Chapter 1
GENERAL
INTRODUCTION

Vanadium is of considerable economic significance as an industrial metal and it is for this reason that the vanadium bearing titaniferous magnetite deposits have gained much importance in the recent years. They are magmatic accumulations of magnetite and ilmenite containing appreciable quantity of vanadium. The titanium content in these ores is high enough to represent a potential alternative to beach sand ilmenite for the production of high titania materials (Reynolds, 1978). In India, the Shimoga-greenstone belt of Karnataka has long been known for the occurrence of abundant V-Ti-Fe ores. The deposits investigated in the present study are that of:

1. Ubrani, Tavarekere, Masanikere and Magyatahalli in Channagiri taluk of Shimoga district, hereafter referred to as Channagiri area,

2. Devaranarsipur, near Bhadravati in Shimoga district, and

3. Mulemame, in Ankola taluk of North Kanara district.

All these deposits are located within mafic-ultramafic suite of rocks of Precambrian age. Apart from the exploratory investigations carried out to establish the economic potentials by the State Department of Mines and Geology and the Geological Survey of India, a few research workers have studied the mineragraphy and chemistry of some of the above deposits. The objective of the present investigation is mainly to know in detail the field occurrence, petrography, mineralogy, geochemistry and genesis of these ores. All the mineral chemical data obtained and much of the geochemical work carried out in the
present study is new and should serve as an up-to-date information to our knowledge of these V-Ti-Fe deposits. Although the present investigation is mainly concerned with the various aspects of the V-Ti-Fe ores, a limited incidental discussion of the associated lithological units has also been accomplished. Several interesting and hitherto undocumented mineralogical and geochemical features of the V-Ti-Fe ores have been observed during the investigation and are described in some detail.

LOCATION AND ACCESSIBILITY

The areas studied form part of Archaean shield of Peninsular India and are situated towards the western and southeastern portions of the Shimoga schist belt (Fig. 1).

The four V-Ti-Fe deposits occurring as bands and lenses of varying size spread over an area of 90 km² in the Channagiri taluk of Shimoga district (Long: 75° 54' 20" to 76° 01' 00" E and Lat: 13° 50' 00" to 13° 53' 35" N) have been named after the nearby villages of Tavarekere, Masanikere, Ubrani and Magyatahalli. The area covers parts of toposheets 48 0/13 and 57 C/1 published by the Surveyor General of India. The village Taverskere is connected by all-season road to Channagiri, a major town in the area at a distance of 22 km towards north. All the other villages are connected from the main road either by metal roads or cart tracks. Channagiri is well connected to places like Bhadravati, Chitradurga, Shimoga and Bangalore which are at a distance of 35, 61, 43 and 276 km respectively. The nearest railway station is Shivani, about 12 km south east of the area on
GEOLOGICAL MAP OF KARNATAKA, INDIA
(modified after Roy, 1983)

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- LATERITES
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- BIMAS & KALADDIS
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- SARGUR GROUP

CHARNOCKITES

1. Channagiri area
2. Devaranarsipur area
3. Mulemane area
the Miraj-Bangalore metre gauge line.

The ore deposit of Devaranarsipur is located 3 km east of Bhadravati near Devaranarsipur village. It forms the eastern portion of the Survey of India toposheet 48 0/9 (Long: 75° 43' 40" E and Lat: 13° 50' 40" N). The area is served by unasphalted road from Bhadravati on the Birur-Talaguppa metre gauge line.

Mulemane area is a part of Ankola taluk (North Kanara district) and is situated about 3 km NE of Sunksal village. The deposit is situated towards the western side of the Hubli-Karwar state highway No.17, near Mulemane cross, about 100 km from Hubli. The village of Mulemane is about 1.5 km from the highway and is connected by cart road. An area of about 9 km² is surveyed, which forms part of Survey of India toposheet 48 J/9 (Long: 74° 30' - 74° 33' E and Lat: 14° 45' -14° 48' N).

