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(Part- I)

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STATE REVIEWS
(Offshore Regions)

(ADVANCE RELEASE)

GOVERNMENT OF INDIA
MINISTRY OF MINES
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OFFSHORE REGIONS

The Government of India notified the Offshore Areas Minerals (Development & Regulation) Act, 2002 (OAMDR Act), No. 17 of 2003 in the Gazette of India, Extraordinary, Part-II, Section-1, dated 31.1.2003. The purpose of the Act is to provide for development and regulation of mineral resources in the territorial waters, continental shelf, exclusive economic zone and other maritime zones of India and to provide for matters connected therewith or incidental thereto. The Act is applicable to all minerals in offshore areas including minerals prescribed under Atomic Energy Act, 1962, but excludes oils and related hydrocarbons as there is separate legislation in force. The Act came into effect from 15.1.2010 vide S.O. 338 (E), dated 11.2.2010 as notified by the Central Government.

The Act makes it mandatory to undertake reconnaissance, exploration or production operation in the offshore areas in accordance with the prescribed terms and conditions for Reconnaissance Permit (RP), Exploration Licence (EL) or Production Lease (PL) granted under the Act and the rules made thereunder. The Act further states that availability of the areas for grant of RP, EL or PL shall be notified within six months from the commencement of the Act, and subsequently at such times as considered necessary. The Act empowers the Central Government to make rules for the purpose of the Act including terms and conditions under the RP, EL, PL, etc. The Rules, namely, the Offshore Areas Mineral Concession Rules, 2006 have been framed and notified on 3.11.2006 by G.S.R.691(E) published in the Gazette of India, Extraordinary, Part II, Section 3 (i), No. 539, dated 4.11.2006. The Rules came into effect on the date on which the Offshore Areas Mineral (Development and Regulation) Act, 2002 came into force, i.e, 15.1.2010.

As per S.O.1341(E) dated 7.6.2010, the Controller General, Indian Bureau of Mines had notified the mineral-bearing offshore blocks available for grant of Exploration Licence. As per the attached Schedule to the said Notification, there were 26 offshore areas available in offshore waters of Bay of Bengal and 37 offshore areas in the offshore waters of Arabian Sea for grant of Exploration Licence.

The orders for grant of exploration licences were issued by the Administering Authority on 05.04.2011 for the 62 exploration blocks (the bounding latitude and longitude of Block Nos. 3 & 32 falling in the Arabian Sea were same and therefore these were considered as a single block and granted as Block No. 3). Before execution of deed granting such licence, the grant of exploration licences in 62 blocks was challenged through the writ petition in the judicature of various High Courts. Due to interim orders passed by various Hon'ble High Courts on the writ petition and non-disposal of the said petition, the offshore exploration licences granted have not been executed. Besides, it was brought to the notice of the Administering Authority that some of the exploration blocks notified for grant of offshore exploration licences vide Notification dated 07.06.2010 overlapped with areas other than offshore area, to which the OAMDR Act did not apply.

The Central Government vide S.O.19 (E) dated 06.01.2011, published in the Official Gazette, declared the extent of the Coastal Regulation Zone (CRZ) and also imposed certain restrictions on the setting up and expansion of industries, operations or processes and the like in the CRZ. The said statutory order also did state that CRZ shall apply to the water and the bed area between the Low Tide Line to the territorial water limit (12 Nm) in case of seas and has prohibited in the area so identified as CRZ, inter alia, the mining of sand, rocks and other sub-strata materials except those rare minerals not available outside the CRZ area. In the context of the said notification, all the 62 offshore blocks lie within the area identified as CRZ which attracts the prohibition of mining (operation undertaken for the purpose of winning any mineral).

The OAMDR Act provides that the holder of an exploration licence for offshore area shall have the exclusive right to a production lease for winning of a mineral. In view of the effect of the CRZ Notification dated 06.01.2011, the purpose of executing the 62 offshore exploration licences could not be realised as the applicants could not undertake operations for winning of minerals in spite of grant of Production Lease after successful completion of exploration operations.

Therefore, taking into consideration all the above stated facts, the Controller General, IBM and administering authority Offshore Areas Minerals (Development & Regulation) vide S.O.19 (E) dated 6th January, 2011, published in the Official Gazette, annulled the Notification issued vide S.O.1341(E) dated 7th June 2010 with effect that all subsequent actions undertaken for grant of the 62 exploration licences hereby would stand rescinded.

