Incidence of Vanadium bearing Titanomagnetites in Gulf of Khambat seabed sediments, Gujarat

Placer mineral distribution in the seabed sediments within the Gulf of Khambhat was carried out under FSP item No. M1AMCS-MME/NC/SR/MCSD-WC-1/2018/18949 pertaining to OPWC-I, Marine and Coastal Survey Division, Mangalore of FS 2018-2019 (Fig.1). This programme of Cruise: SD-285 entitled, "Preliminary search of HM placer in the surface sediments off Alang, Gujarat. (Block-2)" was mounted on Research Vessel Samudra Shaudhikama. The investigation area is a dynamic macro-tidal regime with flood torrents from Rivers like Mahi, Narmada, Tapti, Sabarmati, Dhadhar, Purna, Ambika, Auranga, Bhandar, Padolia, Shetrunji, Limbadi Bhogavo, Sukhbhandar, Utavali, Keri, Vagad, Kalubhar, Rangholi, Ghelo and Maleshree and high tidal effects from Arabian Sea. The tide variation in this area goes even up to 12 m in spring tide.

As a part of the project, 41 Nos. of Vibro cores (VC) & 31 Nos. of Grab (G) samples have been collected to study the heavy mineral concentration and its distribution in seabed sediments by conventional bromoform heavy mineral separation method and studying the relative abundance of heavy minerals by grain mount study. Mineralogical study of heavy mineral fraction of sediment samples collected off Alang, Gujarat shows predominance of opaque minerals represented by magnetite, leucoxene, and ilmenite. Non-opaque minerals like pyroxene and amphiboles are dominant with the traces of sillimanite, zircon, garnet, and monazite. The bulk sediments contain 12 wt.% of heavy minerals on average which goes up to 22 wt.%. Within these heavy minerals more than 6 wt.% of minerals are opaque in nature representing Ilmenite, Magnetite and Titanomagnetite Some of the ilmenite grains in opaque heavy mineral fraction analysed with EPMA revealed the presence of TiO_2 varying from 15 to 35% and fallen in the Titanomagnetite clan in the Rutile-Wustite-Haematite ternary diagram of Deer et., al., 1992. Handpicked opaque grains were analyzed under Scanning Electron Microscope at GSI, Hyderabad and confirmed the presence of Vanadium up to 0.63% (Fig.2).

Geochemical analysis of the magnetic heavy mineral aliquot of sediment samples collected at the water depth of 10 m from Gulf of Khambat has revealed the incidence of higher concentration of Vanadium [about 1486 ppm]. Subsequently, XRD analysis of magnetic heavy mineral fraction of 12 randomly selected samples at Mineral Physics Division, GSI, Nagpur revealed the presence of vanadium bearing mineral phase Melanovanidite (Fig. 3). For further confirmation, again 12 samples including 11 separated heavy mineral bulk samples and one sample containing magnetic heavy mineral fraction separated using hand-magnet were analyzed at XRF Lab, Chennai. The magnetic heavy mineral fraction has indicated the high concentration of vanadium about 1486 ppm.

Electron Probe Mirco Analysis on titanomagnetite at EPMA Lab, NCEGR, Bangalore shows that they are vanadiferous (Fig. 5). The V_2O_3 content in the individual titanomagnetite grains ranges from 0.36 to 1.7% with an average of 1.3% (Table 1).

As per the NMI database, India has only the estimated resource of Vanadium ore of about 24.63 million tonnes but there is no proved/probable reserve of Vanadium established in India. However, Vanadium has wide applications in various fields, particularly it is used as an alloying element in Iron and steel industry in the manufacture of high strength plates, structural steels to pipes, reinforcing bars, forging steels, rail steels, tool steels and also used as a stabiliser in titanium and aluminium alloys used in aerospace applications. Non-metallurgically it is also used in chemical, pigments, catalyst and electronic industries. In modern applications, Vanadium is used as Vanadium Secondary batteries in power plants and as rechargeable Vanadium Redox Battery in commercial applications.

