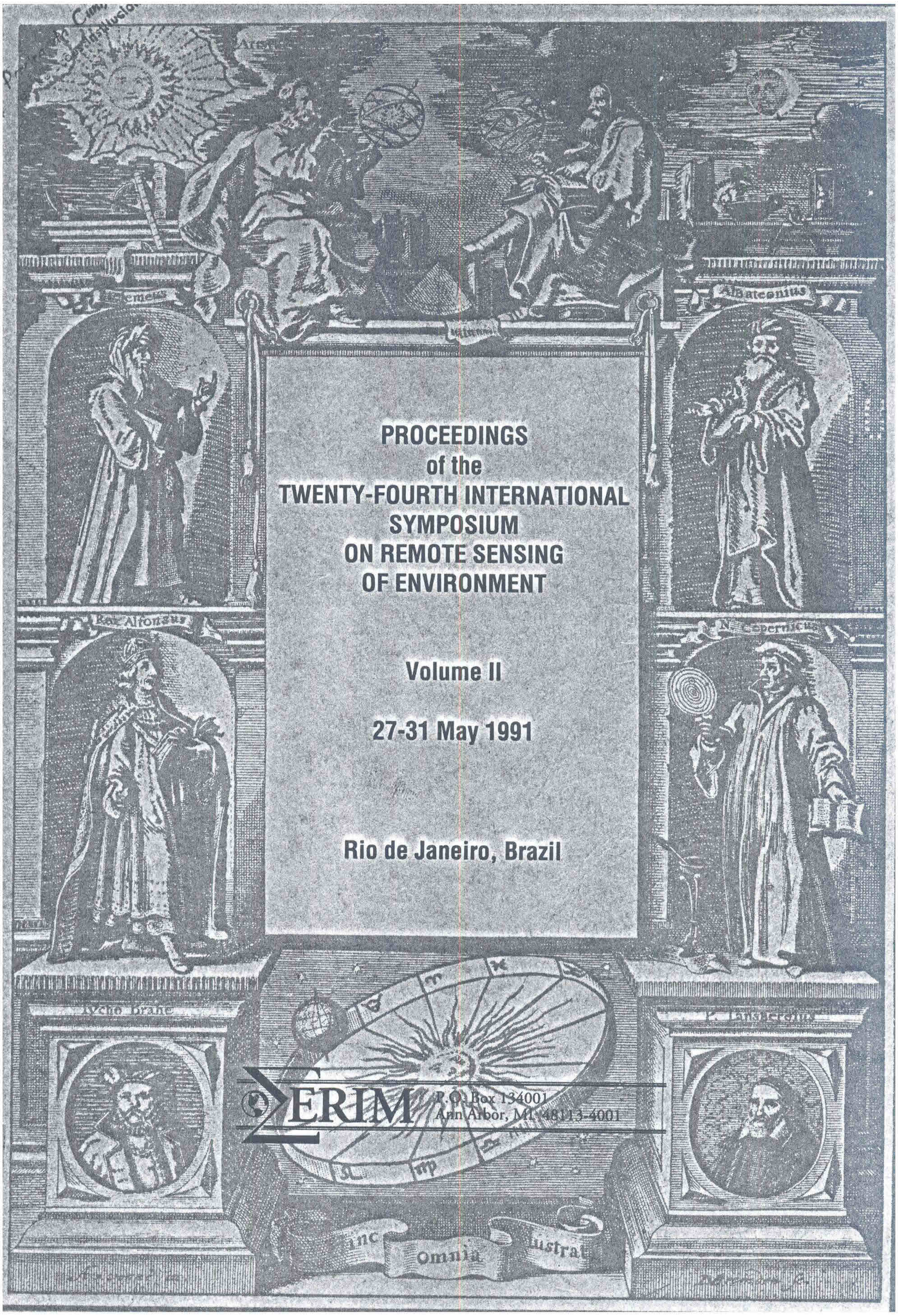

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GLOBAL CHANGE EFFECTS ON EARLY HOLOCENE SEDIMENTATION OF THE BRAZILIAN CONTINENTAL SHELF DETERMINED FROM TM-LANDSAT 5 DATA OF THE SEAFLOOR*

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ABSTRACT

A study of the shaping of the seafloor morphology on the brazilian northeast continental shelf caused by climatic changes in the beginning of the Holocene is being made with the support of TM-Landsat 5 data. Special emphasis is given on analysis of data from ancient shorelines between 20-45m depth, to be correlated with abrupt global climate change between 10000-8000 BP. The transport of a quartz sand deposit by the ocean currents through time, effected by active sandwave fields at the 20 m isobath is also described. Two images were used (path/row 214/64 and 215/63), corresponding to two dates: 1984 and 1989. Geometric correction, filter application and constrast enhancement were performed. A comparison between 84' and 89' images was carried out, to detect changing patterns of the sand waves, along a 5 year period, caused by the seasonal wintertime wind-forced ocean currents. Based on this registration, estimates of displacement rates for the sand deposit could be made.

