

Pleistocene Events Recorded by Shallow Seismic Profiling Over The Continental Shelf off Krishna–Godavari Deltas

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Abstract

Shallow-Seismic Profiling studies using Sparker were carried out over the continental shelf and slope off Krishna and Godavari deltas in the central part of east coast of India to delineate sediment boundaries as well as to identify and map the shores of late Pleistocene and Holocene. Over the outershell several major events of Pleistocene age are recorded within the complex series of three to four sedimentary layers and are separated by well developed unconformities. Off Krishna river three distinct sedimentary facies of varying thickness are recorded, each separated by a well defined erosional boundary. These erosional boundaries are not clear off the Godavari river because of the chaotic and columnar reflections within the sedimentary sequences due to the gas seepage. To the south of Krishna river, the records suggest the presence of depressions which are later filled by recent sediments. The sedimentary sequences and the erosional surfaces separating them appear to be products of fluvial and marine processes during regression and transgression of the sea. The lowest glacial shore occurs at -90 to -100 m which is slightly less than the normal range of global values. The subsequent rise in sea levels covered large part of the then exposed land and left behind many shore features which are later buried under the post transgression deposits.

INTRODUCTION

Several large scale sea-level changes have occurred during the Pleistocene due to the alternate growth and melting of continental ice-sheets. The major drop occurred during the latest Pleistocene when sea-level fell to a low of about 120 m (Milliman and Emery, 1968; Bloom, 1977; Van Andel and Lianas, 1984). the time of onset of ice melting and rise in sea-level was expected from 16000 to 14000 yr B. P. However, it is clear that the rise was discontinuous with a major still stand or even reversal between 13000 and 10500 yr B. P. (Ruddiman and Duplessy, 1985). The sea-level changes resulted in the formation of several discrete depositional facies. Seismic investigations to study these depositional facies is called seismic stratigraphy in which the seismic sequences are only chronostratigraphic in nature and not lithology. Recent developments particularly in data acquisition, processing and understanding the seismic wave response has become a powerful tool in the analysis of sedimentary basins and the exploration of hydrocarbon traps. Therefore, to use seismic stratigraphy successfully one must be well conversant in the basics of geophysics and also should understand the sedimentary evolution and stratigraphic framework of depositional sequences. These are called seismic sequences on a seismic section (Mitchem, 1977). The identification of seismic sequence requires that its boundaries be defined and correlated on seismic record. Determining the boundaries of seismic sequence can be accomplished by location of reflection terminations on the seismic data. These reflection terminations represent

