Fm.; Valanginian	Durango	<i>Astrocoenia hispaniensis</i> Imlay, 1940

Table 1. Continued.

Author	Formation/Age	State	Described species
Wells (1946)	Several units; Lower Cretaceous	Durango, Sonora, Coahuila (see text for details)	<i>Stephanocoenia guadalupae minor</i> Wells, 1946 <i>Isastrea whitneyi</i> Wells, 1932 <i>Montlivaltia coahuilensis</i> Wells, 1946 <i>Montlivaltia burckhardtii</i> Wells, 1946 <i>Placocoenia</i> n. sp. Wells, 1946 <i>Axosmilia mexicana</i> Wells, 1946
Maldonado-Koerdell (1950)	Upper Campanian strata	Chiapas	<i>Trochocyathus</i> cf. <i>T. woolmani</i> Vaughan, 1900 <i>Trochosmilia</i> sp.
Reyerros-Navarro (1963)	San Juan Raya Fm.; Aptian	Puebla	<i>Thamnasteria crespoidi</i> (Felix, 1891) <i>Thamnasteria decipiens</i> (Michelin, 1845) <i>Thamnasteria felixi</i> Reyeros-Navarro, 1963 <i>Procyathophora aguilerai</i> Reyeros-Navarro, 1963 <i>Procyathophora poblana</i> Reyeros-Navarro, 1963 <i>Cyathophora atempa</i> Felix, 1891 <i>Stylina vaughani</i> Reyeros-Navarro, 1963 <i>Baryphyllia confusa</i> (d'Orbigny, 1850b) <i>Felixastraea mexicana</i> Reyeros Navarro, 1963 <i>Polyphylloseris conophora</i> (Felix, 1891) <i>Complexastrea cyclops</i> (Felix, 1891) <i>Plesiastrea sulcatilamellosa</i> (Michelin, 1841)
Myers (1968)	Cárdenas Fm.; Maastrichtian	San Luis Potosí	<i>Epistreptophyllum</i> sp. <i>Trochoseris</i> sp. <i>Synastrea</i> sp. <i>Leptoria</i> sp. <i>Cladocora</i> sp. <i>Lithostrotionoides</i> sp.
Wolleben (1977)	Tanque Fm.; Upper Cretaceous	Coahuila	<i>Trochocyathus gardnerae</i> Wells, 1933
Reyerros de Castillo (1983)	Several units; Lower and middle Cretaceous	Oaxaca	<i>Actinastrea</i> cf. <i>A. decaphylla madagascariensis</i> Alloiteau, 1958 <i>Thamnastraea xipei</i> (Felix, 1891) <i>Thamnastraea crespoidi</i> (Felix, 1891) <i>Cyathophora haysensis</i> Wells, 1932 <i>Stylosmilia gregorii</i> Wells, 1944 <i>Stylina sucrensis</i> Wells, 1944 <i>Stylina tehuacanensis</i> (Felix, 1891) <i>Myriophyllia neocomiensis</i> (Fromentel, 1857) <i>Calamophyllia sandbergeri</i> Felix, 1891 <i>Baryphyllia confusa</i> (d'Orbigny, 1850b) <i>Periseris irregularis</i> (Felix, 1891) <i>Brachyseris morchella</i> (Reuss, 1854) <i>Meandrophyllia montezumae</i> (Felix, 1891) <i>Thecosmilia tobleri</i> Koby, 1897 <i>Thecosmilia oaxaquensis</i> Reyeros de Castillo, 1983 <i>Elasmophyllia tolmachoffana</i> (Wells, 1932) <i>Cladophyllia stewartae</i> Wells, 1944 <i>Plesiastrea sulcatilamellosa</i> (Michelin, 1841) <i>Diploastrea harrisi</i> Wells, 1932
Waite (1986)	Sierra Madre Limestone; middle to Upper Cretaceous	Chiapas	<i>Hydnophora</i> sp. <i>Multicolumnastraea</i> sp.

Table 1. Continued.

Author	Formation/Age	State	Described species
			<i>Astreopora?</i> sp. <i>Cyathophora</i> sp.
Scott and González-León (1991)	Espinazo del Diablo Fm.; middle Albian	Sonora	<i>Stylosmilia</i> sp. <i>Thamnasteria</i> sp. <i>Cladophyllia furcifera</i> Roemer, 1888 <i>Columnocoenia ksiazkiewiczzi</i> Morycowa, 1964
Baron-Szabo and González-León (1999)	Cerro del Oro, Espinazo del Diablo, and Nogal fms., upper Barremian to middle Albian	Sonora	<i>Columnactinastraea</i> sp. <i>Myriophyllia propria</i> Sikharulidze, 1979 <i>Pseudomyriophyllia turnsekae</i> Baron-Szabo and Steuber, 1996 <i>Felixigyra patruliusi patruliusi</i> Morycowa, 1971 <i>Dermosmilia cretacica</i> Turnšek and Buser, 1974 <i>Thecosmilia bassanii</i> Prever, 1909 <i>Columnastrea paucipaliformis</i> Baron-Szabo and González, 1999 <i>Columnocoenia bucovinensis</i> Morycowa, 1971 <i>Columnocoenia ksiazkiewiczzi</i> Morycowa, 1964 <i>Columnocoenia minima</i> Baron-Szabo and González-León, 1999 <i>Placophyllia bandeli</i> Baron-Szabo, 1998 <i>Isastraea</i> cf. <i>I. neocomiensis</i> Fromentel, 1857 <i>Heliocoenia rarauensis</i> Morycowa, 1971 <i>Cladophyllia mexicana</i> Baron-Szabo and González-León, 1999 <i>Pentacoenia pulchella</i> d'Orbigny, 1850a <i>Cyathophora miyakoensis</i> (Eguchi, 1936) <i>Cyathophora haysensis</i> Wells, 1932 <i>Pleurostylina major</i> Baron-Szabo and González-León, 1999 <i>Amphiastraea aethiopica</i> Dietrich, 1926 <i>Keriophyllia roniewiczzae</i> Baron-Szabo and González-León, 1999 <i>Pleurophyllia</i> aff. <i>P. trichotoma</i> Fromentel, 1856 <i>Latusastrea provincialis</i> (d'Orbigny, 1850b) <i>Thecidiosmilia morycowae</i> Kołodziej, 1995 <i>Preverastraea paronai</i> (Prever, 1909) <i>Stiboriopsis sonoraensis</i> Baron-Szabo and González-León, 1999 <i>Meandrophyllia</i> cf. <i>M. lotharinga</i> (Michelin, 1843) <i>Polyastropsis arnaudi</i> Alloiteau, 1957 <i>Microsolena distefanoi</i> (Prever, 1909) <i>Microsolena kobyi</i> Prever, 1909 <i>Meandraraea meandroides</i> Koby, 1898 <i>Mycetaraea</i> aff. <i>M. dimorpha</i> (Bölsche, 1867 [sic, 1866]) <i>Dermoseris</i> sp. <i>Fungiastraea crespoides</i> (Felix, 1891) <i>Latiastrea mucronata</i> Sikharulidze, 1979 <i>Synastraea decipiens</i> (Michelin, 1845) <i>Mixastraea westfalica</i> Löser, 1993



Figure 1. Outline map of Mexico showing locations of most of the main Cretaceous coral occurrences discussed in the text. Hue. = Huetamo. Positions of Mexico City (star), Puerto Vallarta and Acapulco shown for points of reference.

appreciated by the author. The majority of this report is from the section on previous studies in the author's dissertation (Filkorn, 2001).

CRETACEOUS CORAL OCCURRENCES AND HISTORY OF RESEARCH

Explorations during the 1800s: the early discoveries

One of the earliest mentions of Cretaceous corals in Mexico was reported from the vicinity of Jalapa (Xalapa), State of Veracruz, in 1839; this notice also included the first recognized occurrence of Cretaceous limestone in Mexico (Galeotti, 1839). The corals of this area have never been described. The following year, fossil bivalves, echinoderms and accumulations of corals were reported from a locality to the south-southwest of Jalapa, in the vicinity of Tehuacán, State of Puebla (Nyst and Galeotti, 1840, p. 220). The age of this fauna initially was regarded as Jurassic, but later it was determined to be Cretaceous, probably Aptian (Cotteau, 1890).

Probably the earliest description of a Cretaceous coral from Mexico was made in the Report on the United States and Mexican Boundary Survey published in 1857. Only one solitary coral species collected from a

locality between El Paso [now Ciudad Juárez], State of Chihuahua, and Frontera was described in that report: *Turbinolia texana* Conrad, 1857 (p. 144, pl. 2, fig. 3a, b). The type specimen is at the United States National Museum (Wells, 1933, p. 136). This same coral species was later reported from a locality called "Cerro de las Conchas" in the Cretaceous rocks east of Arivechi, State of Sonora (Gabb, 1864, p. 154; Rémond, 1866, p. 252; Gabb, 1869, p. 276; Heilprin, 1891, p. 451). Another coral species, reported only as a "favositiform coral" and not described, was collected from the Cretaceous rocks at Nugal, in the neighboring State of Chihuahua (Gabb, 1872, p. 263).

The first Cretaceous coral species reported from the State of Michoacán were discovered in the western part of the state during explorations in the district of Coalcomán (Urquiza, 1883, p. 41-42, figs. 20-23). The two species described and illustrated in that early report were referred to species that were originally described from Europe, *Trochoseris sinuosa* and *Thamnastrea pediculata* Fromentel, 1857 (p. 20, pl. 1, figs. 11, 12, and p. 61, pl. 9, figs. 6, 7, respectively). A few years later, in a review of the geology and paleontology of the Cretaceous deposits of Mexico, both of these taxonomic determinations were considered to be erroneous (Heilprin, 1891, p. 460; also see Aguilera, 1897b, p. 214). No additional occurrences of these two coral species have

been reported in any subsequent studies of Mexican Cretaceous corals.

