Journal of Coastal Research	7	2	509-516	Fort Lauderdale, Florida	Spring 1991

Buried Late Pleistocene Fluvial Channels on the Inner Continental Shelf off Vengurla, West Coast of India

L.V. Subba Raju, K.S. Krishna, and A.K. Chaubey

National Institute of Oceanography
Dona Paula
Goa 403 004, India

ABSTRACT

Subba Raju, L.V., Krishna, K.S., and Chaubey, A.K. 1991. Buried Late Pleistocene Fluvial Channels on the Inner Continental Shelf off Vengurla, West Coast of India. *Journal of Coastal Research*, 7(2), 509-516. Fort Lauderdale (Florida). ISSN 0749-0208.

Analysis of echosounding, side-scan sonar and shallow seismic data collected west of Burnt islands off Vengurla, west coast of India, revealed a featureless seabed, thicknesses of subsurface layers, and presence of buried channels filled with sediments. Cross sectional dimensions between 15 to 100 m width and 2 to 6 m depth suggest a fluvial origin of the channels. These buried channels appear to mark former positions of rivers flowing from the nearby coast and debouching into the Arabian Sea. These features, which formed during the late Pleistocene, are at approximately the same depth below the seabed. The seismic data suggest that depositions of this system occurred during eustatic sea-level fluctuations and formed an important part of shelf stratigraphy.

ADDITIONAL KEY WORDS: *Buried channels, inner shelf, sea-level fluctuations, subsurface reflectors, Pleistocene sediments, Holocene sediments.*

INTRODUCTION

The continental shelf off the west coast of India consists of four major sedimentary basins *viz.* Kutch, Bombay, Konkan, and Kerala (RAMASWAMY and RAO, 1980) extending from north to south. The Bombay Basin, the location in this study, is between the southeastern edge of the Saurashtra peninsula and Panjim (Goa), extending from the coast to the shelf break (Figure 1). An understanding of regional topography and geological stratigraphy in this area can be found in NAIR *et al.* (1978), SIDDIQUIE *et al.* (1985), BHATTACHARYA *et al.* (1988) and SUBBA RAJU *et al.* (1989).

The west coast of India is shaped by offshore fault that was active during the late Pliocene (KRISHNAN, 1968). Throughout the Quaternary, each major basin was a primary depocenter for terrigenous sediments from western India. The source of these sediments was from moderate to small creeks in addition to major rivers, such as the Indus, Narmada, and Tapti (AHMAD, 1972). Presently, 450 million tons of sediments per year are deposited from the Indus River alone into the Arabian Sea (KOLLA and COUMES, 1987). On land, granites and gneisses of Precambrian age and metamorphic rocks of Dharwar group lie between Parule Hill and Vengurla (G.S.I., 1976) near the survey area (Figure 2). The present study utilizes detailed bathymetric, side-scan sonar, and shallow seismic reflection data along a number of closely spaced profiles off Vengurla to evaluate the seabed, as well as subsurface deposits.

90052 received 21 March 1990, accepted in revision 3 December 1990.

METHODS

A Mini-Ranger MRS-III short range navigation system (accuracy ± 3 m) supplied continuous positioning during the survey. The data base consists of 37 long and 8 short closely spaced profiles (Figure 3) of bathymetry, sonography, and shallow seismic data collected with a Simrad 200 dual frequency echosounder (210 and 38 KHz), a side-scan sonar (105 KHz) and a high resolution seismic profiler (3.5 KHz).

