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Veracruz-Anton Lizardo Reefs, Mexico: A Hybrid Carbonate-Siliciclastic System*

Los Arrecifes de Veracruz-Anton Lizardo: Un Sistema Híbrido Carbonato-Siliciclastico

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ABSTRACT

Veracruz-Anton Lizardo reefs are the only major living patch reefs in the southwestern Gulf of Mexico. These reefs are a classic example of coral reef growth in a terrigenous environment. The reef complex includes 13 reefs and 3 islands near Veracruz Harbor, and 15 reefs and 4 islands off the headland of Anton Lizardo, state of Veracruz, Mexico.

Petrographic study reveals that most of the sediments in reef top and upper flank environments comprise several types of coral-encrusted red-algal boundstones with associated coral-molluscan grainstones. The most common coral is *Acropora palmata*. Almost all reef tops in the carbonate buildups contain at least a few percent quartz, feldspar, and/or volcanic rock fragments. Some even display transported, fresh-water charophytes. Non-carbonate sand in reef top samples averages ~ 5%.

The provenance of fine, non-carbonate sand and volcanic rock fragments in the reefs off the port of Veracruz appears to be the Jalapa (Teziutlán) Province. Terrigenous sediments (and calcified fresh-water algal cells) that occur in reef tops off the Anton Lizardo salient are likely sourced from either the drainage basins of the Río Jamapa (vicinity of Mt. Orizaba/Citlaltépetl) or the Río Papaloapan (Sierra de Juárez source terrane). Multiple recycling of terrigenous glass shards and volcaniclastic sands from the coastal dune fields between Boca del Río (mouth of the Río Jamapa) and the headland of Anton Lizardo may have resulted in additional siliciclastic contamination of these reef tops.

Key words: Reefs Mexico, Carbonate-Siliciclastic Systems

RESUMEN

Los más grandes parches de arrecife vivo en el Sureste del Golfo de México son los de Veracruz-Anton Lizardo. Estos son un ejemplo clásico de arrecifes de coral que se desarrollan en un ambiente terrígeno. El complejo arrecifal se compone de 13 arrecifes y 3 islas frente al Puerto de Veracruz, y de 15 arrecifes y 4 islas fuera del cabo Anton Lizardo, Estado de Veracruz, México.

Estos ambientes en base a estudios petrográficos revelan que la mayoría de los sedimentos en la cima arrecifal y el costado superior comprende ciertos tipos de grandes rocas de coral-incrustado y algas-rojas con asociación de arenas de coral-molusco. El coral más común es *Acropora palmata*. Las acumulaciones en la mayor parte de la superficie arrecifal se componen en mayor o menor porcentaje de cuarzo, fedelpastos, y/o fragmentos de rocas volcánicas, algunas veces se observan clorofitas de agua dulce tranportadas. En promedio el ~5% es de sedimentos no carbonatados en las muestras superficiales del arrecife.

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La procedencia de sedimentos finos no carbonatados y fragmentos de roca volcánica en los arrecifes ubicados frente al puerto de Veracruz provienen de la provincia de Jalapa (Teziutlán). Los sedimentos terrígenos (y las algas calcificadas de agua dulce) que existen en la superficie de los arrecifes de Anton Lizardo son probablemente originarios de la desembocadura de las cuencas del Río Jamapa (de las montañas de Orizaba y Citlaltépetl) o del Río Papaloapan (que proviene de la Sierra de Juárez). El reciclamiento de los fragmentos de cristales y sedimentos volcanoclásticos de las dunas costeras entre Boca del Río (desembocadura del Río Jamapa) y la costa de Anton Lizardo, puede que sea la causa de la presenci a siliclástica en la superficie arrecifal.

Palabras clave: Arrecifes de México, Sistemas Carbonato-Siliciclastico

Introduction

Only three modern scleractinian reefs occur in the western Gulf of Mexico: 1) Flower Garden Banks, a "turtle-back structure" (Rezak, 1977; Rezak *et al.*, 1985), 2) the Isla de Lobos Group (Rigby and McIntire, 1966), and 3) the Veracruz patch reefs off the port of Veracruz and the headland of Anton Lizardo, Mexico (Morelock and Koenig, 1967; Krutak and Rickles, 1979; Krutak, Jordan and Gío-Argáez, 1990). Study of these living reefs, and ones like them, has allowed recognition of similar bioherms in the fossil record. Fossil reefs have enormous hydrocarbon potential, and a huge literature exists concerning their sedimentology, facies geometry, biofacies, etc. (see Pugh, 1950; Rodgers, 1957; Purdy, 1974; Frost *et al.*, 1977; Toomey, 1981; Crevello *et al.*, 1989 for bibliographies). Many living and fossil reefs occur in pure carbonate environments that are essentially free from siliciclastic contamination. However, there are many that occur in mixed carbonate-siliciclastic milieu.

The 1995 Meeting of the Geological Society of America in New Orleans, Louisiana, sponsored Theme Session No. 27 - "Hybrid Carbonate-Siliciclastic Sedimentary Environments." This research session consisted of 16 papers devoted to such mixed systems. The systems involved ranged from modern to as old as Pennsylvanian. As Co-Chair of this Theme Session, the writer presented a paper (Krutak, 1995) on the Veracruz-Anton Lizardo system. These carbonate buildups furnish a classic modern example of hybrid systems. This paper will summarize their petrographic characteristics, and possible source areas of siliciclastic contamination. Citations of other papers that deal with examples of coral reef growth in terrigenous environments may be found in Doyle and Roberts (1988), Budd and Harris (1990), and in Lomando *et al.*, 1991.