The species of a diverse Cretaceous (Neocomian) invertebrate fauna discovered near Tehuacán, State of Puebla, were listed (Felix and Lenk, 1891a, p. 123) in a summary report on the geology of Puebla in 1891. The descriptions of these species were published in the succeeding article in the same journal volume (Felix, 1891). The latter study, "Versteinerungen aus der mexicanischen Jura- und Kreide-Formation" by Johannes Felix, included the first substantial taxonomic treatment of Mexican Cretaceous corals: 34 coral species were described, including 25 that were designated new species (Felix, 1891, p. 142-162, pls. 22-25). Felix's (1891) coral specimens reportedly are in the Johannes Felix Collection (Perrilliat, 1989) at the University in Leipzig, Germany, but the collection is not accessible (H. Löser, personal commun., 1997). The coral species described by Felix (1891) are listed in Table 1. Locality information was not given with the species descriptions because the precise geographic position of the coral locality and a brief description of the geology at that site were provided in the preceding report (Felix and Lenk, 1891a, p. 123), including: "Die Barranca, welche von Ayucingo gegen San Antonio de las Salinas hinabzieht, erschliesst einen mehrfachen Wechsel jener Kalkbänke mit leicht verwitternden, braunen Mergelschichten, welche eine ausserordentlich reiche Fauna enthalten." None of this information was repeated in the later article that contained the species descriptions (see Felix, 1891, p. 142, footnote 1). The place called Ayucingo in the above locality description no longer is identified on modern topographic maps, but its position is shown on some of the earlier maps of that area (for examples, see Aguilera, 1906: Rancho Ayutzingo; Burckhardt, 1930, p. 158; Calderón-García, 1956, fig. 7: Agua Ayucingo). In addition, the unnamed ravine that was referred to in that same quote now bears the name Barranca Ayucingo, and the village that they called San Antonio de las Salinas appears to be now known as San Antonio Texcala. The articles by Felix and Lenk (1891a) and Felix (1891), which were originally published in the journal *Palaeontographica* (volume 37, part 5-6), also were subsequently issued as volume 3 of Felix and Lenk's (1889-1899) comprehensive work entitled "Beiträge zur Geologie und Paläontologie der Republik Mexico" (see Felix and Lenk, 1891b). In addition, the coral species described earlier by Felix (1891) were listed in an article on the development of the geologic formations of Mexico that appeared in volume 2 of that same work (Felix, 1899, p. 169). Based on similarities in the invertebrate faunas and their relative stratigraphic position, R. T. Hill, the pre-eminent pioneer geologist of Texas, correlated Felix's (1891) coral-bearing beds with the Glen Rose beds of the Trinity of Texas (Hill, 1893, p. 311).

Karl (Carlos) T. Sapper, the most scientifically prolific early explorer of Central America (Termer, 1956; Maldonado-Koerdell, 1958), reported the

occurrences of Upper Cretaceous corals at several localities in the State of Chiapas in 1894 and listed five coral taxa from near Tuxtla Gutiérrez: *Heliopora*, *Leptophyllia*, *Goniastraea*, *Stylina*, and *Cryptocoenia* (Sapper, 1894, p. 203-204). These data were reiterated in several subsequent papers (Sapper, 1896a, p. 6; 1896b, p. 941-942; 1899, p. 12; Schuchert, 1935, p. 328; Sapper, 1937, p. 30; Maldonado-Koerdell, 1950, p. 181; Chubb, 1959, p. 753), but none of the species was ever described. Additional reports of these corals from the State of Chiapas were not found and it seems that the coral faunas of this area have not been studied.

In an early outline of the geology of Mexico, José G. Aguilera (1897a, p. 85, 87) noted the occurrence of abundant Cretaceous corals near Zapotitlán, State of Puebla, and listed two species that were described previously by Felix (1891), *Cyathophora atempa* and *Dendrogyra mariscali*. Additionally, in a synopsis of the geology of Mexico that was published as the second part of the work cited above, Aguilera (1897b) reported a Cretaceous species of *Montlivautia* [sic] (p. 199) and listed (p. 214-215) the coral species that were described previously by Conrad (1857), Urquiza (1883), and Felix (1891). Two other coral species, *Heliastrea* sp. and *Smilotrochus* sp.?, also were included in the list, but they were not described and the source of the information was not cited (Aguilera, 1897b, p. 215).

Georg Boehm (1898, p. 325; 1899, p. 147) mentioned the occurrence of Cretaceous corals in the limestone of Cerro Escamela, near Orizaba, State of Veracruz, but his work primarily dealt with the rudist bivalves and the corals were not described. The Cretaceous coral fauna of Cerro Escamela remains unknown.

Late in the 1800s, J. W. Gregory described half of a colonial coral specimen from Neocomian age limestone in the vicinity of a mine at La Trinidad, four miles from Guadalcázar, State of San Luis Potosí, as a new species: *Stylina collinsi* Gregory, 1899 (p. 460-461, fig. 3). The type specimen was collected by H. F. Collins and presented to the British Museum of Natural History. Gregory noted that Felix (1891) had not reported members of this genus from the Neocomian of Puebla, and he also mentioned that a species of *Cryptocoenia* described in that same study probably should be reassigned to *Cyathophora*. During that same year, Sapper (1899, p. 11-14, 22, 66) noted several occurrences of Cretaceous corals in the State of Chiapas, including those that he reported earlier (p. 12; discussed above).

Geologic investigations from 1900 to 1950

The first half of the twentieth century was a period of expanding investigations for reconnaissance geologic mapping and the initial stages of petroleum exploration. Excursion guides and reports for the Tenth International Geologic Congress held in Mexico City in 1906 as well as Bulletins from the Geologic Institute of

Mexico contained substantial contributions. Many of these investigations resulted in discoveries of Cretaceous corals. However, none of the taxonomic treatments of this time period approached the coral diversity recorded by Felix during the latter decade of the nineteenth century. Furthermore, only 12 Cretaceous coral species were described from Mexico during this 50-year interval.

In a review of the geology of the States of Chiapas and Tabasco, Emil (Emilio) Böse (1905, p. 26) reported the occurrence of Lower Cretaceous corals in the State of Chiapas. Only one coral taxon, *Isastraea* n. sp., was listed, and he noted that it was very similar to a species from the Lower Cretaceous of San Juan Raya (State of Puebla). However, the coral species was not described therein and he noted that the other corals that he had encountered were badly preserved. This same occurrence was cited in several later studies (discussed below).

The following year, Böse (1906a, p. 15, 16, 17) noted that he had encountered corals, sometimes abundant or forming banks, at several horizons in the Senonian age Cárdenas beds that crop out along the railroad line between Tampico and San Luis Potosí. However, because of the lack of sufficient material for comparison, the corals were not described (Böse, 1906a, p. 5). Böse only studied the molluscan fauna of these beds, but in a comparison of this fauna with that of the Gosau facies of Jamaica he also included a brief review of the Jamaican coral fauna that was described previously by Duncan and Wall (1865) and Vaughan (1899) (Böse, 1906a, p. 31-32). This same occurrence of corals in the Cárdenas beds was mentioned more than a decade later (Stanton, 1918, p. 606). A few corals from the Cárdenas beds were described half a century afterward (see Myers, 1968, discussed below), but it seems likely that many of the coral species found by Böse remain unknown.

The geologic investigations in the region of Tehuacán, Zapotitlán and San Juan Raya, State of Puebla, were reviewed by J. G. Aguilera (1906) in an excursion guide for the Tenth International Geologic Congress held in Mexico City in 1906. A list of the coral species that were described previously from the Tehuacán area by Felix (1891) was given in this excursion guide (Aguilera, 1906, p. 14), as well as comments on the location and geology of the fossil coral locality. These coral species were listed again in a table (Aguilera, 1906, table) which compared the invertebrate fauna of the San Juan Raya strata with that of the Aptian of Europe. In addition, 34 other scleractinian coral species from the San Juan Raya beds were listed in the same table. However, only three of those 34 species were previously described by other authors: *Latimaeandra* aff. *brachygyra* Reuss, *L.* aff. *tenuisepta* Reuss, and *Astrocoenia* aff. *minima* Fromentel. The remaining 30 named coral species from Mexico listed in the table have "Aguilera" as author. These species were neither described nor figured, but at the bottom of the table Aguilera noted that the species descriptions would

be published in bulletin number 26 of the Boletín del Instituto Geológico de México. However, the species descriptions were not published in bulletin number 26: the volume instead contains a study by Juan D. Villarelo (1908) entitled "Algunas Regiones Petrolíferas de México". The descriptions of Aguilera's coral species have not been found and it has been presumed that he did not have them published (see Müllerried, 1933b, p. 79, 1933c, p. 315). Therefore, the coral species listed in Aguilera's (1906) table which have "Aguilera" as the taxonomic author subsequently have been considered nomina nuda (Calderón-García, 1956, p. 19; Alencáster de Cserna, 1956, p. 2; Reyerros-Navarro, 1963, p. 3; Barceló-Duarte, 1978, p. 55, 89) and they rarely have been mentioned in the literature. Nonetheless, Aguilera's (1906, table) list of 63 scleractinian species indicates the possibility that a large proportion of the coral fauna from that region of Mexico is still unknown. Oddly, relatively few new coral species have been described in subsequent studies of the Cretaceous rocks in the State of Puebla.

In addition to the article by Aguilera (1906) discussed above, several other papers in the excursion guide for the Tenth International Geologic Congress also noted occurrences of Cretaceous corals in Mexico, including the following. Böse (1906b) noted a few corals in an article on the excursion to Cerro de Muleros (about 5-6 km northwest of Ciudad Juárez), State of Chihuahua, one described previously, *Trochosmilia* (*Coelosmilia*) cf. *T. (C.) texana* (Conrad, 1857), and two others, *Placosmilia bravoensis* Aguilera and *Placosmilia mexicana* Aguilera (Böse, 1906b, p. 5, 16, and p. 8, 17, respectively). The latter two species were not described therein, but both were figured in a later report on the geology of Cerro de Muleros (Böse, 1910, discussed below). Burckhardt reported a coral reef, "un banc de coraux", at the Picacho de la Abra, Sierra de Concepción del Oro, in the northeastern part of the State of Zacatecas (Burckhardt, 1906a, p. 2, 18; possibly Upper Jurassic). Similar beds also were noted just to the west, in the Sierra de Santa Rosa (Burckhardt, 1906b, p. 5, 20; possibly Upper Jurassic). Occurrences of Cretaceous corals also were mentioned in the excursion of San Luis Potosí to Tampico, in the vicinity of Cárdenas and eastward (Böse, 1906c, p. 3, 5, 8), and in the excursion to the Isthmus of Tehuantepec, near Tuxtla Gutiérrez, State of Chiapas (Böse, 1906d, p. 10).

Some of the occurrences of Cretaceous corals in Mexico were noted by Aguilera (1907) in a general summary of the geology of Mexico that was presented in the Report of the Tenth International Geologic Congress. In addition to the occurrences in the Tehuacán region of the State of Puebla (p. 235), four others were noted: the solitary coral *Trochosmilia* (*Coelosmilia*) in the State of Chihuahua, northern Mexico (p. 237); *Latiphyllia* [sic; possibly *Latiphyllia*] from the Cenomanian of the State of Michoacán (p. 238); a large number of corals in the State of San Luis Potosí; and the solitary coral *Micrabacia americana* Meek, 1876 (not Meek and Hayden; see

Wells, 1933, p. 250-251), from Ramos Arizpe and Las Esperanzas, State of Coahuila, in northern Mexico (p. 241). Another Cretaceous coral occurrence in northern Mexico, in the vicinity of San Pedro del Gallo, State of Durango, also was reported that same year (Angermann, 1907, p. 12).