As per S.O. 1523(E) dated 06.04.2018, the Additional Director General, National Mission Head-II, Geological Survey of India, has been notified as the "Administering Authority" for the purpose of the said Act by Clause (a) of Section (4) of the Offshore Area Mineral Development and Regulation Act, 2002 ,17 of 2003 and in supersession of the notification published in Gazette of India, Extraordinary Part II, Section 3, Sub-section (ii) vide S.O. 339(E) dated 11th February 2010.

The Government of India further signed 360 contracts under NELP (New Exploration and Licensing Policy) regime with National Oil Companies and Private (both Indian and foreign)/ Joint Venture companies. At present, 186 contracts are operational out of the total 541contracts [(360 NELP, 110 (OALP), 71 (DSF Round) signed so far under various bidding rounds.

The awarded 254 blocks under NELP regime are at locations in inland (114), offshore shallow water (59) and deepwater (81) areas. As a result of exploratory activities, several unexplored and poorly explored areas, in particular, offshore and deepwater areas, have been appraised through geophysical surveys and exploratory drilling. Details of exploration block awarded/ relinquished/operational are provided in Table -1.

In order to explore and produce new sources of natural gas from coal-bearing areas, the Government had formulated a CBM Policy in 1997, wherein CBM being Natural Gas is explored and exploited under the provisions of OIL Fields (Regulation & Development) Act, 1948 (ORD Act 1948) and Petroleum & Natural Gas Rules, 1959 (P&NG Rules 1959) administered by Ministry of Petroleum & Natural Gas (MOP&NG). CBM policy was aimed to provide attractive fiscal and contractual framework for exploration and production of CBM which is an environment-friendly clean gas fuel similar to conventional natural gas. In order to harness CBM (Coal-bed Methane) potential in the country, CBM blocks were offered through international competitive bidding for exploration and production for the first time in the year 2001. Under the CBM policy, till date, four rounds of CBM bidding have been implemented by MoP&NG, resulting in award of 33 CBM blocks [including 2 blocks on Nomination and 1 block through Foreign Investment Promotion Board (FIPB) route]. Till date, most CBM exploration and production activities in India are pursued by domestic Indian companies. These CBM blocks are in the States of Andhra Pradesh, Assam, Chhattisgarh, Gujarat, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu and West Bengal.

Table - 1: Details of Exploration Block Awarded (as on 01.04.2021)

Round	No. of blocks awarded	No. of blocks relinquished	No. of blocks active	Present area (sq. km)
NELP-I	24	21	3	231527
NELP-II	23	22	1	267883
NELP-III	23	19	4	204596
NELP-IV	20	17	3	192810
NELP-V	20	16	4	115180
NELP-VI	52	46	6	306426
NELP-VII	41	35	6	112947
NELP-VIII	32	29	3	52573
NELP-IX	19	12	7	26441
Total	**254**	**217**	**37**	**1510383**
OALP-I	55	4	51	59283
OALP-II	14	-	13	29233
OALP-III	18	3	13	29765
OAPL-IV	7	-	7	18510
OAPL-V	11	7	11	19789
OAPL-VI	21	-	-	35346
OAPL-VII	8	-	-	15766
Total OALP	**134**	**7**	**95**	**207692**
DSF-I	30	11	19	777
DSF-II	24	5	19	3000
Total DSF	**54**	**16**	**38**	**3777**

***Source**:IPNG Statistics 2021-22, Minstry of petroleum and Natural Gas.*

RESERVES/RESOURCES

As on 1.4.2022, balance recoverable reserves of crude oil were estimated at 651.8 million tonnes, out of which 255.8 million tonnes (39.2%) are in onshore and 396 million tonnes (60.8%) in offshore areas. ONGC (nomination) contributed with the largest share of 63.5% in reserves of crude oil followed by Pvt' JVs in production sharing contract (PSC)/Revenue sharing contract (RSC)regime(26.01%) and oil (nommination)(10.4%).