SEA-LEVEL FLUCTUATIONS

One prime factor in the Quaternary development of the continental shelf is the glacio-eus-

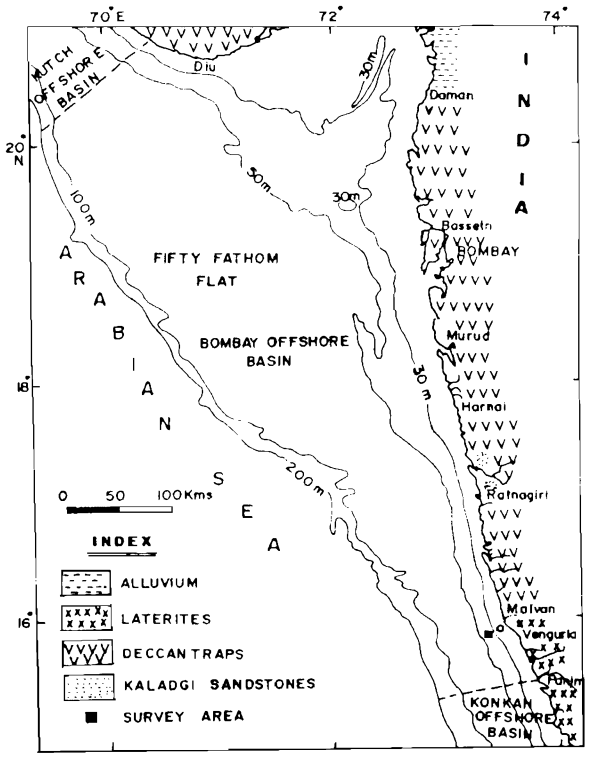

Figure 1. Major sedimentary basins in the continental shelf off west coast of India. Kerala basin lying in the extreme south is not shown.

tatic fluctuations of sea level. The imprint of fluctuating sea levels and associated shorelines vary with the morphology, structure, and sedimentary characteristics of each shelf. The most extensive and prominent feature on the continental shelf of the Arabian Sea is a Fifty Fathom (approximately 90 m) Flat which extends from 17° to 21° N latitude (SHEPARD, 1963) which is developed in the northern part of the shelf (off Bombay) and less prominently in the south. NAIR (1974) reported terraces on the continental shelf at depths of 92, 85, 75 and 55 m and suggested that the former three along with the Fifty Fathom Flat probably correspond to global Holocene still stands of sea level (MACINTYRE, 1972) from their similarities in depth and their nature of the sediments found thereon. Due to the occurrence of recent earthquakes and the activity of hot springs (GUHA *et al.*, 1970) on the adjacent peninsula and along the Konkan coast respectively, the relation between the tectonic activity and the terraces on the continental shelf is not ruled out as envisaged by ORTLIEB (1980) elsewhere.

Repetitive sea level fluctuations during the Quaternary (BLOOM, 1971; BEARD *et al.*, 1982) coupled with the sediment transport caused building and transgression of the shelf margin. Fluvial systems advanced seaward during lowstands and eroded the exposed continental shelf and nearshore region to the margins of the terraces. Glacial melting and transgression later caused global sea level to rise, and submerged the sediment-filled fluvial systems (SUTER, 1986). The subaerial processes and the transgression produced regional unconformities at the top of regression sequences. These sequences can be recognized and mapped through the occurrence of buried fluvial channels (SUTER and BERRYHILL, 1985).

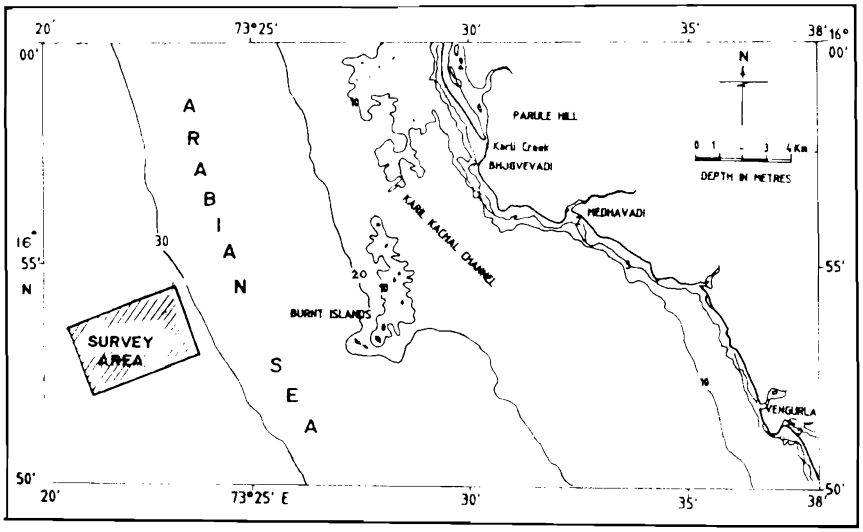

Figure 2. Survey area off Vengurla coast.

