

Letter Section

ACOUSTIC MASKING IN SEDIMENTS DUE TO GASES ON THE WESTERN CONTINENTAL SHELF OF INDIA

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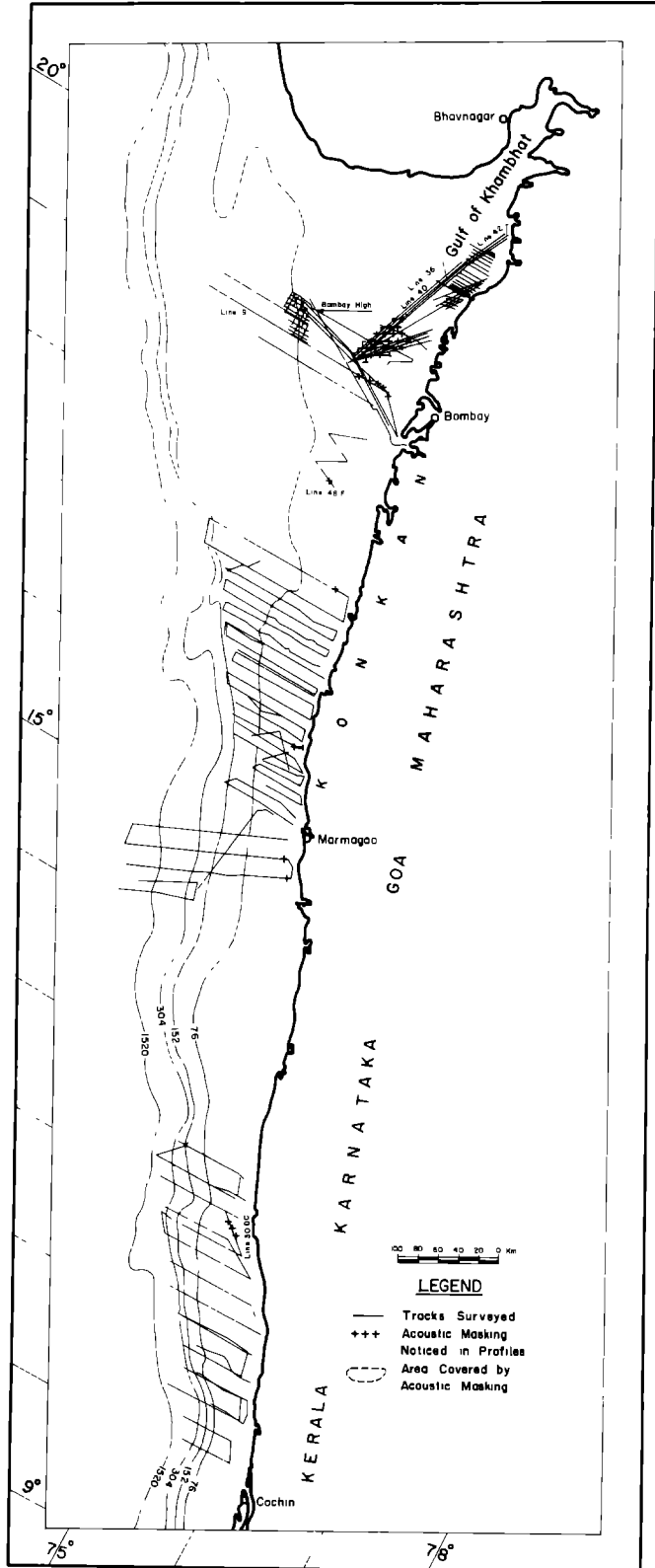
ABSTRACT

Siddique, H N, Gopala Rao, D., Vora, K.H and Topgi, R.S, 1981 Acoustic masking in sediments due to gases on the western continental shelf of India *Mar. Geol.*, 39 M27–M37