A total of four coral species, all solitary forms, were reported in a study of the geology and paleontology of the Cerro de Muleros and La Encantada, State of Chihuahua (Böse, 1910). One of these species, *Trochosmilia* (*Coelosmilia*) *texana*, was described earlier by Conrad (1857), but the other three were not previously known and therefore they were named by Aguilera (in Böse, 1910; see p. 4): *Placosmilia bravoensis* (p. 33, pl. 45, fig. 11), *P. mexicana* (p. 33, pl. 45, figs. 10, 19, 21) and *Trochosmilia* (*Coelosmilia*) *chihuahuensis* (p. 53, pl. 45, figs. 6-8, 13, 16, 17, 23-25). The four coral species were illustrated, but none of them was described in that work. The species of *Trochosmilia* named by Aguilera, *T. chihuahuensis*, has been considered to be a junior synonym of *Coelosmilia texana* (Conrad, 1857) (Wells, 1933, p. 135-138). The other two species, *P. bravoensis* and *P. mexicana*, are poorly known. The type specimens of both species reportedly were deposited at Instituto de Geología in Mexico City (Wells, 1933, p. 146), but neither species was listed in the most recent catalog of the type fossils of Mexico (Perrilliat, 1989).

A few of the occurrences of corals reported previously from the Mexican Cretaceous were noted by Wilhelm Freudenberg (1921) in his book, "Geologie von Mexiko". Specifically, he mentioned the earlier reports of *Isastraea* n. sp. and some badly preserved corals in the State of Chiapas (from Böse, 1905), and the large number of corals that were discovered near Cárdenas in the State of San Luis Potosí (probably from Böse, 1906a, 1906c) (Freudenberg, 1921, p. 91 and p. 111, respectively). The book contains much information on the stratigraphy and geographic distributions of the different ages of rocks found in Mexico, as well as fairly complete descriptions of the geologic processes and geomorphologic provinces of the country. However, the only taxonomy presented therein dealt with vertebrates and the corals were not treated.

A review of the geology of the southern Mexico oil fields by W. A. Ver Wiebe in 1925 included a plate illustrating two stratigraphic sections, one of which indicated that the horizon of the *Isastraea* sp. reported previously from the State of Chiapas (most likely by Böse, 1905, p. 26) was Jurassic in age. However, the author also noted that the horizon "may be Early Cretaceous (Ver Wiebe, 1925, pl. 13)."

Two years later, the solitary coral species reported earlier from Las Esperanzas, State of Coahuila, under the name *Micrabacia americana* Meek (Aguilera, 1907, p. 241), was determined to be *M. cribraria* Stephenson, 1916, after additional specimens were collected from that same area in northern Mexico (Böse and Cavins, 1927, p. 35-36). In addition, the geologic age of the beds

which contained the corals was interpreted to be upper Santonian.

An occurrence of Cretaceous corals was briefly noted by W. S. Adkins (1930, p. 82) in a report on some rudist bivalves from Texas and Mexico. The corals were found in the middle Cretaceous El Abra Limestone at Taninul tunnel, a tunnel on the Tampico - San Luis Potosí railway. This occurrence, which was later noted by Muir (1936, p. 38), is one of the earliest reports of corals in the El Abra Limestone.

A coral-bearing Cretaceous limestone bed was discovered by Charles L. Baker in 1923 during a geological traverse of the Isthmus of Tehuantepec. Baker's journey followed the Tehuantepec railway line from Salina Cruz on the Pacific coast to Coatzacoalcos on the Gulf of Mexico. The coral-bearing unit, a massive, light gray limestone ridge, was exposed at Paso del Buque, a narrow gap a few kilometers north of Palomares station (Baker, 1930, p. 171), State of Oaxaca. This same occurrence was mentioned later by Müllerried (1942a, p. 136). Although Baker noted that the limestone was primarily composed of corals and foraminifera, no coral species are known to have been described from this locality.

Carl Burckhardt (1930), in his comprehensive work entitled "Etude synthétique sur le Mésozoïque mexicain", noted (p. 160, 177, 182-184) several of the previously reported occurrences of Cretaceous corals in Mexico, including the fauna described by Felix (1891). Coral faunas from the Río Nazas (p. 138, 140) and San Pedro del Gallo (p. 174) regions, State of Durango, also were noted, but the corals from these areas still have not been described.

The Cretaceous corals of Mexico were reviewed by John W. Wells (1933) as part of a study of the Cretaceous corals of the Atlantic and Gulf Coastal Plains and Western Interior of the United States. One new Mexican occurrence was reported (p. 167): *Orbicella whitneyi* var. from an Aptian limestone at Bufa, near Mapimí, in the northeastern region of the State of Durango. According to Wells, the specimen is at the United States National Museum. This variety reportedly is similar to the *O. whitneyi* Wells, 1932, from the lower Glen Rose of Texas, except the Mexican variety, which is possibly a new species, possesses larger calices. The coral species described earlier by Felix (1891) were listed, including some with tentative generic reassignments (p. 90, 95), but Wells noted that the fauna needed considerable revision. However, Wells recognized that the *Astrocoenia* cf. *A. globosa* described by Felix was different from the *A. globosa* of Fromentel and that the Mexican form was close to *A. whitneyi* from the lower Glen Rose Formation of Texas. Wells (p. 134-138) reassigned the coral species described by Conrad (1857), *Turbinolia texana*, to the genus *Coelosmilia*, and considered *C. chihuahuensis*, one of the species from La Encantada, State of Chihuahua, figured earlier in Böse (1910), to be a junior synonym. On the other hand, Wells (p. 245) concurred with the previous determination (Böse and Cavins, 1927,

p. 35-36) that the species of *Micrabacia* reported from the State of Durango (Aguilera, 1907) was *M. cribraria*, not *M. americana*. Wells (p. 146-147) also listed two other coral species named by Aguilera (in Böse, 1910), *Placosmilia bravoensis* and *P. mexicana*, as noted earlier. In addition, recently studied corals from the Upper Cretaceous Cárdenas beds, State of San Luis Potosí, were listed (p. 111) but not described therein.

Friedrich K. G. Müllerried, in a series of several papers (1933a, 1933b, 1933c, 1934), reviewed the previous paleontologic and stratigraphic investigations of the region of Tehuacán, State of Puebla, and noted some occurrences of Cretaceous corals in that area (1933b, p. 80, 82, 85, 86; 1934, p. 65-71). Müllerried (1934, p. 61-62) acknowledged Aguilera's (1906) list of 64 coral species and provided two separate lists of corals from that area, one for San Antonio Texcala with 15 species and the other for San Juan Raya - Zapotitlán with 17 species. However, 11 of the coral species are common to both of the lists, so altogether only 21 different coral species were reported and all of them were originally described by Felix (1891) from the same region of Mexico. Based on ammonite faunas from the same area, the ages of the strata were determined to be lower Barremian and upper Aptian (Burckhardt and Müllerried, 1936, p. 318).

Charles Schuchert, in his extensive work "Historical Geology of the Antillean - Caribbean Region," mentioned a few of the occurrences of Cretaceous corals that were reported previously in Mexico. He listed the five coral genera that Sapper (1894) reported from the Upper Cretaceous of Chiapas and noted the *Isastraea* n. sp. and other corals that were found by Böse (1905) in the same state (Schuchert, 1935, p. 328-329). Two other occurrences also were noted by Schuchert (1935), one in the Cenomanian (p. 172) and the other in the lower Senonian (p. 177). Schuchert obtained the information on the latter occurrence from Stanton's (1918, p. 606) remarks on an earlier study by Böse (1906a). The source of the information about the Cenomanian coral occurrence was not directly cited by Schuchert, but it probably was Böse (1910) or Burckhardt (1930).

Two occurrences of corals in the middle Cretaceous El Abra Limestone were briefly noted by J. M. Muir in his thorough study of the geology of the Tampico region of Mexico. One of the occurrences was reported previously by Adkins (1930), whereas the other was based on a fragment that was blown (literally) from Mexican Gulf Oil Company well number 3 Tepetate (Muir, 1936, p. 38 and p. 41, respectively), State of Veracruz.

Several geological studies in the northern and central Mexican states during the latter half of the 1930s incidentally reported occurrences of Cretaceous corals. An extensive project on the geologic evolution of the Coahuila Peninsula reported two coral occurrences: a large colony of a species of *Isastrea* from the Aptian upper Cuchillo Formation in the southwestern part of the

State of Coahuila (Kelly, 1936, p. 1027); and a coral from Valanginian beds of the Torcer - Las Vigas strata in the northeastern area of the State of Durango (Kellum, 1936, p. 1055, 1067). Corals also were discovered by R. W. Imlay during geologic mapping of an area to the east, in the Aptian La Peña Formation of the middle part of the Sierra de Parras in the southern part of the State of Coahuila (Imlay, 1937a, p. 608, 610). That same year Lower Cretaceous (Valanginian) corals also were reported (Imlay, 1937b, p. 554) in a stratigraphic section that was measured previously by C. L. Baker in 1925 at a locality a mile east of Miquihuana, a small town in the western part of the State of Tamaulipas. Imlay (1939, p. 1734) later reported corals from a Lower Cretaceous limestone at the head of the Cañón Santa Rosa, El Tigre area of the Sierra de Teras, in the northeastern part of the State of Sonora. Just to the south, geological reconnaissance of the northern Sierra Madre Occidental resulted in the discovery of Cretaceous (Albian) corals at Cerro El Palmar, a high peak about 8 km southeast of Arivechi, State of Sonora (King, 1939, p. 1661). The latter study also included a compilation of the Cretaceous invertebrate taxa from the Arivechi area which noted the occurrences of *Parasmilia texana* Roemer [sic; a reference to Conrad's (1857) species] that had been reported previously (King, 1939, p. 1670, table 5). Farther to the southwest, in the region of Valle del Mezquital, State of Hidalgo, Müllerried (1939a, p. 226, 228, 242) reported indeterminate forms of Cretaceous corals from the limestones of Cerro de las Minas, Cerro Maguey Blanco, and the hills north of Cerro Cuesta de México. He questionably referred some of the badly preserved coral specimens from Cerro Maguey Blanco to the genus *Latimaeandra*. A few brief notices of an Upper Cretaceous coral occurrence in the southern portion of Mexico, in the State of Chiapas, also were made during this time period (Müllerried, 1936, p. 38; Sapper, 1937, p. 154).

