I.O.S.

RRS CHARLES DARWIN

CRUISE 20

31 JANUARY – 27 FEBRUARY 1987

GLORIA STUDY OF THE INDUS FAN

CRUISE REPORT NO. 198

1987

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

DEACON LABORATORY

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ABSTRACT

GLORIA long-range sidescan sonar, upgraded to the Mk.3 system, surveyed the middle Indus Fan for 15 days. The GLORIA mosaic was of high quality, apart from masking of the records due to the dense scattering layer which came to the surface at night. Good data was obtained throughout the cruise from the 160 cu. inch air gun, gravimeter, magnetometer, 3.5 kHz high resolution profiler and precision echo sounder.

Evidence for sliding and rotational slumping is seen on the large channel-levee complexes of the upper fan. A distributive system of meandering channels was mapped on the middle fan and the most recently active channel identified. Meandering channels continue to the base of the fan. A GLORIA record across the Carlsberg Ridge and the Murray Ridge was obtained on passage.

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INTRODUCTION

The main aim of this work is to improve the existing models for submarine fans, that are still based largely on studies of ancient rocks, by the investigation of a modern fan.

This cruise is the first of two cruises to study the Indus fan and is part of a joint project between IOS and the Department of Earth Sciences, University College, Swansea. The underway geophysical work described here will be followed by a cruise, currently scheduled for September 1987, that will concentrate on more detailed underway investigations and sampling.

When this project was originally proposed in 1983 there had already been encouraging results from long range side scan sonar surveys with the GLORIA system of parts of the Nile, Amazon, Mississippi, Orinoco and West Saharan fans. During the gestation period of this cruise, GLORIA surveys of a large number of other major fans have been carried out as joint projects between IOS and Elf-Aquitaine (the Rhone fan) and IOS and the United States Geological Survey (the Nitinat, Astoria, Gorda, Delgado, Farallon, Monterey and Arguello fans and several fans in the Aleutian Basin). Work on the Indus fan, especially seismic studies of its upper part, has also been reported in the past few years.

This GLORIA data from fans shows that it is common to find extensive areas of strong acoustic reflectivity beyond the ends of the main fan channels. Relatively high sand contents and/or debris flows are found or suspected beneath such strongly reflective ground and it is proposed that these are the main areas of most recent sandy deposition.

Because of the enormous size of the Indus fan, 1000nm long and 600nm wide, it was only going to be possible to survey about one tenth of the fan in the time available. Thus it was planned to run an initial long swath from the lower to the upper fan in order to determine the best areas on which to concentrate. Hopefully areas of strong reflectivity would be found, perhaps corresponding to areas of higher sand/silt contents shown by Kolla and Coumes (1983/84). The upper fan channels, which have the highest relief, would also be looked at on this reconnaisance swath.

Although much of the fan lies outside the 200 mile limits around Pakistan and India, permission was sought from both countries and visiting scientists and observers were invited from both countries. In the event only Pakistan granted permission and copies of the data from within 200 miles of Pakistan has or will be provided to NIO, Karachi.

Kolla, V and Coumes, F. 1983/84. Morpho-acoustic and sedimentologic characteristics of the Indus Fan. Geo-Marine Letters, 3, 133-140.

NARRATIVE

RRS Charles Darwin underwent a refit in Mombasa. In addition to the RVS personnel who were present for the refit there were four from IOS (B. Barrow, R. Clement, J. Campbell and D. Bishop) whose main task was setting up and testing the GLORIA system. Many of the electronic units had been upgraded to the Mark 3 GLORIA specification.

It was learnt just before sailing that permission had been granted to work in Pakistani waters but denied for Indian waters. The invited Indian scientist. Dr. Veeraya from NIO Goa, was unable to come. The Pakistani observers that were expected from the Ministry of Science and Technology and from the Marine Security Agency also failed to show up.