The balance recoverable reserves of natural gas as on 01.04.2022 were placed at 1138.7 billion cu. m, out of which 606.3 billion cu. m (53.2%) are in offshore and 532.3 billion cu. m (46.8%) in onshore areas. ONGC(Nomination) contributed with the largest share

of 49.2% in natural gas reserves followed by PSC/RSC/ CBM regime and OIL (nomination) at 39.9% and 10.9%, respectively.

Table – 2: Balance Recoverable Reserves of Crude Oil & Natural Gas in India including Offshore Areas (As on 1.4.2022)

(Crude oil in million tonnes; Natural gas in billion cu. m)

Area	Crude oil*	Natural gas*
India	**651.8**	**1138.7**
Onshore	**396.1**	**532.4**
Offshore	**255.8**	**606.3**
Western offshore	216.6	337.3
Eastern offshore	39.2	269

Source: *Indian Petroleum and Natural Gas Statistics, 2021-22, Ministry of Petroleum and Natural Gas, Govt. of India.*

Note: ** Proved and indicated balance recoverable reserves. In case of Natural Gas, reserves includes Coal -bed Methane.*

EXPLORATION ACTIVITIES

Conventional Hydrocarbon

ONGC, GSI and other Public & Private Sector companies continued their efforts in respect of exploration for hydrocarbon in offshore region, both shallow and deep water, during 2021-22.

Private Companies/Joint Ventures

In FY 2021-22, about 7,780.5 LKM 2D seismic data was acquired. However, majority of the 2D Data acquisition was carried out under RSC regime (in OALP Blocks) which was approximately 7,481 LKM.

3D seismic data acquired in FY 2021-22 was 6,575.7 SKM out of which approximately 4,659 SKM data was acquired by NOCs/JVs/Pvt. companies under OALP. This year, 86% of 2D seismic and 50% of 3D Seismic data acquisition has been carried out in the onshore basins.

In addition, 101 exploratory wells (including Onland and offshore) amounting to a drilling meterage of 279,867 m has been drilled too during the FY 2021-22 in Table-3.

Table – 3: Exploratory Efforts in Nomination, PSC and RSC Regime during 2021-22

Subject	Parameter	ONGC (Nomination)	OIL (Nomination)	PSC (Pre-NELP & NELP)	RSC (OALP& DSF)	Total
2D Seismic Data acquired	Onland (GLKM)	287.8	0.0	11.5	6,420.3	6719.5
	Offshore (GLKM)	0.0	0.0	0.0	1,061.0	1,061.0
Total 2D Seismic		287.8	0.0	11.5	7,481.3	7,780.5
3D Seismic Data acquired	Onland (SKM)	492.2	219.0	568.3	2,007.7	3287.2
	Offshore (SKM)	636.9	0.0	0.0	2,651.6	3288.5
Total 3D Seismic		1,129.1	219.0	568.3	4,659.3	6,575.7
Exploratory well drilled	Onland	46	7	11	12	76
	Offshore	25	0	0	0	25
Total Exploratory wells		71	7	11	12	101
Exploratory Meterage drilled	Onland (1000 m)	119,112	30.238	27.037	35,637	212,024
	Offshore (1000 m)	67.843	0	0	0	67.843
Total Exploratory Meterage drilled	(1000 m)	186,995	30,238	27,037	35,637	279,867

Source: *India's Hydrocarbon Outlook, 2020-21, Directorate General of Hydrocarbons*

Marine and Costal Survey

Geological Survey of India

The Annual Programme for FS 2021 – 2022(April 2021 – March, 2022) of Marine &Coastal Survey (MCS) Division under the Mission-IA (Baseline Geoscience Data Generation) of Geological Survey of India included multidisciplinary offshore survey and exploration within the Exclusive Economic Zone (EEZ) of India including Territorial Waters (TW) and International Waters.

Economic placer minerals resources have been delineated besides identifying encouraging occurrence of vanadium rich magnetite placers, phosphate bearing sediments,occurrence of metalliferous mud and Fe-Mn crusts /Nodules within the EEZ of India.