Late in the 1930s, Cretaceous corals were reported from Baja California for the first time. Geological reconnaissance of the Sierra San Pedro Mártir, northern Baja California, resulted in the discovery of indeterminate fossil corals and other marine invertebrates in the vicinity of the Buena Vista ranch, just northwest of San José (Woodford and Harriss, 1938, p. 1307). The fossils occurred in limestones and shales that exhibited signs of incipient metamorphism and the geologic age of the fossils was not precisely determined, but the authors noted that "... they have a Mesozoic aspect." However, the field relations between the intrusives and the metamorphosed marine sedimentary rocks indicate that the age of the metamorphosed fossil-bearing strata must predate the age of the intrusives. Investigations of the igneous intrusives and resulting metamorphism in Baja California (Lindgren, 1888, 1889, 1890; Böse and Wittich, 1913; Wittich, 1914, 1915; Darton, 1921; Beal [anonymous], 1924; Hirschi, 1926; Hirschi and de Quervain, 1927, 1928, 1930, 1933; Santillán and Barrera, 1930; Jahns, 1954; Mina, 1956, 1957; Delgado-Argote *et al.*, 1995)

indicate that the age of the intrusives is Late Cretaceous. Therefore, the age of the corals from these beds is probably within the interval of Early Cretaceous to early Late Cretaceous. The same fossiliferous, coral-bearing locality discovered by Woodford and Harriss (1938) was later noted in studies by Beal (1948, p. 40) and Jahns (1954, p. 35).

Several investigations of the Cretaceous of northern Mexico during the 1940s reported fossil corals. However, in contrast to the majority of the studies from the 1930s, some of these articles included descriptions of coral species. Imlay (1940, p. 129) tentatively referred coral specimens from the Barril Viejo Shale in the State of Coahuila to the genera *Montlivaltia*, *Pleurosmilia*, and *Coelosmilia*, and he described one coral species from the Berriasian - Valanginian Carbonera Formation at the northwestern part of the Cuesta del Carbonera, near Las Cuevas, State of Durango: *Astrocoenia hispaniensis* Imlay, 1940 (p. 138, pl. 1, figs. 21, 22). The holotype of this species was placed in the collections of the Museum of Paleontology at the University of Michigan, Ann Arbor. That same year A. Heim (1940, p. 324) reported a Cretaceous coral occurrence in the Tamabra Limestone at Monte Cristo, a locality in the Front Ranges of the Sierra Madre Oriental about 50 km south of Ciudad Victoria, State of Tamaulipas. He also noted the occurrence of corals in the Cárdenas beds (Heim, 1940, p. 332), State of San Luis Potosí, reported previously by Böse (1906a). The following year, Wells (1941, p. 292) also reported a coral occurrence in the Cárdenas beds, specifically the solitary species *Paracycloseris elizabethae* Wells, 1934, but no specimens from this area were described. Farther north, at the thirteenth annual meeting of the South Texas Geological Society, W. E. Humphrey (1941, p. 3) noted the occurrence of corals in the Berriasian - lower Hauterivian Las Cortinas Formation (= Tarras Formation; see comments by Humphrey, 1949, p. 100) at the head of the Cañón de las Cortinas, Sierra de los Muertos, State of Coahuila. Cretaceous corals also were noted in several articles by F. K. G. Müllerried. He reviewed the coral occurrences reported previously from the State of San Luis Potosí by Böse (1906a), Burckhardt (1930), Burckhardt and Müllerried (1936), and Muir (1936), and noted other occurrences in the Cretaceous Cárdenas beds as well (Müllerried, 1941, p. 27-30). The following year, in an overview of the Mesozoic of Mexico and northwestern Central America, he noted the general stratigraphic distribution of the occurrences of Cretaceous corals that were reported previously (Müllerried, 1942a, p. 133-136, 139; 1942b, p. 476). A few years later, Müllerried (1946, 1947) noted occurrences of Cretaceous corals in the middle Albian Escamela Limestone at Orizaba and in middle Senonian limestone at Peñuela, Cordoba region, State of Veracruz. The taxonomic identities of the Cretaceous coral species from the Orizaba - Cordoba region are unknown. Lastly, Müllerried (1949) mentioned that corals occurred in the Upper Cretaceous reef facies of

southern and southwestern Mexico. Several of the previously reported Mexican Cretaceous coral occurrences were noted in studies by R. W. Imlay, including those in the Cárdenas area of the State of San Luis Potosí, the Tehuacán - San Juan Raya region of the State of Puebla, the Orizaba region of the State of Veracruz, the Cañón de los Cortinas and the Sierra de Santa Ana in the State of Coahuila, the Sierra del Rosario in the State of Durango, and other mid-Cretaceous outcrops throughout Mexico (Imlay, 1944a, 1944b). Reports of Cretaceous corals that were briefly noted in 1946 include an occurrence near Santa Ana in the northern part of the State of Sonora (Arellano, 1946, p. 58) and indeterminate corals in the Aurora Limestone at the southeast base of the Sierra de la Encantada, State of Chihuahua (King and Adkins, 1946, p. 287).

Seven species of corals from the Jurassic and Cretaceous of northern Mexico were described by J. W. Wells in 1946. The descriptions were based on coral specimens that were collected during previous geological investigations in that region and mentioned earlier by Kelly (1936), Kellum (1936), and Imlay (1940). Of these seven species, only one was from the Jurassic: *Astrocoenia kellumi* Wells, 1946 (p. 2-3, pl. 1, fig. 1) from the Kimmeridgian La Casita Formation near Las Cuevas Ranch, State of Durango. The six species of Cretaceous corals and their occurrences are as follows. *Stephanocoenia guadalupae minor* Wells, 1946 (p. 3, pl. 1, figs. 2-4), was collected from Trinity age (upper Aptian - lower Albian) strata at Cañón Santa Rosa, a few miles southeast of El Tigre, State of Sonora, and from the Aptian lower Cuchillo Formation of the Sierra de Acatita in the southwestern part of the State of Coahuila. *Isastrea whitneyi* Wells, 1932, a species described previously from the lower Albian lower Glen Rose Formation of Texas, was collected from Aptian strata of the lower Cuchillo Formation in the Sierra de Acatita, and from the lower Albian (?) upper Cuchillo Formation at an outlier of the Sierra del Venado, State of Coahuila. *Montlivaltia coahuilensis* Wells, 1946 (p. 4-5, pl. 1, fig. 5, pl. 2, figs. 4-6), was collected from the middle Valanginian strata of the Carbonera Formation near La Goma station, from the same formation at a locality just southwest of Las Cuevas, State of Durango, and from the lower Hauterivian Barril Viejo Shale at Los Vagos, Potrero de Oballos, State of Coahuila. A similar species, *M. burckhardti* Wells, 1946 (p. 5, pl. 2, figs. 7-14), was collected from the Potrero de Oballos also, and from the Barril Viejo Shale at Barril Viejo, State of Coahuila. *Axosmilia mexicana* Wells, 1946 (p. 6, pl. 1, figs. 6-11), also was collected from the same two localities. A species of *Placocoenia* d'Orbigny, 1849, was described as new, but not named or figured: *Placocoenia* n. sp. Wells, 1946 (p. 5-6), from the middle Valanginian strata of the Carbonera Formation near Las Cuevas, State of Durango. The specimens of *Astrocoenia hispaniensis* described previously by Imlay (1940) also were collected from the latter locality. All of Wells' (1946)

coral specimens are in the Museum of Paleontology at the University of Michigan, Ann Arbor. Wells recognized that the Cretaceous corals belonged to two different faunas and that the older fauna from the Carbonera Formation and the Barril Viejo Shale was "... not related to the penecontemporaneous reef coral fauna of the Tehuacán region of southern Mexico described by Felix (1891), although the two lived in the same embayment (Wells, 1946, p. 2)." He also noted that the older fauna was not related to the younger, Trinity age coral fauna known from northern Mexico and central Texas, and that the younger coral fauna of the Cuchillo Formation probably was distally related to the reef coral fauna of the lower Glen Rose Formation of central Texas.

Late in the 1940s, W. E. Humphrey described limestone beds of the Taraises Formation that were mostly composed of bryozoans and corals (Humphrey, 1949, p. 100-101). The beds were exposed near the head of the Cañón de San Juan, on the northern limb of the Los Muertos anticline of the Sierra de los Muertos, State of Nuevo León. Ammonites indicated that the coral-bearing beds are probably Berriasian in age. Much later it was realized that the fossils that Humphrey identified as bryozoans actually were colonies of microsolenid corals (Ward, 1999, p. 102).

Geologic investigations from 1950 to 1990

The first four decades of the latter half of the twentieth century witnessed an ever widening surge in geologic investigations of Mexico. The Twentieth Session of the International Geologic Congress held in Mexico in 1956 and continued exploration for rich petroleum prospects helped to elucidate the complex geologic history of Mexico as well as provide new discoveries of Cretaceous corals. Most notable during this time interval are two of the investigations published by the Geologic Institute of Mexico in which Cretaceous coral species from the states of Puebla and Oaxaca were described (see Reyerros-Navarro, 1963, and Reyerros de Castillo, 1983, respectively, discussed below). These two studies alone include descriptions of a total of 28 Cretaceous coral species.