The ship sailed at 0830 (local time) on 31 January (Day 31) and went to refuel. The pilot came onboard at 1700, and we left Mombasa, proceeding at full speed to the lower Indus fan, with a small detour around Somali waters as we were running the gravimeter and had not requested permission. Being unable to use the direct diesel drive, because of the expense of the greater fuel consumption, and being opposed by a constant headwind, the speed through the water for this long passage to the north east was only about 10 knots.

Gravimeter watches were kept from 600 GMT, Day 31. The magnetomer, 3.5 kHz profiler and PES fishes were launched at 1200 GMT, Day 33 over the Somali Rise. GLORIA was launched at 1030 GMT, Day 34, but recording was not started until 1515 GMT, Day 35 when we were over the Somali Abyssal Plain. Useful data was obtained on passage at full speed (10 knots) over the Carlsberg Ridge. However it was not until Day 39, eight days after sailing, that the foot of the Indus fan was reached.

The hydrophone and a 160 cu.inch air gun were launched at 1200 GMT, Day 39 but continuous profiling did not start until 1730 GMT, as it took some time for the correct pressures to be determined by trial and error.

A single four day crossing of the fan was run from its foot to the limit of Indian waters. This established that highly sinuous channels would probably be found over most of the fan surface. It would take approximately 130 days to map them completely with GLORIA whereas there was only one tenth of that time available. Fortunately it appeared that we had crossed the most recently active major channel and work was concentrated on mapping this supposedly most recent channel system. Tracks were spaced as far apart as possible, to allow for a minimum of overlap. The spacing was about 12 nm at the upper fan and 18 nm on the middle fan. The very dense scattering layers that are seen to be present near the surface at night, caused considerable interference on the GLORIA records. The worst affected area was that nearest to the continental margin but although a strong, diffuse reflection blanketed the records, interpretation of the seabed features was still possible. For this reason, and because the upper fan is relatively well known, only two lines were run inside Pakistani waters.

We left the middle fan after 15 days of survey carried out at a nominal 8 knots (which turned out to be somewhat faster because of an error in the EM log reading). The air gun was brought inboard at 1200 GMT, Day 56 and we proceeded across the north west Indus fan at full speed, crossing the Murray Ridge into the Oman Basin. All other gear was brought inboard at 1230 GMT, Day 57. The ship docked at Mina Qaboos, Muscat at 0930 local time, Day 58.

While in port we welcomed on board a large party of earth scientists from the Petroleum Development Group of the Oman Petroleum Directorate, organised by Dr. M. Hughes Clarke, and a party of physical oceanographers from the University of Kuwait.

EQUIPMENT

GLORIA

As the GLORIA system had not been used before on the RRS Charles Darwin, a ten day installation period in Mombasa preceded the cruise. The fitting of the gantry and Portakabin along with their associated cable runs presented few problems. Similary, the Logging and Replay electronics were set up in one corner of the main laboratory with no complications.

Before shipment to Mombasa, most of the electronic units had been rebuilt to the Mk3 specification, so upgrading the Mk2 to the Mk3 system. This upgrading was extensive. It included replacing the old Resolver Beam steering unit with a digitally controlled system, new Vehicle power supplies/Monitor unit, COSMAC Logging unit, and a completely new Replay system using an IBM controlled Laser Writer. With so many new units and modications, problems were bound to occur. The ten days were used to the full, and by the time we were due to sail most of these problems had been resolved. Only the Beam steering unit had a likely malfunction. To test this, it was necessary to deploy the Vehicle, and run the Port and St'bd transmitters.

On the transit leg to the survey area the ship encountered head winds, and was incapable of speeds in excess of 10 knots. For this reason, and in order to check the Beam steering unit, the Vehicle was deployed earlier than planned and the system put on line. Powering up the Vehicle electronics showed that the heading readings were approximately 120 degrees out. Reversing the compass data lines corrected this error. In port, with the Vehicle on the gantry this had not been so obvious due to the large steel structures close to and influencing the digital magnetic compass. More serious, was the effect the TX pulses had on the compass clock and on the data signals coming up the towcable. This resulted in beam offsets in the Yaw filter of up to 30 degrees. With the "Zero-on-TX" switch in the OFF position this was not a problem as the offset always returned to its true value prior to the TX pulse. However, with the switch in the ON position this was not the case. Investigations showed that the TX gate pulse to the Yaw filter was missing. On the Mk3 this pulse is derived from an opto-coupler in the Gating relay module which does not exist on the non-updated Mk2 version.