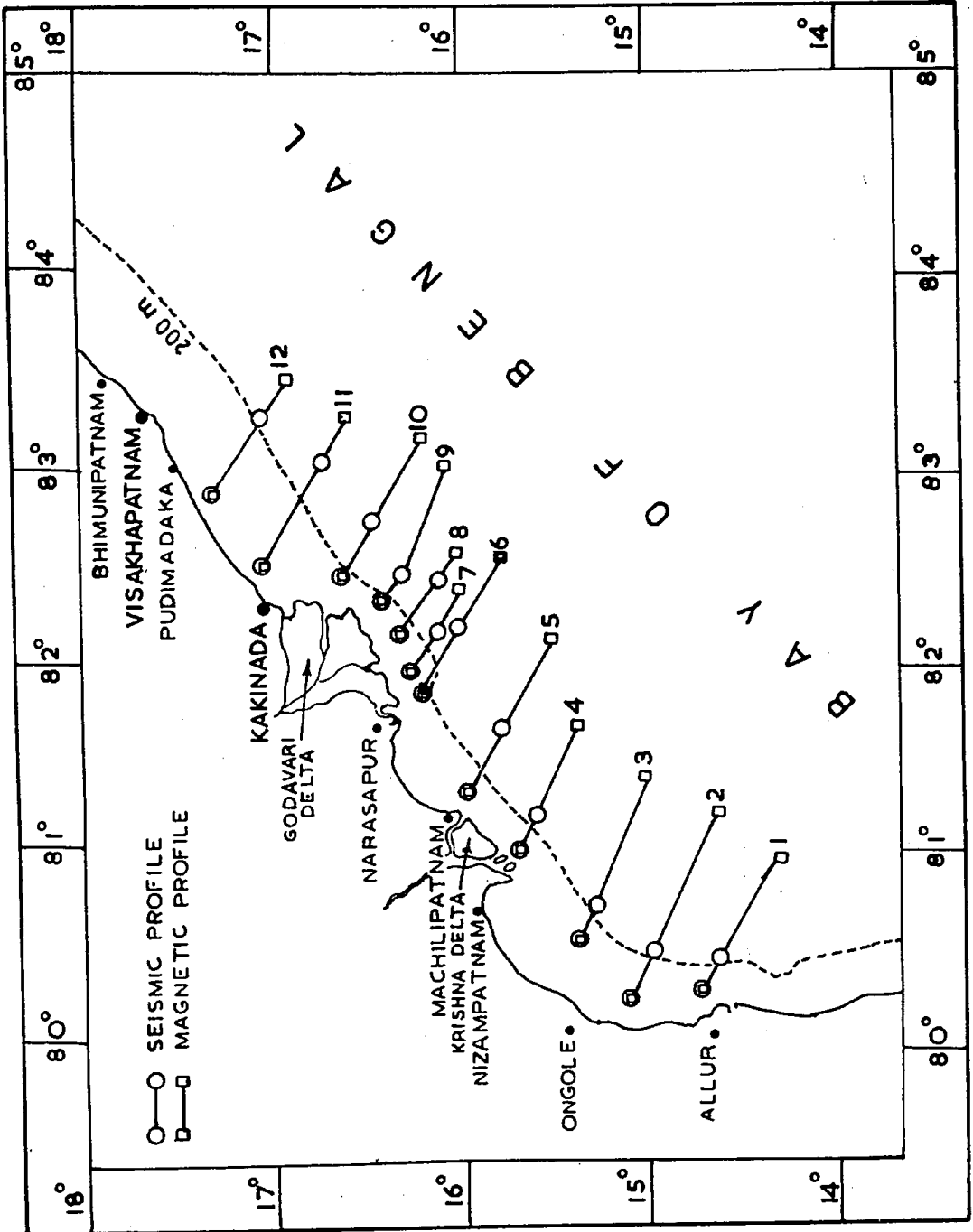


Figure 1. Location of profiles.

unconformities and once identified they can be used to correlate the boundaries of the seismic sequence through areas of conformable seismic reflections. Mitchem and Thompson (1977) have discussed the concept of seismic sequence and its identification in detail.

DATA ACQUISITION

Shallow penetration and high resolution seismic profiling study was carried out over the continental shelf and slope of east coast of India between Allur in Andhra Pradesh in the south and Paradip in Orissa in the north during 178 and 179 cruises of N. I. O. (National Institute of Oceanography) on R. V. Gaveshani during 1987 (Fig. 1). Continuous bathymetry and magnetic data were also collected along these profiles. Nine element spark electrode assembly and the ten element hydrophone streamer were towed behind the ship. The electrical energy varying from 500 to 4000 Joules from the onboard power supply and capacitor bank units was discharged through the spark electrode system into the sea water. The signals reflected from the ocean floor and the sub-surface layers were received by the hydrophone array and were recorded on the single channel analogue recorder. In total 33 profiles were covered with the profile interval varying from 15 km to 50 km. Each profile started at about 30 m water depth and continued upto 2500 m water depth. In this paper only the profiles recorded over the continental shelf and slope between Allur and Kakinada (numbers 1 to 12) are presented (Fig. 1). The stacked bathymetry profiles are given in Fig. 2. The line drawings of the seismic sections for the profiles 2 to 12 are given in Fig. 3. Some representative seismic sections, profiles 2 off Ongole (Fig. 4a) profiles 4 off Nizampatnam near Krishna river (Fig. 4b) and profiles 6 off Narasapur near Godavari river (Fig. 4c) are discussed in detail.

RESULTS

Bathymetry

The ocean bottom topography recorded on profiles 1 to 12 (Fig. 2) in the area between Allur and Pudimadaka reveals that the shelf is narrow and the shelf edge occurs at about 150 m water depth off Allur. However, off Krishna and Godavari rivers the continental slope starts at 90 m water depth. To the north of Godavari river on profiles 11 and 12 the shelf is much broader and the shelf edge is at about 200 m water depth. The gradient of the ocean floor particularly over the continental slope is relatively less off Krishna and Godavari rivers possibly because of abundant and continuous supply of sediments. Marginal Rises (M. R.) are recorded over the continental slope in many profiles.

