

Signatures of Late Quaternary Sea-level Changes and Neo-tectonic Activity Over Visakhapatnam - Gopalpur Shelf, East Coast of India

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ABSTRACT

High-resolution shallow seismic and echo sounding profiles of the continental shelf between Visakhapatnam and Gopalpur reveal prominent morphological features like terraces, reefs and pinnacles at different water depths of 80-100 m, 50-70 m and 25-30 m representing still stands during the late Pleistocene to Holocene. Seismic records obtained off Visakhapatnam-Pudimadaka show two distinct sedimentary units bounded by erosional unconformities. Occurrence of palaeo-channel beneath the seabed in the inner shelf and progradational deltaic sequence over the erosional palaeo-shelf (lower unconformity) at the shelfedge off Pudimadaka indicate active sedimentation at the outershelf during Pre-Holocene. High-resolution echograms indicate diversity of reef configuration in the form of single, double/multi peaked and domal dhaped reef system reflecting variable energy conditions during low stands. Occurrence of about 10 m vertical fall of the seabed off Gopalpur and significant faulting in the underlying sequences off Bhimunipatnam and Pudimadaka suggest a possible neo-tectonic activity.

Key Words : Visakhapatnam, Quaternary sea-levels, palaeo-channel, progradational sequence, Neo-tectonic activity, Gopalpur.

INTRODUCTION

The part of the eastern continental shelf between Visakhapatnam and Gopalpur has been considered as nondepositional area based on the occurrence of relict sediments and morphological features on the seabed (Subba Rao, 1964; Rao et al., 1980; Mohana Rao et al., 1989; Murthy et al., 1987; Murthy, 1989; Mohapatra et al., 1992; Mohana Rao and Rao, 1994). Rao et al., (1980) reported morphological features such as reefs, terraces, karstic structures over the outer shelf of East Coast of India and related them to eustatic sea-level changes. Murthy et al., (1987) delineated two linear trends of Holocene mounds at 60-70 m depth over the Visakhapatnam shelf while Murthy (1989) made preliminary studies on the Quaternary stratigraphy of east coast of India. Mohana Rao et al., (1989) inferred Holocene transgression based on the sediment grain size parameters. Mohana Rao and Rao (1994) have demarcated late Pleistocene regression level around 130 m water depth and different sea-level strand lines during Holocene transgression based on the shallow seismic reflection data and radio carbon dates of the algal limestones. Mohapatra et al., (1992) have also made similar studies and reported stillstand zones over the eastern continental shelf of India. All the above studies dealt with different strandline events, however, stratigraphy prior to Last Glacial Maxima (LGM) and kinds of morphological features were not discussed in detail. In this paper, an attempt

has been made to understand the different kinds of morphological features of the shelf between Visakhapatnam and Gopalpur.

MATERIALS AND METHODS

Echosounding records presented in this paper were collected onboard a hired fishing trawler using dual frequency Echosounder model DF 3200 MK II unit. Sub-bottom data (shallow seismic sections) were obtained using high resolution seismic profiler (EG&G sparker) across the shelf from 30 m isobath to about 1000 m with variable energy from 300 to 1000 joules. In total about 19 vertical profiles with a varying space interval from 1-6 km and one coast parallel profile were taken for the present study (Fig.1). The positions were obtained using satellite navigation system for the R.V.Gaveshani data and model No.JLR 4400 portable GPS for the survey on fishing trawler. For all the practical purposes the sound velocity of 1500 m/sec was taken. All the profiling tracks (both echosounding and seismic) are shown in Fig.1.

RESULTS AND DISCUSSIONS

Seismic stratigraphy and sea-level changes

High-resolution shallow seismic records obtained over the outershelf off Pudimadaka reveal two distinct sedimentary units (Fig.2). The lower unit comprising thick sedimentary sequence lies over the lower unconformity (LU) beneath