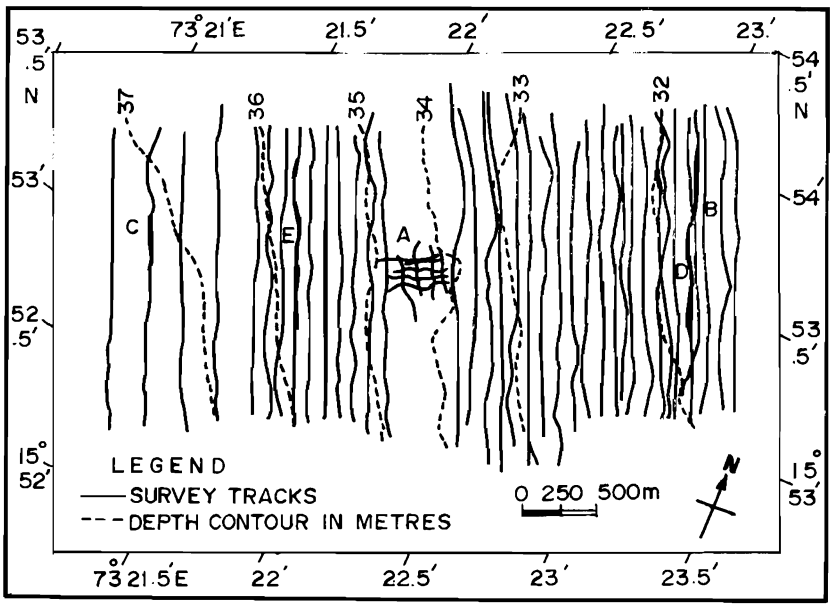

Figure 3. Tracks and depth contours in the area surveyed. Bold lines marked as A,B,C,D and E are the locations of Figures 4,5,6,7 and 8.

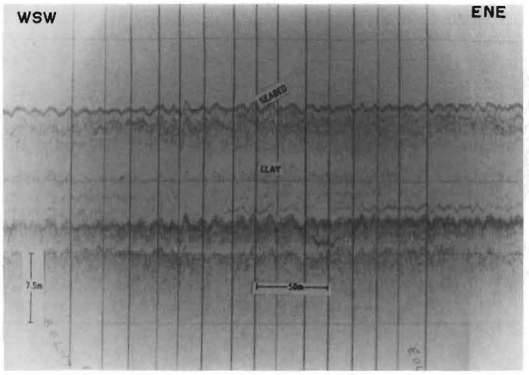

Figure 4. Shallow seismic record and line drawing of location A showing the pattern of reflectors. Sound velocity of 1500 m/sec have been assumed for the water column and the sediments to obtain closely accurate depths and thickness of the sediments. Same assumptions are followed in figures 5,6,7 and 8.

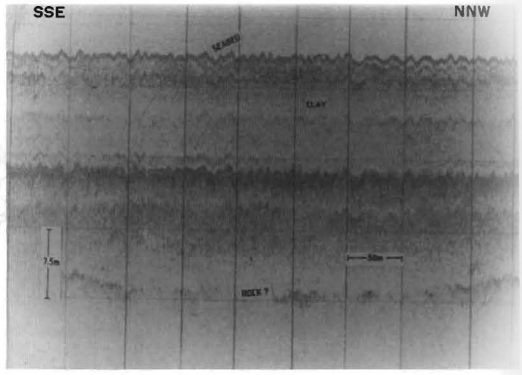

Figure 5. Shallow seismic record and line drawing of location B showing acoustic basement (rock ?) beneath the reflectors.