Cretaceous corals were reported from several localities in Mexico during the 1950s, but only a few coral species were described. Two small, solitary coral specimens, collected earlier by J. T. Singewald Jr. in 1922 from the upper Campanian strata near Ocuilapa, State of Chiapas, were later briefly described and figured by M. Maldonado-Koerdell (1950, p. 196-197, figs. 3, 4): *Trochocyathus* cf. *T. woolmani* Vaughan, 1900, and *Trochosmilia* sp. Neither of these species has been reported from this region of Mexico again. The coral specimens are in the collections of Petróleos Mexicanos, Mexico City. Maldonado-Koerdell (1950, p. 181-183) also reviewed the other occurrences of Cretaceous fossils in the State of Chiapas and mentioned the coral taxa

reported previously by Sapper (1899) and Böse (1905). Corals were now beginning to be reported frequently in studies of the middle Cretaceous rocks of the Tampico region of Mexico, but the coral faunas of this region have yet to be described. Nigra (1951, p. 149, 157) noted occurrences of corals in the El Abra and studies by F. Bonet resulted in a few reports of corals, including a thin-branched colonial form referred to as *Cladophyllia*, in the Sierra de El Abra and vicinity (Bonet, 1952a, p. 182, 183, 221, 253, figs. 11, 13; 1952b, p. 5, 61, 67, pl. 19, fig. 21, pl. 21, fig. 23). Maldonado-Koerdell (1953, p. 114) briefly mentioned some of the earlier works that dealt with the Cretaceous corals of Mexico, but no information on any new occurrences was provided. An occurrence of Cretaceous corals in the Alisitos Formation of the Punta San Isidro area, west coast of Baja California, was noted early in the 1950s (Kirk and MacIntyre, 1951, p. 1505). Subsequently, in 1955, E. C. Allison reported the discovery of corals in the Alisitos Formation at Punta China, Baja California, a locality in the same area. Overall, the diverse marine invertebrate fauna from the Alisitos Formation is most similar to faunas known from the middle Albian (Popenoe, 1954, p. 17). Among the corals, Allison (1955) listed *Astrocoenia* sp., *Cyathophora* sp., *Myriophyllia* cf. *M. cuyleri* (Wells, 1932), *Dermosmilia* sp., *Isastrea whitneyi* Wells, 1932, *Montlivaltia* sp., *Montastrea* sp., and *Placosmilia* sp., but none of the species was described therein. The corals from the Alisitos Formation subsequently have not been described.

Some of the field guides for the Twentieth Session of the International Geologic Congress held in Mexico in 1956 noted occurrences of Cretaceous corals. Corals were reported from localities in the Zapotitlán and San Juan Raya formations in the Tehuacán region of the southern part of the State of Puebla (Calderón-García, 1956, p. 17, 19, 70), the same region from which Felix's (1891) coral fauna was collected. Two other Cretaceous coral localities also were noted in the same region (Calderón-García, 1956, p. 41, 62), as well as some belonging to the Jurassic (p. 29, 81). Just to the west of the Tehuacán region, Carl Fries Jr. (1956, p. 27, 28 [not published until 1962], 1957, p. 300, 301) reported the occurrence of corals in the Turonian Cuautla Formation of the State of Morelos. Two of the coral species were listed in a later report (Fries, 1960).

Geological studies in the northern Mexican states during the 1950s produced only a few reports of Cretaceous corals. Occurrences were noted in the Aurora Limestone of the Sierra de Tlahualilo, State of Coahuila (Kellum, 1956), and in the Walnut and Kiamichi formations in the State of Chihuahua (Ramírez and Acevedo, 1957, p. 721, 724, 726). The only coral species identified in these studies, *Trochosmilia texana*, was listed in the latter article as part of the fauna from the Kiamichi Formation (Ramírez and Acevedo, 1957, p. 726).

Several occurrences of corals were noted by L. J. Chubb (1959) during investigation of the Upper

Cretaceous strata in the central region of the State of Chiapas. He reported some newly discovered occurrences, acknowledged the coral taxa reported earlier by Sapper (1894, and subsequent papers cited above) and Böse (1905), and briefly re-evaluated their taxonomy as well (Chubb, 1959, p. 726, 753). He noted that he found a massive coral specimen in the section of Campeche beds at Rancho Campeche, near Ocozocuahtla, and tentatively referred it to *Astrepora* [sic] sp. He also found coral in another section northwest of Ocozocuahtla, a species of *Actinacis* that resembled *A. martiniana* d'Orbigny (Chubb, 1959, p. 747). He suggested that Sapper's *Heliopora* sp. possibly was the form that he referred to *Actinacis* cf. *A. martiniana*, that Sapper's *Leptophyllia* sp. may be a species of *Montlivaltia*, and that the *Stylina* sp. was the form that he assigned to *Astrepora*. He also recognized that none of his coral specimens could be referred to *Isastraea*, the genus reported earlier from this region by Böse (1905). As a summary remark on the coral fauna, he noted that: "In any case corals are among the rarest and least characteristic fossils of the Ocozocuahtla series" (Chubb, 1959, p. 753). Contrary to Chubb's statement, recent investigations of the Upper Cretaceous strata in this same area have demonstrated that corals are abundant and diverse at certain horizons and that they are a significant component of the Latest Cretaceous marine fauna in this region of Mexico (Filkorn, 2003).

Several studies of the Mexican Cretaceous during the 1960s reported fossil corals. Fries (1960, p. 66-67, 181, 189, 195, 221, pl. 15, fig. B) listed two coral species from the Turonian Cuahtla Formation that were identified by J. W. Wells: *Multicolumastraea* [sic] *cyathiformis* (Duncan, in Duncan and Wall, 1865), and *Columastraea* n. sp. However, neither of the two species was described in that study and the latter species probably was never described. In that same study, Fries (1960, p. 49, 55, 198) also reported the occurrence of corals in the lower Cenomanian strata of the Morelos Formation, State of Guerrero, and listed a species that also was identified by Wells, *Epistreptophyllum* sp. cf. *E. budaensis* Wells. A description of the latter species could not be found in the literature and thus it seems likely that it was never described.

The occurrence of Cretaceous corals in the Alisitos Formation at Punta China, Baja California, which was initially reported by Allison (1955), was noted later in a field guide article for that area (Allen *et al.*, 1961, p. 62-63). However, members of only two coral genera were listed in the later article: *Isastrea*, including the species *I. whitneyi* Wells, 1932, and *Montlivaltia*.

Geological investigations by K. Segerstrom in the south-central part of the State of Hidalgo and the adjacent northeastern part of the State of Mexico, a region just to the north of Mexico City, resulted in the discovery of corals in the middle Albian - lower Cenomanian El Doctor Formation (Segerstrom, 1962, p. 101). However, geologic mapping was the major emphasis of

his investigation and no corals were described.

The most significant contribution to the taxonomy of Mexican Cretaceous corals during the 1960s was the description of a coral fauna from the Lower Cretaceous (Aptian) of the San Juan Raya region, State of Puebla, by María M. Reyerros-Navarro in 1963. The coral species described by Reyerros-Navarro are listed in Table 1. A total of 12 species were described in that study, including five that were described as new: *Thamnasteria felixi*, *Procyathophora aguilerai*, *P. poblana*, *Stylina vaughani*, and *Felixastraea mexicana* Reyerros-Navarro, 1963. Four of the remaining seven species were described previously from this region of Mexico by Felix (1891), but three of the four were now reassigned to other genera: *Thamnasteria crespoi* (Felix, 1891), *Cyathophora atempa* Felix, 1891, *Polyphylloseris conophora* (Felix, 1891), and *Complexastrea cyclops* (Felix, 1891). The three remaining species described by her, *Thamnasteria decipiens* (Michelin, 1845), *Baryphyllia confusa* (d'Orbigny, 1850b), and *Plesiastrea sulcatilamellosa* (Michelin, 1841; see Fromentel, 1886, p. 575), were described previously from occurrences in Europe and reported from Mexico for the first time. Reyerros-Navarro's study was based on corals that J. G. Aguilera gathered during the latter years of the 1800s and placed in the collections of the Museo de Paleontología of the Instituto de Geología, Mexico City. She indicated that the corals were from the San Juan Raya Formation in the vicinity of the town of the same name, but no other locality information was provided and no fossil localities were plotted on her geologic map of the area (Reyerros-Navarro, 1963, fig. 2). She noted that her fossiliferous locality was very near to the Tehuacán region, the source of Felix's (1891) coral specimens (Reyerros-Navarro, 1963, p. 3), but according to her geologic map the stratigraphic horizon of Felix's (1891) coral locality would be in the Barremian Zapotitlán Formation, not the Aptian San Juan Raya Formation. The Cretaceous coral faunas of this entire region of the State of Puebla require further study to better determine their taxonomic affinities and their stratigraphic and geographic distributions. The coral specimens that were described by Reyerros-Navarro (1963) are at the Museo de Paleontología, Instituto de Geología, Universidad Nacional Autónoma de México, Mexico City (Perrilliat, 1981, 1989).

A few other Cretaceous coral occurrences also were noted in 1963. The coral occurrence reported previously from the State of Chiapas by Ver Wiebe (1925) and others was later noted by H. G. Richards (1963) in his study of the early Mesozoic stratigraphy of southeastern Mexico and western Guatemala. Richards (1963, p. 1869) listed the same coral taxon that was originally reported by Böse (1905), *Isastraea* n. sp., a species that was never described. In northern Mexico, geological studies of the Cañón de la Huasteca area of the Sierra Madre Oriental in the State of Nuevo León resulted in the discovery of corals in the Valanginian - Hauterivian

Taraies Formation and the Barremian Cupido Formation (Vokes, 1963, p. 130, 140, 142). In addition, corals were reported from the mid-Cretaceous Taninul facies of the El Abra Formation in the Sierra de El Abra, State of San Luis Potosí (Rose, 1963, p. 58, 60), but no species were listed.

The following year, Allison (1964, p. 13) noted the occurrence of corals in the Alisitos Formation of Baja California that had been reported previously. In addition, he reported that F. H. Kilmer discovered corals in the Upper Cretaceous Rosario Formation near El Rosario, also in Baja California (Allison, 1964, p. 16). The coral faunas of these two formations have not been described.

Some corals from the Upper Cretaceous Cárdenas Formation in the State of San Luis Potosí were described and figured in a biostratigraphic study of that formation by R. L. Myers (1968), but the corals only received a very cursory taxonomic treatment and none of the species was named. Six coral species were reported from Maastrichtian strata: *?Epistreptophyllum* sp., *Trochoseris* sp., *Synastrea* sp., *Leptoria* sp., *Cladocora* sp., and *?Lithostrontionoides* sp. (Myers, 1968, p. 80-82, pls. 15-16). Along with the brief descriptions, he also noted the local stratigraphic and geographic distributions of each coral species. Myers' (1968) coral specimens were placed in the W. S. Adkins Collection of the Department of Geology, University of Texas, Austin.

Late in the 1960s, the occurrence of corals in the Lower Cretaceous San Ricardo Formation of the State of Chiapas was noted (Sánchez-Montes de Oca, 1969, p. 7), but coral species were not described or named. Similarly, relatively low percentages of both branching and massive corals were noted in an environmental analysis of the middle Cretaceous El Abra Formation of the State of San Luis Potosí (Griffith *et al.*, 1969), but no coral species were listed.

