CHAPTER II

MARINE GEOPHYSICAL INVESTIGATIONS
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2.1 INTRODUCTION

The National Institute of Oceanography (N.I.O), has launched a major program for the delineation of polymetallic nodule rich areas in the Central Indian Basin in 1982, following the initial success of recovering the nodules during the 86th cruise of R.V. Gaveshani in 1981. For this purpose, besides the Institute's vessels R.V. Gaveshani and ORV Sagar Kanya, four more chartered vessels namely MV Farnella, MV G.A.Raey from U.K., MV Skandi Surveyor from Norway and DSV Nand Rachit from India, were deployed. The exploration program involved the collection of nodule and sediment samples by free fall grabs, coring, dredging, under water photography and the collection of underway data. As a part of the Polymetallic Nodule project the Central Indian Basin between latitudes 10°S and 16°S and 71°E to 80°E longitudes was covered extensively with conventional echosounding, magnetics and in part by gravity surveys.

Integrated analysis of the data acquired under the project, led to the delineation of nodule rich prime area of 300,000 km² and enabled India to claim Pioneer Investor status from PrepCom (Preparatory Commission for the International Seabed Authority & International Tribunal for the Law of the
Sea). In August, 1987 India acquired the Pioneer Investor status and was allocated an area of 150,000 Km$^2$ (Figure 2.1), to carry out Pioneer activities involving detailed investigations.

The second phase of exploration is aimed at more detailed studies. One of the advanced swath bathymetric data acquisition system, Multibeam Sonar System, was used to map the seabed in detail during the second phase of exploration.

For the purpose of present study, bathymetric, magnetic, gravity and multibeam sonar data has been used. The bathymetric and magnetics data were collected during the cruises of *MV Farnella* and *DSV Nand Rachit*. Multibeam sonar, magnetics and gravity data were collected during the expeditions of *ORV Sagar Kanya*.

### 2.2 DETAILS OF THE EQUIPMENT USED FOR DATA ACQUISITION

#### 2.2.1 POSITION FIXING

A dual channel satellite receiver, *MX1107*, was used for achieving position fixing during the surveys on the chartered vessels *MV Farnella* and *DSV Nand Rachit*. On *ORV Sagar Kanya* an Integrated Navigation System (INS) was used for the accurate navigation.
Figure 2.1 The 1,50,000 km² area in the Central Indian Basin, allocated to India for the exploration and exploitation of the Polymetallic Nodule resources, by the PrepCom of the United Nations.
The Magnavox MX1107 satellite navigation system contains a dual channel satellite receiver with a digital processor and an antenna. The system makes use of the satellite signals transmitted from the Navy Navigation Satellite System (NNSS), often known as the Transit Satellites to compute the position of the vessel. The transit satellite system consists of six polar orbiting satellites at an altitude of 600 nautical miles. These satellites transmit very stable 400 and 150 MHz signals which are phase modulated with several types of information. A part of the message from the satellite signal contains the navigation data which precisely describes the position of the satellite as a function of time.

The transit satellites travel roughly at a speed of 4 miles/sec and this motion with respect to an observer on earth causes a Doppler shift in the radiated 400 and 150 MHz signals. This Doppler shift is measured by the satellite receiver to compute the slant range between the observer and the satellite. The slant range data and the satellite position data are used to compute the position of the receiver vessel at that time. Thus accurate position fixing can be achieved only when the satellite passes above the horizon of the user. The availability of satellite fix depends on the latitude of operation and varies between 30 minutes at poles to 110 minutes at the equator. The satellite receiver computes the position of the vessel in between
the satellite passes with the aid of gyro and speed log information. These positions are called as the dead reckoning positions. The accuracy of the position during a satellite fix is about ±50 m RMS and the positional accuracy deteriorates during dead reckoning process.

### ii Integrated Navigation System (INS)

The research vessel *ORV Sagar Kanya* is equipped with Magnavox series 5000 Integrated Navigation System (INS). The INS integrates the data from several navigational aids such as MX1107 satellite receiver, the Global Positioning System (GPS) receiver, Omega etc., to achieve most accurate position of the vessel. A schematic network of the INS is shown in Figure 2.2. Prior to the installation of Global Positioning System (GPS) receiver, the basic reference for the INS was the transit satellites. *Hewlett Packard* HP2117F computer serves as the processing control of the system. It accepts data from various navigational aids and control the devices attached to it and communicates with the operator. The system software provides optimal position information and also logs the underway data at user specified intervals on magnetic tape.