SEISMIC PROFILING

The penetration was fairly good and an excellent record of the late Pleistocene and Holocene marine deposits was obtained. Over the continental shelf off Ongole,

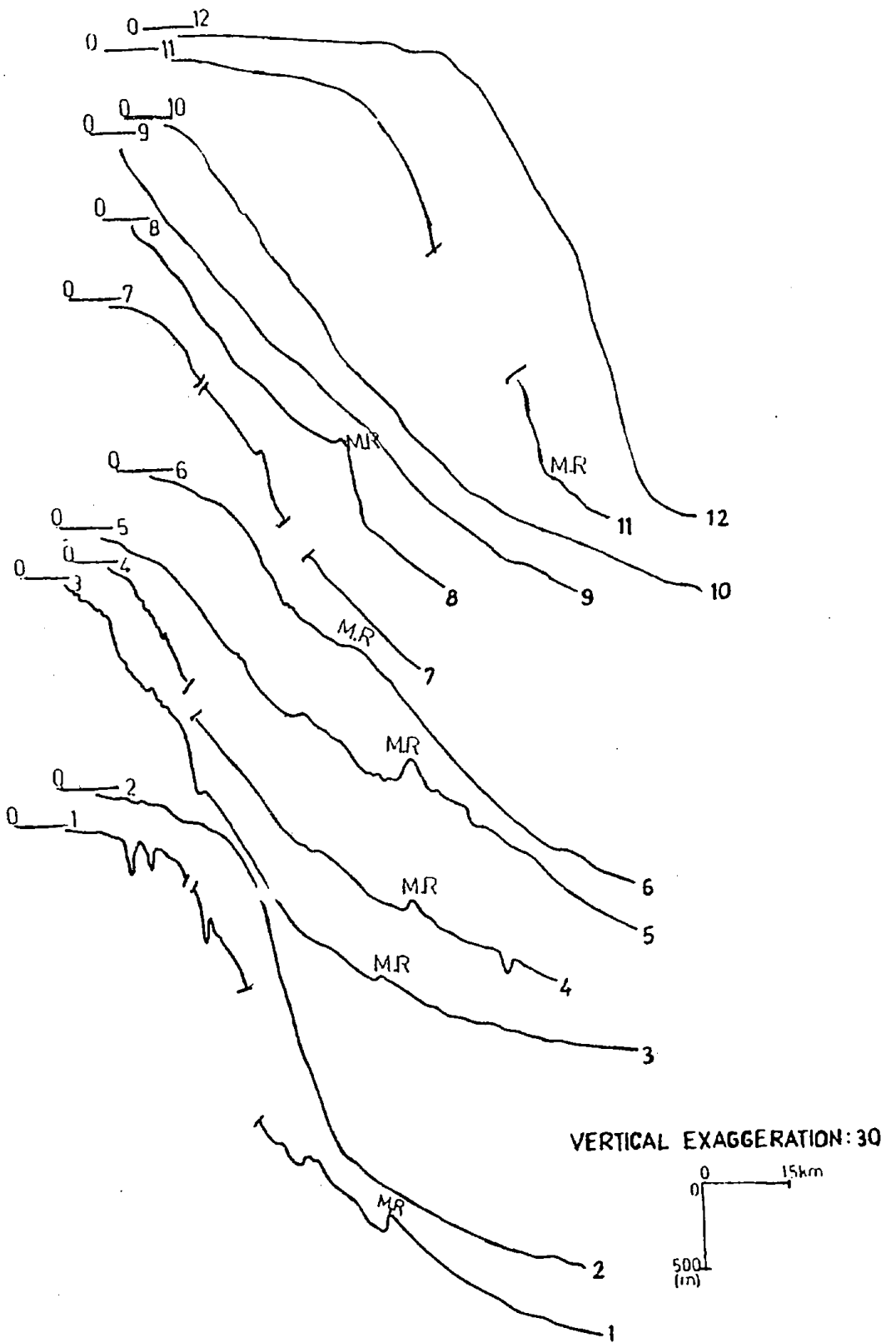


Figure 2. Stacked bathymetry for Profiles 1 to 12.