Cretaceous corals were reported in several studies of the Mexican Cretaceous System during the 1970s, but no corals were described and very few coral species were listed. In a biostratigraphic study, A. Becerra (1970) noted the occurrence of corals in the middle Cretaceous Tamabra Formation in the Poza Rica district, State of Veracruz, but no taxonomic information was provided. Study of the Lower Cretaceous stratigraphy in the northern part of the State of Coahuila by C. I. Smith resulted in the discovery of corals at several horizons and localities including: the Aptian Cupido Formation at the southern end of the Coahuila Peninsula; the Glen Rose Formation at Rincón de María, Sierra de San Gerónimo, and Sierra El Cedral; the combined upper Glen Rose and lower Devils River formations southeast of Rancho El Melón; and the Devils River Formation at Puerto de Aguacate, Sierra de San Gerónimo (Smith, 1970, p. 30, 32, 43, 86, pl. 2). The Cretaceous corals of this region are poorly known.

Investigation of the geology of the Valles - San Luis Potosí platform by J. Carrillo-Bravo (1971, p. 35, 39) produced reports of scarce corals in the

mid-Cretaceous Taninul facies (Albian) and post-reef El Abra facies (Albian - Cenomanian) of the El Abra Formation, State of San Luis Potosí. He also noted coral occurrences in the Tamasopo Formation (upper Turonian? - upper Senonian) and the Cárdenas Formation (Campanian - Maastrichtian) in the same state, including the six corals described previously by Myers (1968) (Carrillo-Bravo, 1971, p. 51-52, 54, and p. 58, 60, respectively). Corals also have been reported in the reef facies of the El Abra Formation of the Actopan platform in the State of Hidalgo (Carrasco, 1971, p. 11), an area just to the southwest of the Valles - San Luis Potosí platform. A report of the geologic investigations for a hydroelectric project in an area even farther to the southeast, at the Cañón del Sumidero on the Río Grijalva, State of Chiapas, included a brief mention of corals in the Aptian San Ricardo Formation (Zavala-Moreno, 1971, p. 22). However, no coral species were described or listed in that article.

Study of the depositional environments and geologic history of the Golden Lane and Poza Rica trend, State of Veracruz, by A. H. Coogan and others resulted in reports of corals in the middle Cretaceous Tamabra and El Abra formations (Coogan *et al.*, 1972). The taxonomic identities of the Cretaceous coral species from this region are unknown.

A report on the stratigraphy of the Morelos - Guerrero basin by G. Ontiveros Tarango (1973) included several mentions of Cretaceous corals. Fragments of corals were observed in the upper Aptian Acahuizotla Formation of the Sierra de Chilacachapa, State of Guerrero, and in the Albian - Cenomanian Morelos Formation in that same area and at the eastern flank of the Cerro del Acuitlapan, State of Morelos (Ontiveros-Tarango, 1973, p. 201, 208, 210). He discussed the paleontology of the formations, but no coral species were listed in his report. The coral faunas of these two formations have not been described.

The occurrence and distribution of corals in the El Abra Formation, State of Veracruz, were discussed by Cabrera-Castro and Meneses-López (1973) during their investigation of the applications and economic importance of the microfacies of that formation. They noted that typical reef boundstone was usually absent from the reef cores and that the corals that they found were of the type that did not construct true growths of organic reefs. They recognized a coral-algal zone at a horizon stratigraphically just above the lower Albian, but they noted that corals also were observed at lower horizons. The authors considered the age of the El Abra Formation to range from late Aptian through early Albian and into later Albian.

The occurrences of corals in the Aptian - Albian Alisitos Formation of Baja California were noted in a study of the type area of that formation by E. C. Allison (1974, p. 29, 45-47). Two of the coral taxa that were reported previously (Allison, 1955; Allen *et al.*, 1961) from the Albian strata in the Punta China area, *Isastrea*

and *Montlivaltia*, were listed, but the corals were neither described nor determined to species level.

In an overview of the middle Cretaceous deposits of northeastern Mexico, P. Enos (1974, p. 804) noted that corals had been reported from the Taninul reef facies of the El Abra Formation, State of San Luis Potosí, but they were only minor components of the reef facies. The corals of the El Abra Formation still are not known well.

Two occurrences of Cretaceous corals were discovered during study of the stratigraphy and structure of the Parras and La Popa basins in northeastern Mexico (McBride *et al.*, 1974, p. 1616-1617). The corals were found in two of the formations of the Upper Cretaceous Difunta Group: the Lower Siltstone Member of the Potrerillos Formation in the La Popa basin, State of Nuevo León; and the Medranos Lentil, a limestone bed in the Noria Member of the Tanque Formation, at a locality in the eastern part of the Parras basin, State of Coahuila. The coral specimens from the latter locality were identified as *Trochocyathus gardnerae* Wells, 1933 (McBride *et al.*, 1974, p. 1620), whereas those from the Potrerillos Formation were not determined. The specimens of *T. gardnerae* were described later by Wolleben (1977).

Geologic investigations of the Lower Cretaceous strata in the State of Coahuila by C. I. Smith and others resulted in reports of fossil corals at several localities. Thin sections of microsolenid corals collected from the Upper Tamaulipas Formation at Rancho Los Ojos, San Rafael, and El Cedral were figured in a study by Smith and Bloxson (1974, pl. 2, figs. 2, 4, 6). They also illustrated corals from the Glen Rose Formation, including a thin section of a thamnasteroid coral from El Cedral and field photographs of large growths of dendroid corals at Puerto Aguacate (Smith and Bloxson, 1974, p. 73, pl. 3, figs. 1-4, pl. 4, fig. 4). Occurrences of corals also were noted in measured stratigraphic sections of the Stuart City facies of the Glen Rose Formation at Puerto de Aguacate, Sierra de San Gerónimo, and the Cupido Formation at Potrero de Agua Chiquita (Smith *et al.*, 1974, sections 5, 6). However, no coral species were described or listed in these studies.

The occurrence of corals in the Alisitos Formation that was reported earlier by Allison (1955, 1964) was later noted in a reconnaissance of the geology of the State of Baja California by R. G. Gastil, R. P. Phillips, and E. C. Allison (1975). In addition, they reviewed the different age determinations that were applied previously to the Alisitos Formation and presented evidence for an overall age range of Aptian to Albian (Gastil *et al.*, 1975, p. 19). Subsequently some of the same invertebrate taxa that were identified from the Alisitos Formation were discovered in the partially metamorphosed Olvidada Formation, a contemporaneous unit in the same region (Phillips, 1993). However, there have been no additional studies of the coral fauna of the Alisitos Formation.

A study of the paleontology of the Difunta Group

of northeastern Mexico by J. A. Wolleben (1977) included a brief description and a figure of the Upper Cretaceous coral species that was collected earlier (McBride *et al.*, 1974, p. 1616, 1620) from the Medranos Lentil of the Tanque Formation in the eastern part of the Parras basin, State of Coahuila. The three solitary specimens were assigned to *Trochocyathus gardnerae* Wells, 1933 (Wolleben, 1977, p. 396, pl. 3, fig. 1), a species that was originally described from the Navarro Group of Texas. These coral specimens are in the collection at the University of New Orleans, Louisiana.

Several occurrences of corals were reported in a study of the mid-Cretaceous rocks of the Poza Rica and Golden Lane fields, State of Veracruz, by P. Enos (1977). He noted occurrences of corals in certain lithologies of the Tamabra Limestone (Enos, 1977, p. 297) and recognized massive coral heads and coral-rich intervals with delicate branching corals in well cores from the Golden Lane. The latter intervals were interpreted as patch-reef coral thickets or coral fringes of a mud shoal (Enos, 1977, p. 302). However, no coral species were described or listed.

A report of investigations of the Cretaceous carbonates of Texas and Mexico (Bebout and Loucks, 1977) contains several mentions of coral occurrences in Mexico. Study of a Lower Cretaceous shelf margin near Monterrey, State of Nuevo León, and vicinity yielded reports of coral occurrences, including *Cladophyllia*, in the Hauterivian - Barremian Taraises and Cupido formations (Wilson and Pialli, 1977). In the Sabinas basin, coral reefs were discovered in surface exposures of the Hauterivian Padilla Formation at Potrero Oballos and Potrero Pájaros Azules, and a similar facies was recognized in the subsurface of that area as well (Stabler and Marquez, 1977). Several coral occurrences in the Cupido Formation of northeastern Mexico were noted in a paleoenvironmental analysis of that unit (Conklin and Moore, 1977), the most notable at the localities of Bustamante Canyon, Pajaros Azules Canyon, and Potrero Chico. Fragments of branching corals that resembled *Cladophyllia* also were noted in the latter study.

A study of the sedimentary environments and diagenesis of the El Abra Limestone by J. E. Aguayo-Camargo (1978) yielded a few mentions of solitary and colonial corals, including *Cladophyllia*, in the monopleurid-requienid-coral biolithite facies of the shelf-edge reef zone. A thin section of a specimen of *Cladophyllia* from this facies was figured (Aguayo-Camargo, 1978, pl. 9, fig. A). However, he noted that the colonial corals were a minor constituent of the biostromes in that facies. His remarks on the shelf-edge reef zone were based on observations of the El Abra strata at Taninul quarry, State of San Luis Potosí.

Several of the Mexican Cretaceous coral occurrences were mentioned in a review of the distribution of Cretaceous marine faunas of southern Mexico and northern Central America by G. Alencáster (1978). She noted the extraordinary abundance of corals in the Lower

Cretaceous of the San Juan Raya region, State of Puebla, as well as the corals of a diverse marine fauna from the Albian strata in the vicinity of Ensenada, Baja California. Alencáster (1978, p. 53) listed *Montastraea*, *Isastraea*, *Astrocoenia*, and *Myriophyllia*, some of the colonial reef coral taxa reported previously from Baja California (Allison, 1955), but no new occurrences were noted and no coral taxa were described.

The Lower Cretaceous corals reported previously from the vicinity of Tehuacán, State of Puebla, were reviewed by J. Barceló-Duarte (1978) as part of a detailed study of the stratigraphy and petrography of the Tehuacán - San Juan Raya region. However, because he could not determine the exact position of the fossil locality, he listed the coral species described previously by Felix (1891) twice, once in the faunal list of the Zapotitlán Formation and again in the faunal list of the San Juan Raya Formation (Barceló-Duarte, 1978, p. 55 and p. 89, respectively). Based on the geologic map of this area in Calderón-García (1956), Felix's (1891) coral locality in the Barranca Ayucingo would plot within the outcrop of the Zapotitlán Formation. In the faunal list for the Zapotitlán Formation, Barceló-Duarte (1978, p. 56-57) also listed some of Aguilera's (1906, table) nomina nuda coral species and some of the coral species reported previously by Müllerried (1934). In the faunal list for the San Juan Raya Formation, he also listed many of Aguilera's (1906, table) nomina nuda coral species, two of the coral species reported previously by Müllerried (1934, p. 62), and the 12 coral species described from the San Juan Raya area by Reyerros-Navarro (1963) (Barceló-Duarte, 1978, p. 91-95). In addition to the lists of previously reported taxa, he included a table that noted occurrences of solitary corals and species of five colonial coral genera, *Pollyphylloseris* [sic] sp., *Procyathopora* [sic] sp., *Cyathopora* [sic] sp., *Thamnastraea?* sp., and *Latimaeandra* sp., that were collected from the San Juan Raya Formation at five localities in the study area. These five new coral localities were at San Nicolás Tepostitlán, Las Lomas, Arroyo del Salitrillo, Santa Ana Teloxtoc, and La Mesa. Further studies of the corals from this region are needed to revise their taxonomy and clarify their local stratigraphic and geographic distributions.