Transferring the wiring to a pair of normally open contacts should have solved the problem, but did not. Due to contact bounce at the end of the pulse, the problem persisted. The solution lay in a large fat 470uF smoothing capacitor across the relay contacts.

The next problem to occur, after logging had started routinely, was in the Replay system. It took several days to find the correct intensity law for the Laser writer by trial and error. This law is programmed into two Eproms which have to be re-programmed every time the law is changed. Finally a compromise was reached which coped with strong echoes from the large features of the Carlsberg Ridge and the more subtle features on the Indus Cone. The change in topography did, however, require the neutral density filter in the Laser writer to be changed. Later in the cruise the exposure time of the 35mm film was noted to vary by anthing from 5 to 9 seconds. This was attributed to the Laser output drifting and, although not serious, it was annoying. No cure was found. Several other problems occured with the Laser writer which fortunately did not reduce the quality of the prints.

Owing to a well defined thermocline, perhaps produced by the extremely calm sea conditions, affecting the sound propagation, the range on the records was limited in places to less than 8 nautical miles. This condition prevailed for most of the Indus Cone survey. In some places after dark, the scattering layer coming to the surface was so dense that the records were masked by 'biological noise'. Despite these problems and the varying Laser intensity, the mosaic was of good quality.

In total 4830 nautical miles of track were surveyed at an average speed of 9.24 knots, the mosaic covering an area of 100,000 sq. miles.

D.B.

Magnetics

The Varian magnetometer operated well throughout the cruise with no malfunction. The fish was streamed from the SCAT davit on the starboard quarter. The data was reduced to IGRF85.

High frequency, low amplitude anomalies appeared from the end of Day 50 through into Day 51. The normal sampling and filtering procedure eliminated most of this from the final data and a system check failed to locate their source within the magnetometer. The 'noise' characteristics were not symptomatic of sensor defects.

The GLORIA survey tracks were ideally placed to detail the Maastrichtian-Paleocene seafloor spreading magnetic anomalies in the northern Arabian Sea. These have been mapped to some extent by Karasik et al (1986). Initial analysis of the stacked profiles shows a correlatable set of magnetic anomalies up to anomaly 25 with evidence of fracture zone definition, which will enable the earlier interpretations to be quantified. Anomalies 31-28 are complicated by phases attributable to basement topography and some previous picks are in error through correlation across more widely separated tracks. In particular, the Anahita fracture zone appears to be associated with a small difference in spreading direction to each side.

Karasik, A.M. et al., 1986. Peculiarities in the history of opening of the Arabian Sea from systematic magnetic survey data. Doklady Akad. Nauk. U.S.S.R. 286, 933-938.

P.M.

Gravity

Mombasa gravity tie.

The gravity meter was tied in to the base station located at the AMGECO Repair Dock, Kilindini Harbour.
Base station value = 978022.79 mgal IGSN
Gravity meter q value = 978023.72 mgal
Gravity meter reading = 06344.0 meter units
Ship alongside base station, meter 3M below quay.

The Mina Qaboos gravity tie.

Base station value = 978973.00 mgal

Gravity meter q value = 978975.60 mgal
Gravity meter reading = 07304.1 meter units

Ship meter difference Mombasa - M. Qaboos = 952.13 mgal
Gravity base difference Mombasa - M. Qaboos = 951.88 mgal
This gives a mean drift of 0.007 mgal/day

The gravity meter operated without problems in the excellent weather conditions. Only one cross over comparison was possible given the GLORIA survey requirements and this gave a cross over error of less than 2 mgal for data 2.5 days apart. A preliminary contour chart of the data showed the northern part of the survey area adjacent to the ocean-continent transition beneath the upper fan to have the free air anomaly reflecting the basement topography. This area also coincides with the basement extension of the Laxmi Ridge to the SE. Correlation of acoustic basement topography observed on the SRP was possible between adjacent tracks using the gravity data. This interpretation led to the identification of magnetic anomalies related to basement topography rather than seafloor spreading reversal sequences. In addition an E-W trending acoustic basement high correlated directly with a gravity low over oceanic crust. The oceanic crust had been previously identified as having magnetic anomalies 31-29.