In view of the geoscientific studies carried out over decades with the specialised laboratory backup, the Marine and Coastal Survey Division has developed adequate expertise in the fields of seabed mapping with geological, geophysical, geotechnical and geochemical parameters, resource evaluation for placer minerals, geochemical scan for hydrocarbons,etc. Till March 2022, M&CSD has completed the seabed mapping of 1,43,386 sq km out of 1,58,005 sq km in 5 km x 2 km grid within

Territorial Waters (TW) and 18,98,312 sq km in the Exclusive Economic Zone (EEZ) beyond Territorial Waters on reconnaissance scale with collection of preliminary baseline data on bathymetry (Single beam & Multibeam), sediment (both surface and subsurface) since last few decades and gravity, magnetic, seismic (shallow /deep) data since inception of R.V. Samudra Ratnakar in FS 2013-14. The total EEZ coverage including TW is 20,41,698 sq km out of a total EEZ area of 21,59,620 sq km.

During the cruises of R.V. Samudra Ratnakar, RV Samudra Shaudhikama and RV Samudra Kaustubh of FS: 2021-22, baseline geoscience data collection on systematic seabed mapping were carried out over an area of 23,911 sq. km. Preliminary mineral investigation over an area of 4500 sq km and close grid mineral investigation to the tune of 450 sq. km were also carried out in TW and EEZ of India for augmentation of offshore mineral potentials in Indian EEZ. Along with these, a total of 6,612 lkm of multichannel and shallow seismic surveys have also been taken up as a part of generation of Baseline Geoscientific Data and to study the sub-surface disposition of sediment sequences in TW and contiguous zone and to identify the possible locales of offshore minerals through advance processing techniques. Marine geoscientific programme taken up during the period under review comprises of 7 complete and 1 spill over cruises onboard RV Samudra Ratnakar in deep waters, out of 9 proposed. In shallow water domain seven cruises each onboard RV Samudra Kaustubh and RV Samudra Shaudhikama were taken up. Besides these, one coastal item using mechanised boat was also taken up during the period. The programmes were undertaken under Eastern and Southern Regions and highlights of the work completed are given under the heads of the Regions. The list of cruises and coastal programmes taken up by M&CSD during FS: 2021-22 is given below.

Close grid geophysical surveys for studying the characteristics of shallow sediment layer, subsurface geological structure and thermal gradient within the submarine plateau and search for phosphorite off Quilon-Alleppey sector, Kerala coast, Arabian Sea (Cruise: SR067) (FSP ID: M1AMCSSMM/NC/SR/ MCSD-WC-1/ 2021/ 38444).

The sensor surveys are carried out with gravity, magnetic, bathymetric, and sub-bottom profiling at 5lkm line intervals, and the heat-flow probe was deployed at 11 locations over the Quilon-Alleppey platform (encompassing an area of 19,395 sq.km, bounded by the co-ordinates (a) 74°49’12"E, 09°32’47.04"N (b) 75°48’32.9796"E, 10°0’4.608"N (c) 76°16’47.1756"E, 08°36’55.818"N (d) 75°16’43.0464"E, 08°9’9.4212"N), which is a typical marginal plateau constrained by the crustal-scale fracture Vishnu Fracture Zone (VFZ), off Kerala, India. The sediment sampling has been done along the platform covering an area of 2223 sq.km on engaging the grab sampler and spade corer at 5 x 5 km and 10 x10 km grid intervals respectively. Rock samples and a drill core sample were collected with the manipulator of a Remotely Operated Vehicle (ROV) within the submarine plateau. Sound Velocity Probe data along with Conductivity-Temperature-Depth (CTD) has been collected at one location.

Swath bathymetry data indicates that part of the Quilon plateau, having a relief of nearly 1200m has been demarcated with a flat-topped area along the eastern part of the area. The linear free air anomaly pattern

derived from gravity contour map (Fig.2.74) may be attributed to the presence of the Vishnu Fracture Zone (VFZ). The eastern part of VFZ shows a high gravity anomaly that may correspond to the Alleppey Trivandrum Terrace Complex (ATTC). The VFZ constraints the ATTC which is considered an extension of the South West Indian shield. Total Field (TF) magnetic anomaly of the area with trend of the anomaly NW-SE. The highest values over north and north-eastern side of the platform whereas the lowest values have been noticed towards south (Fig.2.75). The marine magnetic data have continued upward for 120 meters and knitted with the aeromagnetic data of southwest India and the high-altitude magnetic data of south India and the initial analyses clearly establishes the offshore extension of the major shear zones and fracture zones including the Achankovil Shear Zone and Thenmala fault. The sub-bottom records over the plateau indicated a thin sediment layer of a few centimetres to meters in thickness.