Studies of the Cretaceous System of Mexico increased greatly in the 1980s and occurrences of corals were reported frequently. However, as in earlier decades, relatively few coral species were listed or described during this time. Corals were noted in the middle Cretaceous strata at Paso del Río, State of Colima, during a study of the faunal zonation and hydrothermal diagenesis of a rudist reef (Huffington, 1981a, 1981b), but the taxonomic identities of the corals were not determined. The occurrence of reef corals that was reported previously from the Cupido Formation of the Sabinas basin, northeastern Mexico, was briefly discussed in a study of the age-equivalent Sligo and Hosston formations of south Texas (Bebout *et al.*, 1981), but no taxonomic data were

provided. Studies of the Lower Cretaceous stratigraphy in the Monterrey - Saltillo area, northeastern Mexico, reported occurrences of corals at several localities including the coral-rudist reef of the Cupido Formation at Huasteca Canyon and Potrero Chico (Wilson, 1981), and the upper portion of the Stuart City reef facies of the Glen Rose Formation, with massive colonial corals, at Puerto de Aguacate (Smith, 1981). The coral faunas from these localities have not been described. Study of the Cretaceous fauna of the Franklin Mountains, El Paso County, Texas, and adjacent areas in New Mexico and the State of Chihuahua, Mexico, resulted in the discovery of corals at several localities (LeMone and Simpson, 1981). Subsequently 21 species of corals from Cerro de Cristo Rey in Dona Ana County, New Mexico, and the State of Chihuahua, Mexico, were listed in an abstract (Turnšek *et al.*, 1984), but none of the species was described or figured. Among these corals, one was from the Cenomanian Buda Formation and the others were from Albian age formations. Although the authors indicated that three of the 21 coral species were new, they were not described.

Some of the Cretaceous coral occurrences reported previously were reviewed in a study of the late Mesozoic paleogeography of Mexico by P. Enos (1983). He utilized occurrences of corals and other shallow-water organisms to help define regional paleogeography during the Cretaceous Period. Included in his discussion were mentions of the corals in the Barremian - Aptian reef facies of northeastern Mexico, the mid-Cretaceous of the Sierra de El Abra, the Upper Cretaceous (Turonian) of the Valles - San Luis Potosí platform, and the Cárdenas Formation in the State of San Luis Potosí (Enos, 1983). His study exemplifies the fact that corals can be very useful in certain studies even though their precise taxonomic identities are completely unknown.

Coral occurrences were noted frequently in a study of the sedimentation and diagenesis of the mid-Cretaceous platform margin of east-central Mexico by Minero *et al.* (1983). The majority of the reported occurrences were in the El Abra Formation or its basal equivalent, the Tamabra Formation, in the vicinity of the Sierra de El Abra, State of San Luis Potosí, and Laguna Colorada (also known as El Madroño), State of Querétaro. Despite the numerous occurrences of corals that were noted, the only coral taxon that was determined by them was *Cladophyllia*, a branched colonial coral that formed scattered thickets around caprinid-rich lenses in the reefal Taninul facies of the El Abra Formation at Taninul quarry, State of San Luis Potosí (Minero *et al.*, 1983, p. 150). The species of *Cladophyllia* and other morphologically similar species with a branched growth form that occur in these strata have not been described.

The most significant contribution to the taxonomy of Mexican Cretaceous corals during the 1980s was the description of a coral fauna from the vicinity of Huajuapán de León in the Mixteca Alta region of the State of Oaxaca by M. M. Reyerros de Castillo in 1983. A total of

19 coral species were described by her, including one that was described as new: *Thecosmilia oaxaquensis* Reyer de Castillo, 1983 (p. 24-25). Of the remaining 18 species, seven had been both described and reported previously by Felix (1891) from the Tehuacán region of the State of Puebla: *Thamnastraea xipei* (Felix, 1891); *T. crespoid* (Felix, 1891); *Stylina tehuacanensis* (Felix, 1891); *Myriophyllia neocomiensis* (Fromentel, 1857); *Calamophyllia sandbergeri* Felix, 1891; *Periseris irregularis* (Felix, 1891); and *Meandrophyllia montezumae* (Felix, 1891). Two of the remaining 11 species, *Baryphyllia confusa* (d'Orbigny, 1850b) and *Plesiastrea sulcatilamellosa* (Michelin, 1841), as well as one of the species just listed, *Thamnastraea crespoid* (Felix, 1891), were reported previously from the San Juan Raya region of the State of Puebla by Reyer de Castillo in 1963. The remaining nine species were described earlier by other authors and reported from the Cretaceous of Mexico for the first time by Reyer de Castillo (1983). Among these nine species are six that were originally described by J. W. Wells, three from the Glen Rose Formation of Texas: *Cyathophora haysensis* Wells, 1932; *Elasmophyllia tolmachoffana* (Wells, 1932); and *Diploastrea harrisi* Wells, 1932; and three others from the Barranquin Formation of northeastern Venezuela: *Stylosmilia gregorii* Wells, 1944; *Stylina surensensis* Wells, 1944; and *Cladophyllia stewartae* Wells, 1944. The remaining three species described by Reyer de Castillo (1983) were originally described from other localities: *Actinastrea* cf. *A. decaphylla madagascariensis* Alloiteau, 1958 (p. 185), which was known only from the Campanian(?) of Signal de Bodaroka, Madagascar; *Brachyseris morchella* (Reuss, 1854), a species known from the Senonian of Nefgraben, Gosau region (Alloiteau, 1957, p. 309); and *Thecosmilia tobleri* Koby, 1897, from the Neocomian of Switzerland. The occurrence of the latter three species in Mexico also constitutes their first reported occurrence in the Western Hemisphere. Reyer de Castillo's (1983) coral specimens were collected from: the Teposcolula Limestone (?Aptian - lower Cenomanian) at localities called Coixtlahuaca and El Rodeo; the Upper(?) Cretaceous Yucunama Formation at a locality northeast of San Pedro Yucunama; and an unnamed Lower Cretaceous limestone at localities in the vicinity of the Cañada del Toro, near the Río Mixteco, at Boquerón de San Juan Reyes, and at Vereda a Papalutla. The relatively broad geographic and stratigraphic distributions of the Cretaceous corals in this region suggests that many more coral species will likely be discovered here during future studies. The coral specimens that were described by Reyer de Castillo (1983) are at the Museo de Paleontología, Instituto de Geología, Universidad Nacional Autónoma de México, Mexico City (Perrilliat, 1992).

Geologic investigations of the Vizcaíno Peninsula on the western margin of Baja California have resulted in the discovery of fossil corals in two formations. Corals and other fossils were found in conglomerates of

the Tithonian - Valanginian Eugenia Formation at Punta Eugenia, on the western tip of the Vizcaíno Peninsula (Hickey, 1984) and also in the paraconglomerate - breccia of the upper Lower Cretaceous Asuncion Formation near Bahía Asunción, on the southern coast of the Vizcaíno Peninsula (Barnes, 1984). The fossils in these units were reworked and their exact source was not determined.

Occurrences of Cretaceous corals in the Albian carbonate rocks of the Sierra Pena Blanca and the Sierra Gomez, State of Chihuahua, were noted during a study of the paleoenvironmental setting of the Cretaceous stratigraphic sequence of that area (LeMone, 1984). The Cretaceous corals from these mountains have not been described.

Several occurrences of Cretaceous corals in Mexico were reported in the articles presented for the Third Congress of Latin-American Paleontology held in Mexico during 1984. Corals were reported from the lower Albian strata of the Teposcolula Formation at Apoala a Apasco and at Apoala a Santa María Huautla, in the Coixtlahuaca - Tomellín area, State of Oaxaca (Alencáster *et al.*, 1984), but none of the species was identified. Two coral species, *Epistreptophyllum* sp. and *Axosmilia* sp., were reported from the Lower Cretaceous rocks of the Lampazos area, just southeast of Tepache, State of Sonora (González-León and Buitrón-Sánchez, 1984), but neither was described or figured. Three of the coral taxa reported previously from the Alisitos Formation of Baja California Norte, *Cyathophora* sp., *Montastrea* sp., and *Montlivaltia* sp., were observed in Alisitos outcrops in the same region, at Los Torotes and La Bocana, and listed in a review of the biostratigraphy of that unit (Almazán-Vázquez and Buitrón-Sánchez, 1984). The precise taxonomic identities of the corals from the Alisitos Formation are unknown. An occurrence of corals in the Upper Cretaceous Mendez Formation, northwest of Ciudad del Maíz, State of San Luis Potosí, also was briefly noted (Hurtado-González, 1984), but no coral species were listed or described.

Many studies of Mexican Cretaceous rocks during the middle and late 1980s reported occurrences of fossil corals, but coral species were listed in relatively few of these works and only one study included a taxonomic treatment of coral species. Occurrences of corals in the Lower and middle Cretaceous strata of northeastern and eastern Mexico were frequently cited, including those of the La Peña (Cantú-Chapa *et al.*, 1985), Cupido (Wilson and Selvius, 1984; Wilson *et al.*, 1984; Selvius and Wilson, 1985), and El Abra (Bebout and Kupecz, 1985; Enos, 1986; Alencáster, 1987; Collins, 1988; Johnson *et al.*, 1988; Minero, 1988) formations. One study specifically concentrated on the Berriasian coral-rich limestone of the Taraises Formation, called the San Juan Lentil, at San Juan, Cortinas, and El Ranchero canyons in the States of Coahuila and Nuevo León (Frame and Ward, 1987). They alluded to an abundant and diverse coral fauna in the unit, including massive and laminar

microsolenids, dendroid calamophyllids, and other branched forms, but the only genus listed was *Stylosmilia*, a phaceloid form. In the northwest of Mexico, corals were noted in a study of the Lower Cretaceous biostratigraphy of Cerro de las Conchas, near Arivechi, State of Sonora, and one species was listed: *Parasmilia texana* (Roemer) [sic; probably Conrad's species] (Almazán-Vázquez and Jose Palafox, 1985). Other reports of corals from the State of Sonora include occurrences in several members of the Lower Cretaceous Mural Limestone at Montes Canova and the Sierra del Caloso in the northeastern part of the state (Warzeski, 1987) and the Represo Formation at Cerro Pima, near Santa Ana (Pérez-Ramos, 1986). The only other Cretaceous corals described from Mexico during the 1980s were from the middle Cretaceous Sierra Madre Limestone of the State of Chiapas (Steele, 1986; Waite, 1986). Four coral species were briefly described and figured: *Hydnophora* sp., *Multicolumnastraea* sp., *Astreopora?* sp., and *Cyathophora* sp. (Waite, 1986, p. 180-181, pl. 19). However, based on the figures of these taxa, the determinations seem doubtful.