Study Area

Veracruz-Anton Lizardo reefs include 13 reefs and 3 islands near Veracruz Harbor, and 15 reefs and 4 islands off the headland of Anton Lizardo that are contaminated by terrigenous sediment. The names of the major reefs (but not the smaller islands) are shown on Fig. 1. A much more detailed, large-scale map of this area may be seen in Krutak, Jordan, and Gío-Argáez (1990, Enclosures 1-3).

The coastal plain near Veracruz is quite narrow, being only about 16 km (10 mi) wide. Across it flow several streams that drain the Sierra Madre Oriental, which bounds the plain on the west. These streams, the largest of which is the Río Jamapa (Fig. 1), cut through Tertiary and Quaternary sandstones and siltstones on the coastal plain and erode headward into andesitic volcanic and granitic rocks in the Sierra. The Sierra Madre Oriental is the site of two very high composite andesitic volcanic peaks. Mt. Orizaba (Citlaltépetl), at 5700 m (18,700 ft), is Mexico's highest mountain; its northern neighbor, Cofre de Perote, reaches an elevation of 4282 m (14,048 ft). These peaks are about 128 km (80 mi) west of Veracruz, and streams flowing eastward from them have steep gradients (Self, 1971). Thus, a large volume of mixed terrigenous material is supplied to rivers flowing eastward out onto the Mexican continental shelf.

The coastline in the region near Veracruz (Fig. 1) trends northwest-southeast, except for two salients or headlands, one of which occurs at Veracruz, and the other at Anton Lizardo, a small fishing village to the southeast. The Río Jamapa enters the Gulf of Mexico at Boca del Río where it debouches into a large open bay between the two headlands. A spit blocks the mouth of the river, and no significant delta exists today.

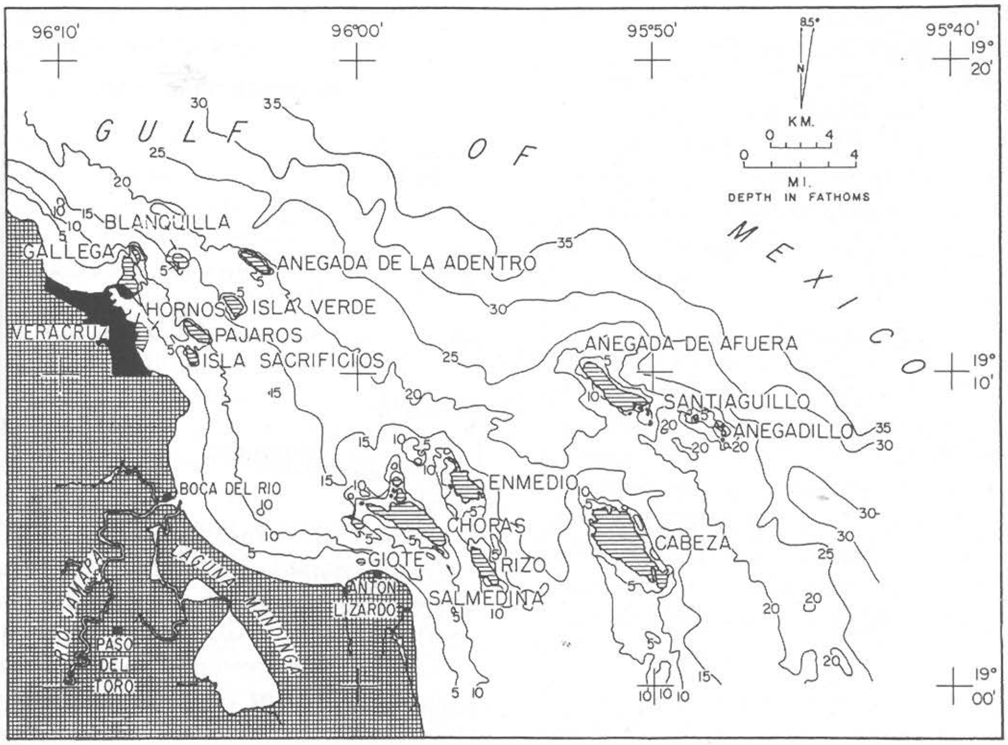

Fig. 1 - Location map, Veracruz-Anton Lizardo reefs, Mexico. From Krutak, 1982, p. 259.