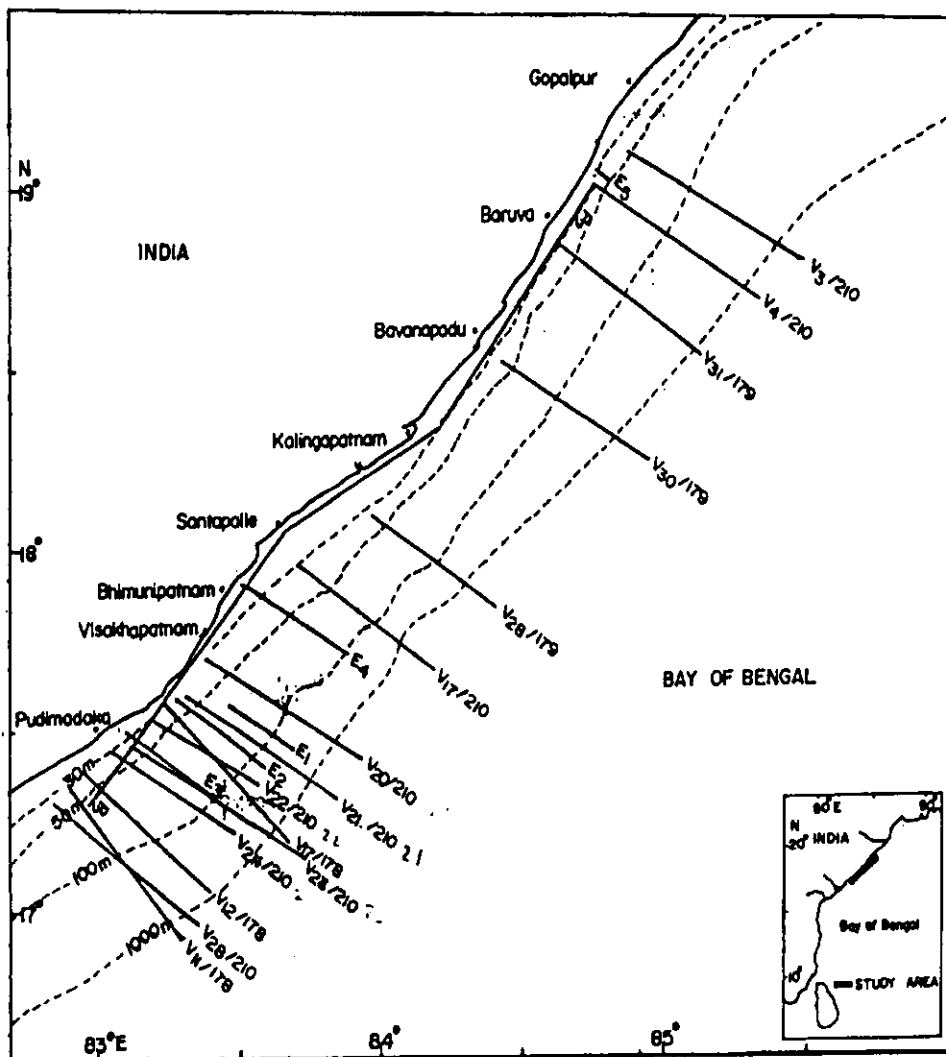


Fig.1 Area map showing profiling lines

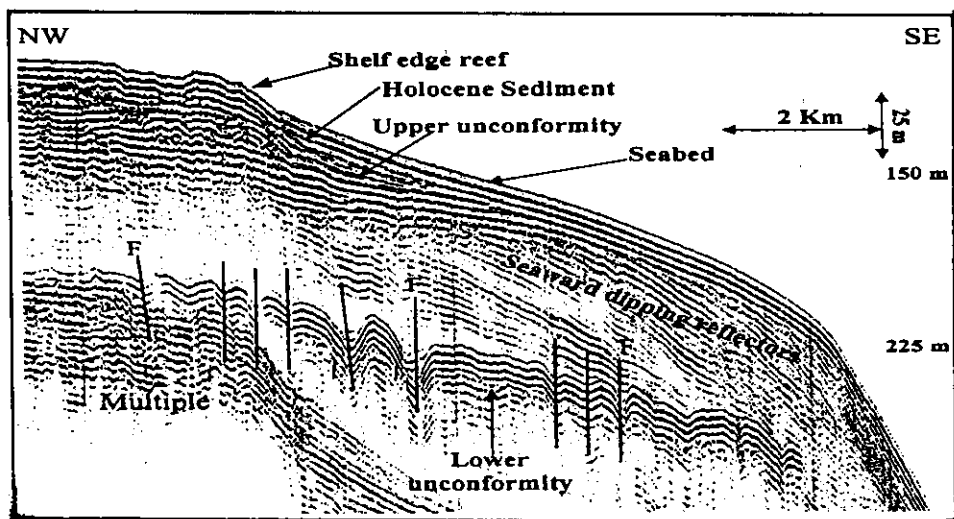


Fig.2 High-resolution seismic record off Pudimadaka showing erosional unconformities and associated faults and folds.

the present day outershelf and the upper unconformity (UU) was outcropped as shelf edge reef in the outershelf. The seaward sloping erosional surface of the LU with possible truncation below the present day midshelf suggests topography analogous to palaeo-shelf. This erosional palaeo-shelf is associated with a series of folds and faults depicting deformation on the acoustically strong reflector. The upper unconformity (UU) is either exposed or buried under thin veneer of sediment in the outershelf regions. The sediment wedge formed at the foot of the shelf edge reef bypassing the outershelf is probably caused by the deposition of modern fine sediments.