SUBSURFACE REFLECTORS

Bathymetric records across the survey region show a gentle seabed relief while the sonograms indicate a common tone for the seabed throughout the area. The nature of the seabed is clayey, determined by bottom sampling. The shallow seismic profiles record the stratigraphic sequences (Figure 4). Three reflectors occur at subsurface depths 7.5, 12 and 15.5 m and lie horizontally. At some places, reflector at former depth appears mild (Figure 4) as the layers lying above and below this may not be having notable difference in their acoustic impedances while at other places (Figures 5 and 6), the reflector appears to be fair due to the contrast in acoustic impedances. Reflector at 12 m is strong and prominent throughout the survey area while the same at 15.5 m appears to be fair/good except in the identified locations of the buried channels.

Burnt islands off Vengurla (Figure 2) are the extensions of the land formations at a distance of nearly 10 km from the coast and mainly contain ferruginous quartzites of Dharwar group (ANONYMOUS, 1962). These islands are submerged towards the deeper waters and lie below sediments (N.I.O., 1989). The strong reflector (rock?) noticed in some regions of the survey area at subsurface depths of 24–26 m (Figure 5) is probably the extension of these Burnt islands.

Buried channel systems are interpreted immediately below the second reflector (Figure 6). It is found that this reflector nevertheless merges with the seabed at a water depth of about 9 to 10 m lying adjacent to the narrow strip of sand bordering the coast (NAIR *et al.*, 1978). The third reflector lying 15.5 m beneath the seabed unlike other reflectors is fuzzy and incised by filled channels. The extent of deposits in the buried channels are 15 to 100 m in width and between 2 and 6 m in depth. Interpretation of acoustic reflections suggests that the channel fill consists of coarse grained material (sand?) with a mixture of clay. In some profiles, a single buried channel (Figure 6) is recorded while others have recorded two or three buried channels (Figures 7 and 8). Some

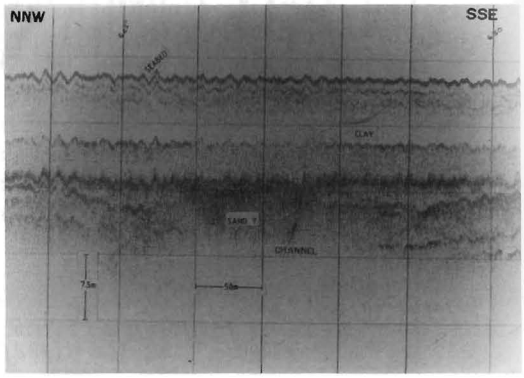

Figure 6. Shallow seismic record and line drawing of location C showing the buried channel filled with sediments (sand?).

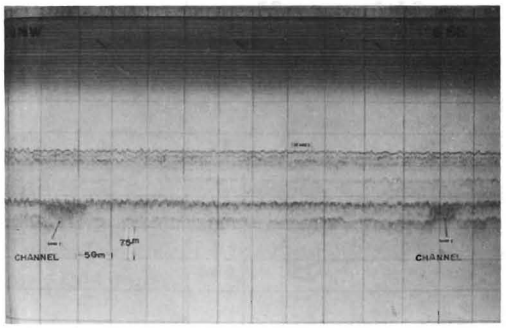

Figure 7. Shallow seismic record and line drawing of location D showing two buried channels on a single profile.

of these channels possibly originate in the coastal areas and are most likely extensions of the Karli creek, which flows on the adjacent coast and north of Vengurla (Figure 2). As observed in Figure 9, some originate in the survey area too. The locations of channels are mapped and found that they merge into a single channel towards the western side of the survey area. The entire trend appears to continue toward the outer shelf.

LATE PLEISTOCENE FLUVIAL CHANNELS

Outer shelf sediments off the central west coast were radiocarbon dated at 11,330 ± 350 to 9,960 ± 160 years BP, (NAIR and HASHIMI, 1980). Shallow seismic profiles across the shelf indicate that the late Pleistocene surface continues under the inner shelf (SIDDIQUIE *et al.*, 1977). The reflector observed at subsurface depth of 12 m in the survey area thus appears to be a late Pleistocene surface. Since these channels lie below this reflector, they appear to be nevertheless late Pleistocene in age.

