THE EFFECTS OF HOLOCENE SEA-LEVEL FLUCTUATIONS ON THE MORPHOLOGY OF BRAZILIAN CORAL REEFS

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ABSTRACT The most common growth form of the Brazilian coral reefs is coral pinnacles with an unusual mushroom-like form called *chapeirões*. Adjacent *chapeirões* coalesce on top, whereby forming large compound reef structures which do not display the marked zones of the Caribbean reefs and have horizontal tops that stay completely uncovered during low waters. Numerous C^{14} dates from the top of the reefs, being older than 3,000 years B.P., provide evidence to suggest that these coral reefs reached heights above today's sea level and this would only occur if the Holocene sea level along Eastern Brazil had higher stands than the present position. These extensive and exposed reef flat surfaces were formed by the erosion of the upper part of the reefs that occurred during sea level fluctuations in late Holocene time, along the eastern coast of Brazil.

RESUMO Os recifes de corais do Brasil crescem em colunas com a forma de cogumelos, conhecidas como "chapeirões". Chapeirões adjacentes podem coalescer formando estruturas recifais maiores, as quais apresentam o topo recifal aplainado e emerso durante as marés baixas. Numerosas datações radiométricas em amostras coletadas do topo de vários recifes localizados nas costas nordeste e leste do Brasil mostraram idades superiores a 3 000 anos A.P. Considerando que o nível do mar, durante o Holoceno, na costa do Brasil, alcançou níveis mais altos que o nível médio atual, e sabendo-se que o crescimento vertical dos recifes acompanha o nível do mar, conclui-se que este topo aplainado dos recifes brasileiros se formou em consequência da erosão das partes mais altas dos recifes, expostas subaeramente durante as duas regressões súbitas que ocorreram a partir de 4 200 anos A.P.

INTRODUCTION Brazilian coral reefs differ significantly from North Atlantic reefs. The most important difference is in their morphology which consists of a mushroom-like growth form and the presence of a flat top, which stays subaerially exposed during low waters.

The morphology of Brazilian coral reefs associated with the history of the Brazilian Quaternary sea level changes offers an important opportunity to broaden the knowledge of reefs and perhaps to produce some new insights into the variations of the North Atlantic reefs, as well as further comparison with the Pacific examples.

THE MORPHOLOGY OF THE REEFS The most common growth form of the Brazilian coral reefs is an isolated reefs structure with an unusual mushroom-like form called *chapeirão*. One single *chapeirão* can vary in height from less than 1 m to more than 20 m and the diameter of the flattened top varies from less than 1 m up to 50 m.

Adjacent *chapeirões* can coalesce, by their tops, forming large compound reef structures with varied heights and lateral dimensions. These reef structures are represented by poorly developed fringing reefs, small bank reefs, and large reef platforms (Plate 1 A, B, and C) (Leão 1982, I Leão & Lima 1982, Leão *et al.* 1982; Araújo *et al.*, 1984, Nolasco

& Leão 1984, Araújo 1985).

These reefs do not display the well-marked zones of the Caribbean reefs. The fore reef zone drops abruptly into deeper waters and lacks the spur and groove system. It is also bordered by small isolated *chapeirões*. In most of the reefs a well-developed algal rim protrudes from their windward borders (Plate 1D).

The isolated bank and platform reefs do not have a back reef with a lagoon. Behind these reefs, the water conditions are similar to those of the sea. In the back reef zone of the fringing reefs, which usually grown on a non-reefal substrate (Araújo *et al.* 1984, Nolasco & Leão 1984), there are extremely shallow lagoons without patch reefs (Plate 1A).

The reefs have horizontal tops which are exposed during low waters (Plate 1 D to H). In these exposed reef limestone, large coral heads are truncated by erosion (Plate 1 E). Although flat, the top of the reefs are somewhat irregular. There are numerous small pools, some shallow and sandy, others deep (maximum 3 m), and with a rocky bottom. Carbonate sand with ripple marks, of all sizes, accumulates on these exposed surfaces (Plate 1 F). But they are mostly covered by a carpet of calcareous, fleshy red and green algae, as well as zoanthids (Plate 1 G). Also patches of *Penicillus red.* and isolated algal-laminated structures are present on this rugged surface (Plate 1 H).

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Plate 1-A: The Itaparica fringing reef and part of its shallow lagoon. B: Oblique aerial view of a bank reef and isolated chapeirões on the Abrolhos area. C: Oblique aerial view of a large platform reef on the Abrolhos area. D: The surface of the Coroa Vermelha reef (Abrolhos area) showing the reef rim on the back. E: A truncated coral head on the top of a reef at the north coast of the State of Bahia. F: A rippled carbonate sand mound on the top of the Areia reef (Abrolhos area) G: Carpets of soft and fleshy green and red algae covering part of the truncated surface of a reef at the coast of the State of Alagoas. H: *Penicillus* red and laminated algal mushroom (oncolitic) growth on the top of the Area reef (Abrolhos area).