The palaeo-shelf (LU) overlain by thick sediments and the seismic facies of this sequence is characterised by continuous clinoformal reflectors that downlap on to sloping palaeo-shelf (Fig.2). These tangential and sigmoidal reflectors suggest the progradational deltaic sedimentation in the area. Similar pattern obtained in the adjacent profiles indicate active sedimentation during the period. The palaeo-shelf that is associated with faulting and folding in the sedimentary sequence, is nearly surfacing in the midshelf region, where the submerged ridges exist (Fig.3). The growth of

these ridges must have taken place over the buried late Pleistocene hard bottom. In the absence of radio carbon dates for these ridge samples, it may be tentatively inferred these ridges to be of pre-Holocene period as they are cropped up from the buried hard reflectors which probably belongs to late Pleistocene. However, these ridges are inferred as carbonate mounds formed during Holocene transgression (Murthy et al., 1987). Proper rock core drill sampling over the ridges may reveal the history of the sea-level variation back to Early Wisconsinan glaciation that occurred around 150,000 years B.P. (Kindinger, 1988 and Colemans et al., 1991). Occurrence of thick progradational sediments over the palaeo-shelf indicates that deltaic sedimentation existed in this part of the area subsequent to Early Wisconsinan glaciation. Though this part of the shelf is presently said to be non-depositional area, the occurrence of about 1 km wide buried channel beneath the innershelf of Pudimadaka (Fig.4) depicts active sedimentation during sea-level lowstands which resulted in the occurrence of progradational sediments below the present day outershelf.

High resolution shallow seismic records collected over the outer shelf off Visakhapatnam reveal prominent morphological features like shelf