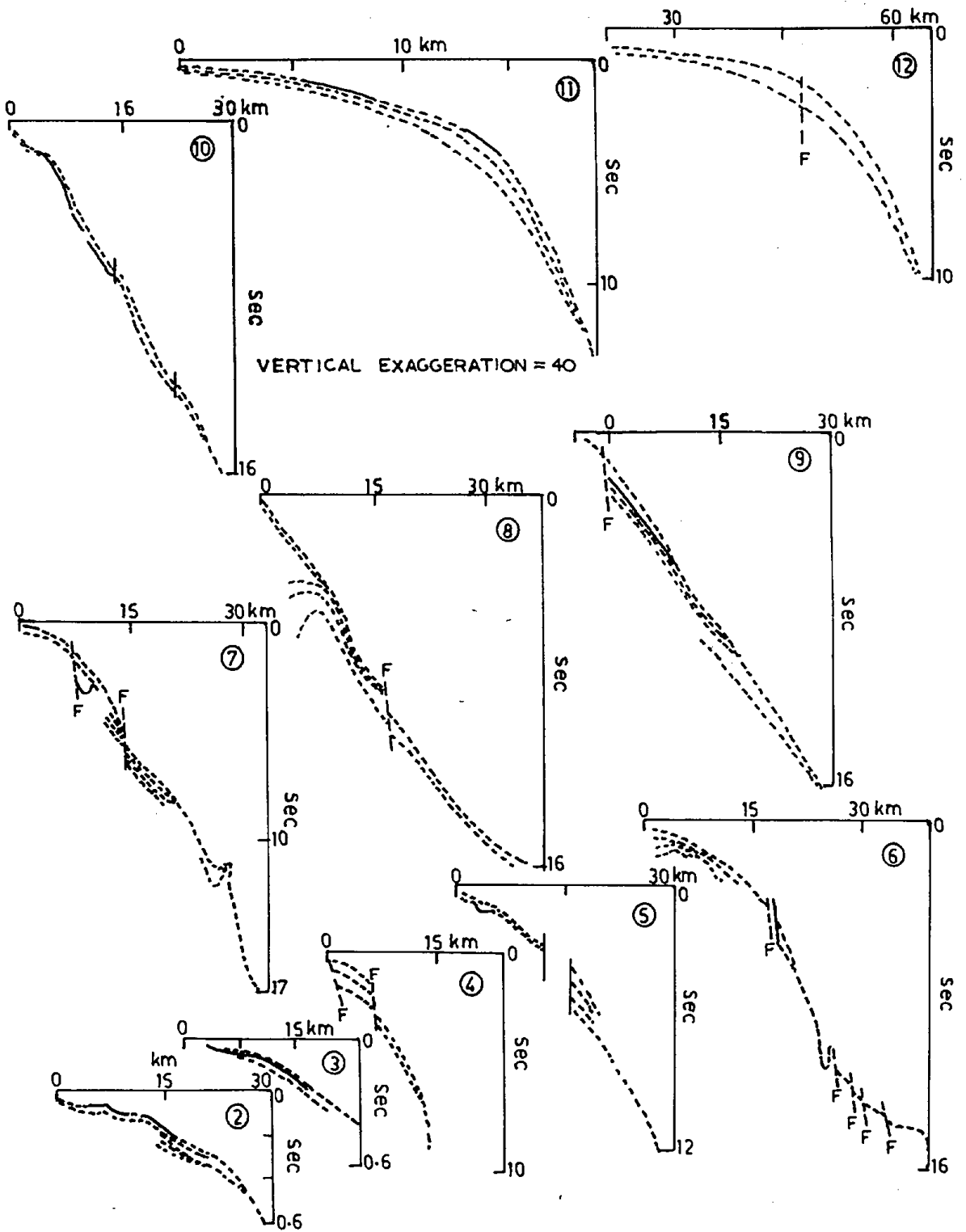


Figure 3. Line drawings of seismic sections for profiles 2 to 12.