The titaniferous magnetite is the most important source accounting to about 85% of current world V_2O_5 production in world along with Fe and Ti ores. Hence, further detailed sampling and analysis are required to identify the lateral and vertical continuity of Mineral Occurrence in the investigation area. Even the source of this mineral also needs to be traced and tapped in the hinterland.

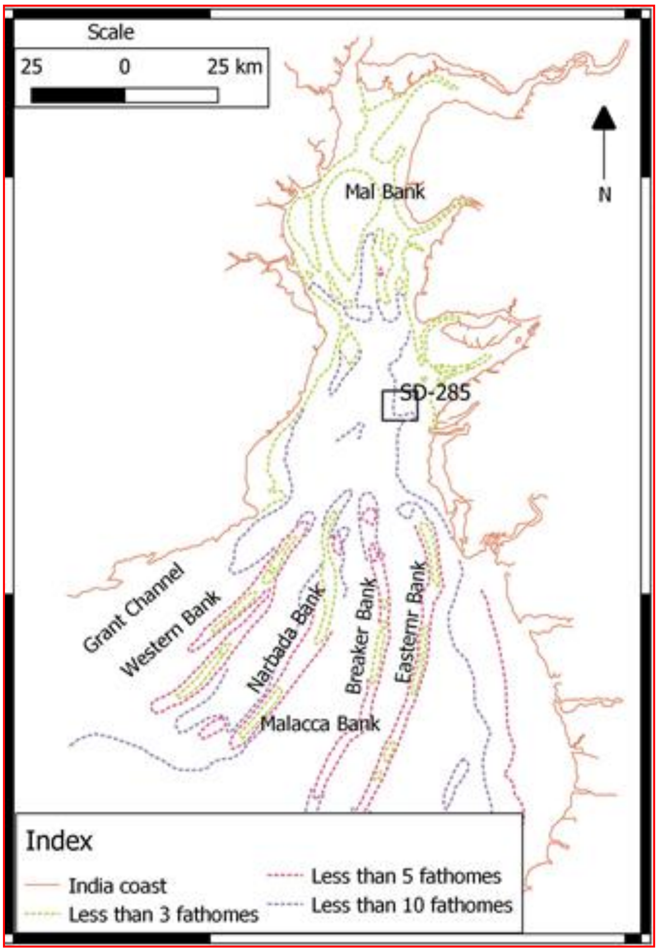
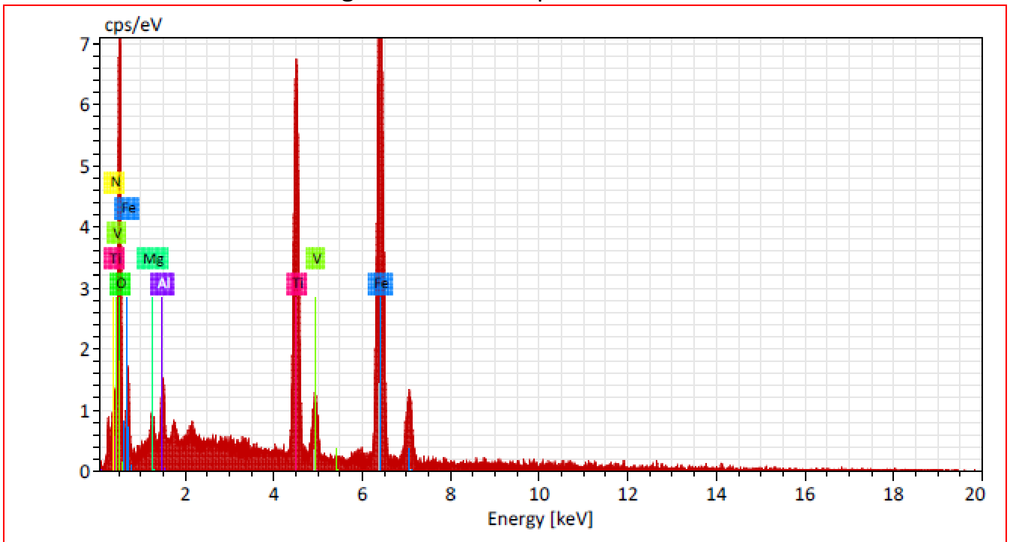