Late in the 1980s, corals were discovered in the lower Albian Espinazo del Diablo Formation at the Sierra Espinazo del Diablo, Cerro Coloso, Cerro Encinal, and the Sierra Las Azules in the Lampazos area of the State of Sonora (González-León, 1988). Several coral taxa were listed, including *Stylina* sp., *Montlivaltia* sp., *Cladophyllia* [sic] *furcifera* Roemer, 1888, *Epistreptophillum* [sic] sp., and *Axomilia* [sic] sp., from the Sierra Espinazo del Diablo and *Thecosmilia* sp. and *Thamnasteria* sp. from Cerro Encinal, but none of these species was described or figured. However, the coral species of the Espinazo del Diablo Formation subsequently were described in later studies (see Scott and González-León, 1991, and Baron-Szabo and González-León, 1999, discussed below).

Geologic investigations from 1990 to the present

The geologic investigations reviewed in this section are arranged by geographic region instead of chronologically in order to achieve a more cohesive presentation of the information. Cretaceous coral species are described in only two of the articles cited below. Nonetheless, both articles altogether contain descriptions of 39 coral species (see Table 1), more than three times the number described during the entire first half of the twentieth century.

Fossil corals were commonly encountered in studies of the Mexican Cretaceous during the 1990s and early 2000s. However, as with earlier periods, only a few of the investigations listed coral species and even fewer provided taxonomic descriptions. In northeastern Mexico, occurrences of corals were reported from the Barremian - early Aptian Cupido Formation (Goldhammer *et al.*, 1991; Wilson and Ward, 1993;

Goldhammer, 1999; Lehmann *et al.*, 1999; Marrett *et al.*, 1999; Wilson, 1999; Lehmann *et al.*, 2000) and the Berriasian - Valanginian San Juan Lentil of the Taraises Formation, States of Coahuila and Nuevo León (Michalzik and Schumann, 1994; Ward, 1999). From the latter unit, Ward (1999) listed the same coral taxa reported earlier by Frame and Ward (1987). Also from the State of Nuevo León, corals of Late Cretaceous (Maastrichtian) age were noted at several localities in the Potrerillos Formation at Sierra El Antrisco (Vega-Vera and Perrilliat, 1990, p. 5-6), but no coral species were described or listed. However, one coral species from the Potrerillos Formation was listed in a later study, as well as one from the Cárdenas Formation in the State of San Luis Potosí: *Siderastrea* sp. and *Trochocyathus* sp., respectively (Vega *et al.*, 1995).

In northern Mexico, occurrences of corals were reported from the Albian Benigno Formation (Cantú-Chapa, 1993) and the upper Albian Loma Plata Limestone (Monreal and Longoria, 1999), State of Chihuahua, and from Lower Cretaceous strata in the northern part of the State of Sonora (Scott and Warzeski, 1993; Jacques-Ayala, 1995). In addition, corals were listed or described in a few of the studies in the State of Sonora. Four colonial coral species, *Stylosmilia* sp., *Thamnasteria* sp., *Cladophyllia furcifera* Roemer, 1888, and *Columnocoenia ksiazkiewiczi* Morycowa, 1964, from the middle Albian Espinazo del Diablo Formation were described and figured in a study of the Cretaceous strata of the Lampazos area, State of Sonora (Scott and González-León, 1991). Just to the northwest, in the central region of the same state, a taxonomically diverse assemblage of fossil corals, including *Callamophyllia* [sic], was reported from the upper part of the upper Aptian Cerro de Oro Formation at Cañada los Tubos, State of Sonora (González-León and Lucas, 1995). These corals and others from the Espinazo del Diablo Formation in the Lampazos area were subsequently described by Baron-Szabo and González-León (1999). They described a total of 36 coral species from the Lower Cretaceous Bisbee Group (see Table 1). Six of the 36 species were described as new: *Columastrea paucipaliformis*, *Columnocoenia minima*, *Cladophyllia mexicana*, *Pleurostylina major*, *Keriophyllia roniewiczzeae*, and *Stiboriopsis sonoraensis*. Of the remaining 30 species, only two were described earlier from Mexico: *Columnocoenia ksiazkiewiczi* Morycowa, 1964, and *Fungiastraea crespoi* (Felix, 1891). All of the other remaining 28 species were reported from Mexico for the first time. The coral specimens described by Baron-Szabo and González-León (1999) are in the paleontology collection of the Instituto de Geología, Universidad Nacional Autónoma de México, Hermosillo, State of Sonora. In addition, two other coral species, *Actinastrea scyphoidea* (Wells, 1932) and *Microsolena* sp. cf. *M. kugleri* (Wells, 1932), have been reported from the Bisbee Group of the northeastern part of the State of Sonora (McKee and Anderson, 1998, p. 1522). Both species were discovered

in Albian limestones that are stratigraphically equivalent to the upper Mural Formation.

A comparative study of the biostratigraphy of the Alisitos Formation, Baja California, and the Lower Cretaceous of the State of Sonora (Almazán-Vázquez, 1991) reported that the faunas of both areas indicated an Aptian - Albian age and that several taxa were common to both sequences, including the coral genus *Montlivaltia*. Corals also have been reported from the Upper Cretaceous Rosario Formation at Las Minas, Baja California (Lescinsky *et al.*, 1991), but the coral species from this formation have not been identified.

In eastern and southeastern Mexico, corals frequently were reported in studies of the Lower and middle Cretaceous El Abra Formation at the Sierra de El Abra, State of San Luis Potosí (Scott, 1990; Minero, 1991; Wilson and Ward, 1993; Basáñez-Loyola *et al.*, 1993; Alencáster *et al.*, 1999), and at El Madroño, State of Querétaro (Alencáster, 1991; Aguilar-Pérez *et al.*, 1993; Aguayo-Camargo, 1998; Alencáster and Oviedo-García, 1998). One coral genus, *Calamophyllia*, from the El Abra Formation has been noted (Aguayo-Camargo, 1993), but the coral fauna of this formation has not received a taxonomic treatment. Corals also have been reported from the Tamabra Formation, a basal facies and lateral equivalent of the El Abra Formation, near El Lobo, State of Querétaro (Enos and Stephens, 1993), and the Lower Cretaceous (Aptian) limestone of Cerro Matzitzí, near San Luis Atolotitlán and about 65 km south of the Tehuacán region, State of Puebla (Hernández-Láscara and Buitrón-Sánchez, 1992). None of the coral species from these latter occurrences has been identified. In southern Mexico, an occurrence of corals was reported from the Lower Cretaceous strata of the Ixtapa - Soyaló area, State of Chiapas (Ferrusquía-Villafranca, 1996), but no specific determinations were noted.

In southwestern Mexico, Cretaceous corals were noted in several reports during the middle and late 1990s. The coral occurrence in the Cuautla Formation of Guerrero reported earlier by Fries (1960) and another one in that same formation in the State of Morelos were noted (Hernández-Romano *et al.* 1998), but no coral species were listed. Scarce corals were noted in the Aptian - Albian Encino Formation of the Tamazula area, State of Jalisco (Buitrón-Sánchez, 1993b), but no species were listed and their taxonomic identities are unknown. To the south, occurrences of corals have been reported from the Albian El Cajón Formation (Pantoja-Alor, 1993a, 1993b; Omaña-Pulido and Pantoja-Alor, 1998) and Aptian strata of the San Lucas Formation (Buitrón-Sánchez, 1993a), both in the State of Michoacán, but the coral taxa from these units have not been described. Corals also have been reported from the upper Albian - lower Cenomanian Mal Paso Formation, State of Guerrero (García-Barrera, 1993, p. 45: *Actinastrea guadalupe* [sic], *Pollyphilloceris* [sic] *convexa*, and *Thammnastheria* [sic] sp.; Buitrón-Sánchez and Pantoja-Alor, 1994; Filkorn

and Pantoja-Alor, 1994, 1995a, 1995b; Chávez and García-Barrera, 1996; Buitrón-Sánchez and Pantoja-Alor, 1998), and the lower Aptian Cumburindio Formation, State of Michoacán (Alencáster and Pantoja-Alor, 1993; Pantoja-Alor, 1993a, 1993b; Filkorn and Pantoja-Alor, 1994, 1995a; Alencáster and Pantoja-Alor, 1995, 1996a, 1996b; Pantoja-Alor and Filkorn, 1995). Geologic investigations of fossiliferous Cretaceous outcrops in the Huetamo region, including the lower Aptian Cumburindio Formation near Turitzio, State of Michoacán, and the upper Albian - lower Cenomanian calcareous upper member of the Mal Paso Formation in the State of Guerrero, just north of Chumbútaro, State of Michoacán, have yielded diverse coral faunas that recently have been studied (Filkorn, 2001). The results of the latter study currently are being prepared for publication.

CONCLUSIONS

- 1) Corals have been reported from more than 170 Cretaceous localities in Mexico, from the Berriasian to the Maastrichtian, but very few of these corals have been studied.
- 2) About 60 percent of these 170 occurrences are Early Cretaceous in age.
- 3) Although there are more than 200 published reports of Cretaceous corals in Mexico, only 16 of these gave detailed descriptions of coral species.
- 4) Approximately 116 species of scleractinian corals have been described from Cretaceous occurrences in Mexico.
- 5) Approximately 90 percent of these 116 coral species are known from the Lower Cretaceous.
- 6) Most of the Cretaceous Mexican corals are known from the adjacent States of Puebla and Oaxaca in the southern part of the country and from the State of Sonora in the northwestern region.
- 7) Based on these data, the Cretaceous corals of Mexico still are poorly known and what little that is known is disproportionately weighted toward the Early Cretaceous species.
- 8) The taxonomic identities of the vast majority of the Mexican Cretaceous coral species are still unknown and they await future investigation.

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