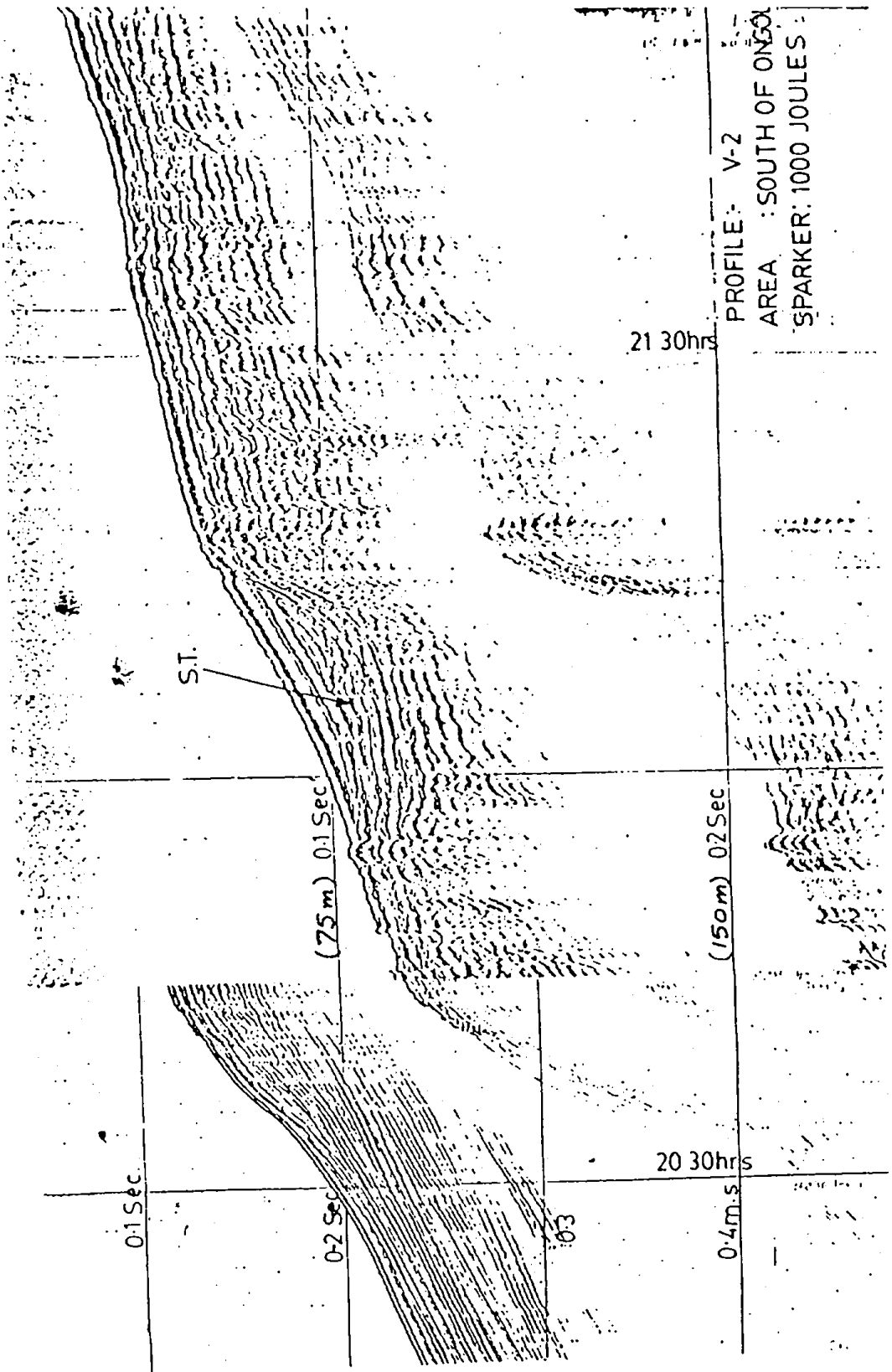


Figure 4a. Seismic profiler record off Ongole.