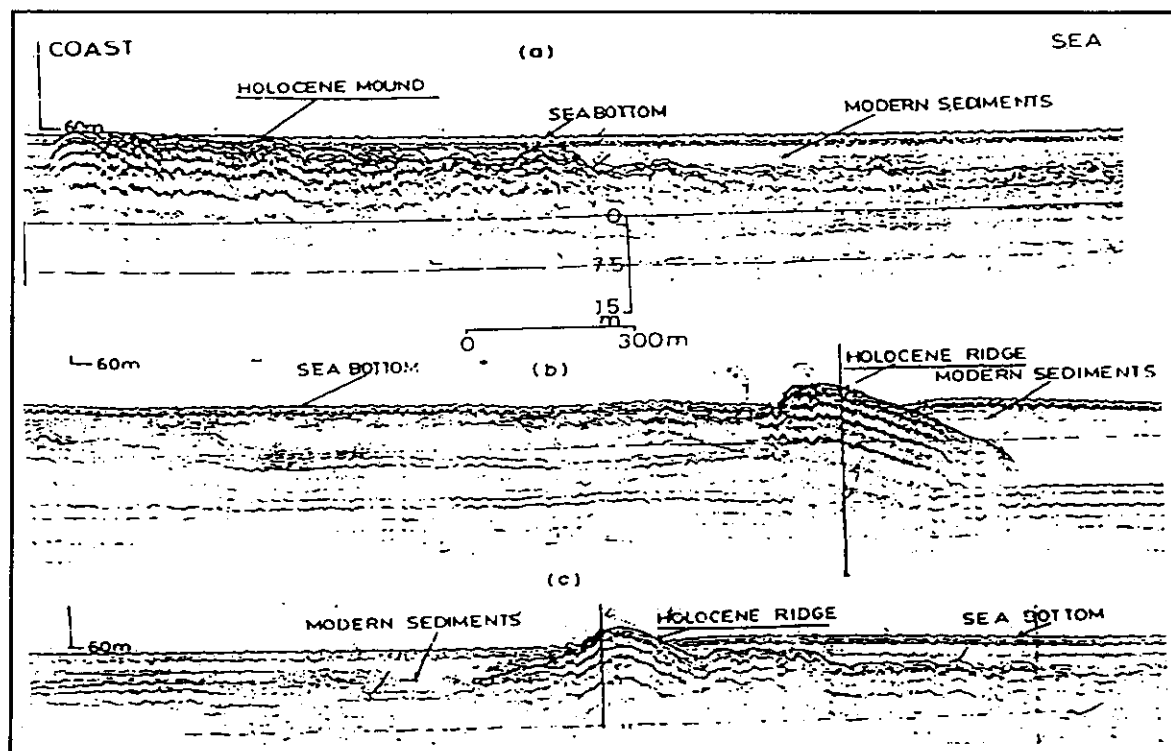


Fig.3 High-resolution seismic records of mid-shelf area showing (a) partially exposed ridge, (b) and (c) exposed ridge

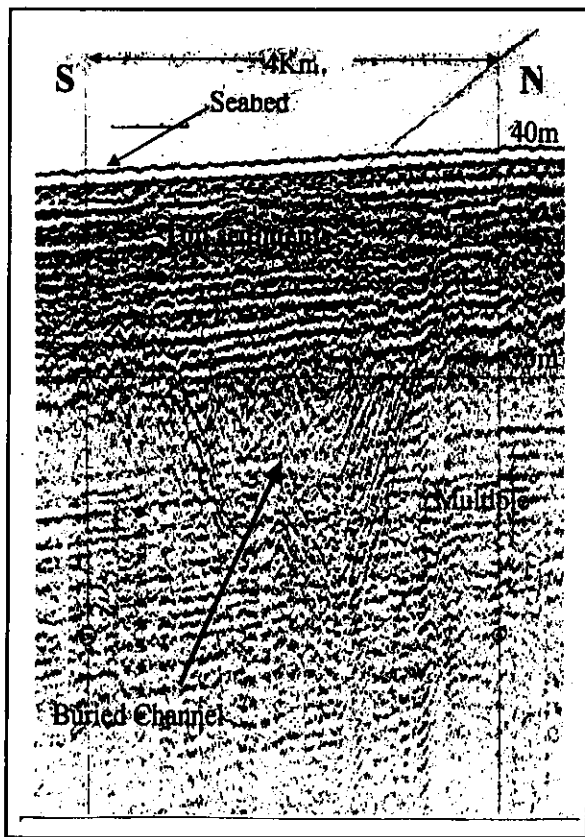


Fig.4 High-resolution seismic record showing palaeo-channel/buried channel off Pudimadaka

edge barrier reefs, terraces, mounds and pinnacles. Mohana Rao and Rao (1994) described these features and related them to the sea-level still stands during early Holocene. They reported the late Pleistocene regression down to about 130 m below the present sea-level and also inferred a major transgressive sea at about 80 m water depth. Carbonate rock samples obtained by them over some of the outer shelf morphological features have indicated the early Holocene ages of $12,530 \pm 170$ yrs. B.P. (100 m) and $10,790 \pm 170$ yrs.B.P. (85 m) suggesting that Holocene transgression started earlier than 12,500 yrs.B.P. The age of 14,500 yrs.B.P. for the dead coral sample at 115 m off Madras (Vaz, 1996) indicate that the Holocene transgression even initiated prior to 14,500 yrs.B.P. in the eastern continental shelf. These dates also show that the sea-level rise during the early stages of Holocene transgression was rapid. Sharp fall of the seabed at the shelf edge barrier reef around water depth of 130 m (Mohana Rao and Rao, 1994) nearly coincides with the maximum sea-level drop reported by Fairbanks (1989) during Last Glacial Maxima (LGM), i.e., around 18,000 yrs B.P.

Holocene sea-level studies for the west coast of India were made by several workers and some of them have drawn the sea-level curves of the coast (Nair, 1979; Kale and Rajguru, 1985; Hashmi et al., 1995; Rao and Veerayya, 1996 and Vora et al., 1996). A detailed sea-level curve with enough data set has not yet been reported for the east coast of India. Based on the geological indicators of the coast, Banarjee (1993) reported a sea-level curve since LGM on the east coast of India and inferred a delayed sea-level fall after LGM. In this paper, a tentative sea-level curve for the Holocene has been drawn (Fig.5) based on the information obtained from the available sources (Vaz, 1996; Mohana Rao and Rao, 1994; Nageswara Rao and Sadakata, 1993; Srinivasa Rao et al., 1990) over which the widely accepted sea-level curve of Fairbanks (1989) was superimposed. The curve nearly matches with that of Fairbanks except in the late Holocene period during which the present curve shows the highstands.