1.0 INTRODUCTION

Coastal marine sedimentary data obtained in the last two decades has proven useful in providing an initial picture of major climatic variations in the thousand year time-scale by detection of major sea-floor topographic features caused by global sea-level changes. Sea-level changes and their environmental consequences are the principal informations that relation to Holocene sea-level changes, process-oriented studies one can extract from the coastal oceanic record (Shackleton et al., 1990). For the case of the last deglaciation, especially in on the shallow shelf can augment in a direct way our knowledge

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using diving techniques for direct observation of the environment and to collect sediment samples, granulometric analysis and digital imaging processing routines were combined using Geographical Information System (GIS). This latter part will be described by the present work.

2.0 STUDY AREA

The study area represents the east portion of the Rio Grande do Norte State Continental Shelf (Brazil), east of the Cabo Calcanhar (4°55'S to 5°10'S and 035°10'W to 036 10'W). An unidirectional topographically rectified current in the SE-NW direction is predominant with higher velocities values appearing in the period of June-October (Vianna et al., 1991a). The shelf breaks near the 50m isobath forming the shallow shelf.

The river discharge contribution is presently non-existent, leading to a low suspended sediment concentration. This aspect, associated with a low phytoplankton productivity, causes the higher water transparencies observed in the Atlantic Ocean (Sorokina, 1984). These conditions allow the acquisition of remote sensing data of the seafloor until the 45m isobath (Vianna et al., 1991 b).

Concerning sediment facies mapping and seismic profiling, there is a modest data base. However, a rough description can be obtained based in França et al. (1976) and Vianna et al. (1991a).

3.0 FIELD WORK, DIGITAL PROCESSING AND GIS METHODOLOGIES

Sedimentological data was extracted from Vianna et al. (1991a), where scuba diving techniques were carried out to conduct observations and collect bottom samples in test sites. Soft bottom samples were treated in the laboratory and granulometric separation was performed. Beachrock samples were collected too. Samples of calcareous and foliaceous algae were analysed for composition and taxonomy. The test sites were dispersed along the work area to determine the nature of every distinguishing feature detected by TM data (Figure 1).

Two TM-Landsat images were used, corresponding to passages in Nov 17, 1984 and Jan 05, 1989, path/row 214/64, quadrant A, Bands 1 and 4. A second image set (path/row 215/63, quadrant D, acquired in Jan 05, 1991) to the west of the 214/64 A swath was analysed only to help in the features discrimination. Band 4 was used to delineate the coastline and Band 1 to explore the maximum transmittance zone of the visible spectral range on water at 475 nm.

Data was obtained from CCT's produced at INPE-Cachoeira Paulista. These were geometrically corrected by using a cubic of the abrupt climate changes evidenced by deep sea and ice core analysis.

A simple method of detecting old submerged sea-level stillstands by use of non-expensive equipment has been recently proposed by Van Andel (1984). However, the discovery of the applicability of Landsat TM imagery for seafloor mapping up to 40m depth on the Northeast Brazilian continental shelf (Vianna and Solewicz, 1988; Vianna et al., 1991a), which follows Van Andel's philosophy, prompted the formulation of a Project Proposal (TOPSUB/INPE - Vianna, 1989) aimed at a process-oriented study to model the evolution of the shelf topography by reworking of surface sediments during the high growth rate phase of the trangression between 9000-7000 B.P. (1m/century). Sedimentary features observed by Landsat Thematic Mapper imagery using bands 1 and 4 (Vianna and Solewicz, 1988) in the inner continental shelf of Rio Grande do Norte nearby the city of Touros also outlined the presence of a sand wedge with longitudinal and transverse bedforms, overtaking a conspicuous lineament proved to be an ancient shoreface.

Efforts are being carried out to better understand the relationship of the rapid changes in sea-level that may have occured between 10000-9000 yr. B.P. (Vianna et al., 1989; Vianna et al.,1991a) with the present day sediment transport structure in the area evidenced by the active bedforms evolving according to known specific flow patterns. After a first description of this sandstream (Vianna et al., 1991a), new insights into the sea-level change effects on the same area are here presented.