Fig 1. Location map of the area



Spectrum	Nitrogen	Oxygen	Vanadium	MgO	Al2O3	TiO2	FeO
VC-6/7	1.68	0.00	0.58	1.26	2.90	30.66	62.93

Fig. 2. EDX spectrum of Vanadium in Titanomagnetite, off Alang, Gujarat.

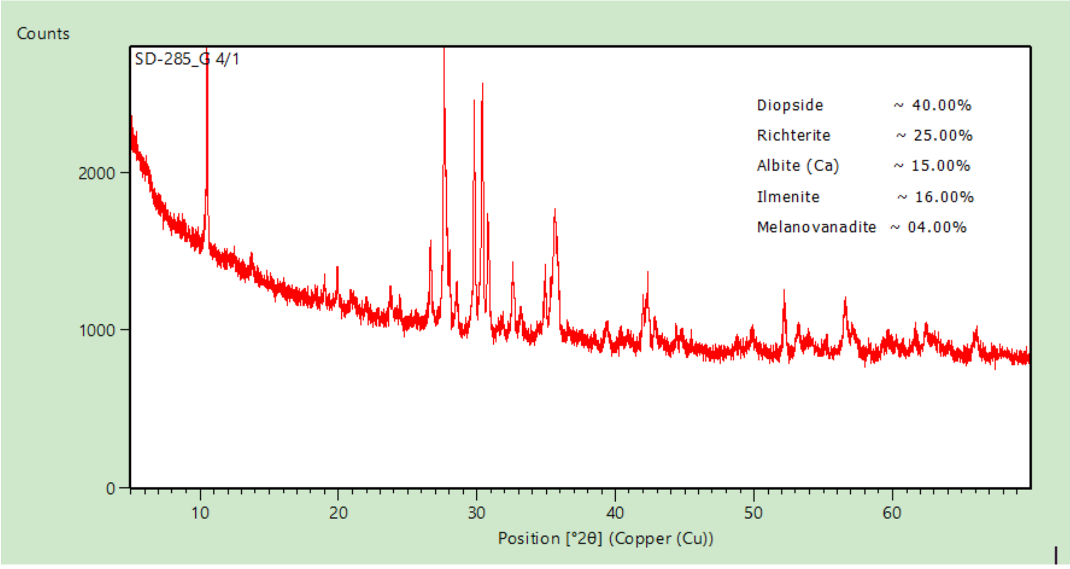


Fig 3. X-ray diffractogram of Vanadium enriched heavy minerals, off Alang, Gujarat.