Types of morphological features

High-resolution echograms obtained upto the water depth of 70 m indicate different types

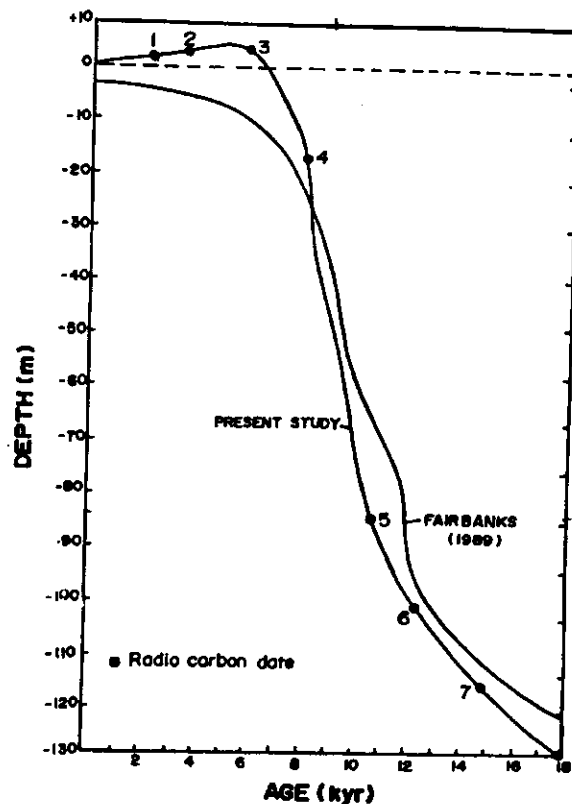


Fig.5 Tentative sea-level curve since LGM on the east coast of India

of morphological features in the depth zone between 60 and 70 m of the study area and between 20 and 30 m off Gopalpur. These echograms show different kinds of peak configuration, viz., single peaked and double/multi peaked reef system in the area (Fig.6 and 7). All these sections were obtained in the inner to midshelf regions of the study area and they reflect variable nature in their existence. The echograms collected off Bhimunipatnam suggests rugged topography due to pinnacles of variable heights of 2-4 m for about 2 km distance between the water depth of 65 and 70 m (Fig.6a). This complex pinnacled reef configuration is indicative of longer duration of static sea-level associated with very high wave energy conditions. The echograms obtained between Bhimunipatnam and Visakhapatnam at more or less similar depths in the midshelf exhibits a sharp single peak pinnacle reef of about 4 m and is associated with erosional troughs at the foot of the pinnacled reef reflecting high energy environment (Fig.6b). The bathymetry record of the midshelf region off Visakhapatnam shows a gentle dome shaped or hump shaped elevation without any rugged nature indicating comparatively low energy condition (Fig.6c). Based on the occurrence of different kinds of morphological features in the midshelf region, it can be postulated that variable energy conditions prevailed around 60 m water depth during the lower sea-level time.

Variation in the elevation of pinnacled reefs in midshelf region of western continental shelf of India is attributed to differential burial of ridges by terrigenous flux due to humid tropical climate associated with strong south-west monsoon during middle/late Holocene (Wagle and Veerayya, 1996). This change in the coverage pattern of ridges by modern sediments is well documented in the seismic records obtained in the midshelf regions of some parts of Visakhapatnam (Fig.3). These records reveal the exposure of ridges at some places on the seabed and burial of the ridges at the other places below the modern sediments. The difference in the nature and shape, either single peaked or multi peaked or domal caused due to differential burial, of the reefs on the midshelf further supplements the fact that variable energy conditions prevailed during lowered sea-levels.

NEO-TECTONIC ACTIVITY

Seismic records as well as echograms in many parts of the study area display structural changes in the form of folds and faults. One such record obtained around 25 m water depth over the innershelf region off Gopalpur reveal double peaked pinnacle reef system associated with about 10 m vertical fall of the seabed suggesting an abrupt faulting in the seawardside of the reef (Fig.7). Similar displacement of the seabed observed in other parts of the coast are attributed to be the results of vertical movements of the seabed (Banarjee, 1993).