Sonobuoys

Three disposable sonobuoy stations were successfully occupied, all on the lower fan at the southern end of the survey area where bottom topography was minimal. The stations were:

	Day	Start	Position	Depth	End	Position	Depth
SB1	46	1111	15°09.1'N 64°18.2'E	3888	1630	14°57.5'N 64°14.4'E	3912m
SB2	47	0835	16°21.1'N 64°20.7'E	3710m	1000	16'33.3'N 64°23.7'E	3667m
SB3	52	0840	16°42.5'N 63°51.0'E	3707m	1012	16°54.8'N 63°54.7'E	3685m

Seismic Profiling

A 160 cu. inch Bolt airgun was used with a 270m long hydrophone. Firing rate was 10 sec. Filtering was 35 to 120 Hz. The data was recorded on an EPC recorder with a 4 sec. sweep. No problems of any significance occurred and the system operated well at 9 knots in the favourable sea conditions.

The IOS 3.5 kHz and PES fish worked well throughout the cruise.

SCIENTIFIC RESULTS

The long passages into and out of the main survey area provided data from the Carlsberg Ridge, the Murray Ridge and the Somali and Oman Basins.

On the Carlsberg Ridge a ridge parallel spreading fabric was seen, with little evidence for other trends, apart from a presumed fracture zone at 57°25'E. The spreading axis is characterised by a broad zone of very strong reflectivity.

The Murray Ridge, which is a part of the Owen fracture zone, is 1200m high, where we crossed it, with steep walls and a flattish sedimented crustal area. Small canyons and a broad flat slide scar were noted on the landward side of the Oman Basin. The basin floor slopes seaward at a gentle angle and the superficial sediments have well defined continuous sub-bottom reflectors.

The Indus Fan

The upper fan has large channel-levee complexes with channels up to 350m deep. The banks of these channels have scalloped rims that are believed to be due to rotational slumping into the channels. Some sliding also occurs down the levee flanks in a direction away from the channels.

The channel fed by the Indus canyon differs from the others and is believed to be the most recent. The floor of this channel is more strongly reflective and appears to be free of muddy sediment fill. At about 18°N-19°N the height of its levees decreases considerably and smaller channel-levee complexes spread out in a distributive system. Only one of these channels, the deepest, is continuous with the feeder channel. The others appear to be older, having been abandoned by a process of avulsion. It is possible to use superposition, seen on seismic profiles, to work out the relative ages of the small channel-levee complexes.

The uppermost channels are sinuous, as are those at the very bottom of the fan, but all of the rest are meandering. The degree of meandering and the size of the distributive channel-levee complexes is uniform. On the larger channel, terraces and abandoned meanders are seen.

Several kinds of seismic 'facies' are distinguishable on the 3.5 kHz profiles. On the upper fan and to the west of the fan the commonest type are sharply defined parallel horizons traceable over very large distances. In places the beds drape over pre-existing channel-levee topography, in others there is some ponding of sediments. Penetration is relatively deep on 3.5 kHz records and they appear uniformly weakly reflective on GLORIA sonographs.

In the area of the distributive system there are discontinuous horizons that wedge out over relatively short distances. Semi-prolonged echoes are common and penetration on 3.5 kHz records is moderate. On GLORIA sonographs there is medium to strong reflectivity. The main areas of stronger reflectivity are the channel floors and walls and broad areas associated with the levees. Many of the latter have a streaky appearance with the streaks elongated downslope.

Coring, geotechnical measurements and camera work are required to investigate the various features that have been identified from the records.

The airgun data is probably not good enough for a comprehensive seismic facies analysis. However there are seismic sequences extending across the mid fan and high amplitude reflectors that mark the sites of former channels are clearly seen. A basement high beneath the middle fan is probably an extension of the Laxmi Ridge.