PHYSIOGRAPHY, DRAINAGE, CLIMATE AND VEGETATION

CHANNAGIRI AREA:

The area surveyed forms the eastern fringe of Malnad in Shimoga district. It is a rugged terrain dominated by hills and rolling plains. The highest peak in the area rises up to a height of 1030 m above the mean sea level. The hill ranges of Tavarekere, Masanikere and Magyatahalli are covered with shrubs and thorny bushes. The slopes of Gaurapur and Ubrani hill ranges are covered by moderately thick jungle and thorny shrubs while the top of the ridges are covered by grass. The area enjoys tropical climate. April is usually the hottest month with a mean daily maximum temperature of 35.8°C and minimum of 22.2°C.
Average rainfall in the area is less, i.e., 767 mm, compared to other parts of the district. Tavarekere village is the major settlement in the area situated on the main road.

DEVARANARSI PUR AREA:

The area is 608 m above the mean sea level and is covered by isolated low mounds with an elevation of 612 to 624 m trending NNW and NNE, having a gentle slope to the west. The climate is similar to that of Channagiri area.

MULEMANE AREA:

The Mulemane-Sunksal area forms a rugged terrain characterised by steep ridges rising up to 700 m. It is the extension of the Sahyadri ranges with many waterfalls and rapids. The area is characterised by dendritic and sub-parallel drainage mostly guided by the geological structure. Gangavalli (Beldi) is the major river flowing through the area which shows a matured stage.

The area has a thick vegetative cover. While the hill tops support thinner vegetation, the valleys support luxuriant growth, with valuable teak forests having the most common undergrowth, bamboo.

The area has tropical monsoon climate and receives heavy rainfall. The average rainfall of the district is 2741.7 mm and that received in the nearby raingauge (Arbail) is 3094.7 mm. About 89% of the annual rainfall is received during June-September. The highest average temperature recorded at the nearby
The observatory is 30.2°C and the lowest 22.8°C. The relative humidity ranges from 74% to 82%.

NATURE AND FREQUENCY OF THE OUTCROPS

In Channagiri and Devaranarsipur areas, the exposures are generally good, occurring in the elevated portions and the plains; low grounds are mostly under cultivation. The V-Ti-Fe ore bodies with gabbro-anorthosite suite of rocks occur as prominent hillocks or mounds in an otherwise plain area. While the schists with meta-gabbro and ultrabasics are poorly exposed, the basement granitic rocks are well exposed. Mulemane area of North Kanara district has a thick forest cover with few rock exposures. However, good outcrops are seen over the ridges.

REVIEW OF THE PREVIOUS WORK

CHANNAGIRI AREA:

The first geological survey and mapping of the area was carried out by Slater (1905). Later, Jayaram (1915) conducted revision survey in parts of Channagiri taluk and Smeet and Sampath iyengar (1916) reported the occurrence of titaniferous iron ores of Ubrani. The prospecting of the titaniferous magnetite deposits of Tavarekere and Ubrani areas was subsequently carried out by the officers of the MISL, Badravati by putting some trial pits on the float ore zone. Channappa and Subramanya (1973) carried out systematic prospecting and estimated a reserve of 3.6 million tonnes for Ubrani deposit analysing 0.53% V₂O₅. More recently, Channappa and Subramanya (1979), estimated the existence of a total reserve of 1.7 million
tonnes for Tavarekere and Gaurapur deposits analysing 0.45% and 0.35% V₂O₅ respectively.

Chayapathi (1976), Ramiengar and Chayapathi (1977) have described the vanadiferous magnetite bodies of Channagiri taluk. Based on detailed examination and drilling in Masanikere area, they have indicated the reserve at 4.18 million tonnes of in-situ and 0.535 million tonnes of float ore with an average V₂O₅ content of 1.00%. They have also given a comprehensive account of the stratigraphy and petrology of the area and have given selected major element geochemical data for the Masanikere ores. Sulphide mineralisation in the area was reported for the first time by Chayapathi (1976).