Surveys carried out on the western continental shelf of India indicate that the inner and middle shelf to a depth of 50–60 m is covered by acoustically transparent clays. On the shelf off Bombay, the clays are thin near the shore where they overlie rocks or sands, and increase to 20–35 m on the middle shelf, beyond which they thin out at a depth of 50–60 m where relict oolitic sands are exposed. The shallow seismic and echosounding records of these clays at places are marked by turbidity which may be categorised as (1) extending over a distance of 50–60 km and covering large areas of over 2500 km² and (2) resembling isolated inverted “U” shaped features. The turbidity appears to rise from the underlying reflectors to within 5–10 m of the sea bed. These features are very prominent in two areas, viz. on the middle shelf off Bombay and on the inner shelf. The shallow bore holes drilled and the cores collected in the area show bubbles or fissures in the clays of the turbid zone. The gas predominantly consists of methane with terraces of higher hydrocarbons. The composition of the gas and the occurrence of the gassy sediments on the middle shelf and in the vicinity of the estuaries and rivers favours their biogenic nature. The common depth of occurrence of 5–10 m may represent the boundary between the sulfate-reducing zone and the underlying methane-producing zone. Perhaps the gases were formed by the degradation of large quantities of organic matter produced by increased productivity, or because of higher influx of organic matter in the recent past. However, the location of some of the occurrences in the vicinity of an oil and gas field indicate that the gases in the sediments of the outer shelf off Bombay may be petrogenic and those on the middle and inner shelf off Bombay, Konkan, Karnataka and Kerala may be biogenic.

INTRODUCTION

The occurrence of acoustic masking in sediments has been reported from seismic profiles and echograms of lakes (Glangeand et al., 1964), and estuaries and bays (Schubel, 1974). The anomalous high seismic velocities and structures in the deep sea sediments of the Blake-Bahama Ridge, the Bering Sea (Bryan, 1974) and the continental margin of Africa have been interpreted as due to gas-rich sediments (Emery, 1974). More recently McQuillm and Fannin (1979) have described the occurrence of acoustic masking and pock-



marks in a large area in the North Sea, and Watkin and Worzel (1978) from the Texas offshore. The inferences based on underway records have been subsequently confirmed by shallow coring and detailed studies in Chesapeake Bay, and deep-sea drilling on the Blake outer ridge and in other areas.

As a part of a systematic study of the continental margin of India, the RV "Gaveshani" of the National Institute of Oceanography has been surveying the shelf on tracks spaced at about 20 km normal to the coast. The surveys comprise echosounding (Kelvin and Hughes MS 45:30 kHz), side-scan sonar (EG and G Mark 1B, dual channel recorder 259-3 and tow fish 272), shallow seismic profiling (Huntec Hydrosonde M 2A; main pulse 5 kHz), and magnetics followed by sampling with grabs, snappers, dredges and corers. The surveys carried out during the last three years have covered large areas of the continental shelf from Bombay to Cochin (Fig. 1).

ACOUSTIC MASKING IN SEDIMENTS

Sediments

The shallow seismic profiles of the western shelf indicate that the inner shelf to a depth of 50–60 m is covered by acoustically transparent clays. On the shelf off Bombay, the clay a few metres thick near the shore increases to 20–35 m on the inner shelf and then decreases seaward; beyond a depth of 50–60 m the relict oolitic sands are exposed on the seabed. The underlying relict oolitic sands may shoreward grade into terrigenous sands.

Acoustic masking in seismic profiles

The shallow seismic profiles of the acoustically transparent clays are at places marked by turbidity. The turbidity is confined to the clays only, usually rises to within 5–10 m of the surface and in no case reaches the top. The turbidity resembles inverted U-like features which extend from the underlying reflector, which is usually a sand. The rise from the underlying reflector may be deceptive as the overlying acoustic masking would perhaps mask the underlying reflector as well. The sides of these turbid zones are steep, almost vertical, their tops flat with rounded edges. These features are not only confined to the shallow seismic profiles, but are seen in the echograms as well (Figs. 2 and 3). It is, however, surprising that no bubbling or pockmarks are seen on the side-scan sonar records. Initially, the acoustic masking was observed on the seismic profiles of the continental shelf off Bombay. However, as the surveys progressed, it became clear that the acoustic masking is not an isolated feature but is widespread over the areas of the western shelf.