### iii The Global Positioning System (GPS)

The basic system of *Global Positioning System* consists of satellite signal receiver *MX4400* with a microprocessor and an antenna. The system
Figure 2.2 Schematic diagram showing the configuration of the Integrated Navigation System (INS), onboard ORV Sagar Kanya.
is based on a set of satellites called \textit{NAVSTAR} (Navigation System with Time and Ranging), satellites. These satellites orbit the earth at an altitude of about 10,900 nautical miles with an orbital period of 12 hours. This system is based on 18 satellites in six orbital planes. These orbits are configured to make a constellation covering the earth in such a way, that at least four satellites are in line of sight from any point at any given time.

Determining position involves recovery of time of arrival (TOA) measurement on satellite signal and the use of satellite ephemerides to compute the position of the satellite being tracked. Navigation is accomplished by using Kalman filter, a software based navigation model stored in receiver processor. It provides continuous navigation solutions based on TOA and Doppler measurements. The satellite derived position has an accuracy of 15 meters RMS. The dead-reckoning process may not be required as the GPS is aimed at giving 24 hours coverage. However, the \textit{MX4400} satellite receiver has the capability of providing dead-reckoning positions from the speed and heading information of the vessel.

2.2.2 ECHOSOUNDING

The echosounder consists of a transceiver, control electronics and a graphic recorder. The system continuously transmits acoustic pulses and receives the reflected signal from the seabed. The time elapsed between the transmission and reception of the acoustic pulse is measured. The elapsed
time is converted into depth considering the velocity of sound (1500 m/sec) in sea water.

The following echosounders were used for the collection of bathymetric data. On ORV Sagar Kanya, the Honeywell-Elac narrow beam echosounder (NBS) system which can operate at frequencies 12 kHz, 20 kHz and 30 kHz was used. The system was operated at 12 kHz frequency. On the chartered vessels MV Farnella and DSV Nand Rachit, Raytheon echosounder with precision depth recorder was used at 12 kHz frequency.

2.2.3 PROTON PRECESSION MARINE MAGNETOMETER

Marine proton precession magnetometer model G801/3, manufactured by EG&G Geometrics, was used for the acquisition of total magnetic intensity data. The system consists of a sensor, cable, control electronics cabinet and a recorder (Figure 2.3).

The principle of proton precession magnetometer is based on the fundamental properties of atomic nucleus and the phenomenon of Larmour precession. The protons (hydrogen nuclei) have a spin which makes each nucleus equivalent to a tiny magnet. Under the normal conditions the spin axes are randomly oriented and their individual fields cancel each others. When a polarizing field is applied perpendicular to the earth's field, the spin axes of the protons get aligned in the direction of the polarizing field. When
Figure 2.3 Photograph showing the Geometrics G 801/3 proton precession marine magnetometer. The bottom part of the figure illustrates the schematics of various modules of the system.
the external polarizing field is removed, the spinning nuclei behave like tiny tops and precess towards earths field at a frequency, that is proportional to the magnitude of the ambient field.

The frequency of precession $F$ is given as:

$$F = \frac{\gamma}{2\pi} \cdot T$$

Where,

- $T$ is the total field of the Earth
- $\gamma$ is the gyromagnetic ratio, given as 0.267513 gamma $^{-1}$ sec$^{-1}$
- The total magnetic field of the earth in gammas = 23.4874 $F$

In modern proton precession magnetometers this frequency ($F$) is measured with high accuracy and displayed. A schematic diagram showing the working principle of magnetometer is illustrated in Figure 2.3.

During the data acquisition the sensor is towed behind the ship and the measurements are made continuously. The sensor was towed at a distance of three times the ship's length in order to avoid the magnetic noise generated by the ship.
2.2.4 THE MARINE GRAVIMETER

The marine gravimeter KSS-30 manufactured by the Bodenseewerk of Germany was used for the acquisition of gravity data. This system consists of three major subsystems, the gravity sensor subsystem GSS 30, the stabilization subsystem KT 30 and the data handling subsystem ZE 30.