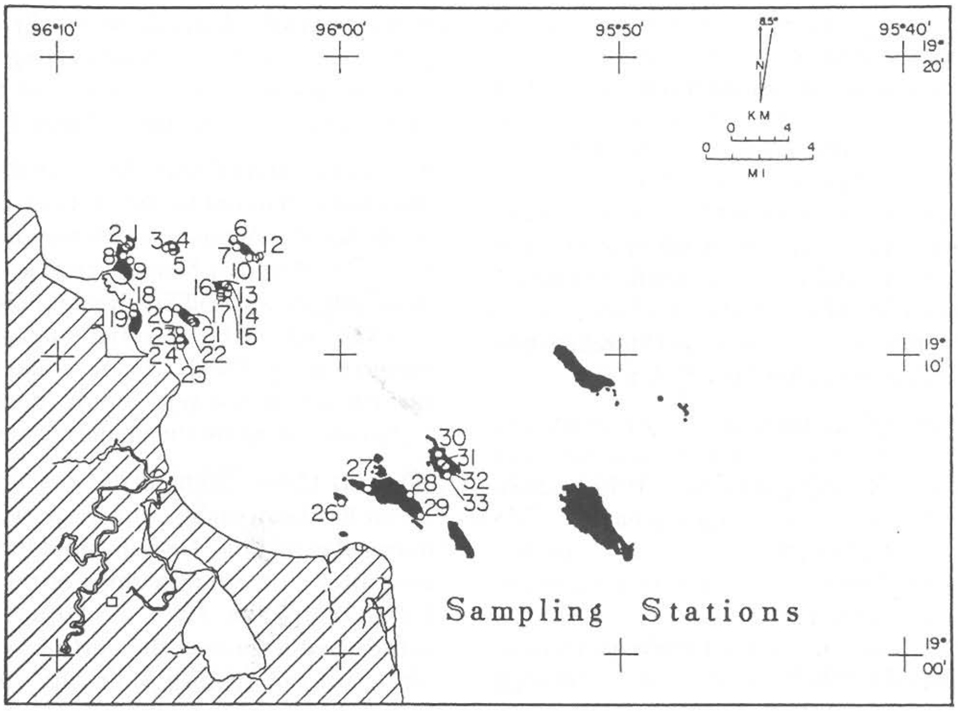

Fig. 2 - Sampling stations, Veracruz-Anton Lizardo reefs, Mexico. Adapted from Krutak, 1982, p. 260.

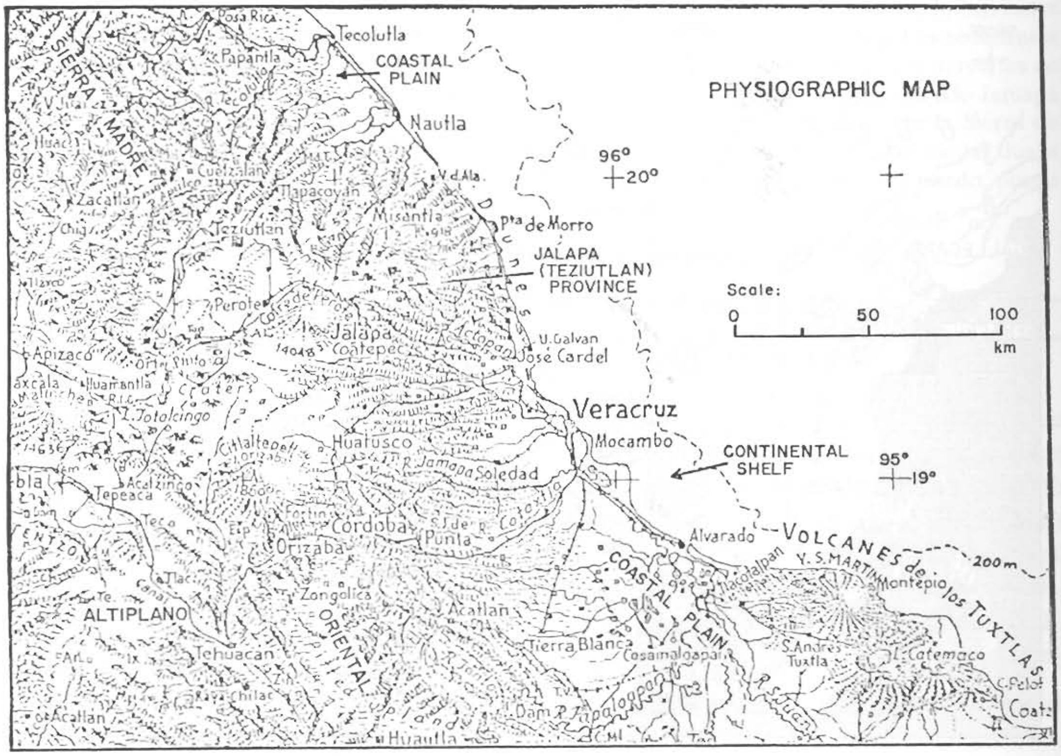

Fig. 3 - Physiographic map of the Veracruz, Mexico area. Adapted from Raisz, 1959.

Río Jamapa, located midway between Anton Lizardo and the port of Veracruz, drains an area of 3,627 km^2 and has an annual discharge of 2,689 million m^3 (Tamayo, 1949). It rises out of the Teziutlán source terrane (Fig. 3) of the 14,000 km^2 Veracruz Basin (Tamayo, 1949; Ordoñez, 1936). The river descends through the foothills of the Sierra Madre Oriental approximately 80 km (50 mi) west of Veracruz, and carries andesitic sediments derived from Mount Orizaba (Citlaltépetl), a quiescent composite volcanic cone (Morelock and Koenig, 1967, p. 1001; Krutak, 1974, p. ll).

Río Papaloapan (Fig. 3) also affects sedimentation on the Anton Lizardo headland and the reef complex there (Krutak and Rickles, 1979, p. 265). This river drains a much larger area than Río Jamapa, and has significantly larger annual discharge - 36,524 km^2, 22,280 million m^3 (Tamayo, 1949). It rises in the Sierra de Juárez of Oaxaca state, and originates from the Papaloapan source area (Edwards, 1969). It descends through Precambrian and Paleozoic igneous, sedimentary, and metamorphic terranes from 200 km (120 mi) to the west in the Sierra de Juárez (Freeland, 1971, p. 33). The river enters Alvarado Lagoon near the town of the same name about 38 km (24 mi) southeast of the headland of Anton Lizardo.