Fig. 1. Map showing the shallow seismic profiling carried out on the western continental shelf of India and areas where acoustic masking has been noticed

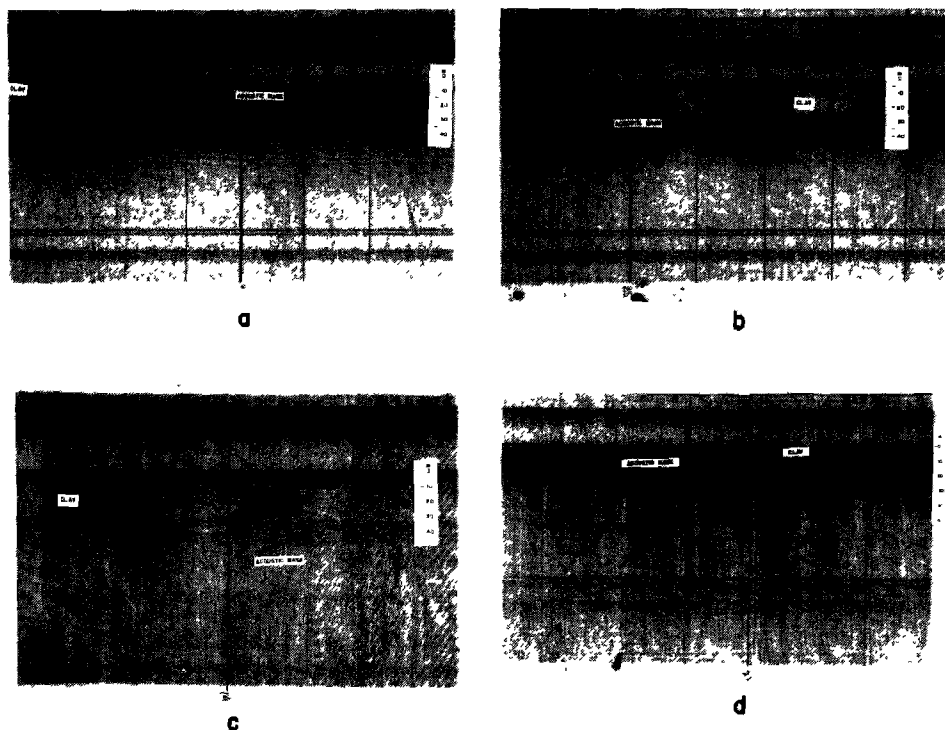


Fig 2. Shallow seismic profiles showing acoustic masking due to gases
 A Continental shelf off Bombay. The masking is from the extensive area near Bassein Field (Line 40: Fix 35: 0 m is at the sea bed).
 B. Isolated masking at the fringe of the extensive area of masking near Bassein Field on the Continental Shelf off Bombay (Line 40: Fix 25: 0 m is at the sea bed).
 C. Isolated masking on the Direction Bank off Bombay (Line 48 F: Fix 14).
 D. Extensive masking on the continental shelf off South West India (Line 30 DC Fix 21).
 Vertical scale is given on photographs, the horizontal scale in A and B between fixes is 200 m and C and D cover a track of about 1.3 km

The acoustic masking may be categorised in two different types, i.e., one covering large areas (Fig. 2A) (relatively small), the other isolated inverted "U" shaped features (Fig. 2B, C, D). On the shelf off Bombay acoustic masking characterises records continuously for a distance of 50–60 km on some tracks. This forms one of the largest areas of acoustic masking on the western shelf and covers more than 2500 km² (Figs. 1, 4 and 5).