The sensor consists of a tubular shaped mass attached to a zero length spring guided by five ligaments in a friction less manner and the motion of the sensor mass is limited to one degree of freedom in vertical direction. The tubular mass forms the moving plate of a capacitive transducer (Figure 2.4). Any change in the gravity varies the capacitance and is balanced by passing equivalent current through an electromagnetic system which brings back the spring mass to the original position. The current required for the electromagnetic system is a measure of change in gravity. The sensor is mounted on gyrostabilized platform in order to compensate for the roll and pitch motions of the vessel. The platform is controlled by stabilization subsystem and the stabilization is achieved with the aid of vertical gyros and the two accelerometers mounted in the pitch and roll axes.

The data handling subsystem ZE 30 represents the command and control part of the total system. The ZE 30 microprocessor acts as the control unit and monitors the logic of the sensor stabilization platform, performs signal processing, logging of the data and error handling of the system. The
Figure 2.4 Photograph showing the Bodenseewerk KSS 30 marine gravimeter and the sensor mounted on gyrostabilized platform. The bottom part of the figure shows the principal elements within the sensor.
control electronics cage the sensor automatically in case of failure to any sub
system or in case of ship exceeds the tolerable limits of rolling and pitching.
The ZE 30 is interfaced with navigation computer and receives various data,
in order to perform gyro erection, turn manoeuvre compensation and on-line
processing to make Eotvos, Free-air and Bouguer corrections.

The accuracy of the system is about 0.02 mgals which is the minimum
change in gravity that can be detected. However, the effective accuracy,
which depends on the accuracy of navigation and sea conditions is about 0.8
to 1.0 mgals.

During data acquisition, at the start of the cruise, the gravimeter is
calibrated to check the performance of the system and the gravity reading at
harbour is taken while the ship is at the berth and the absolute gravity at that
place is noted. The harbour gravity reading and absolute gravity values are
entered into the system. The absolute gravity values at Marmugao harbour
were established by tying to the nearest network of known gravity
bases (Subbaraju and Sreekrishna, 1989).

2.3 MULTIBEAM SONAR INVESTIGATIONS

The extensive use of echosounders on research vessels during years
following World War II have contributed immensely towards the general
understanding of the bottom topography of the world oceans and resulted in
the compilation of regional bathymetric maps (Heezen and Tharp, 1965; Udintsev, 1975; GEBCO, 1983). These maps played an important role in the development and acceptance of the ideas of seafloor spreading and plate tectonics in the mid and late 1960’s. Once the first order features were delineated, the attention of the researchers shifted to the more detailed mapping of the seafloor with an objective of investigating the volcanic, tectonic and sedimentological processes of the ocean basins.

The need for much higher resolution bathymetric maps and new techniques for rapidly covering large areas led to the development of new instruments like Seabeam, Sea MARC I and II during late 1970’s. The Sea MARC I and II are medium range (6 km swath) and long range (10 km swath) side looking sonars which can operate at moderate towing speeds and can provide images of large areas.

The Seabeam system, introduced in 1977 was the first multibeam bathymetric equipment which operates at 12 kHz and provides real time contour maps of the seafloor. This system makes use of 16 pre-formed beams and provides a swath coverage of 73% of the water depth. During 1986, a new and more efficient multibeam bathymetric system was introduced by the Krupp Atlas Electronic of Germany by the name Hydrosweep (cf. Gutberlet and Shanke, 1989; Grant and Schreiber, 1990). The major advantage of this system is that it provides a swath coverage of twice the depth of operation by making use of 59 pre-formed beams and
incorporates cross fan calibration method for the compensation of variation of sound velocity in the sea water.

2.3.1 THE HYDROSWEEP SYSTEM

The *Hydrosweep* multibeam sonar system was acquired by the Government of India and was installed on the vessel *ORV Sagar Kanya*, during 1990. The system consists of hydroacoustic transducer arrays, the transmission/reception electronics cabinets, an EPR 1300 process computer, two magnetic tape drives, a control and display console and a printer/plotter (Figure 2.5). The system receives position information from navigation computer (INS), heading information from Gyro, roll, pitch and heave information from Heave platform. The operational frequency of the system is 15.5 kHz, a swath is surveyed for each sounding, covering an area of twice the depth of operation ensuring 59 depth samples, resulting from one center beam and 29 beams on both port and starboard sides of the vessel.