Two other rivers may also contribute some siliciclastic material to the reefs of the Veracruz headland. Río Actopan, which rises near Cofre de Perote northwest of Jalapa, Veracruz, and the Río de la Antigua, a subsidiary stream (Edwards, 1969), also rise out of the Teziutlán (Jalapa) drainage basin (Fig. 3). These streams could conceivably furnish additional terrigenous detritus to the carbonates along this headland.

Edwards (1969) pointed out that the Veracruz Basin has been stable with respect to sea level during Recent time. He noted that the iron "eyes" used to secure Spanish ships-of-the-line to the Castillo de San Juan de Ullua, a fortress constructed to protect the port of Veracruz from pirates of the Spanish Main, are still the same height above mean tide level as they were when the fort was first built in 1582 (Heilprin, 1890).

Terrigenous Contamination on the Veracruz-Anton Lizardo Reefs

Fig. 2 shows the 33 sampling stations where the writer collected sediments from the sediment/water interface on the various reefs in this area (Krutak, 1982). Loose sedimentary material covering the reefs was collected by hand into a core tube, or the tube itself was scraped along the reef surface until at least half of it was filled with sediment. The writer used a 3.5 cm inside diameter Phleger core tube 0.30 m long for the sampling device. The initial goal of the study was the ecology and taxonomy of the modern ostracodes living on these reefs. Sample depths, salinity values, and other ecological measurements may be found in Krutak (1982).

Subsequently, the writer became interested in the siliciclastic mineralogy/petrology of these reefs. Cuts of the original samples were impregnated with petropoxy blue resin, thin-sectioned, and studied petrographically. A survey of the 33 samples revealed that certain samples had relatively high percentages of terrigenous, siliciclastic contaminants. Jordan (in Krutak *et al.*, 1990) pointed out that most of the sediments in reef top and upper flank environments consist of several varieties of coarse-grained, reef-derived grainstones. Any lime mud that may have been produced on these reefs is apparently winnowed by wave action on the reef crests and is transported off-reef in suspension. The reefs at Veracruz are patch reefs, whose general morphology and sediment types are illustrated in Fig. 4.

However, petrographic study reveals that almost all reef tops off Veracruz and Anton Lizardo contain at least a few percent quartz and/or feldspar. Some of the reefs also display volcanic rock fragments. Since the reefs are steep-sided and are physically higher in elevation than adjacent quartz-rich shelf areas, and are sources of large volumes of carbonate sand-sized material, it is anomalous that any non-carbonate sand occurs in reef top environments.

Following is an analysis of the terrigenous detritus detected in some of these samples. The Figures that follow (Figs. 5-8) are arranged in two groups.

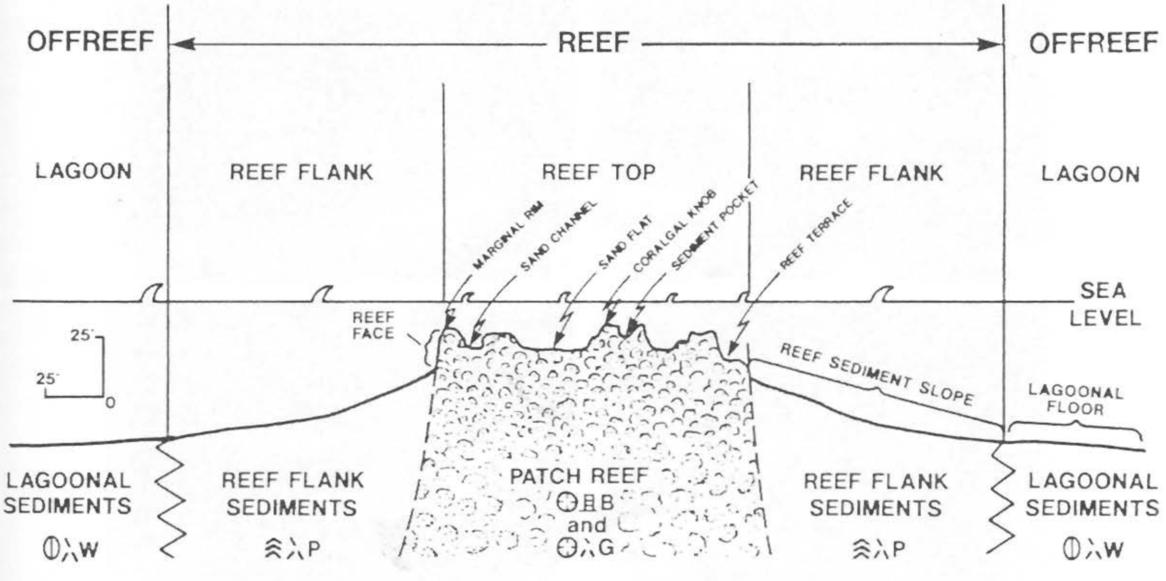

Fig. 4 - Generalized features associated with patch reefs. Listed from top to bottom are depositional environments, interfaces at the sediment-water boundary, and sedimentary deposits. After Jordan, 1985.

The symbols along the bottom of each depositional environment are modified versions of Dunham's classification of carbonates: lagoonal sediments = wackestones; reef- flank sediments=packstones; patch reef = boundstones and grainstones.