Vasudev and Srinivasan (1979) while giving a comparative account on the geology, mineralogy and geochemistry of the magnetite deposits of Karnataka, based on morphology and structure, have classified these deposits as deformed, conformable and layered type. Ramiengar et al. (1978) have provided some details on the chemistry of the magnetite deposits of Masanikere.

Chadwick et al. (1987, 1988) based on the results of reconnaissance mapping have sub-divided the Dharwar supergroup in the Shimoga basin east of Bhadravati into seven formations. The lowest is dominated by metabasites including metagabbros with local seams of titaniferous magnetite and ultrabasic schists.

Based on the field characters, mineralogical and textural
studies, Govindaiah et al. (1989) have opined that the V-Ti-Fe ores of this area are products of fractional crystallisation of iron-rich basic magma with in-situ bottom crystallisation of V-Ti magnetite crystals, later injected into the quartz-chlorite schists of the Chitradurga group.

DEVARANARSIPUR AREA:

Slater (1905) was the first to carry out regional survey of the area to the east of Bhadravati and in the Channagiri taluk and has classified the rock formations exposed in the vicinity of Devaranarsipur village as of igneous suite. Jayaram (1915) carried out revision survey of this area and classified these formations as of ultrabasic suite. Venugopal (1921) was the first to report the occurrence of titaniferous magnetite ore bands of Devarinarsipur and later Lakshmana Rao (1942) examined them in some detail with a view to ascertain their economic potential.

Channappa and Raghuvendra (1974) laid special emphasis on the economically important titaniferous magnetites and mapped the area on 1:1000 scale with drilling of 3 bore holes and estimated the reserves at 2.5 lakh tonnes.

Naganna et al. (1976) studied the textural and mineralogical characters of these ores and reported the occurrence of caulsonite in the martitized magnetite grains.

Vasudev and Srinivasan (1979) have made a brief reference to these deposits in their review on V-Ti-Fe deposits of Karnataka.
MULEMANE AREA

There are very few publications dealing with this area. The only publication in which there is a specific reference to Mulemane V-Ti-Fe deposit is of Vasudev and Srinivasan (1979). The officers of the Department of Mines and Geology of Karnataka, during the field season of 1981-82 have estimated the ore reserves at 3.2 million tonnes.

Devaraju et al. (1985) have reported the occurrence of diaspore in the joints, fissures, cavities and other weak planes of the V-Ti-Fe ore body.

Most of the earlier work on these areas has been done by the Officers of the State Department of Mines and Geology and the Geological Survey of India, mainly in connection with prospecting of the ore deposits. It is clear from the foregoing review, that except for detailed exploratory investigations carried out to establish the economic potentials, there exists very little published information dealing with mineralogy, mineral chemistry and geochemistry of these deposits, especially for those of Magyatahalli, Devaranarsipur and Mulemane. Much of the mineralogical and geochemical work carried out in the present study is new and should serve as an up-to-date information to our knowledge of these V-Ti-Fe deposits.

GENERAL GEOLOGY

The areas covered in the present study form part of Shimoga greenstone belt of the Karnataka craton. The lithostratigraphic successions of these areas are given in Table-1.
### TABLE 1  LITHOSTRATIGRAPHIC SUCCESSION OF THE AREAS