Core in the acoustically turbid sediments

Some of these areas have been surveyed in considerable detail and a location where the acoustically turbid sediments occur at a comparatively shallow depth was selected for coring (Fig. 5). The coring was planned to penetrate the top of the acoustically transparent zone which was expected in this re-

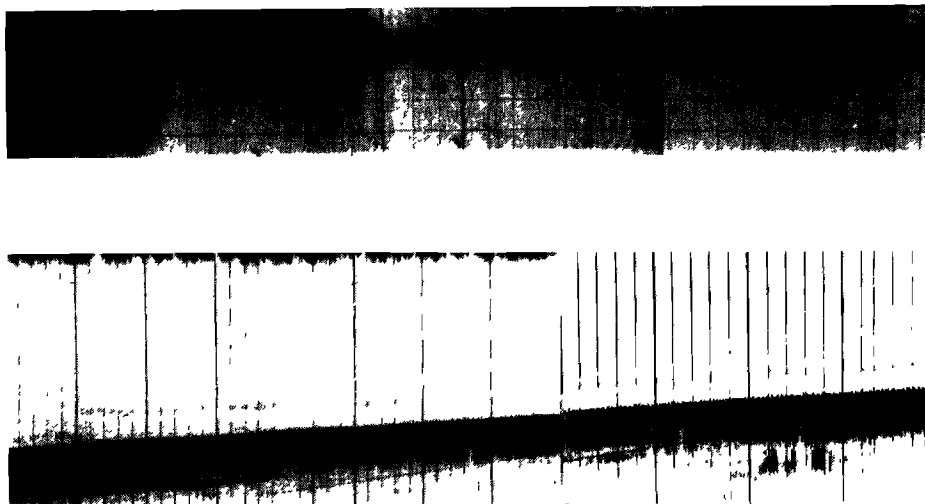


Fig. 3. *Upper part.* Shallow seismic profile shows the transparent clays overlying a sandy horizon. The reflector within the clay represents a change in lithology from clays in upper part to sandy clays with shells in the lower part. The vertical scale is shown on the profiles while the horizontal scale is 200 m between fixes

Lower part Echogram showing the topography in the area, because of the lower frequency (Kelvin and Hughes MS-45:30 kHz), subbottom penetration is also achieved. The echogram shows similar acoustic masking as in seismic profiles due to gases, it is more pronounced between fixes 200 and 205.

gion at a depth of about 5 m. An examination of the core collected (G 37) showed bubbles at about 3.5 m and fissures below 4 m (Fig. 6). Some of these fissures and bubbles are 2–3 mm long and are estimated to form about 10% of the volume of the sediment. The depth of the top of the turbid zone in the seismic record matches well with the observation of bubbles and fissures in core (Fig. 6). A study of the bore-hole records in the area also showed either bubbles or flocculated clay. The top of the zone in two of the bore holes was demarcated at 7 m which extends down to 14–18 m.

A study of the cores or bore hole records from the adjacent turbidity free area indicate the absence of any such bubbles or fissures in clays.

Analyses of gas from core

The gas from the fissures and bubbles in core G 37 (Fig. 6) was extracted for analyses. An air tight syringe needle was inserted in the acrylic liner and the gas in the bubble or fissure was extracted and stored in a tube with the displacement of mercury. The gas was analysed on a Shimadzu gas chromatograph with a thermal conductivity detector and helium was used as a carrier gas with a flow rate of 30 cc per minute. Two columns were used for the analyses:

Column I: 6' × 1/8'' stainless steel 10% D.C. 200 Silicone Oil on AW-DMCS

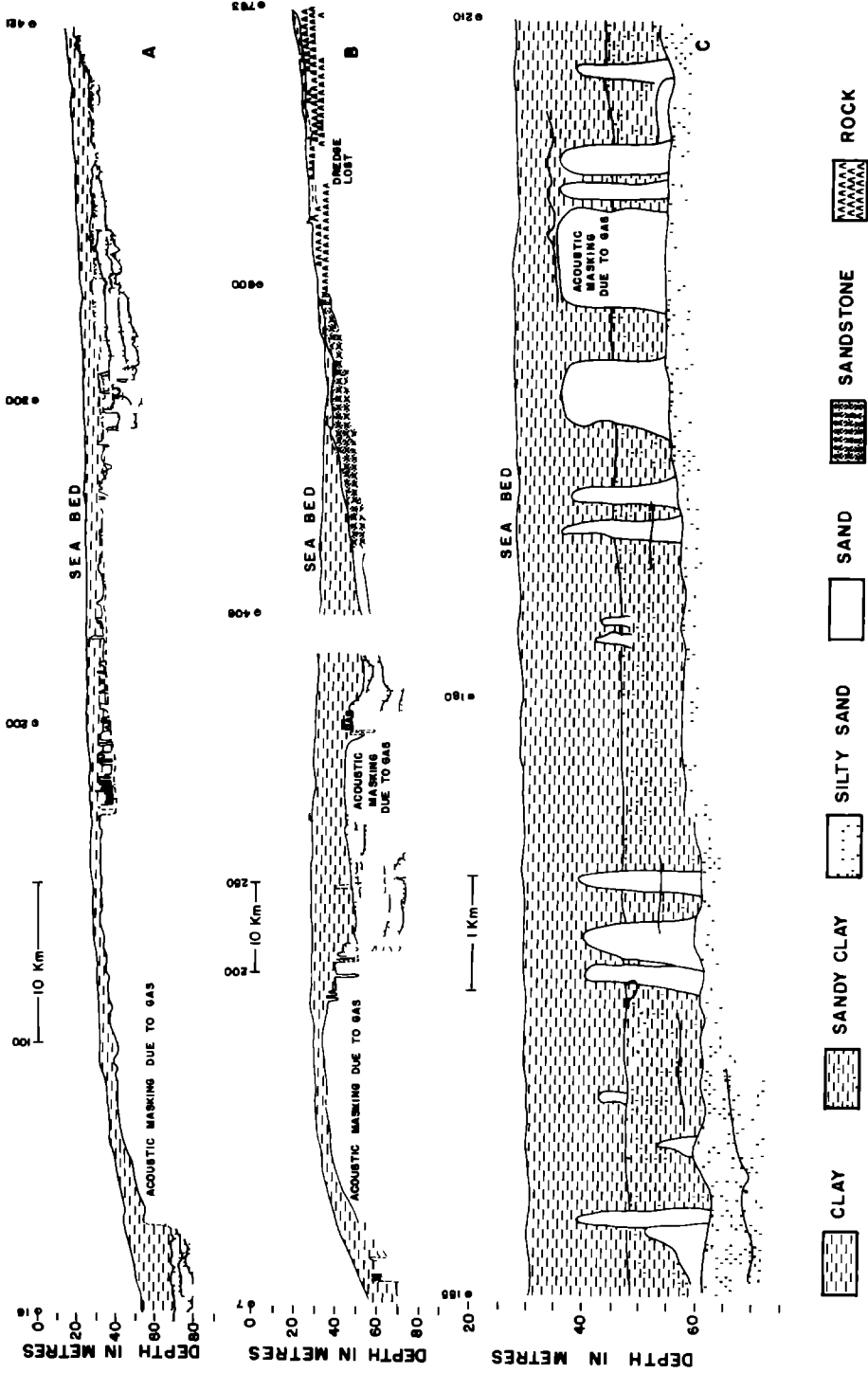


Fig. 4. Interpreted profiles based on echograms and shallow seismic records. A. Profile along Line 49. B. Profile along Lines 36, 42. C. Profile along Line 9 (same as shown in Fig. 3).