The erosional palaeo-shelf off Pudimadaka shows a series of folds and faults suggesting deformation on the strong subsurface reflector (Fig.2). Occurrence of similar features with different resolution in the adjacent profiles indicate that the strike axis of these folds is NE-SW. The prominent and systematic deformation in the palaeo-shelf underlying the sigmoidal late Pleistocene sequence shows a contemporaneous deformation that has taken place in the area due to sliding down of sediments and the strike axis is nearly right angle to the direction of sediment sliding. This kind of deformation generally occur when the sediments slide over gentle slopes and the axes of the folds and the strike of the thrusts will be at right angle to the direction in which sediments slide (Billings, 1972). The erosional features along with regular faulting (growth faults) and its traces in overlying sediments reflect the likely occurrence of neo-tectonic activity caused due to cumulative effect of diastrophic and eustatic changes in addition to sliding down of sediments.

A seismic record collected from the innershelf off Bhimunipatnam shows some deformation in the subsurface layer (Fig.8). Though the structure at a glance appears like a buried channel, clear observation of the subsurface layer indicates a significant faulting. Uniform and parallel bedding is noticed in the left side segment of the subsurface unit while the other segment is inclined downward towards the fault plane suggesting deformation in the nearly uniform bedding. In view of several deformations noticed in the