Based on reported occurrences of phophorite nodules and phosphatic sediments in various cruises, close grid (at 5x5 and 10x10 grid intervals) grab and core sampling was carried out in the southern part of Quilon Plateau over an area of 2223 sq.km to evaluate phosphorite occurrences. Study reveals that the plateau area is covered by sandy sediments composed mainly of bioclasts, including foraminifers, gastropods and bivalves. Geochemical analyses indicate no P2O5 enrichment in the sediments. Petrographic study of these rocks reveal that they contain bioclasts of large benthic foraminifers and planktic foraminers bound together by micrite matrix. These rocks can be classified as bioclastic packstones.

Tectonic evolution study of Lakshadweep ridge and basin morphology with integrated multichannel seismic, gravity and magnetic survey (Cruise-SR-069). (FSP ID: M1AMCS-SMM/NC/SR/MCSD-WC-1/ 2021/ 35177).

Cruise SR-069 was taken up with an objective to study the geological characteristics of the Lakshadweep ridge and basin, their formation and seismic signatures. The area covered under cruise SR-069 is bounded by coordinates a) 11°4’37.2" N, 69°54’0" E b) 12°6’0" N, 73°27’36" E c) 15°9’36" N, 72°54’36" E d) 13°59’24" N, 69°21’36" E off Marmagao, Karwar and Mangalore coast.

The Seismic, Gravity and bathymetry surveys have been conducted along 4 coast perpendicular traverses at an interval of ~ 110 km in almost E-W direction and 1 coast parallel transect in almost NNW-SSE direction. The basic observation is that FAA (Free air Anomaly) and Bathymetry follow similar trends in conformity with each other. However, slight to noticeable deviations may be observed due to the subsurface inhomogeneity, lateral density contrast and structural control etc. in the subsurface geology. The preliminary interpretation of two seismic lines indicated that the major physiographic divisions observed along the sections from east to west are continental shelf, shelf break, continental slope, laccadive basin/trough, laccadive ridge, west laccadive slope and abyssal plain. Thick accumulation of sediments of about 700m to 1000m are observed in the Laccadive basin area. Submerged Pratap Ridge was identified in the Laccadive basin. A fault scarp is the boundary between Laccadive Ridge and the abyssal plain also noticed. In Profile L-4, a fault observed in the boundary of continental slope and Laccadive basin which may be an extension of onshore lineament/shear zone.

High resolution seabed mapping and exploration in Cherbaniani Block, Lakshadweep Trough (Cruise-SR-070) (FSP-ID-: M1AMCS-SMM/NC/SR/MCSD-WC-2/ 2021/ 35572).

The cruise SR-070 was taken with the objective to understand the geological and geophysical characteristics of the ocean floor, to study the morpho-tectonic elements and to understand the economic potential of phosphorites, metalliferous mud and ferromanganese crust and nodules in the northern part of Laccadive Ridge. Brownish black coloured, with characteristic knotty surface (botryoidal texture having larger knot like protrusions ferro-manganese crusts pieces were recovered from the flanks of sea mounts located north western part of Byramgore Reef during three dredge operations (D2, D3 and D4) from a water depth of 1600 m. Spheroidal to near spheroidal shaped having botryoidal/gritty textured brownish black ferromanganese nodules were recovered from western part of Cherbaniani Reef near the periphery of seamount flanks during spade core operation (SC-15) at a water

depth of 1546 m. The crusts and nodules contain ΣREE concentrations ranging from 179 ppm to 2041ppm (average 1305 ppm) with high Ce contents.

High resolution seabed mapping and exploration in Peremul Par Block, Lakshadweep Trough (Cruise-SR-071). FSP ID: M1AMCSSMM/NC/SR/MCSD-WC-2/ 2021/ 35413).

An area of 5100 sq. km has been surveyed to understand the geological and geophysical characteristics of the surface and sub-surface of the ocean floor along with studies of the morpho-tectonic elements, and search for Fe-Mn encrustations, phosphorite and metalliferous mud occurrences in Lakshadweep area. In the survey area, two NNE-SSW trending reefs, namely Bitra par reef in the NE and Peremul Par reef in the SE part of the surveyed area. Prominent terrace on either side of east and west flanks of the Peremul Par reef have been noticed. Pock marks, Valley, sea mounts and crescent shaped seamounts and guyots, sshaped ridges, dissected structures, step faults and regional faults and scour marks are also observed in the survey area.