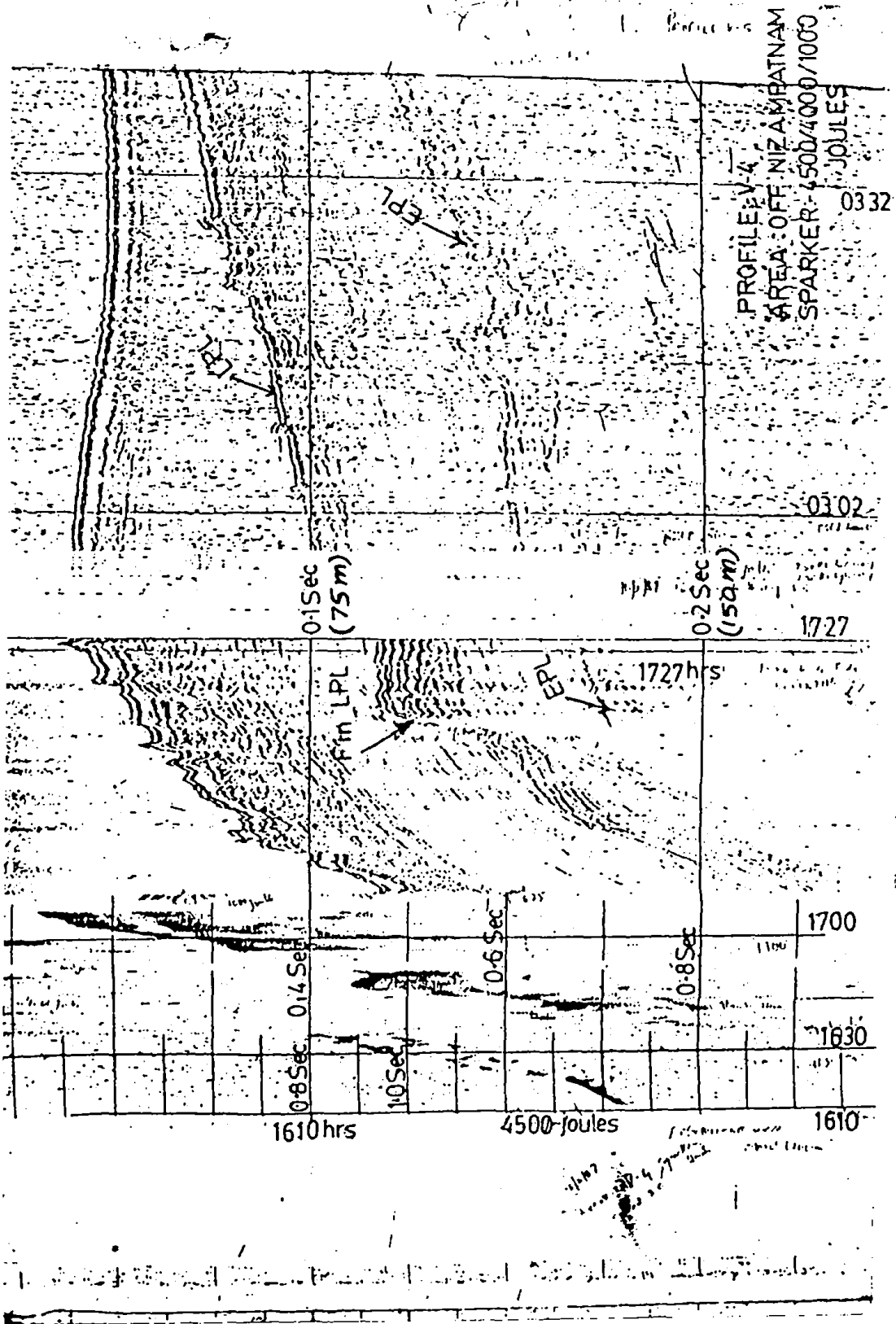


Figure 4b. Seismic profiler record off Nizampatnam.