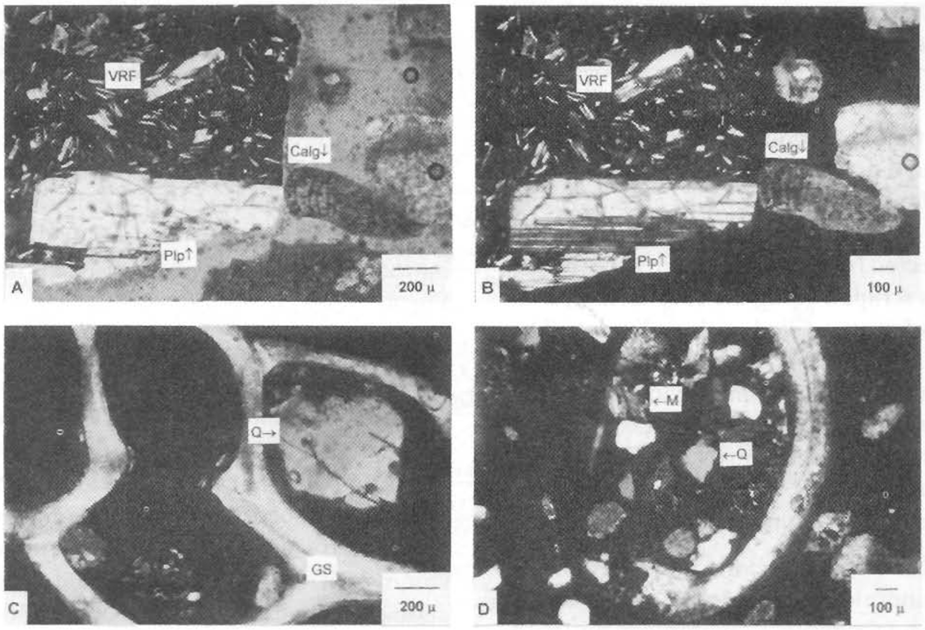

Fig. 5 - Thin section photomicrographs of blue epoxy-impregnated modern sediments from the Veracruz reef complex off the port of Veracruz, Mexico. See Figs. 1 and 2 for sample location numbers and reef names. Scale bars are in microns (µ) A-Gallega Reef, Station 18, plane-polarized light: volcanic rock fragment (VRF) with plagioclase phenocryst (Plp) and coralline alga (Calg); B-Gallega Reef, Station 18, cross-polarized light: volcanic rock fragment (VRF) with plagioclase phenocryst (Plp) and coralline alga (Calg); C-Hornos Reef, Station 19, crossed-polarized light: quartz grain (Q) trapped inside gastropod shell (GS); D-Gallega Reef, Station 9, crossed-polarized light: angular quartz grains (Q) and mica fragments (M) inside a piece of mollusk shell.

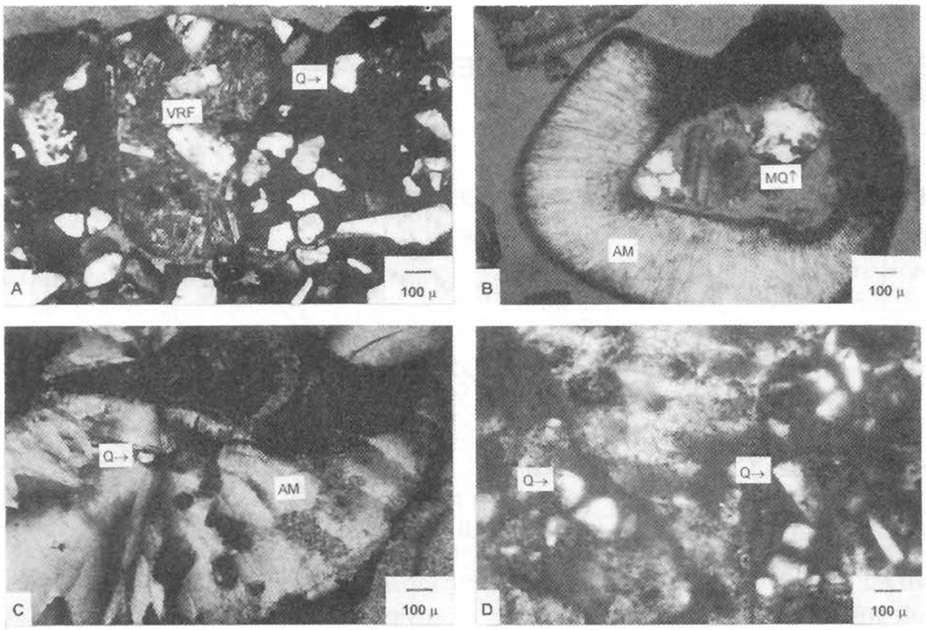

Fig. 6 - Thin section photomicrographs of blue epoxy-impregnated modern sediments from the Veracruz reef complex off the port of Veracruz, Mexico. See Figs. 1 and 2 for sample location numbers and reef names. Scale bars are in microns (µ). A-northwest Pajaros Reef, Station 20, plane-polarized light: volcanic rock fragment (VRF) and angular quartz (Q) grains: B-Sacrificios Reef, Station 23, plane-polarized light: metamorphic quartz (MQ) trapped inside an aragonite mollusk shell (AM). C-Blanquilla Reef, Station 5, crossed-polarized light: angular quartz (Q) trapped inside an aragonitic mollusk shell (AM). D-Anegada de Adentro Reef, Station 7, plane-polarized light: abundant angular quartz (Q) in micritic matrix.