<table>
<thead>
<tr>
<th>Intrusives</th>
<th>CHANNAGIRI AREA</th>
<th>DEVARANARSIPUR AREA</th>
<th>NULEMANE AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quartz veins</td>
<td>Pyroxenite-serpentinite</td>
<td>Laterite</td>
</tr>
<tr>
<td></td>
<td>Dolerite dykes</td>
<td>with U-Fe-Fe ores</td>
<td>Dolerite &amp; epidiorite dykes</td>
</tr>
<tr>
<td></td>
<td>Gabbro-anorthosite suite with U-Fe-Fe ores</td>
<td>talc schist, steatite</td>
<td>Peridotite-serpentinit, gabbro with U-Fe-Fe ores</td>
</tr>
<tr>
<td></td>
<td>Actinolite schist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chitradurga group of Dharwar Supergroup</td>
<td>Quartz-chlorite schist, quartz-chlorite-carbonate schist, quartzite, phyllite</td>
<td>Quartzite</td>
<td>Quartzite, phyllite</td>
</tr>
</tbody>
</table>

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Granitic gneiss (Peninsular gneiss complex)

* after Râmiengar et al. (1978)
In Masanikere, Taverekere, Ubrani and Magyatahalli areas (Fig.2), medium to coarse grained granitic gneisses of Peninsular gneissic complex are the most abundant and oldest (2.90-3.36 b.y. old- Taylor et al.1984) rocks recognised. These are predominantly of tonalite character. The other rock types met with are schists (viz: quartz-chlorite schist, quartz-chlorite-carbonate schist, actinolite schist), the gabbro-anorthosite suite of rocks with bands and lenses of V-Ti-Fe ores, quartzites with interbeds of phyllites, dolerite dykes and quartz veins. The V-Ti-Fe ore bodies are essentially confined to magnetite gabbro. The gabbro-anorthosite suite of rocks seem to have emplaced as basic intrusions within the schistose rocks of the area. The area has suffered regional metamorphism and deformation.

The area to the south of Devaranarsipur village (Fig.3) is dominated by ultramafic rocks of pyroxenite and serpentinite character which have a general NNW-SSE trend with variable dip towards east. The ultramafics occur as minor intrusions within the granitic rocks of the area. The other rock types include talc-mica schist, steatite, and quartzite. V-Ti-Fe ore occurs as isolated bands and lenses within the ultramafics over an area of 0.35 km².

Peridotite/serpentinite and gabbro are the principal rock types of Mulemane area (Fig.4). Metasediments like quartzite, phyllitic schists occur as small bands. The ultramafics host the V-Ti-Fe deposits which occur as NW-SE trending bands over a strike length of 1 km, with a thickness of upto 30 m. The
Fig. 3 Geological map of Devaranarsipur area

After Channazza & Raghuveera (1974)
Fig. 4 Geological map of Mulemane area

- Dolerite
- Epidiorite
- V-Ti-Fe Ore
- Gabbro
- Peridotite / Serpentine
- Phyllite
- Quartzite
- Granitic Gneiss
ultramafic rocks intrude the basement Peninsular gneisses and in turn are intruded by epidiorite and dolerite dykes. Laterites occur as patches capping the V-Ti-Fe zone.

PRESENT STUDY

This work is aimed at supplementing the existing information on the V-Ti-Fe deposits and the closely associated rocks. This study has accomplished:

1. Preparation of geological maps on 1 cm = 0.125 km scale for 90 km² and 9 km² in Channagiri and Mulemane areas, respectively (Figs. 2&4).

2. A comprehensive discussion of the field occurrence, petrography, mineralogy, mineral chemistry, geochemistry and genesis of the V-Ti-Fe deposits and a limited incidental discussion of the associated lithological units.

This work is based on a total of three months field study and geological mapping, microscopic examination of 140 thin sections (including ores) and 50 polished samples of V-Ti-Fe ores, modal analysis of 53 rocks, XRD study of separated ore samples, chemical analysis of 24 ores and 16 associated rocks both for major and trace elements and electron-probe micro analysis of 116 individual minerals or V-Ti-Fe ores.

METHODS OF INVESTIGATION

FIELD INVESTIGATIONS:

Field study, mapping and collection of samples was carried out mostly in the months of January and February of 1988, 1989
and 1990. Mapping was done on 1:12500 scale. The geological maps presented here have been prepared on the basis of detailed ground survey. A total of about 200 surface samples were collected representing V-Ti-Fe ores and the associated rock types. Sampling has been done so as to include all noted variations in field characters and to have a good geographic coverage, and care has been taken to study almost all the outcrops of the area.