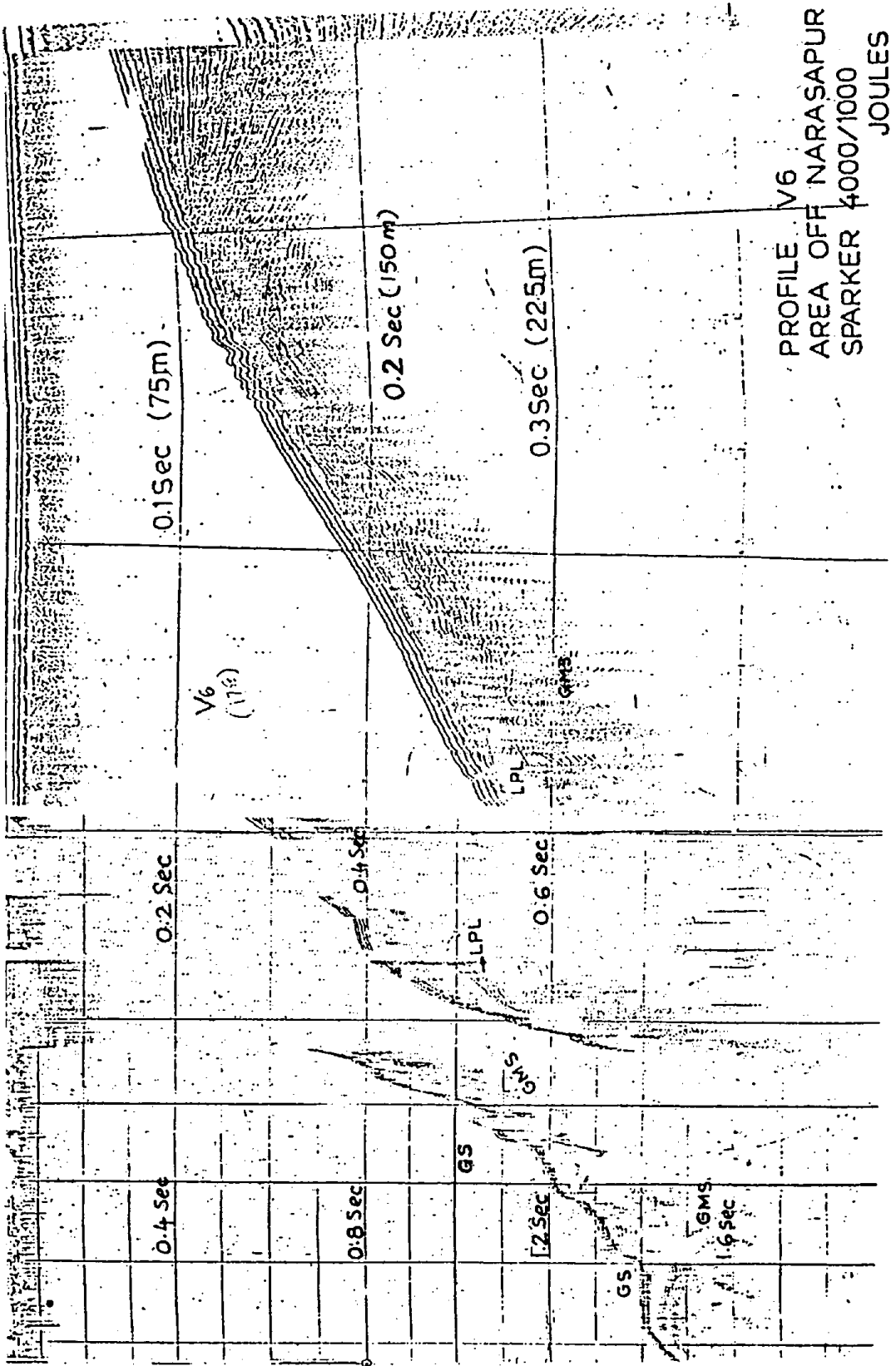


Figure 4c. Seismic profiler record of Narasapur.

the penetration was restricted to only few meters below the ocean floor (Fig. 4a). The deepest reflector is fairly well defined and it is less than 10 m (10 m sec) below the ocean bottom except in sediment trapped bays (ST) and beyond 90 to 100 m contour where the penetration is much greater. The basal alluvial surface can be traced continuously from the start of the profile upto shelf edge. There it is replaced by a set of parallel, discontinuous fan shaped reflections that dip gently seaward. These are designated as layered sequence (B) by Murthy (1989). The increased sound penetration of more than 60 m (80 m sec) below the ocean floor suggests a soft, fine grained deposit, and the wedge as a whole closely resembles the sediments of modern continental slopes (Curry and Moore, 1963; Van Andel and Calvert 1971). The transition from basal alluvial reflectors to the slope deposits is also well displayed in other profiles of this area. The basal reflector terminates in a low cliff or is interrupted by broad channels. Beyond this point, marine conditions evidently prevailed continuously. From this it can be inferred that the termination of basal alluvial reflector at 90 to 100 m depth as the lowest position of the sea during the last glacial maximum. There are many irregularities in the basal alluvial surfaces. Scarps are the common features and they occur at many depths. In many places the basal surface is cut by channels which vary greatly in width from narrow V-shaped ones to broad depressions (Fig. 4a). The channel floor is generally concealed under semitransparent well stratified sediments. Because the streams in this region normally possess a highly reflective bed of sand and gravel it can be considered that the fill to be the product of transgression as it flooded the lower reaches of the channels. An acoustically transparent layer overlying the stratified fill may correspond to the offshore deposits.

