

bowls, jars, dishes and dish-on-stand besides in Red Ware. Identical pottery has been dated 16th-14th century B.C. at Lothal, Prabhas, Rangpur and Rojdi in Saurashtra. A copper-smith's stone mould used for casting tools like chisel or small spearheads found in the beach is comparable to the stone moulds from Lothal and Mohenjo-daro. Chank-shells (Shanka) worked into bangles, spoons and vessels are found in abundance in the intertidal zone. From the eroded beach a few hundred metres away a sprinkler of the Red Polished Ware, a small terracotta bottle with a loop handle similar to those found in Roman harbours of the 2nd-5th century A.D. have been recovered. The early historic site is situated away from the protohistoric one. Another important ceramic ware found in the intertidal zone of Beyt Dwarka and in the onshore excavation of Dwarka is the Lustrous Red Ware, which is assigned to 15th-14th century B.C. at a number of post-Harappan sites including Prabhasa and Rangpur in Saurashtra and Ahar in Udaipur district of Rajasthan. Having found considerable evidence of a submerged township in the intertidal it was decided to excavate in seabed. The expert Indian divers employed by Dive India used the airlift and loosened the sediment. As the box-like caisson sank in the soft floor, excavation in the floor under the caisson was also undertaken. Sediment was brought up by the airlift and collected in nylon bags of a fine mesh. Besides fragments of pottery two chert blades were also found at 1.5 to 2 m depth below a loose sandy deposit. Probing with iron rods showed some rock in some locations, loose stones in others and hard compact silty deposit in yet other locations. The overburden of sand and silt (1 to 2 m) if removed, further evidence of the submerged remains is likely to come to light. Owing to high density of water and the suspended sediments visibility was very poor. Even so the divers have taken very satisfactory underwater photographs of the seabed strewn

with pottery.

This is the first successful underwater excavation undertaken in India for tracing the archaeological remains buried in the sea. The result is of great historical and cultural significance. It corroborates the Mahabharata and Puranic tradition regarding the construction of a fortified town by Lord Krishna on the ruins of an earlier town. In Shankhodhara (Beyt Dwarka) we have evidence of a settlement, not only of the 15th century B.C. which was submerged by the sea in the 14th century B.C. but also of the Late Harappan period (17th-16th century B.C.) in greater depth seaward of the wave-cut bench. The former may be the remains of Dwarka of Mahabharata fame but more evidence is needed to know the full story of submergence.

Dwarka :

The sounding done during the offshore exploration of Dwarka in April, 1983 indicates the existence in the sea, almost half a kilometre from shore, of a row of boulders resembling a wall on either flank of the entry point (Sangam) of the ancient harbour. It appears that both the mainland Dwarka and Beyt (island) Dwarka were flourishing ports, the former serving as an exist point for overseas trade and the latter as a centre of Chank-shell industry. The dense forest in the island yielded timber necessary for shipbuilding. Both Dwarkas seem to have been submerged in the 14th century B.C.

I am highly indebted to Dr. S. Z. Qasim, Secretary, Department of Ocean Development, Dr. V. V. R. Varadachari, Director, National Institute of Oceanography and Dr. T. S. S. Rao, Head, Biological Oceanography Divisions (NIO) for the encouragement and help given in conducting research and underwater exploration.

With SOSRUTI
5 & 6 June 84

PAPER

SHALLOW SEAFLOOR CHANNEL-AN INDICATOR OF CURRENT SCOURING OFF THAL, MAHARASHTRA

V. Subrahmanyam and G. C. Bhattacharya
National Institute of Oceanography, Dona-Paula,
Goa 403 004.

High resolution acoustic surveys were carried out along a proposed submarine pipeline route for effluent discharge off Thal, Maharashtra by the National Institute of Oceanography, Goa in 1981. The surveys comprised of echosounding, side scanning by sonar and subbottom profiling, followed by seabed sampling for outcrop control. Echograms, sonographs and seismic records were used to prepare seismic sections bathymetric, isopach and shallow subsurface geological maps which in turn were used to evaluate the seabed condition. The surveys indicate that the varying

thickness of overburden composed of softer clay overlies the harder substratum and thickness reaches a maximum of 9 metres towards the offshore end of the line. About 2 km northwest of Underi Island, a shallow channel-like feature was observed on the seafloor which was carpeted by soft clay. The origin of this feature was attributed to the erosion/non deposition due to strong bottom current. It is expected that a seafloor structure (pipe lines etc.) laid across this feature is likely to be affected by scouring. Integrated high resolution acoustic data can be effectively used to identify the areas of this type of hazards.