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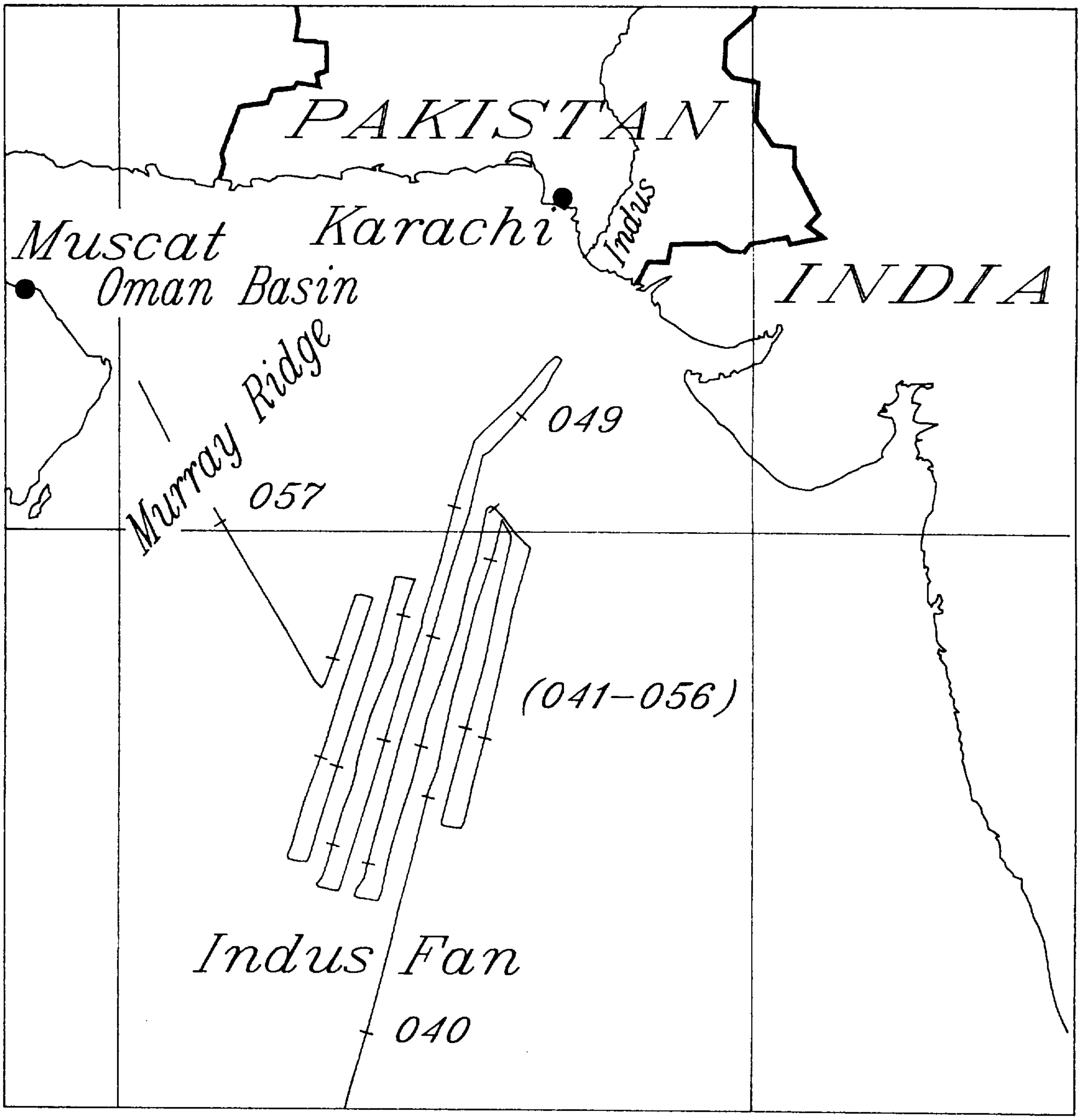

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