Over the continental shelf and slope of Nizamapatnam (Fig. 4b) two distinct erosional unconformities are recorded below the ocean floor. The upper conformity which is considered as boundary between the Late Pleistocene and Holocene is called as Late Pleistocene Layer (LPL). It is about 15 m (20 m sec) below the ocean floor at the start of the profile and deepens to more than 60 m (80 m sec) below the ocean floor at about 50 m water depth. The Late Pleistocene Layer has faulted at about 50 m water depth (Fin LPL) and downthrown by more than 20 m (25 m sec). The landward sediments above this discontinuity are acoustically transparent and without internal stratification. This indicates slow deposition of fine grained material in offshore waters possibly because of transgression advancing too rapidly for much sediment to accumulate in the nearshore region. Above the subsea depth of 50 m, the stratification becomes more common and the sediments are less homogeneous. Several irregularities are recorded in this layer. These include the scarps, ridges and channels and they are present at different depths over the continental shelf. Numerous shore features of this kind are seen in many seismic records all along the east coast of India in the surveys carried out by NIO. They are specially well documented in the area between Kakinada in A. P. and Gopalpur in Orissa where they either protrude over the ocean floor or are covered under thin layer of sediments. To the north of Gopalpur these features are again covered under the recent sediments, as reported by Murthy (1989, Fig. 6). If we assume that the sea level at the time of their formation corresponds approximately to the tops of the ridges and the bases of the scarps, the position of the past sea levels can be

determined within about 2 m. Another unconformity is recorded about 40 m below the LPL and it is called here as Early Pleistocene Layer (EPL) while the sediments above the LPL have gradually become thicker towards the shelf edge; the sediments between EPL and LPL are fairly of uniform thickness of about 40 m (50 m sec). The surface of the EPL is also irregular associated with ridges and channels. Because of the poor quality of the record, the stratification of the sediments is not seen distinctly. However, close examination of the records reveals intermittent stratified layers within this sedimentary column.

Over the continental shelf and slope of Narasapur (Fig. 4c) the Late Pleistocene Layer is about 30 m (40 m sec) below the ocean floor at the start of the profile where the water depth is about 35 m. From here upto about 70 m water depth, the sedimentation was continuous and they are well stratified. The scarps, ridges and channels recorded in the earlier profiles are not seen in these records. Beyond 90 m water depth the basal reflector is rugged, uneven and locally incoherent suggesting a set of discrete points or columnar features than specular reflecting surface. They represent typical gas mixed sediments (GMS) which are totally disturbed by the upward movement of gas and resulting in the formation of columnar features (Murthy and Rao 1990). From 700 to 900 m water-depth diapheric structures showing the gas seepages (GS) are also recorded in profile 6. The differences in the structural features observed in the profiles off Narasapur compared to the other profiles off Nizamapatnam and Ongole suggest that the development of outershelf has varied significantly from one location to another and only those profiles adjacent to one another are similar (Fig. 3). The deposition of sediments appears to have been interrupted by periods of erosion as indicated by the bench like features.

CONCLUSIONS

Among the twelve profiles covered in the area between Allur and Pudimadaka, the record obtained on profile 4 (Fig. 4b) is typical and most representative with reference to which the other records (Fig. 3) of this area could be explained. In profile 4 located off Nizamapatnam (Fig. 4b) more than 50 m (60 m sec) thick, recent/modern sediments are recorded. The ocean floor is very uneven and several small scale surface channels are recorded. Beneath the recent sediments a distinct erosional unconformity called as Late Pleistocene Layer (LPL) is recorded. It has faulted with more than 20 m (25 m sec) downthrow and the present shelf break on the ocean floor occurs almost above the fault in LPL. Below this, another erosional unconformity is recorded and is designated as Early Pleistocene Layer (EPL). This layer also appears to have been faulted but the downthrown portion could not be seen clearly in the record. On profiles 2 (Fig. 4a) thickness of recent sediments decreases considerably and the LPL is recorded quite clearly almost near to the ocean floor. Near the shelf edge wide and deep channels filled with sediments are also recorded. In profiles 6 to 12 (Fig. 3) in the areas off Godavari and Krishna, the thickness of the recent sediments progressively decreases. The shelf edge faulting that is observed in profile 4 could also be delineated in these profiles. In profile 6 which is located off Narasapur the gas seepages are recorded at 700 to 900 m water

depth and the ocean floor is relatively flat and forms a plateau in this region (Murthy and Rao 1990). The sediments on the outershelf and slope are highly distorted and forms columnar features which clearly resembles the gas mixed sediments. The gas seepages associated with the faults and gas mixed sediments are also recored on profiles 7 and 8 (Fig. 3). Thus the seismic profiling technique which is relatively easy to operate, proved to be promising tool for identifying the past glacial depositional facies which has wide application for the environmental reconstruction of submerged coastal zones.

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