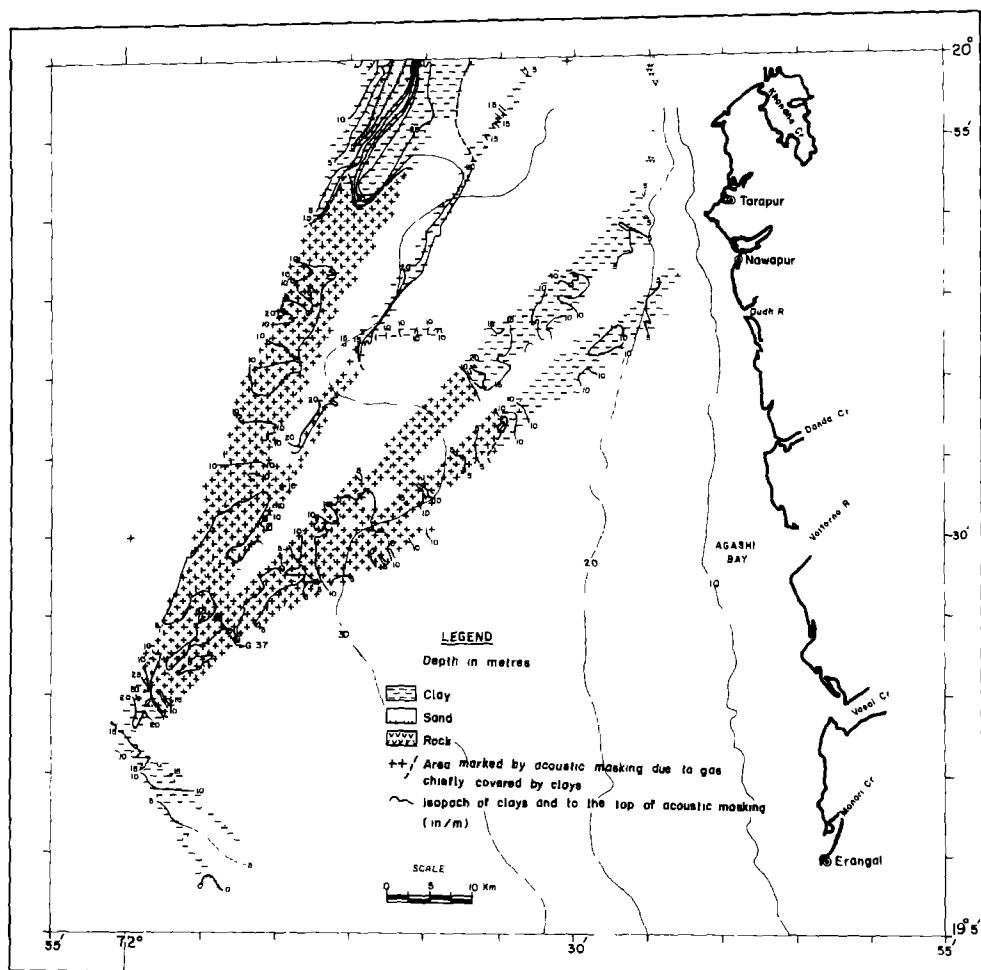


Fig 5. Isopachs of clays and to the top of the acoustic masking on the continental shelf off Bombay.

Chromosorb G for nitrogen, carbon dioxide, carbon monoxide and hydrocarbons.

Column II: 6' × 1/8" stainless steel with Molecular Sieve 5 × 60/80 mesh for hydrogen, argon, oxygen, nitrogen and methane. The sample was injected through an air-tight syringe and sampling loop. The presence of various gases was confirmed in comparison with standards, while quantitative estimates were made for some hydrocarbons of interest. Some gases, such as ethane, propane, and butane, were identified qualitatively in accordance with retention time because of the lack of standards. Other possible gases, such as hydrogen sulphide and organometalloids, could not be confirmed because of the lack of instrumental set up and standards. Though the resolution between argon and oxygen is very poor, the presence of argon was confirmed with the help of