For the sake of completeness, let us make a fast review of the literature in electomagnetic remote sensing of the sea floor. Besides the use of conventional data collecting techniques, the application of Remote Sensing data to bottom composition determination and bathymetric mapping have been improved in the last two decades. Many authors developed algorithms to extract bottom composition information from radiometric data (Polcyn and Rollin, 1969; Polcyn and Lyzenga, 1975; Lyzenga, 1978, 1979; Spitzer and Dirkis, 1987). These works deal with the study of multispectral seafloor responses to incident solar radiance. They also explain the importance of field data acquisition to calibrate the radiometric information obtained.

Neverthless, the approach of these works focus mainly on the remote sensing aspects. In this work we describe the Landsat Thematic Mapper data used to perform the preliminary sedimentological and geomorphological characterization of a sector of the Northeast Brazilian Continental Shelf to understand aspects of the Holocene sedimentation, as related to the Global Change in sea-level during that period. Field work convolution algorithm. All image processing techniques were applied using the Images Treatment System (SITIM), developed by INPE.

To minimize striping effects, a median recursive filter using a 7 x 3 points mask was used, following the methodology used in Cabral et al. (1990). Further, a contrast enhancement using histogram modification tecniques contributed to the features discrimination (Figure 2).

To examine if the sand wave field pattern migrated or changed, registration of the 84' and 89' images was carried out. Five control points with known geographical coordinates were depicted: 3 points in the land (Cabo Calcanhar Lighthouse, Touros Church, Ponta da Gameleira); 2 at the ocean zone (the first sand wave crest at the south portion of the field and the beachrock reef called "Risca do Liso"). The position of these latest two points were obtained from the radar positioning system of the ship used in the field work. An analysis of the registration parameters leads to an error of around 2 pixels (60m).

Existing bathymetric data, retrieved from Brazilian Navy smooth sheet B800-3/71, were inserted in the GIS system (SGI-INPE). The digitization and data treatment are based on methodology described in Solewicz et al. (1989). Isobath charts and a 3D model were produced to permit a better visualization of the larger scale bottom topography. A bathymetric slicing was accomplished to discriminate depth intervals of 5m (Vianna et al., 1991 a)(Figure 3).

The bathymetric chart producted in the GIS system was registred with the TM image, to locate the bathymetric intervals in which the sedimentary features are located. This registration was implemented in the SITIM, with the same control points mentioned above.

4.0 RESULTS AND DISCUSSIONS

The lineament L in Figure 2, at 20 m depth, is surely an ancient shoreline due to the following observations (Vianna and Solewicz, 1988): (a) Offshore of it the bathymetry has an offshore gradient characteristic of a shoreface; (b) A long, slender, beachrock reef was found along it, and these reefs are good sea-level indicators according to, e.g., Hopley (1986).

Between the sandwave field, characterized by a bright and fine-grained homogeneous texture obtained due to the quartz sand facies supporting them, and the lineament, we find an area with different texture. We found that this texture corresponds to a bottom type corresponding to an algal gravel facies, with soft algae using rhodoliths as hard substrates for their support.

Let us imagine that the deposit represented by the quartz sand facies was displaced by 8 km as a whole to the northwest from its original position and typical beach morphology, which would feature aeolian dunes adjacent to this ancient shoreline. If we assume that sand transport after submergence would be accomplished effectively by sandwaves with crests drifting at a rate of 1m/year, we would arrive at a estimated time of 8000 years for the pattern to evolve to its present position.

This estimate is not far off the probable timing for a sea-level stand at that depth in early holocene times according to published eustatic sea-level curves (see, e.g., Van de Plassche, 1986), which would admit a sea-level stand at 20 m depth at around 9000 BP.

On the other hand, appart from possible occasional avalanches at steep and high (> 10m) lee slopes, images registration showed that displacements are consistent with sandwave migration velocities below 5m/year.

5.0 CONCLUSIONS AND FINAL CONSIDERATIONS

The sea-level changes during the early phases of the Flandrian transgression were relatively rapid giving no conditions to adjusment of the shoreface with the new levels, and nowadays the continental shelf shows relictual morphology and sediments (Coutinho, 1981). Moreover, the shelf presents a terraced morphology probably due to these sea-level stands (Figure 3).