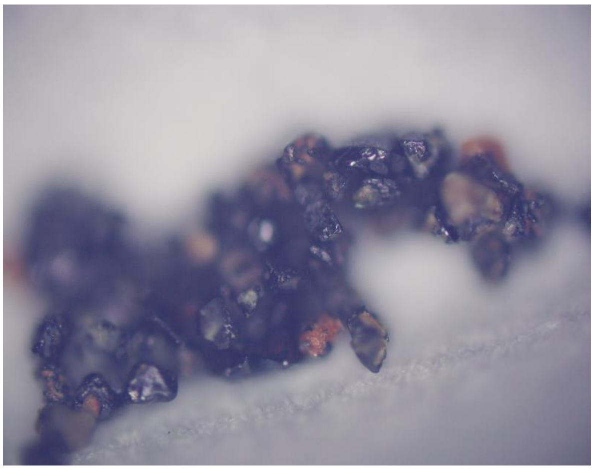


Fig 4. Vanadium bearing opaque minerals, off Alang, Gujarat

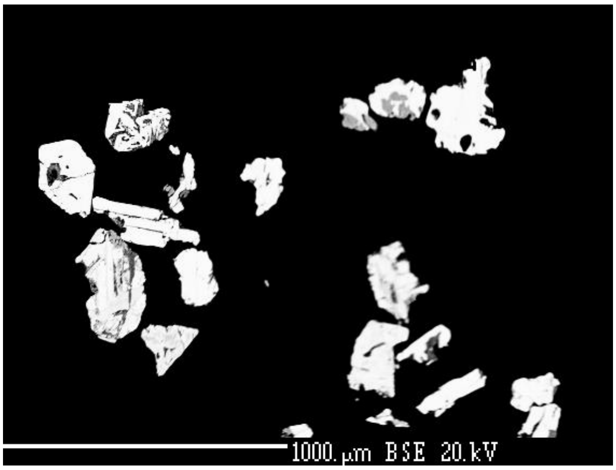


Fig. 5. BSE image of vanadium bearing titanomagnetite.

Table 1: EPMA data of Vanadium bearing Titanomagnetite.

Wt%	G6/C1/1	G6/C1/2	G6/C1/3	G6/C1/5	G6/C1/6	G6/C1/7	G6/C1/8	G6/C1/9	G6/C1/10	G6/C1/12	G6/C1/13	G6/C1/14	G6/C1/15
CaO	0.18	5.5	0.07	0.01	0.14	0.1	0.09	0.21	6.42	0.09	0.04	6.56	0.1
FeO	66	48.1	67.9	67.32	56.38	58.6	69.5	56.8	54.64	67.5	43.2	47.4	60.8
SmO	0.02	0	0	0.04	0	0	0	0	0.01	0	0	0	0
EuO	0	0.03	0	0	0.1	0.05	0.06	0	0	0	0	0	0.1
Al_2O_3	2.02	1.75	1.65	1.98	2.04	2.1	1.66	0.89	1.63	0.89	0.04	1.91	1.84
V_2O_3	**1.16**	**1.4**	**1.25**	**1.11**	**1.48**	**1.51**	**1.11**	**1.22**	**1.11**	**1.15**	**1.39**	**1.26**	**1.28**
Y_2O_3	0	0.05	0	0.02	0.07	0.01	0.06	0	0.03	0	0	0.02	0
Ce_2O_3	0.02	0	0.05	0.07	0.04	0	0.06	0.17	0	0	0.17	0.12	0
Pr_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0.01
Nd_2O_3	0.08	0	0.03	0.02	0.02	0	0.02	0	0	0	0	0	0.01
Gd_2O_3	0.01	0	0	0	0.02	0	0	0.03	0	0	0	0.03	0
Dy_2O_3	0	0	0	0	0	0	0	0	0	0	0	0	0
Yb_2O_3	0	0	0.16	0	0.07	0.07	0.05	0.05	0.05	0	0	0	0.09
SiO_2	0.67	6.29	0.23	0.15	0.7	1.29	0.45	1.51	6.63	1.14	0.09	6.28	0.43
TiO_2	22.5	36.7	23.5	27.38	32.5	29.2	23	35	26.36	23.5	58.6	34.4	34.2
ZrO_2	0	0.01	0	0.06	0	0	0.06	0	0.02	0	0.1	0.08	0.08
ThO_2	0.03	0.02	0.07	0.02	0	0.01	0.07	0.01	0.05	0	0	0.05	0
P_2O_5	0.05	0	0.11	0.04	0.02	0.12	0.03	0.18	0	0.05	0.01	0.15	0.14
Total	92.8	99.9	95	98.23	93.57	93.1	96.2	96	96.95	94.4	104	98.3	99

In the placer minerals category, magnetite or titanomagnetite is not being considered under economic mineral. But with the presence of V_2O_5 content in titanomagnetite, they will be of high economic value and thus add on to the offshore mineral resource of India. Based on this aspect, the presence of Vanadium bearing titanomagnetite horizons may be demarcated specifically in the zones where magnetite or titanomagnetites were reported earlier all along the continental shelf of India falling within territorial water limit.

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