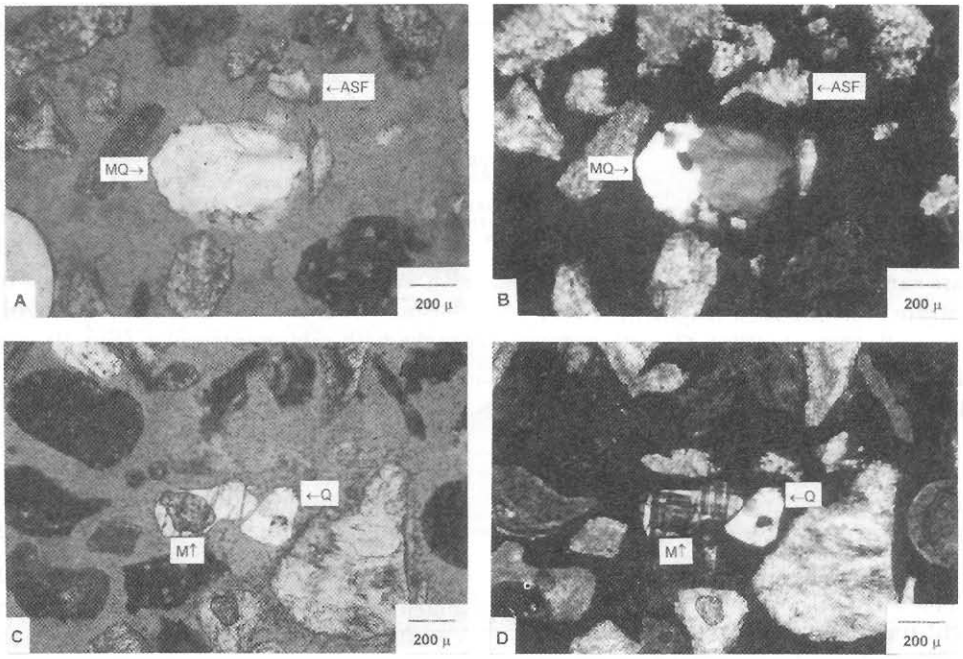

Fig. 7 - Thin section photomicrographs of blue epoxy-impregnated modern sediments from the Veracruz reef complex off the headland of Anton Lizardo, Mexico. See Figs. 1 and 2 for sample location numbers and reef names. Scale bars are in microns (μ). A-middle Enmedio Reef, Station 31, plane-polarized light: aragonite shell fragments (ASF) and metamorphic quartz grain (MQ); B-middle Enmedio Reef, Station 31, the same section in cross-polarized light; C-southeast Enmedio Reef, Station 32, plane-polarized light: microcline (M) and quartz grains (Q); D-southeast Enmedio Reef, Station 32, the same section in cross-polarized light.

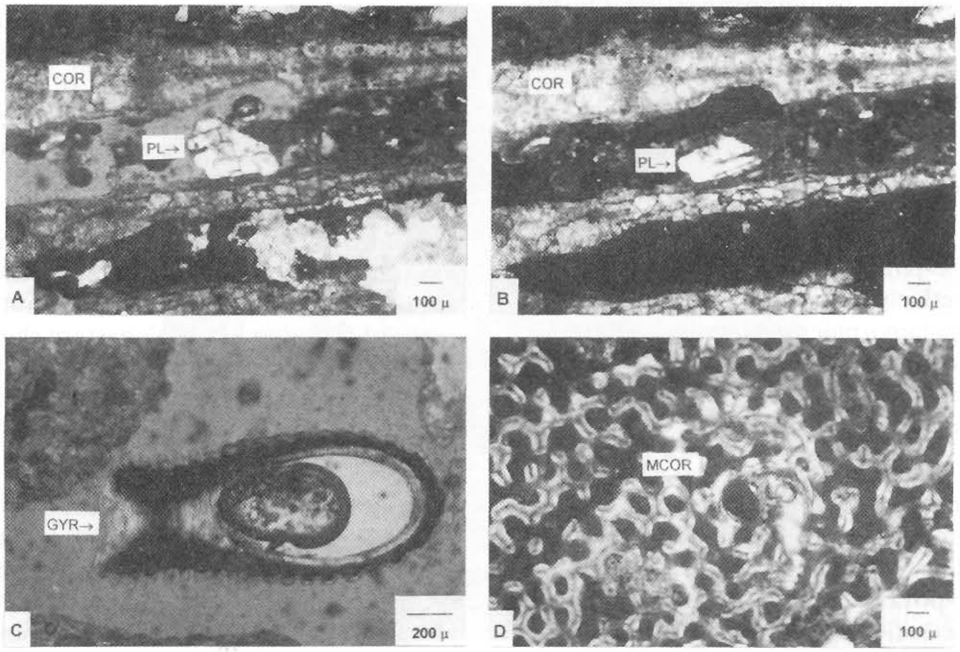

Fig. 8 - Thin section photomicrographs of blue epoxy-impregnated modern sediments from the Veracruz reef complex off the headland of Anton Lizardo, Mexico. See Figs. 1 and 2 for sample location numbers and reef names. Scale bars are in microns (μ). A-northwest Chopas Reef, Station 29, plane-polarized light: corallum (COR) with plagioclase (PL) fragment; B-northwest Chopas Reef, Station 29, the same section in cross-polarized light; C-Chopas Reef, Station 26, plane-polarized light: gyrogonite (calcified egg cell) of a fresh-water alga; D-southeast Chopas Reef, Station 28, plane-polarized light: massive corallum (MCOR) of a scleractinian coral.