Free air gravity anomaly map with 5 mGal contour interval shows anomalies of shorter and longer wavelength and exhibits NESW and N-S contours trends and clearly reflects the bathymetric and morphological characteristic of the area. Magnetic analytic signal map shows that, the high analytic signal amplitude that trending in approximately NNW-SSE and E-W direction in the study area.

Fe-Mn crust and nodules were collected by deploying dredge sampler, spade corer and ROV within a depth range of 800 to 1700 m. A large composite nodule of 41cm x 29 cm x 22 cm and weighing 17.5 kg, was also recovered from spade core at water depth of 1220 m. Study of subsurface sediments from cores revealed presence of clayey sediments with varying proportion of fine to medium sand.

The Fe-Mn crusts /encrustations are jet black coloured, hard, massive with or without botryoidal and knotty structures and are exposed as slabs/ layer/ boulders/fragments of varying sizes or as thin coating over coral reef. At many locations the Fe-Mn crusts / encrustations are partially buried by thick sediment cover. The nodules observed are black colored, spheroidal or ellipsoidal (well rounded, sub rounded, elongated, heart shaped), with smooth or mixed morphology, with well-developed botryoidal structures. Analysis of Fe-Mn samples shows high concentration of Co, Ni and Pb with average concentration 3965 ppm, 4469 ppm and 1440 ppm respectively. Concentration of Total REE concentration varies from 1130 to 1710 ppm with an average of 1499 ppm.

Multi thematic mapping of contiguous zone beyond territorial waters off Kasaragod, Kerala (Cruise-SD-304) (FSP ID: MIAMCSSCWTEEZ/NC/ SR/MCSD-WC-2/ 2021/ 36214).

During the cruise SD-304, a total of 750 sq. km area was covered with systematic survey in the Territorial Water of West Coast of Kasaragod, Kerala to bring out the bathymetry, surface and subsurface geology of the area through geological and geophysical studies and generation of baseline data.

The survey area is bounded by coordinates (a) 74° 31' 08.82"E, 12° 31' 31.80" N(b) 74° 42' 45.60" E, 12° 37' 13.44" N (c) 74° 49' 17.82" E, 12° 21' 43.02" N and (d) 74° 38' 45.48" E, 12° 14' 41.28" N (Fig.2.81). Study of 73 nos. of grab samples (collected at 2 x 5 km interval within water depth range 42 to 64.5 m) revealed that seabed is mainly carpeted by fine sand as well as medium sand. A hard compact cemented shelly bottom / substratum (13 cm x 11 cm) had also been recovered at location G24. Study of 19 Vibro Core samples revealed presence of thick sediment column with rich carbonaceous components, indicative of a swampy, back water system where burial/sudden sedimentation is possible. The vibrocores VC-03 and VC-14, collected beyond 54.3m are rich in sand, having very coarse sand to coarse sand with minimal clayey components.

The thick column of sand may be indicative of palaeo strandline. Palaeontological studies indicated that Foraminifera is predominant followed by bivalves, microgastropods, Pteropods, ostracods. Foraminifer is further subdivided in to planktic and benthic forms. The observed planktic genus are like Globigerinoides sp. and Globigerina sp. and the dominant benthic genus like Ammonia sp., Cancris sp., Cibicidoides sp., Nonion sp., Brizalina sp., Bolivina sp., Fursenkoina sp.,

Elphidium sp., Amphicoryna sp., Bulimina sp., Amphistegina sp., Cassudilina sp., Lagena sp., Lenticulina sp., Operculina sp., Quinqueloculina sp., Spiroloculina sp., Textularia sp., Triloculina sp., Uvigerina sp.

Multi thematic mapping of contiguous zone beyond territorial waters off Muttam Point, Kerala- western Tamil Nadu coast (Cruise-SD-305) (FSP ID: MIAMCS-SCWTEEZ/NC/SR/MCSDWC-2/2021/35321).