LABORATORY INVESTIGATIONS:

Microscopic study: In all 190 rock/ore samples were examined in transmitted/incident light. The rocks have been classified based on textural features and mineral assemblages. The grain size values reported here are an average of more than 20 individual determinations. The optical properties were determined with the help of 4-axes universal stage. The modal composition of representative rock samples is obtained using Leitz 6-spindle continuous counter. For each analysis a thin section area of 4 cm² was covered.

Specific gravity determination:
Specific gravity for V-Ti-Fe ores was determined using Walker's steel yard. The ore specimens measuring upto 2 cm³ dimensions were used. The samples were washed thoroughly to remove loose fragments and soil adhering to them and were dried before weighing. The air bubbles on the specimen (while in water) were brushed off before the final readings were recorded.
X-ray study:

Powder X-ray diffraction patterns were obtained for a few V-Ti-Fe ores, ground to less than 200 mesh size, employing a Philips powder diffraction unit (type PM 9920/05). The instrumental setting comprised of 35 kv to 20 mA current, Cu Ka radiation and a scanning speed of 0.04°/sec.

Mineral separation required for XRD study was done by combined bar magnet and high intensity 'Frantz Isodynamic magnetic separator' (Model 2-1, New Jersey). Fuller separation was ensured by repeatedly passing of the samples through the isodynamic separator using 0.2 and 0.4 amp. current and giving 5° side and 25° forward tilt.

Mineral analyses:

The mineral analyses were carried out by Prof. Devaraju and Dr. Beate Spiering at Mineralogisch-Petrologisches Institut and Museum, Der Universität, Bonn, Germany. The samples were analysed with CAMEBAX Microbeam using the ZAF correction programme. The operating conditions of the microprobe were 15 kV acceleration potential and a take off angle of 40°. For V, Cr, Fe, Co, Ni and Mo pure metal standards and for the remaining elements oxide standards were used.

Chemical analyses:

The analysis of 24 ore samples was carried out by the author mainly at AMSE wing of GS1, Bangalore, under the direction of Dr. P.P.Naidu, Director of geochemistry. All the elements except FeO were determined using Atomic Absorption Spectrophotometer (Varian
SpectrAA-30 and Perkin Elmer-403). Precision and accuracy of the analyses were checked by repeatedly analysing rock/ore standards. Since the oxidation state of iron cannot be determined by AAS method, the ferrous iron content was analysed titrimetrically, and ferric iron was obtained as the remainder after subtraction of the ferrous iron from the total iron content determined by the AAS technique.

Major and trace element determinations of a few rock samples closely associated with the V-Ti-Fe ores were carried out mainly by XRF using PW 140 Philips X-ray spectrometry system at the AMSE, GSI Petrological laboratory, Bangalore. Some trace elements viz: Co, Zn, Cu, V, and Sr were determined by the AAS method.

**Digestion procedure for AAS analyses:** The determination of concentrations were made by digesting 0.1 gm (for major elements) and 0.2 gm (for trace elements) of the finely powdered samples in teflon acid digestion bombs by using 10 ml 48% EL grade hydrofluoric acid and 2-3 drops of conc. sulphuric acid. The digestion temperature required was 130°C for two hours in a thermostat controlled oven. After thorough digestion and cooling, the teflon cup was taken outside and heated on a hot plate to complete dryness. 5 ml of 1N HCl was added and after making upto 100 ml (for major elements) and 50 ml (for trace elements) by using double distilled water, the solution was stored in polythene bottles.

For SiO$_2$ determination, after thorough digestion of 0.1 gm
of the sample on the same lines as mentioned above, 50 ml of saturated boric acid was added and the volume made upto 100 ml by adding double distilled water.