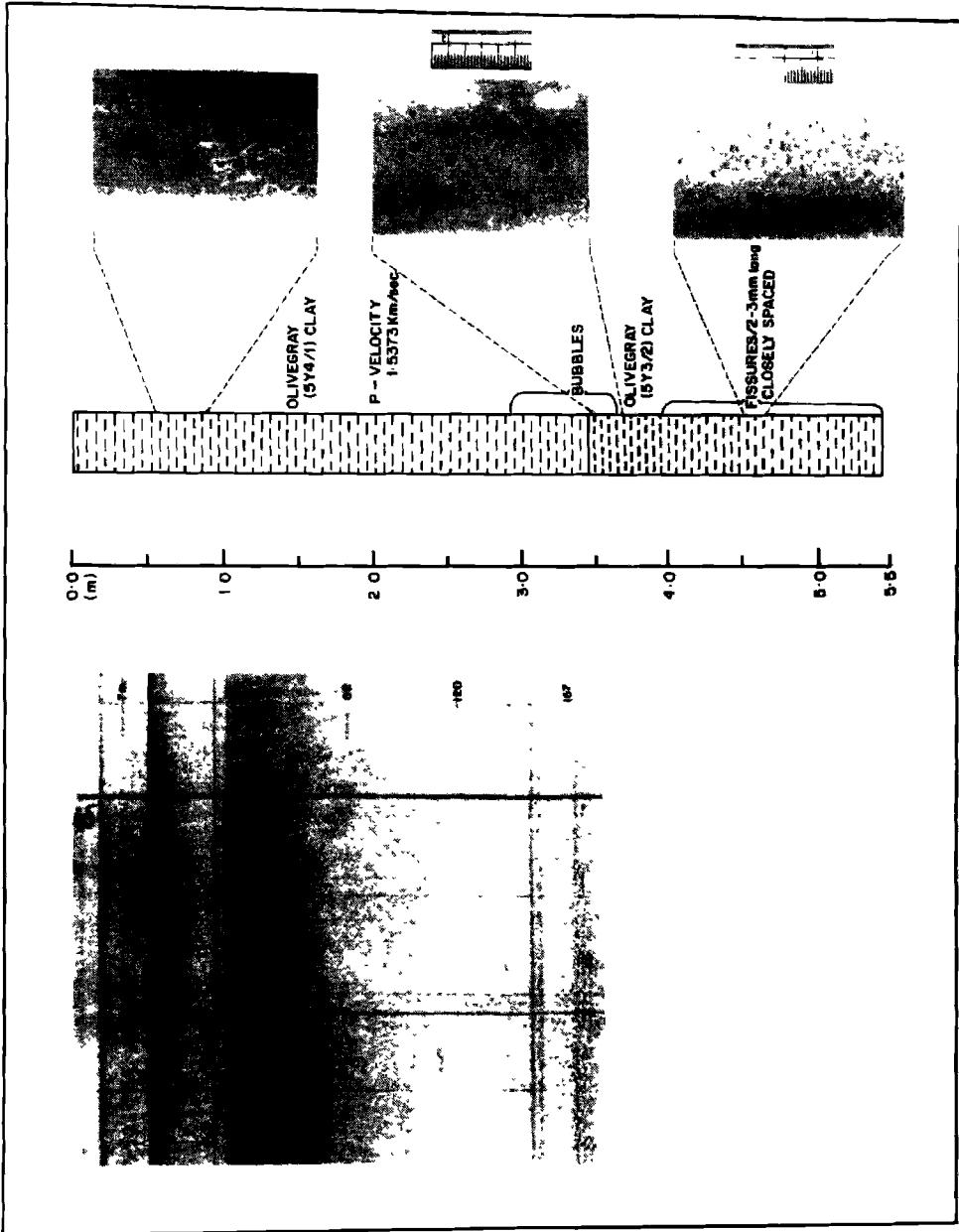


Fig. 6 Lithological log of the core collected from the region of acoustic masking. The seismic record from the region as also photographs of portions of the core are reproduced here for comparison.

pure argon and oxygen. The presence of hydrogen was confirmed even though the carrier gas was helium.