Cruise SD-305, was taken up with an objective to bring out the bathymetry, surface and subsurface geology of the survey area through geology and geophysical studies and to generate the baseline data bounded by coordinates (a) 76° 50' 58"E, 07° 59' 30"N (b) 77° 00' 56"E, 08° 08' 12"N (c) 77° 07' 28"E, 08° 03' 21"N (d) 77° 13' 41"E, 07° 57' 16"N(e) 77° 04' 11"E, 07° 48' 36" N. Geophysical surveys (magnetic and shallow seismic) were also conducted concurrently with bathymetric survey. The total magnetic field anomaly profiles along transect L1 shows that the magnetic anomaly values are increasing towards the sea whereas low magnetic anomalies are observed in the western part. It was found that higher amplitude anomalies are recorded near to the coast. Geological studies indicated that seabed is carpeted mainly by fine to medium sand, with presence of coarse sand in the northern and eastern parts.

Parametric shallow seismic survey in the gap area off Karwar- Devgarh sector, West Coast, Arabian Sea. (Cruise-SD308) FSP ID No. M1AMCSAPS/NC/SR/MCSD-WC-1/2021/38446.

Systematic coverage of shallow seismic data gap along West Coast has been initiated from southern most gap area. Seismic data gap from off Karwar, Karnataka coast to off Devgarh, Maharashtra coast has been proposed for compilation and collective interpretation. Cruise SD-308 has been taken up as a part of generation of Baseline Geoscientific Data and to study the sub-surface disposition of sediment sequences in TW and contiguous zone. Study reveals that the bathymetric contours are aligned near parallel to the coast configuration and is gently sloping towards the southwest. The processed and interpreted seismic records reveals that the depth to the seafloor is from 7.6 to 49.8 m. Regarding sub-sea bed, 5 to 6 prominent subsurface reflectors with good reflectivity contrast, are deciphered. The reflector R1 occurs below the sea floor. In the seismic record the reflection character for the material lying above the reflector R1 indicates soft sediments of unconsolidated nature. The three sequence boundaries (erosional surface (ES), transgressive surface (TS) and maximum flooding surface (MFS) are recognized in the seismic Line -3 and 21 (Fig.2.82) off Karwar- Devgarh sector, West Coast, Arabian Sea. The undulating erosional surface cutting through late Pleistocene sediments represents an incised valley and may be attributed to emergence of the shelf during the last glacial maxima. The TS mark the post glacial rise of the sea level and represents the initial flooding surface. The transgressive system tract (TST) overlying TS shows strong reflections suggesting a possible sandy nature of the sediment package. TS is overlain by the MFS which marks the time of maximum flooding or transgression of the shelf and it separate the transgressive and high stand system tracts.

SCWTEEZ/NC/SR/MCSD-WC1/2021/35180).

Cruise-SD-310 with the objective of to fill up the shallow seismic gap areas between Ponnani-Karwar off West Coast, Arabian Sea under Baseline Geoscientific Data Generation and to study the subsurface disposition of sediment sequences & sediment thickness in TW & Contiguous Zone.

Block1: Single beam bathymetric survey reveal gradual slope of 0.03° to 0.09° away from shore (SW) with minor undulations. The seismic two-way-time sections of all transects show a smooth and slightly undulating seafloor gently increasing depth towards southwest without any significant geomorphic feature.

Block 2: The seismic survey has delineated 4 acoustic reflectors designated as Seafloor (R0), R1, R2 and R3. The reflector R1 strong, continuous and more or less subparallel to the seafloor and dipping towards sea.The reflectors R2 R3, R4, R5 are dipping towards sea and characterized by erosion and top lap features. A buried river channel, U and V shaped streams are noticed in western parts of the survey area.

Block 3: The isochron (TWT) map of Seafloor also depicts a smooth and gently dipping seafloor to southwest of the surveyed area in agreement with the bathymetry. All the contours are trending parallel to the present day coast with minor undulations and they

are oriented generally along NW-SE. Block-4: The seismic section show a wedge shaped sediment package characterized by low amplitude continuous parallel reflectors extending seaward up to a water depth of 48 m. The weak reflectors below the wedge shaped sediment layer against a planar surface referred to here as maximum flooding surface. The acoustic blankings observed in high resolution seismic data suggest that the late Holocene sediment wedge is amenable for accumulation of gas. The observed acoustic masking is attributed to the presence of gas bubbles (predominantly free methane gas) in the sediments.