Figs. 5-6 are photomicrographs of epoxy-impregnated samples collected from the Veracruz group. Figs. 7-8 are photomicrographs of similarly prepared samples that are from the Anton Lizardo group of reefs.

Veracruz Reef Group

Figs. 5-A,B are samples from Gallega Reef (Station 18) that illustrate volcanic rock fragments (VRF) with plagioclase phenocrysts (Plp). Coralline algae (Calg) are also labeled. Fig. 5C is from Hornos Reef (Station 19). The crossed-polarized light micrograph shows a quartz grain (Q) trapped inside a gastropod shell (GS). Fig. 5D, from Gallega Reef, (Station 9) is a crossed-polarized light view of angular quartz grains (Q) and mica fragments (M) inside a piece of mollusk shell. Fig. 6A is from northwest Pajaros Reef (Station 20). The plane-polarized light micrograph shows a volcanic rock fragment (VRF) and angular quartz (Q) grains. 6B, from Sacrificios Reef (Station 23), is a plane-polarized light view of metamorphic quartz (MQ) trapped inside an aragonite mollusk shell (AM). 6 C, from Blanquilla Reef (Station 5), is a crossed-polarized light view of angular quartz (Q) trapped inside an aragonitic mollusk shell (AM). Fig. 6D, collected on Anegada de la Adentro Reef (Station 7), is a plane-polarized light micrograph of abundant angular quartz (Q) in a micrite matrix.

Anton Lizardo Reef Group

Figs. 7A,B, from middle Enmedio Reef (Station 31) are plane-polarized and cross-polarized light views respectively, of aragonite shell fragments (ASF) and metamorphic quartz grains (MQ). Figs. 7C,D are similar micrographs from southeast Enmedio Reef (Station 32) showing microcline (M) and quartz grains (Q).

Figs. 8A,B, from northwest Chopas Reef (Station 29) are plane-polarized and cross-polarized light micrographs of coralla (COR) with plagioclase (PL) fragments. Fig. 8C, from Chopas Reef (Station 26) is a plane-polarized light micrograph of a gyrogonite (calcified egg cell) of a fresh-water alga. Fig. 8D depicts a plane-polarized light view of a sample from southeast Chopas Reef (Station 28) that contains abundant massive coralla (MCOR) of scleractinian corals. Thus, this sample shows little terrigenous contamination.

Possible Sources of Siliciclastic Contaminants

The volcanic rock fragments and angular quartz grains (some apparently of metamorphic origin) that contaminate the sediments of the Veracruz reef complex (Figs. 5, 6) may have originated from the Ríos Actopan-de la Antigua drainage basin. This basin, which consists mostly of Cenozoic volcanic rocks with minor intrusives (Fig. 9), seems to be the most likely source for these materials, especially since in the winter, from September through February, storms called "El Nortes" blow in from the north. Such storms are likely to transport sediment southward from the Actopan drainage area onto reef tops along the Veracruz headland.

Metamorphic quartz grains, microcline, and plagioclase fragments are fairly common as minor constituents of the carbonates on the Anton Lizardo reef complex (Figs. 7,8). A calcified egg cell of a fresh-water alga (gyrogonite or charophyte) also occurs in these sediments.

Edwards (1969) contoured the percentage of heavy minerals in the 3.5-4.0 phi range on both the Veracruz and Anton Lizardo reef complexes. He noted that the Río Jamapa zone displayed a lower percentage of heavy minerals, while samples southward of the midsection of the complex contained over 50 percent with the highest value being 85 percent. His map indicates that values on the Veracruz complex varied between 10 and 20 percent, with the highest percentage being 26 percent. He also showed that there was another low concentration of heavies between the 5 fathom contour line to approximately 2 nautical miles seaward of Anton Lizardo's eastern shoreline. He attributed this area of low concentration to dilution of the heavies by lighter sediment fractions being carried northward from the Río Papaloapan by longshore currents.

Such northward transport may occur; however, Fig. 10, a February LANDSAT image of the reefs off Veracruz and Anton Lizardo, shows the southeasterly flow of turbid water from the mouth of the Río Jamapa along the coast toward the reefs off Anton Lizardo. This flow may have transported the charophyte shown in Fig. 8C. It also displays a better developed sediment plume exiting Laguna de Alvarado, which comprises the mouth of the Río Papaloapan.