The gas was found to be rich in methane and the following other gases were also detected: nitrogen, argon, oxygen, hydrogen, ethane, propane, i-butane, n-butane, i-pentane, n-pentane, hexane, heptane and aromatics as cyclopentane, methyl cyclopentane, cyclohexane, benzene, etc. The gas was devoid of carbon dioxide and carbon monoxide. The partial analyses for the hydrocarbons is given below:

Methane	11.15%
Pentane	1.1 ppm
Hexane	1.3 ppm
Heptane	0.82 ppm

The partial analyses were carried out under some limitations and no quantitative estimates could be made for ethane.

DISCUSSION

The occurrence of gases in the inner and middle shelf sediments is interesting because in some cases the occurrences, particularly those on the shelf off Bombay lie in a producing oil and gas basin. The shallow depth of occurrence on the inner and middle shelf and the warm waters in these latitudes preclude the possibility of these features being due to gas hydrates. The gas occurs in cores as free gas in bubbles and fissures in clays. According to Kaplan (1974) gases in marine sediments could be from four sources i.e., atmospheric, biogenic degradation of organic matter, diffusing upward by thermocatalytic cracking of more complex hydrocarbons and gas produced by submarine volcanic or geothermal processes. The above possibilities could now be examined with reference to the terrain. The coast between Bombay and Goa is marked by thermal springs and recent seismic activity which may continue to the offshore area also. However, the terrain and predominance of methane in the gas favours two alternatives, viz. bio-degradation of organic matter, or thermocatalytic cracking of more complex compounds. The organic matter in the sediments of the central western continental shelf of India (Paropkari, 1979) ranges from 0.4 to 3.86% (average 1.64%). The concentration of organic matter in the recent sediments is comparatively less and lower than the world average of 2.5% for the nearshore sediments. However, it is possible that even this low content of organic matter because of rapid deposition is degraded to form gas which occurs as bubbles and cavities in clays. The bubbles and fissures occur below 3 m in core G37 and between 7 and 18 m in bore holes. It is evident that the gas is originating at, or just below, this depth by degradation of organic matter or even conduits from greater depths. Its common occurrence between 5 and 10 m depth may be interpreted as the boundary between the sulfate-reducing and the underlying methane horizon. This could also be due to a sudden influx of organic matter rich sediments due to an uplift on land or higher biological productivity followed by rapid deposition dur-

ing an earlier period of sedimentation. The occurrences south of Bombay (off Konkan, Karnataka and Kerala) lie on the inner shelf in the vicinity of estuaries while the one off Bombay lies on the middle shelf. The occurrences south of Bombay in the vicinity of the estuaries and river entrances would have provided the ideal conditions for entrapment of organic matter in sediments. The occurrence on the shelf off Bombay is in an oil and gas basin while those south of Konkan do not have any such association. On the outer shelf off Bombay, i.e., on Bombay High oil field, gaseous hydrocarbons have been reported in Holocene relict sands (Bhattacharya et al., 1974), but the ratio of methane to heavier hydrocarbons is $11:28 \cdot 10^{-2}$. Though no analyses for ethane could be carried out on the present cores (G37), the ratio of methane to other hydrocarbons is high and indicates the gas to be biogenic.

The low ratio of methane to heavier hydrocarbons in the gases of sediments on the outer shelf (Bombay High) and the higher ratio of methane to other hydrocarbons (G37) on the middle shelf to the east indicates that perhaps both petrogenic and biogenic gases are present in the area. A similar situation was reported by Brooks et al. (1974) from the Gulf of Mexico also. In this context, the occurrence of traces of higher hydrocarbons in the gases of G37 is also interesting and may even indicate admixture from two different sources. Perhaps it is also possible that the acoustic masking on the outer shelf off Bombay has a different origin than those on the inner shelf off Bombay, Konkan, Karnataka and Kerala and further detailed studies are required.

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