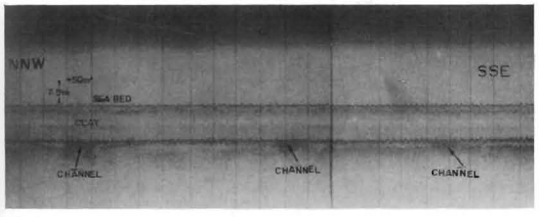

Figure 8. Shallow seismic record and line drawing of location E showing three buried channels on a single profile.

The trend of global sea level curves changes from Pleistocene to Holocene periods and considerable disagreement about the fine structure of these curves is noted by BERGER (1983). CLARK *et al.* (1978) explained the causes of the discrepancies in differing tectonic activities in various regions of the world, the influence of isostatic compensation wherever applicable and the selection of dated samples.

Sea-level rise from 12,000 yrs BP to the present has been studied by radiocarbon age datings of samples collected off the west coast of India by KALE and RAJAGURU (1985). The water depths obtained by them are not much different to those by CURRAY (1965) for Holocene and modern periods. The trends of these curves are strikingly different for the Pleistocene indicating a discrepancy in water depths. This discrepancy may be due to the dating of the few samples by the former. With such limited data, the trend of the sea level curve is not confirmed; it is possible that there was rise during the late Pleistocene followed by an abrupt decrease during the early Holocene. Sea level along the west coast must have reached its current level at 6,000 to 5,000 yrs BP (Figure 10). Although present data are not adequate to determine relative sea level changes on the west coast, the tide gauge data on the Bombay coast show a rise in the relative sea level, at the rate of 0.7 mm/yr during the last 100 years. However, the last 10 years of records indicate a relative sea level drop that counter-balances the rise of thirty previous years (PIRAZZOLI, 1986). This fluctuation maintains the average sea level seen for the last few centuries.

Further, the sediment accumulation rate is also estimated on the basis of the thickness of the layers and the radiocarbon dating of the second reflector at 12 m subsurface depth. In this context, 2.5 mm/yr was indicated as the sediment accumulation rate at water depths of around 50 m by DILLI (1986), based on the analysis of a single core sample. BOROLE (1988) reported clay accumulation rates between 6.0 to 1.8 mm/yr on the western continental shelf and slope regions of India. The sediment accumulation rate of 2.5 mm/yr in the Bombay shelf region appears to be anomalous in order to account for the sediment thickness

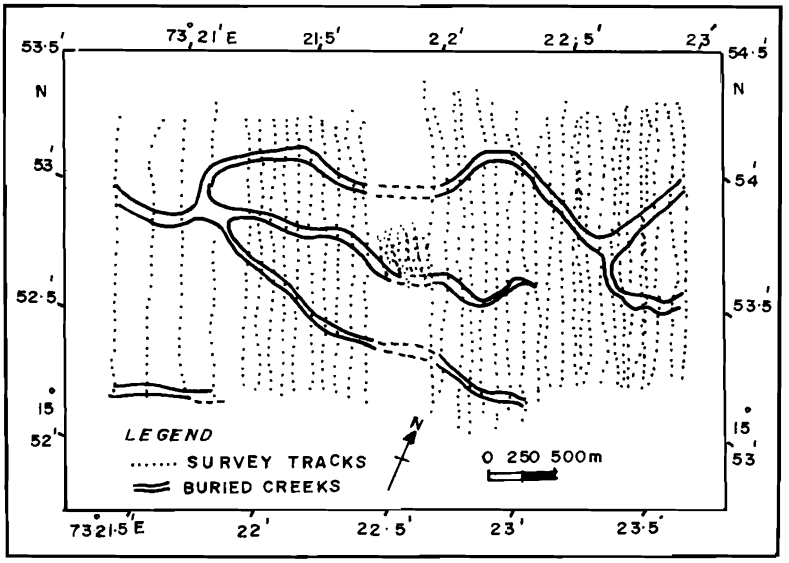

Figure 9. Located tracks of buried fluvial channels (late Pleistocene age) off Vengurla.