INTRODUCTION .

EQUIPMENT AND METHOD

The National Institute of Oceanography has carried out high resolution acoustic surveys along the proposed submarine effluent discharge pipeline route off Thal, Maharashtra during January 1981. The survey was carried out on a shallow draught vessel along three parallel lines each of 5 Km length and laterally spaced at 500 metres apart (Fig. 1). The surveys comprised of echosounding.

Position Fixing: The position of the boat was determined by sextant angles of shore objects and plotting of the boat's position on board was done by using a station pointer at regular intervals.

Echosounding: The echosounding was carried out mainly with an Atlas Deso-10 dual frequency (30 KHz

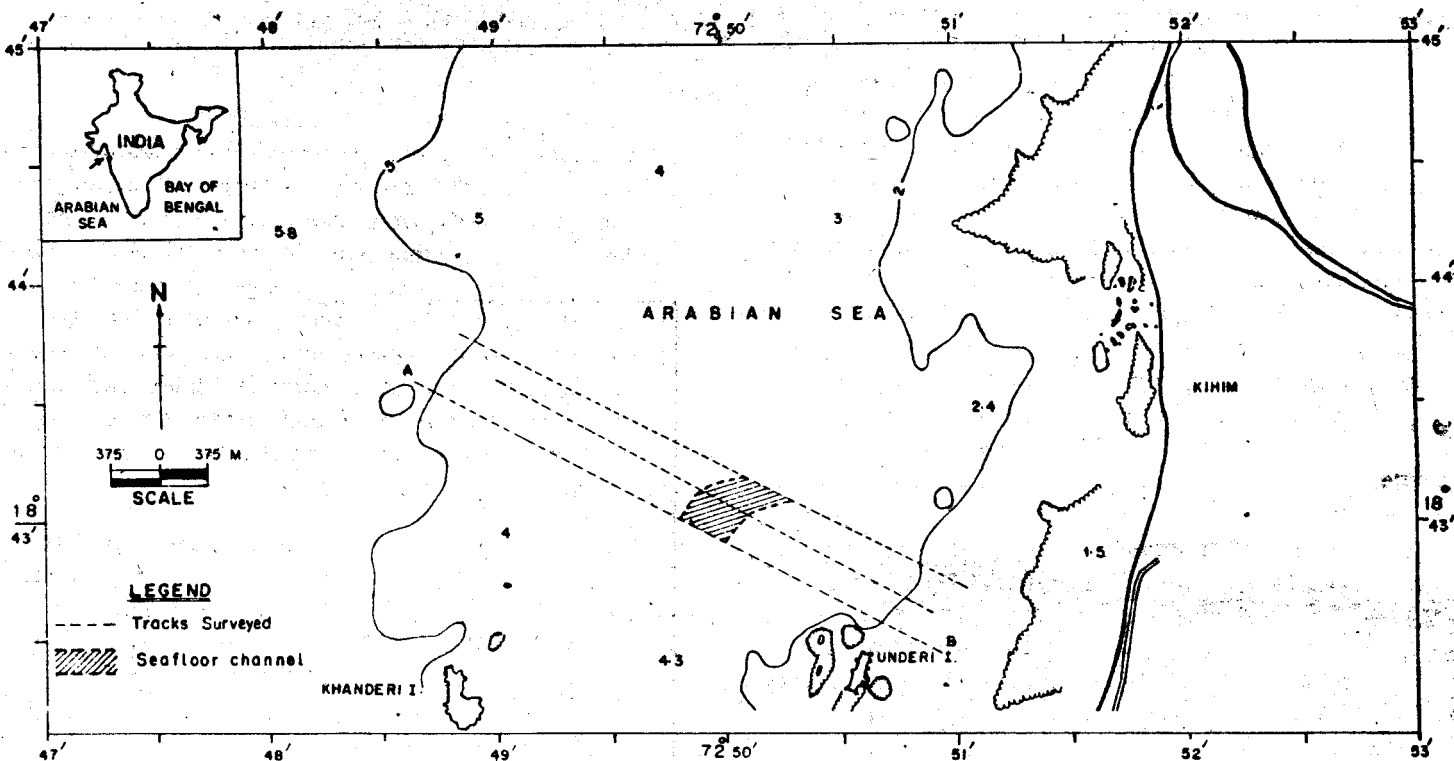


Fig.—1 Map showing the tracks surveyed and the seafloor channel

side scanning by sonar, and subbottom profiling, followed by seabed sampling using piston gravity corer for outcrop control. The primary position control during the survey was obtained using the sextant angles of the shore objects.

One of the most common problems for the submarine pipe lines is its destabilization due to scouring of the sea floor by strong water currents (Brownfield 1973). The purpose of the present paper is to illustrate the use of the high resolution acoustic surveys to locate areas where the offshore structures are likely to be affected by scouring of the seafloor.

and 210 KHz) echosounder. The low frequency (30 KHz) provided subbottom penetration whereas the high frequency (210 KHz) provided a good resolution. The water depths obtained were corrected for tidal variations. In addition to determining the depth, the echograms were also used to classify the seafloor into even, uneven and rugged.

Side Scan Sonar Surveys: An EG & G mark 1B side scan sonar (Model 259-3, 11" wide dual channel recorder and towfish model 272) was used. Because of very shallow depths the fish was towed almost at the surface and it was operated in 125 meters range.

Shallow seismic profiling: An EG & G seismic system was used for continuous seismic profiling. The system consists of transmitter (UNIBOOM Model 234 with acoustic energy 300 joules) source and hydrophone. The reflected signals were recorded on a EPC Model 3200 dry paper graphic recorder. Using the seismic records the thickness of the clay overburden, sub cropping rocks, shallow tectonically-disturbed areas, buried channels etc., were demarcated.

Sampling: Based on the seismic records and sonographs, sites were selected for sampling. The sediment samples were collected using a piston gravity corer.