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Geophysical (shallow seismic and magnetic) surveys within continental shelf off Baruva, Andhra Pradesh coast, Bay of Bengal **(Cruise ST-287). (FSP ID: M1AMCSAPS/NC/SR/MCSD-EC-2/2021/35430).**

Geophysical surveys (magnetic and shallow seismic) and bathymetric survey was taken up within the continental shelf off Baruva, Andhra Pradesh Coast, Bay of Bengal during the Cruise ST-287 with an objective to identify seabed morphology, sub-surface structural features and tectonic fabric of the area. The water depth in the surveyed area varies from 10m to 480m. Based on the contour pattern, it can be inferred that the shelf area is wider in the southern part when compared to the northern part. The undulatory nature in bathymetry contours between 50 m to 70 m appears to be due to a ridge in NE–SW direction which is also confirmed by seismic surveys.

The magnetic anomaly map can be broadly classified into a) low anomaly zone is prominent over the Shelf-Break zone, b) bipolar magnetic anomaly zone was observed over intra basement intrusive within the continental crust and c) moderate anomaly zone was observed over the area where placer deposits have been reported. The stacked profile of observed magnetic (TF) and bathymetry responses over transects L-1, L-3, L-5 and L-6 has been prepared. As observed over the qualitative variation, the moderate magnetic zone is having southward continuation and is limited by a high anomalous zone present towards the deep sea. The disposition of the liner high frequency anomaly zone extending in the NNE-SSW direction may be attributed to the intra basement intrusive within the continental crust. This zone seems to act as a limiting margin for the aforementioned moderate anomalous zone. Moreover, high frequency anomalies have been noticed almost over all the profiles.

The significant observation over the FAA map is the high gravity anomaly zone where the bipolar magnetic anomaly is noticed (Fig. 2.84). This indicates the presence of terrace like feature and acts as a restricting boundary to the seaward flow of placer minerals from hinterland. The occurrence of HM is most likely to be concentrated in the western part of this terrace like feature.

The shallow seismic survey has brought out the morphological and stratigraphic distinction in terms of several reflectors. Broadly, three to four acoustically strong reflectors have been identified within a probing depth of 480 m. There are some seafloor undulations and significant ridges are observed at 56 m and 96 m water depths (Fig. 2.85; Box-I). The occurrences of such ridges from the coastline can be attributed to the postglacial strandlines formed during the standstill positions of recent Holocene transgression

Gas Hydrates

Gas hydrates are formed when gas and water mixtures are subjected to high pressure and low temperature conditions in the sea, usually in water depths of more than 800 m, within sediments just below the sea bottom. They are also formed in some permafrost region of the world. The gas hydrates also act as a cap under which natural gas can get accumulated. Gas hydrates can be an unconventional energy source of the future.

In India, gas hydrate research and exploratory activities are being steered under National Gas Hydrate Programme (NGHP). Under NGHP, technically coordinated by Directorate General of Hydrocarbons (DGH), various R&D studies are in progress to develop vast resources of gas hydrates in western and eastern offshore and Andaman offshore areas.

NGHP Expedition-01 exploration programme was carried out in 2006 for mapping gas hydrate zones in Krishna-Godavari, Kerala, Konkan, Mahanadi and Andaman offshore areas. A total of 39 holes were drilled at 21 sites and the physical presence of gas hydrate was established predominantly in Krishna-Godavari, Mahanadi and Andaman Basin in clay dominated complex geological settings.

NGHP-02 was conducted successfully in Eastern offshore from 09.03.2015 to 31.07.2015. A total of 42 wells were drilled at 25 sites in Krishna-Godavari and Mahanadi areas in sand reservoirs for gas hydrates. NGHP-02 has discovered two world class gas hydrate

reservoirs, namely, Block KG-DWN-98/5 and Block KG-DWN-98/3. Based on the post-expedition studies and review by international experts, the site located in KG-DWN-98/5 has been found suitable for pilot production test during NGHP-03 expedition for which various studies like sand control measures, well design, reservoir and production simulation modelling as prerequisite for the pilot production have been completed.