Shallower bedforms (sand ribbons) are located between 5-15m, and must be due to a higher current regime wind-forced during each winter season, followed by a field of large-scale sandwaves (underwater sand dunes) with an average depth of 20m, limited offshore by shore-parallel sand banks that spills over the northern section of the conspicuous lineament at about 20m depth.

By the time of preparation of this paper, newly observed lineaments at dephts around 40m using TM-Landsat images from 1989 (Vianna et al., 1991b) came out to reinforce the evidences of former stabilizations of sea-level prior to the Holocene period described in this paper.

More detailed field work will take place this year with emphasis in dating suitable carbonate cements, and more detailed sedimentological sampling by coring of the soft bottom. These data will hopefully confirm our model of possible linkages of past eolian processes and present day subaqueous deposits. To try to understand the effective sandwaves field migration pattern, current meter time series must be obtained from this area.

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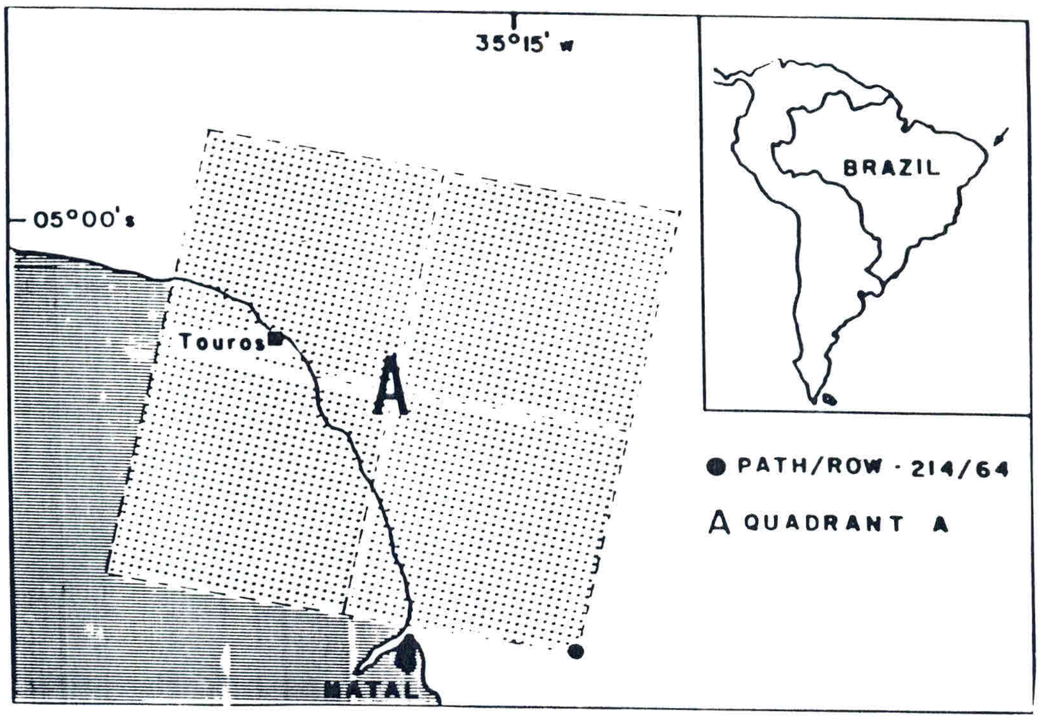

Figure 1. Study Area Location.