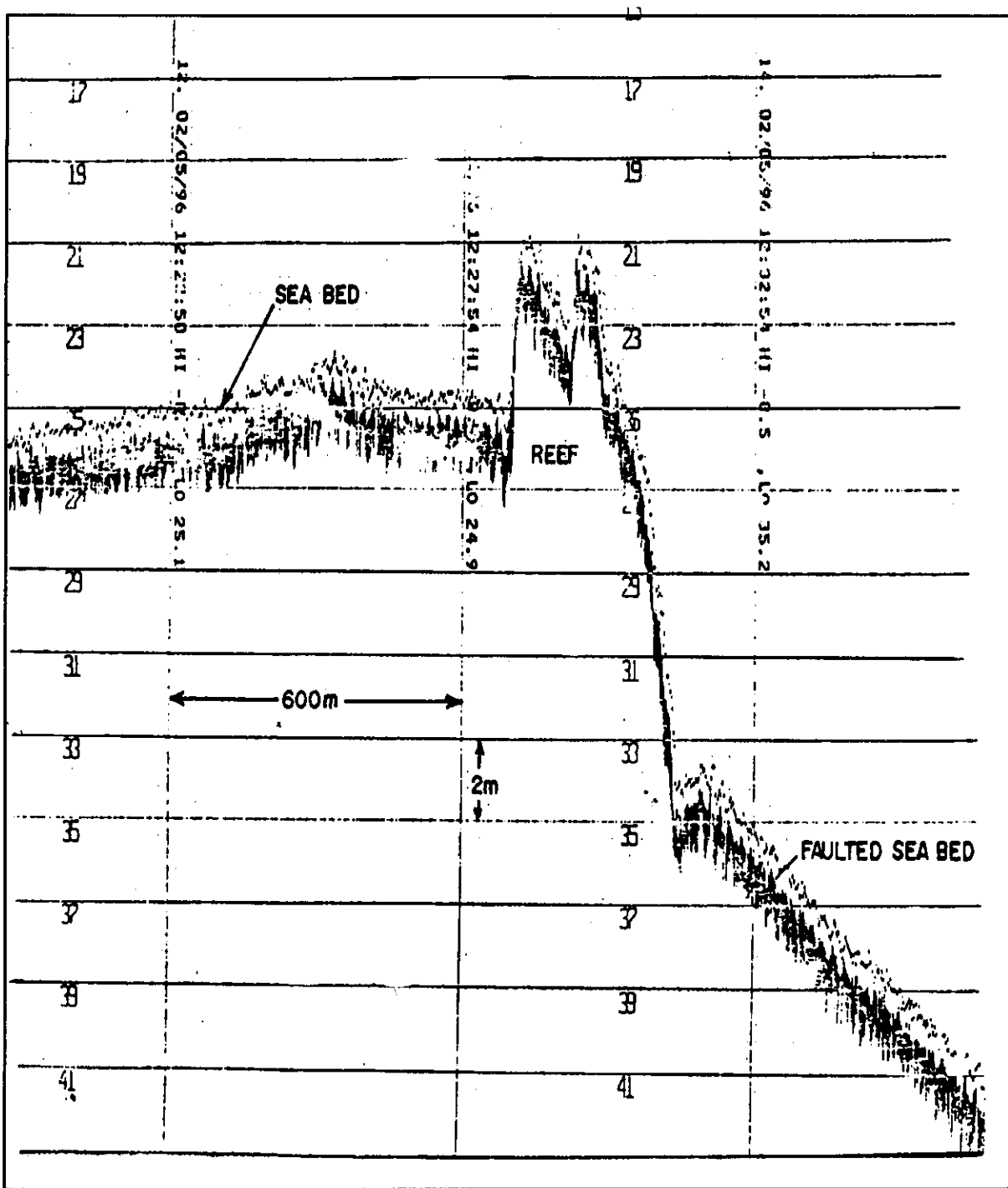


Fig.7 Echogram showing vertical fault of the seabed off Gopalpur

sedimentary units above and below the seabed, it may be understood that possible neo-tectonic movement exists in the region. The reported neo-tectonic activity in the southern Indian Peninsular as well as offshore regions (Ramasamy and Balaji,

1993; Subrahmanyam et al., 1996 and Murthy, 1997) supplements to the view that these structural deformations in the present study area are probably related to neo-tectonic activity.

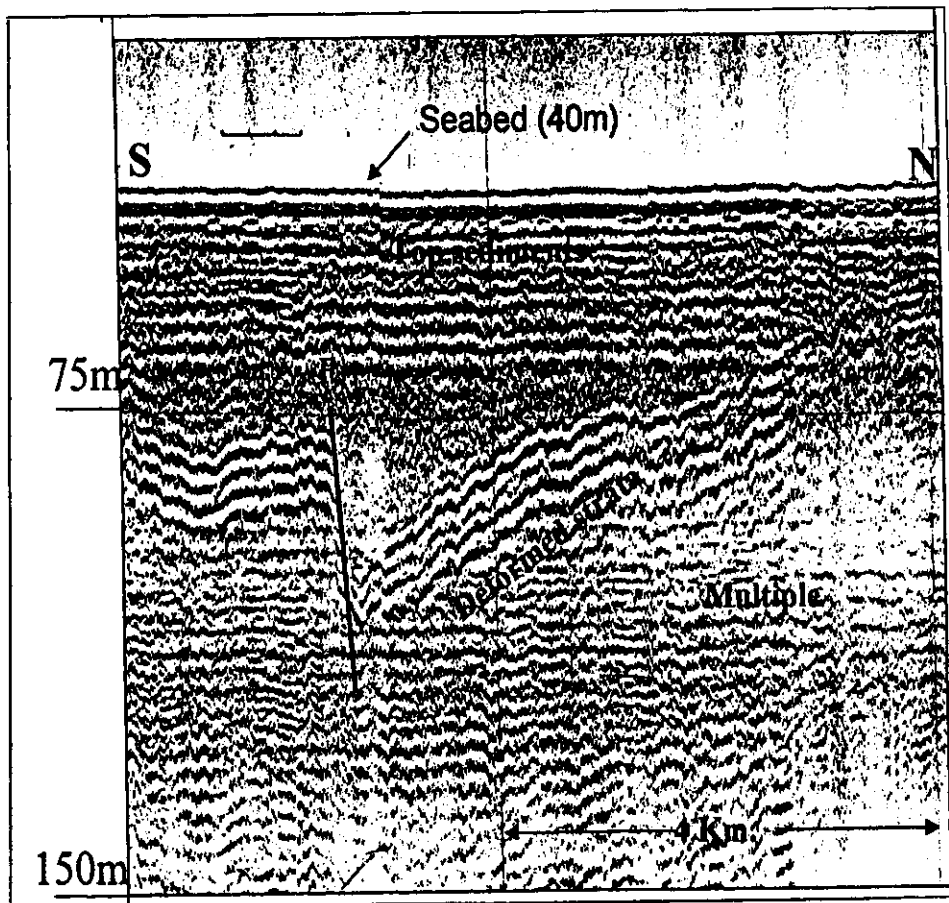


Fig.8 High-resolution seismic records showing structural deformation in the subsurface layer off Bhimunipatnam

CONCLUSIONS

The seismic records have revealed evidences of two glacial cycles of Early Wisconsinan and Last Glacial Maxima (LGM) of late Pleistocene in the form of erosional unconformities. Records of Holocene sea-level strandlines are noticed by way of morphological features on the seabed. Structural disturbances associated with morphological features as well as in the subsurface layers indicate possible neotectonic activity.

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