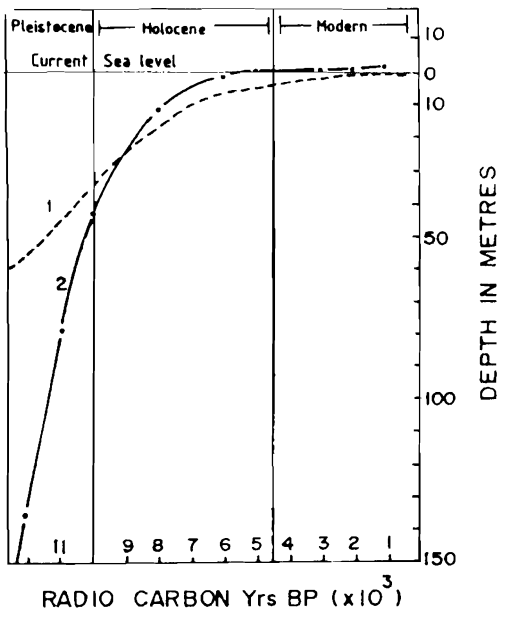

Figure 10. Late Quaternary sea-level curves for the west coast of India. (Modified after 1. Curray (1965) and 2. Kale and Rajaguru (1985)).

of 12 to 15.5 m reported in the survey region. Due to the absence of subsurface radiocarbon control and the fluctuating palaeoclimatic records since 10,000 years BP, the sediment accumulation rate probably varied depending upon the monsoons, drainage patterns, erosion and other factors. However, the reflector at 12 m as envisaged earlier join the seabed towards outershelf with thin clay cover over its surface. This reflector is assigned the age range of 11,330 ± 350 to 9,960 ± 160 yrs BP. The sediment accumulation rate estimated from the present study thus ranges from 1.0 to 0.85 mm/yr.

CONCLUSIONS

The following inferences may be drawn from the present study.

(1) A prime reflector at a subsurface depth of 12 m in the survey region is identified. A late Pleistocene age is estimated for this reflector exposed on the outer shelf; it indicates a sediment accumulation rate of maximum 1 mm/yr in the inner shelf.

(2) Channels were formed prior to 10,000 yrs BP and belong to a late Pleistocene age; and

(3) The buried channel fill is derived from riv-

ers on the adjacent coast draining sediments into the Arabian Sea.

ACKNOWLEDGEMENTS

The authors thank Shri P.S.N. Murty fo. his encouragement and Dr. D. Gopala Rao for help in field work. We benefitted from discussions with Drs. R.R. Nair, Ch. M. Rao, B.G. Wagle, and N.H. Hashimi. We are grateful to Dr. B.N. Desai, Director, for his kind permission to publish this paper.

LITERATURE CITED

AHMAD, E., 1972. *Coastal Geomorphology of India.* New Delhi: Oriental Longman, 222p.

ANONYMOUS, 1962. Physical features and natural resources. *In: Maharastra State Gazeteer*, Govt. of Maharastra, India, pp. 1–1027.

BEARD, J.H.; SANGREE, J.V., and SMITH, L.A., 1982. Quaternary chronology, palaeoclimate, depositional sources and eustatic cycles. *American Association of Petroleum Geologists Bulletin*, 66 (2), 158–169.

BERGER, R. 1983. Sea levels and tree-ring caliberated dating. *In:* Masters and N.C. Flemming) (Eds.), Quaternary Coast Lines and Marine Archaeology P.M. London: Academic pp. 51-62.

BHATTACHARYA, G.C.; ALMEIDA, F.; VORA, K.H., and SIDDIQUIE, H.N., 1988. Subsurface geology of Bombay with palaeoclimatic inferences interpreted from shallow seismic profiles. *Journal of Coastal Research*, 4(3), 521-530.

BLOOM, A.L., 1971. Glacial-eustatic and isostatic controls of sea level since the last glaciation. *In: The Late Cenozoic Glacial Ages.* New Haven: Yale University Press, pp. 355-380.

BOROLE, D.V., 1988. Clay sediment accumulation rates on the monsoon-dominated western continental shelf and slope regions of India. *Marine Geology*, 82(3/4), 285-291.