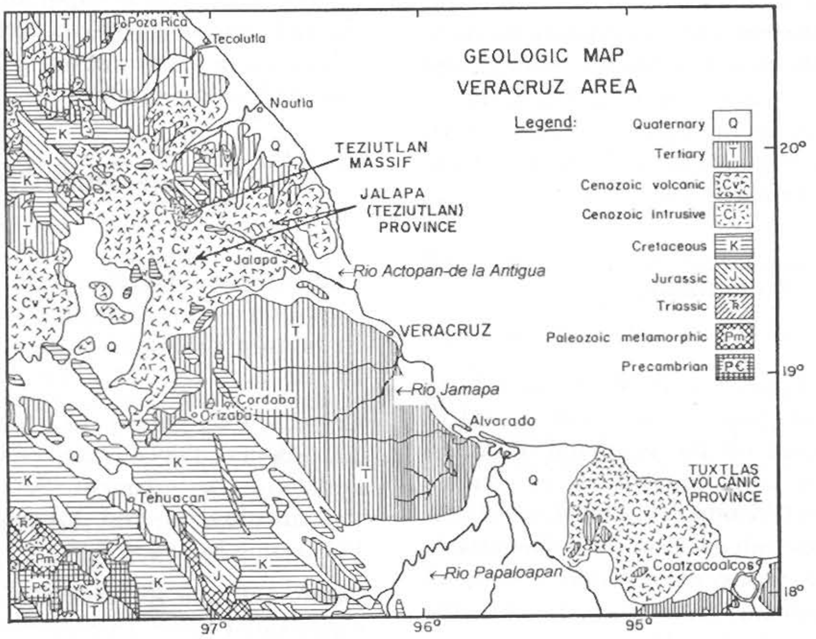

Fig. 9 - Geologic map of the Veracruz area, Mexico. The Jalapa or Teziutlán Province (or Uplift) is essentially volcanic at the surface, but includes the plutonic Teziutlan massif. Compare this map with Figure 3. The rivers Actopan and de la Antigua rise from this source terrane. The Río Jamapa originates near Córdoba in the foothills surrounding Orizaba; thus most of its drainage basin consists of Tertiary and Cretaceous sedimentary rocks. Río Papaloapan crosses the coastal plain and drains into the Laguna de Alvarado near the coastal town of Alvarado. Adapted from Freeland, 1971.

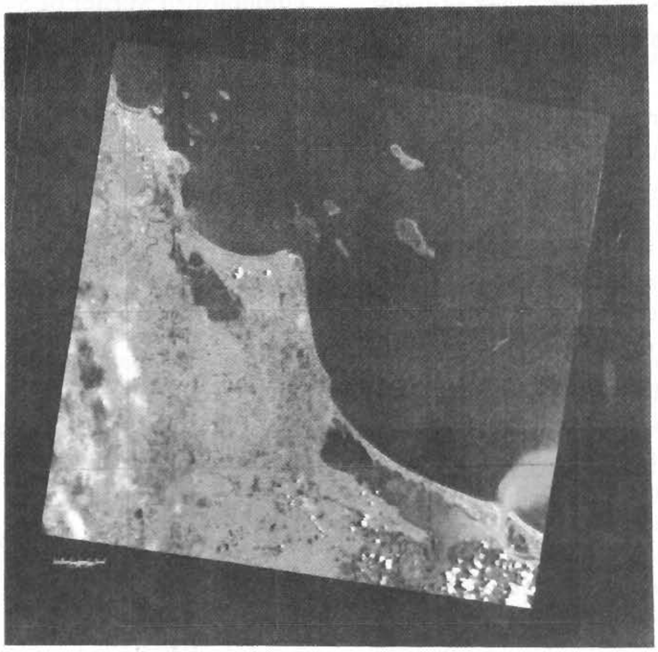

Fig. 10 - LANDSAT image of the Veracruz-Anton Lizardo reefs, state of Veracruz, Mexico (compare this image with Fig. 1). Note the southeasterly flow of turbid water from the mouth of the Río Jamapa along the Anton Lizardo headland and towards the reefs off this salient. Another much better developed sediment plume exits the Laguna Alvarado, into which the mouth of the Río Papaloapan debouches (southeastern edge of image). Also note the suspended sediment saturating the waters off the headland of the Port of Veracruz (northwest end of image), as well as the expanded nature of the Laguna Mandinga. From Krutak *et al.*, 1990, p. 5).

It is also possible that some of the siliciclastics on the Anton Lizardo reefs are sourced from the dune fields between the mouth of the Río Jamapa and the headland of Anton Lizardo. These dunes appear to be developing parallel to the eastern coastline of the point, and are eroding on the northern shore (Edwards, 1969, p. 4).

Conclution

Veracruz-Anton Lizardo reefs, Mexico include 13 reefs and 3 islands near Veracruz harbor, and 15 reefs and 4 islands off the headland of Anton Lizardo that are contaminated by terrigenous sediment. The reefs consist of coral-encrusted red-algal boundstones with associated coral molluscan grainstones. The most common coral is *Acropora palmata*, the dominant species of most reefs in the Caribbean and the Gulf of Mexico. Few reef top samples at Veracruz-Anton Lizardo are truly arenaceous (have at least 10% non-carbonate sand). However, all reef tops off Veracruz and Anton Lizardo contain at least a few percent quartz, feldspar, and/or volcanic rock fragments. Some of them even display fresh-water algal remains (charophytes). An average value for non-carbonate sand in reef top samples is ~5%.

Storm transport of fine non-carbonate sand onto reef tops is the likely cause of this mixing on the northern suite of reefs (off the port of Veracruz). The source area of these sediments appears to be the drainage basins of the Ríos Actopan-de la Antigua. These rivers drain the Jalapa (Teziutlán) province, which lies northwest of the city of Veracruz in the foothills of the Cofre de Perote.

Terrigenous sediments that occur in reef tops off the Anton Lizardo headland are likely sourced from either the drainage basins of the Río Jamapa or the Río Papaloapan. The Río Jamapa rises in the Sierra Madre Oriental, near the town of Córdoba, and drains the slopes of Mt. Orizaba (Citlaltépetl), the highest composite andesitic volcano in Mexico. Alternatively, some of the terrigenous component on the Anton Lizardo reefs may have come from the Río Papaloapan drainage basin, which drains a very large area of the Sierra de Juarez, southeast of Veracruz. Additional secondary reworking of sand from the beach dunes between Boca del Río (mouth of the Río Jamapa) and the headland of Anton Lizardo may have occurred, and may have resulted in deposition of terrigenous debris on the Anton Lizardo reef tops.

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