THE SEA-LEVEL CURVE DURING THE LAST 7,000 YEARS B. P. ALONG THE EASTERN COAST OF BRAZIL

Based on about 40 C^{14} dates from vermetid gastropodes and corals Bittencourt *et al.* (1979) and Martin *et al.* (1979, 1980a, 1980b) constructed a curve showing the sea-level fluctuations during the last 7,000 years along the coast of Salvador (Fig. 1). This curve indicates that:

1. the Holocene sea-level reached the present-day position of mean sea level, for the first time, at about 7,000 years B.P.;
2. three high stands of sea-level were detected at about 5,200 years B.P., 3,500 years B.P., and about 2,500 years B.P. During the first maximum the sea was about 4.7 m above the mean present sea-level (m.p.s.l.), the second maximum reached 3 m above m.p.s.l. and during the third, the sea was 2.5 m higher than m.p.s.l.;
3. between 4,100 and 3,800 years B.P. and between 2,800 and 2,600 years B.P., sea-level was approximately at the same level as m.p.s.l.;
4. about 1,000 years B.P., sea-level was still one meter above m.p.s.l.; and it dropped progressively to the present position.

For the southern part of the Brazilian coast (states of Rio de Janeiro and São Paulo) two other curves were constructed (Martin & Suguio 1975 and 1978, Suguio *et al.*

Figure 1 – The Holocene sea-level curve for the coast of the State of Bahia (after Martin *et al.* 1979).

1980). These curves show the same trend with very small displacements relative to the time when sea-level reached the present position for the first time.

For the northeastern coast (states of Pernambuco, Alagoas, and Sergipe), a curve was not constructed, but several C^{14} dates indicate Holocene high stands of sea-level, which coincide with the curves mentioned earlier (Delibrias & Laborel 1971, Bittencourt *et al.* 1983, Dominguez *et al.* in prep.).

CONCLUSION The presence of flat tops which are sub-aerially exposed during low waters and having large truncated coral heads, associated with the age of the surface of the reef structures, show the effects of Holocene sea-level fluctuations on the reef morphology.

Figure 2 – Location of the coral samples dated by C^{14} , taken from the exposed surface of the studied reefs.

Numerous C^{14} dates of coral samples from the reef surfaces older than 3,000 and 4,000 years B.P. (Table 1 and Fig. 2) provide evidence which suggests that the Brazilian coral reefs reached heights higher than the present sea-level, and that they were truncated by erosion after the two falls of sea-level that occurred between 4,100 and 3,800 years B.P. and between 2,800 and 2,600 years B.P. (Fig. 1).

Also, two additional observations suggest that the growth of the reefs was limited probably due to these two rapid drops of sea-level:

1. radiocarbon dates from the border of the Abrolhos reefs (Fig. 2) (Leão 1982), with ages younger than 2,500 years B.P., indicate a lateral growth of the reef after it had reached a maximum height at an earlier time, and.
2. the reef material recovered from two cores from the beach bordering the Itaparica reef (Fig. 2), as well as a seismic refraction profile, shows a landward extension of the reef (Araújo *et al.* 1984). This probably occurred due to the accumulation of reef debris, within the back reef zone, produced by the erosion of the reef surfaces which were exposed during sea-level drop.

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Location	Lab./Ref.	Position related to mean present sea-level (in meter)	Age
State of Bahia (1)	Bah 1249	+ 1.2	6,000 $\pm$ 150
	Bah 632	+ 1.5	5,890 $\pm$ 150
	Bah 1248	+ 1.2	5,840 $\pm$ 150
	Bah 521	+ 2.0	5,410 $\pm$ 150
	Bah 726	+ 0.8	5,400 $\pm$ 160
	Bah 1250	+ 1.3	5,330 $\pm$ 150
	Bah 776	+ 2.2	4,970 $\pm$ 90
	Bah 717	0	4,670 $\pm$ 110
	Bah 802	+ 1.3	4,600 $\pm$ 100
	Bah 621	+ 1.5	3,545 $\pm$ 105
	Bah 512	+ 1.6	3,290 $\pm$ 105
	Bah 515	+ 1.0	3,180 $\pm$ 60
	Bah 1149	+ 0.3	5,700 $\pm$ 230
State of Alagoas (2)	Bah 1148	+ 0.3	5,420 $\pm$ 230
	Bah 1015	+ 0.7	4,740 $\pm$ 200
	Bah 1016	+ 0.7	4,520 $\pm$ 150
	Bah 1022	+ 1.0	4,210 $\pm$ 190
State of Pernambuco(3)	Bah 1219	0	5,710 $\pm$ 230

(1) Martin *et al.* (1980b), Araújo *et al.* (1984), Araújo (1985)

(2) Barbosa (in prep.)

(3) Dominguez *et al.* (in prep.)

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MANUSCRITO

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