CLARK, J.A.; FARRELL, W.E., and PELTIER, W.R., 1978. Global changes in post glacial sea-level: A numerical calculation. *Quaternary Research*, 9, 265-287.

CURRAY, J.R., 1965. Late Quaternary history, continental shelves of the United States. *In: The Quaternary of the United States* Wright, H.E. Jr. and Frey, D.G., (Eds.). Princeton; Princeton University Press: pp. 723-735.

DILLI, K., 1986. Geochronology and geochemistry of a sediment core from the Bombay coast. *Mahasagar, Bulletin of National Institute of Oceanography*, 19 (2), 87-95.

G.S.I., 1976. Geology of the Ratnagiri district, Maharashtra. *125th Anniversary celebration brochure*, 1-9.

GUHA, S.K.; MURTI, N.G.K.; GOSAVI, P.D., and PADALE, J.G. 1970. Seismological, geophysical and geotectonic significance of recent crustal disturbances in western Maharashtra. *Journal of Indian Geophysical union*, 7, 75-86.

KALE, V.S. and RAJAGURU, S.N., 1985. Neogene and Quaternary transgressional and regressional history of the west coast of India—An overview. *Bulletin of Deccan College Research Institute*, 44, 153-165.

KOLLA, V. and COUMES, F., 1987. Morphology, internal structure, seismic stratigraphy, and sedimentation of Indua Fan. *American Association of Petroleum Geologists Bulletin*, 71(6), 650-677.

KRISHNAN, M.S., 1968. *Geology of India and Burma.* Madras: Higginbothams, 536p.

MACINTYRE, I.G., 1972. Submerged reefs of eastern Carribbean. *American Association of Petroleum Geologists Bulletin*, 56(4), 720-738.

NAIR, R.R., 1974. Holocene sea levels on the western continental shelf of India. *Proceedings of Indian Academy of Sciences* (New Delhi), 79, 197-203.

NAIR, R.R. and HASHIMI, N.H., 1980. Holocene climatic inferences from the sediments of the western Indian continental shelf. *Proceedings of Indian Academy of Sciences* (New Delhi), 89, 299-315.

NAIR, R.R.; HASHIMI, N.H.; KIDWAI, R.M.; GUPTHA, M.V.S.; PAROPKARI, A.L.; AMBRE, N.V.; MURALINATH, A.S.; MASCARENHAS, A., and D'COSTA, G.P., 1978. Topography and sediments of the western continental shelf of India—Vengurla to Mangalora. *Indian Journal of Marine Sciences*, 7(4), 224-230.

N.I.O., 1989. Seabed surveys off Mormugao and Vengurla islands. *Unpublished Technical Report* 31p.

ORTLIEB, L., 1980. Neotectonics from marine terraces along the Gulf of California, *In:* Mörner, N.-A. (Ed.), *Earth Rheology, Isostasy and Eustasy.* New York: Wiley pp. 497-504.

PIRAZZOLI, P.A., 1986. Secular trends for relative sea level changes indicated by tide-gauge records. *Journal of Coastal Research*, SI(1), 1-26.

RAMASWAMY, G. and RAO, K.L.N., 1980. Geology of the continental shelf of the west coast of India. *In: Facts and Principles of World Petroleum Occurrences, Canada*, pp 801-821.

SHEPARD, F.P., 1963. Thirty-five thousand years of sea level. *In: Essays in Marine Geology, Southern California Press, Los Angeles*, pp. 1-10.

SIDDIQUIE, H.N.; RAO, D.G.; VEERAYYA, M., WAGLE, B.G.; ALMEIDA, F., and BHATTACHARYA, G.C., 1977. Surficial geology of Bombay-Bombay High region and its implication in offshore engineering problems. *Proceedings of the Seminar on Coastal Engineering* (Goa), (Abstract), p. 55.

SIDDIQUIE, H.N., RAO, D.G., and VORA, K.H., 1985. An appraisal of the seabed conditions on the northwestern continental shelf of India. *Proceedings of Offshore Technology Conference* (Texas), 3, 83-92.