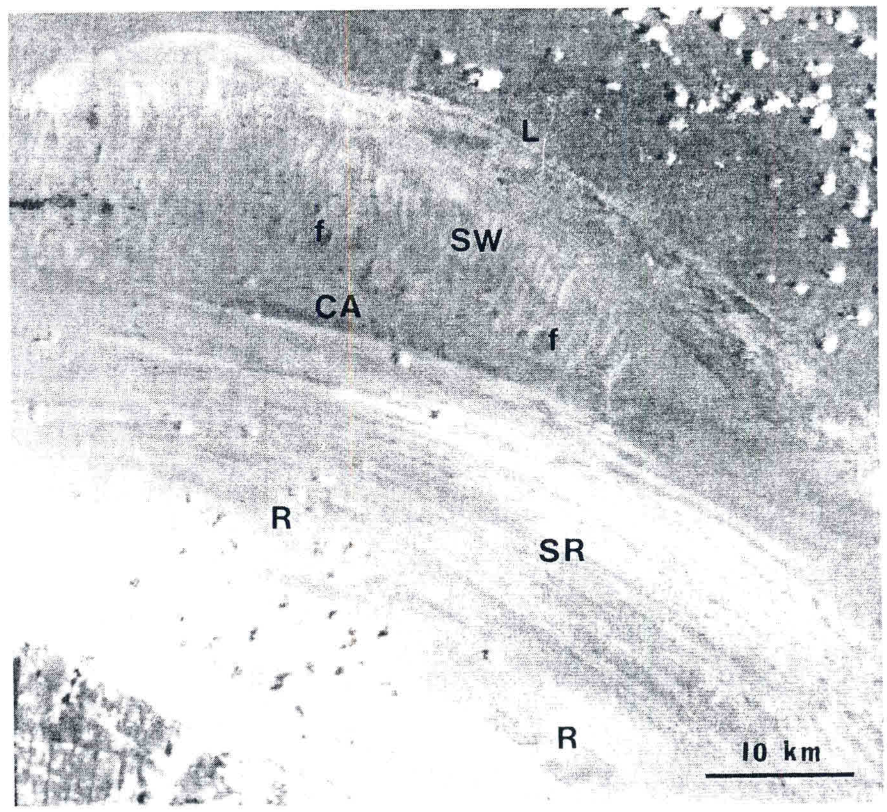

Figure 2. TM Image Subscene, Path/Row 214/64 A, Band 1.
Distinguished Features;
(f) Foliaceous Algae; (CA) Calcareous Algae;
(L) Lineament; (R) Coral Reef;
(SR) Sand Ribbons; (SW) Sand Waves.

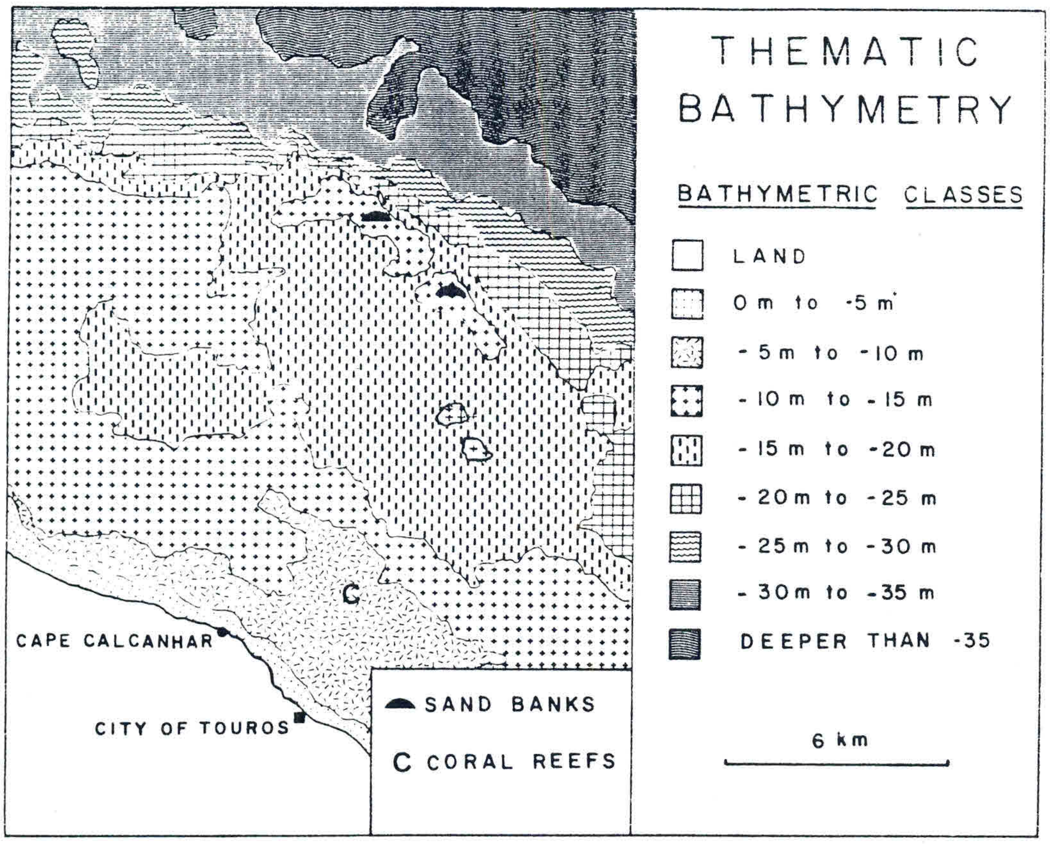

Figure 3. G.I.S. Generated Thematic Bathymetry.