RESULTS AND OBSERVATIONS

The depths in the survey area range from dries near

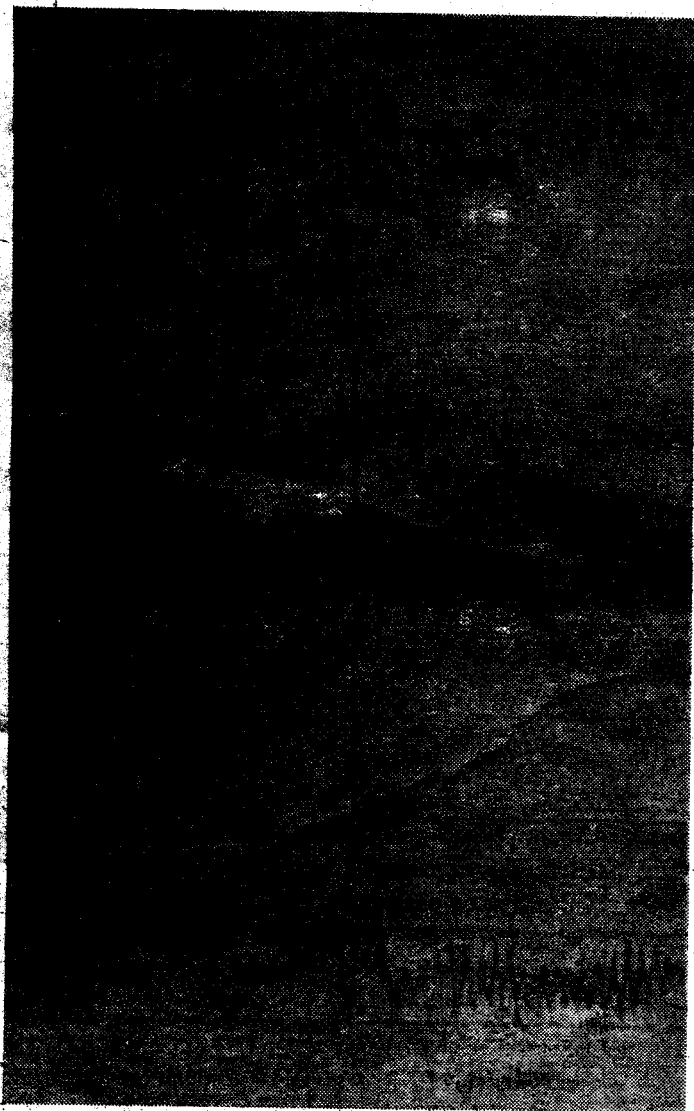


Fig. 2—Echograms showing the edge of the channel in different profiles. Note the gradual decay of the offset towards north,

the shore to about 5.5 m towards the offshore end of the lines. The seabed in the near shore area on the northern and southern lines is marked by uneven topography due to the rock outcrops while on the central line it is marked by even topography and is apparently free from rock outcrops. Further offshore beyond a depth of about 3 m the seabed (excepting some isolated rock outcrops) is covered by acoustically transparent clay. The thickness of overburden ranges from 0 m over the outcrops to more than 9 m towards the offshore end of the survey lines.

A seafloor feature in the form of a shallow channel (350 m wide and 1 m deep) was observed in the area about 2 km northwest of Underi Island (Fig. 1). The channel was found to possess the following characteristics:

(a) The offset in the seafloor reflection from the edges of this channel can be distinctly identified in the echograms (Fig. 2) and it is very abrupt at the western side whereas at the eastern side it is gradual.

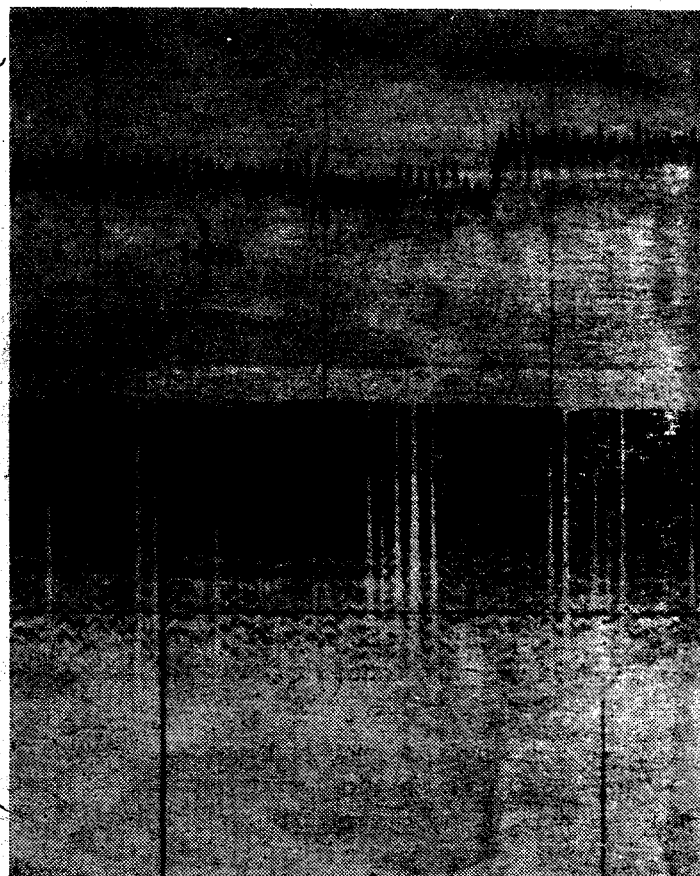


Fig.—3 Echogram and seismic record over the edge of the channel.

(b) The offset which is about 1 m in the southern line gradually pinches towards north.

(c) The channel is traceable in all the three parallel profiles and its trend is NE-SW.

The echogram and the seismic record section across this channel (Fig. 3) do not indicate the presence of any outcrop or sandy deposit in the seafloor, instead it is clearly noticed that this feature is formed on top of an acoustically transparent clay layer (Fig. 4). It may be noted that

fied in the present study is locally continuous and owes its origin to the scouring by the intensified bottom currents.

(2) Any seafloor structure such as a pipe line built across this feature is likely to be affected by the instability of the sea bottom.