SUBBA RAJU, L.V.; DIVAKAR NAIDU, P., and ALMEIDA, F., 1989. Marine geoscientific surveys in ports and nearshore regions of the Arabian Sea off central west coast of India. *Proceedings of the Recent Geological Studies on the Arabian Sea off India, Mangalore*, Geological Survey of India special publication No. 24, pp. 291-297.

SUTER, J.R., 1986. Buried late Quaternary fluvial channels on the Louisiana Continental Shelf, USA. *Journal of Coastal Research*, SI (1), 27-37.

SUTER, J.R., and BERRYHILL, H.L. Jr., 1985. Late Quaternary shelf margin deltas, northwest Gulf of Mexico. *American Association of Petroleum Geologists Bulletin*, 69(1), 77-91.

☐ RÉSUMÉ ☐

L'analyse des écho-sondages, des données de sonar latéral et les données sismiques recueillies à l'ouest des Iles Burnt au large de Vergula (côte ouest de l'Inde), ne révèlent past de formes spécifiques sur les fonds marins; les épaisseurs des couches de surface, la présence de chenaux ennoyés par des sédiments sont aussi révèlees. Ces chenaux ont 15 à 100 m de large et 2 à 6 m de profondeur, ce qui suggère qu'ils ont une origine fluviale. Ces chenaux correspondent à d'anciens lits de rivière coulant depuis le poche littoral et débouchant dans la mer d'Arabie. Ces formes qui se constituèrent durant la fin du Pléistocène sont à peu près à la même profondeur sous le niveau du fond. Les données de sismique suggérent que le dépôt de ce système a eu lieu au cours des dernières variations eustatiqes du niveau de la mer et contribuent pour une part importante à la stratigraphie de la plateforme continentale.—*Catherine Bousquet-Bressolier, Géomorphologie EPHE, Montrouge, France.*

☐ RESUMEN ☐

Los análisis de ecosonda, sonar y datos sísmicos recogidos al Oeste de las Islas Burnt de Vengurla, costa Oeste de La India, revelan un fondo sin características, sin espesor en las capas bajo la superficie y la presencia de riachuelos rellenos con sedimentos. Las secciones transversales de éstos, entre 15 y 100 metros de ancho y de 2 a 6 m de profundidad, sugieren un origen fluvial de los mismos. Estyos riachuelos aterrados parecen ser anteriores posiciones de ríos fluyendo desde la costa y desembocando en el Mar Arábigo. Estas formaciones, las cuales se formaron en el Pleistoceno tardío, son aproximadamente de la misma profundidad bajo el fondo. Los datos sísmicos sugieren que las deposiciones de este sistema ocurrieron durante las fluctuaciones del nivel del mar y que formaron una parte importante de la estratigafría de la plataforma.—*Department of Water Sciences, University of Cantabria, Santander, Spain.*

☐ ZUSAMMENFASSUNG ☐

Mit Echogrammen, Seitensonar-Aufnahmen und Flachseismik-Daten, die an der Westküste Indiens vor Vengurla westlich der Burnt-Inseln gewonnen wurden, konnte ein strukturloser Meeresboden, die Mächtigkeit der submarinen Schichten und das Vorhandensein von begrabenen, mit Sedimenten verfüllten Rinnen nachgewiesen werden. Breiten zwischen 15 und 100 m und Tiefen von 2 bis 6 m sprechen für einen fluvialen Ursprung dieser Rinnen. Sie scheinen ehemalige Flußläufe nachzuzeichnen, die von der nahegelegenen Küste in das Arabische Meer mündeten. Diese Formen, die sich im Spätpleistozän bildeten, befinden sich in etwa gleicher Tiefe unter dem Meeresboden. Die seismischen Messungen lassen vermuten, daß dieses System sich wäkrend eustatischer Meeresspiegelschwankungen bildete und einen wesentlichen Teil der Stratigraphie des Schelfs ausmachte.—*Helmut Brückner, Geographisches Institut, Universität Düsseldorf, F.R.G.*