The transducer assembly consists of two transducer arrays composed of several individual elements. These arrays are mounted flush to the bottom of the vessel in a T-shaped configuration. The array which acts as the transmission array during the survey mode is installed parallel to the longitudinal axis of the vessel and the reception array is perpendicular to this axis. The functions of the transmission and reception arrays are interchanged during the calibration mode by means of change over switches.
Figure 2.5 Schematic diagram showing various modules of the *Hydrosweep* system.
The preamplified transducer signals are passed through TVC (time varied gain control) amplifiers and fed to the beamformer. In the beamformer 59 pre-formed beams (PFB's) are generated by phased addition of the signals, taking into account the roll and pitch angles and sound velocity dependent corrections. The PFB's are filtered with a band width in accordance with the measuring range and these signals are passed to the echo logic unit. In this part several processors run while the echo evaluation process is active. These include the bottom detection by using echo processing, computation of digital depth to each of the 59 PFB's and assignment of positions to the depth data.

One distinctive feature of the Hydrosweep system is the provision to correct the errors resulting from sound velocity variations during the data acquisition without interrupting the survey. In the conventional echosounders a constant value of sound velocity (1500 m/sec) is used to compute the measured depth. The sound velocity varies in the water column and affects the travel time of the acoustic pulse, resulting in errors in the measured depth. This problem is accentuated in multibeam echosounders as the outer beams deviate from their actual angle of transmission/reception. Sound velocity information is required to correct for these effects. In some of the multibeam echosounders this information is provided by separately measuring the sound velocity in the region of survey at regular intervals. This procedure is time consuming and expensive. The Hydrosweep system uses a patented calibration process to estimate the sound velocity. During the
survey mode the center beam depths are stored in the system memory. The system at regular intervals (for every 1000m distance traversed) enters into calibration mode; during which the transmission and reception arrays are inter-changed, resulting in a swath along the longitudinal axis (Figure 2.6). The depth values obtained along the longitudinal axis are compared with the stored center beam values collected during survey mode. A correction factor is applied to produce best fit result and an estimate of the average sound velocity is obtained. This sound velocity value is used by the system to compute the water depth till next calibration is performed.

The system's process control computer EPR 1300 continuously monitors the performance of the system besides communicating with the user through the consol/display unit and providing data to various output devices. The depth data from all the 59 beams along with the position and related information is recorded on magnetic tapes for the purpose of post processing. A real time contour map is generated by the system and is plotted on the printer as isobath lines and displayed on the console as a colour coded bottom map.

2.4 LAYOUT OF THE CRUISE TRACKS

Earlier studies in the Central Indian Basin by McKenzie and Sclater (1971) and Fisher and Sclater (1974), have indicated near east-west trending magnetic lineations. As the magnetic anomalies are best reflected when
Figure 2.6 Swath coverage during the survey and calibration modes. The principle of calibration illustrated.
surveyed perpendicular to the lineation pattern, a set of 15 profiles in the north-south direction were planned between latitudes 10°S and 16°S and longitudes 70°E and 80°E. Bathymetric and magnetic data were collected along these tracks which are spaced at 30 miles (Figure 2.7). This set of 15 profiles consisted of about 8494 line kms (lkms) of total magnetic intensity and bathymetric data.

A part of the study area encompassing the 79°E fracture zone was selected for detailed studies using multibeam sonar surveys by the Hydrosweep system. The area selected is between 10°15'S, 14°45'S latitudes and 78°E to 79°20'E longitudes. The Hydrosweep cruise tracks are planned to ensure 100% coverage of the seabed. Accordingly north-south tracks were planned with a spacing of 5 miles (9.2 Km) (Figure 2.8). As the average depth is about 5000 m in the region, this track spacing has resulted in 100% coverage of the seabed with considerable overlap, between the swath coverages of the individual tracks (Figure 2.9). With this layout a total number of 16 profiles were covered along which multibeam bathymetric and gravity data were collected. These surveys resulted in 8000 lkms of Hydrosweep data and 4100 lkms of gravity data. The total area insonified by these investigations is about 73000 Km².

In total about 8494 lkms of magnetics and bathymetric data, 4100 lkms of gravity data and 73000 Km² of multibeam bathymetric data comprised the data set for the present investigations.
Figure 2.7  Cruise tracks are shown with dotted lines along which total magnetic intensity and bathymetric data were collected. The hatched box shows the area covered by multibeam sonar investigations. The 3000, 4000 and 5000 m bathymetric contours are from the Hydrographic chart.
Figure 2.8  The cruise tracks at 5 mile interval along which multibeam bathymetric and gravity data were collected.
Figure 2.9 Swath coverage map. The swath coverage along the survey tracks is indicated by horizontal line segments.