(3) The intensification of the bottom currents is due to funneling during its passage between two Islands. Similar situation can be expected to exist near other closely spaced islands or submerged rock out-crops.

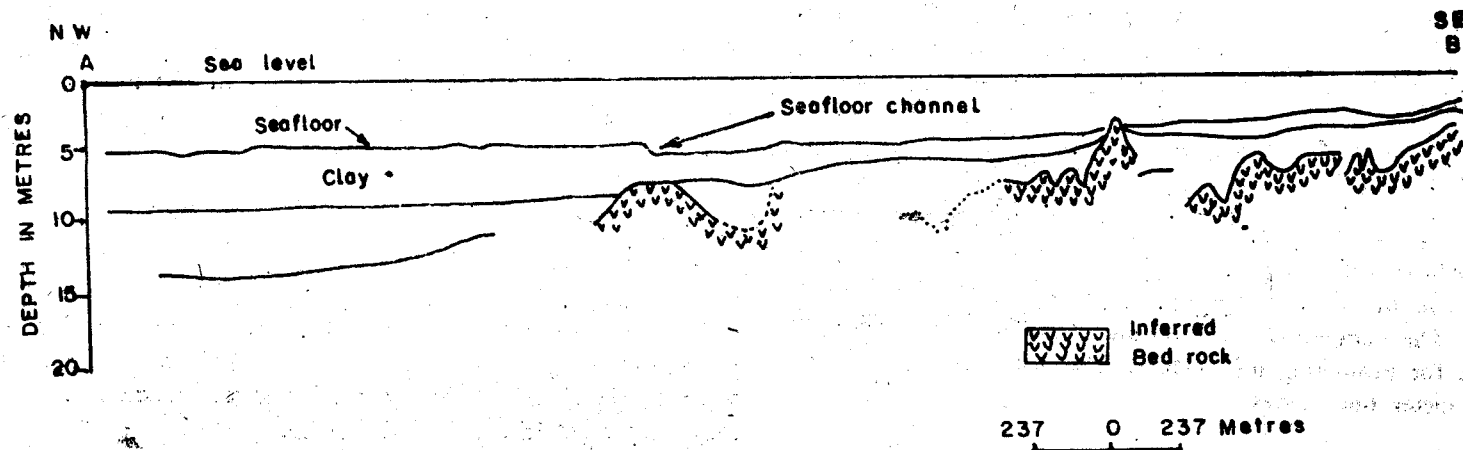


Fig. 4 LINE DRAWING OF THE REPRESENTATIVE SEISMIC SECTION SHOWING THE SEAFLOOR CHANNEL. POSITION IS SHOWN IN FIGURE 1.

under normal circumstances the soft clay which carpets the seafloor in this area cannot sustain a feature like this. The subbottom reflectors below this channel are rather horizontal, which indicate that this channel does not owe its origin to any tectonic disturbance, instead may be representing an erosional/non depositional regime.

Observations of the physical processes in the seas in this area reveals that the currents are mostly tide-induced and there is an appreciable variation in the current speed from surface to bottom. It is also indicated that the longitudinal currents are intensified due to funneling in the vicinity of the two Islands (Swamy, G. N., 1983).

Perhaps this intensified bottom current is in a narrow band and it picks up the fine sediments deposited in the bottom. Between the Islands this phenomena is at its peak and it gradually weakens towards north where the open sea is encountered.

CONCLUSIONS

(1) The shallow seafloor channel-like feature identi-

(4) High resolution acoustic surveys can be used effectively to identify the areas with this type of geological problems.

ACKNOWLEDGEMENTS

The paper is based on the surveys carried out by the Institute for the Rashtriya Chemicals and Fertilizers Ltd., (RCF). The authors are grateful for the financial support received for the surveys.

The authors thank Dr. V. V. R. Varadachari Director, NIO for critically going through the manuscript and for permitting to publish the work and to Shri H. N. Siddiquie, Deputy Director, NIO for his keen interest and valuable suggestions during the work.

REFERENCES

- Brownfield William, G. (1973). Submarine Geologic Problems, ASCE National Transportation Engineering Meeting, July 1973, Tulsa, Oklahoma.
Swamy, G. N. (1983). Coastal circulation off Thal, Bombay (under publication).