CHAPTER I

1.1 INTRODUCTION:

The study of sulfide ores is gaining increasing importance in recent times, since they are considered to be the potential source for many valuable metals, particularly base metals. The crustal rocks of various composition have been found to host sulfides, though the geological conditions of formation vary considerably from one type to other. From the literature available on sulfides, it can be seen that there appears to have been a favourable geological environment for the sulfides to get segregated and get emplaced during Precambrian period. The wide spatial distribution of sulfides is noticed in rock types of plutonic, volcanogenic and sedimentary origin and in most of the cases they are to a greater extent hydrothermally influenced. Close spatial association of sulfides, particularly with mafic and ultramafic rocks of Precambrian age have been traced out in many parts of the world. Owing to their diverse association with crustal rocks of different nature, they pose challenging problems regarding their evolution and mode of emplacement.

The State of Karnataka, from where the area for present study is selected, is a cratonic portion and forms the southern part of the Peninsular India (Map 1). The cratonic portion is a site of intense mineralising activity which contributes
substantial parts of many metals. The rich mineral resources are associated with the early Precambrian schists, greenstones and granitoids which have been intensely altered, metamorphosed and structurally disturbed to various degree. Occurrence of copper sulfides in this region have been reported from time to time by Officers of State Department of Mines and Geology engaged in regional geological survey. The potentialities of many of these individual occurrences, however, have hardly been reported. The known occurrences of copper sulfides in Karnataka have been broadly grouped into six categories as 1) those associated with ultrabasic complexes connected with the early stages of magmatic activity; 2) those associated with quartzite and quartz schists of lower Dharwars; 3) those associated with shear zones in the greenstone schists; 4) those associated with hydrothermal lode deposits parallel to gold bearing lodes; 5) those associated with major fault zones cutting across regional foliation and 6) those associated with platform sediments (Radhakrishna 1974).

A unique occurrence of copper sulfides in a diabase which is confined to a fracture zone in the Precambrian basement complex, is located near Thinthini, a village in Gulbarga district of Karnataka State. In the vicinity of this village, old workings are evidenced in the form of pits and mine dumps which have helped in locating this deposit. As a result of deformative activity the diabase, along with the adjacent rocks
is sheared and fractured and these shears and fractures have been mineralised. This mineralised fracture zone cuts across the regional foliation with an east-west trend. Apart from the sulfide minerals like chalcopyrite, pyrite, pyrrhotite, bornite and cobaltite, oxide minerals like magnetite-ilmenite and specular hematite are also present. Textural relationship between these minerals and mineral assemblages await a detailed study to understand the physico-chemical conditions of formation of these minerals. The major rock types surrounding this deposit are porphyritic granite, granitic which are gneiss and migmatite/traversed by pegmatite and aplitic granite. Scattered amphibolite outcrops are seen with granitic rocks as enclaves. Abundant epidote veins are seen traversing all these rock types.

The present study, though confined to the detailed study of the highly mineralised diabase and surrounding rocks, an attempt is also made here for a detailed field investigation in the entire area (about 150 sq.kms.) to collect evidences, through which the extent of mineralisation can be understood. Besides this, a careful ore microscopic study of major diabase intrusives, other than the ore bearing dyke, have also been undertaken to recognise the possible presence of the ore minerals.
1.2 LOCATION, EXTENT AND ACCESSIBILITY:

Thinthini is a village (Lat. 16°23'; Long. 76°43') in Gulbarga district of Karnataka State (Fig.1.1). The discovery of the copper deposit in the vicinity of this village has brought it on the mineralogical map of India. It is situated on the northern bank of river Krishna, close to the Krishna bridge. It is connected by a good road to Yadgir (about 80 kms.) on the main Guntkal-Bombay line which is the nearest railway station. The opening of Thinthini bridge across Krishna river has enabled easy access by road from Raichur and Bellary. The Hutti Gold Mines is close to the Thinthini copper deposit (about 40 kms. south). The total area of present study covers about 150 sq.kms. lying between Lat. 16°20' - 16°25' and Long. 76°35' - 76°45' and it is covered in the toposheet No.56 D/11 of Survey of India. The sulfide mineralised zone occupies almost the central portion (Map 2). The presence of small network roads and cart roads makes the area easily accessible for investigation.

1.3 PHYSIOGRAPHY:

The area forms a plain with local undulations at an elevation of 471 mtrs. above MSL, forming part of the Krishna valley (Figs.1.2 & 1.3). Rapid erosion in the neighbourhood of the river Krishna has resulted in an intimate dissection of the plain land into numerous hillocks of porphyritic granite
causing local undulations. A stretch of low lying hillocks lie along the southern bank and isolated hillocks along the northern bank of the river (Figs. 1.2 & 1.3). To the northwest of Thinthini extensive outcrops of porphyritic granite are exposed in the form of hillocks. The prominent peaks are

△500 mtrs. S30°W of Bankaldoddi, △495 mtrs. southwest of Pidoddi, & △508 mtrs. southeast of Basapur. The elevation of mineralised zone is 380 mtrs. above MSL. The Krishna river in the area flows at an elevation of around 368 mtrs. above MSL, with a breadth of about 700 mtrs. The deposit under investigation forms a low mound, to the north of Krishna river and stretches to east and west of the Gulbarga-Lingasugur main road (Map 2).

1.4 CLIMATE AND RAINFALL:

The climate is generally dry and arid. The hottest months are between March and May. The maximum recorded temperature is 42.7°C in the month of May 1966. Lower temperature prevail in the months from November to January. The rainfall is low averaging 749 mm. per year. Usually June to October is the rainy season. The monthly average rainfall for the last 12 years (till 1975) indicate that the rainfall will be maximum in the month of September and minimum in the month of January.
1.5 SOIL COVER AND VEGETATION:

Major part of the area is covered by red soil which is resulted from the weathering of granitic rocks. Patches of dark soil, which have been brought by river floods are also seen along the low lying river banks. Around the copper deposit red soil is predominant which has been cultivated. The black soil which resembles black cotton soil is mainly spread as plain land in the north and northwestern portions of Thinthini. In some places mixture of red and black soil is seen, which is mainly resulted due to the mixing of clay soil brought by the river, with the pre-existing red soil. Groundnut (Arachis hypogea) and jowar (Sorghum volgare) are the common agricultural crops grown in these soils. Natural vegetation is scanty. Herbs and bushy shrubs are found in the open jungles, which are generally confined to small hillocks of porphyritic granite. Pareneal trees are almost nil.

1.6 FREQUENCY AND NATURE OF OUTCROPS:

Extensive outcrops of porphyritic granite are seen in the form of hillocks. They are represented by boulders of various dimensions (Figs.1.4 & 1.5). These ridges of granites are frequently intruded by diabase dykes, and their contacts are well seen. The frequency of outcrops of other rock types like granitic gneisses, migmatites and amphibolites is far less. Around the mineralised dyke near Thinthini, isolated
but good outcrops of all the rock types are exposed in the form of small patches, and bands. The remaining portion is red soil and is cultivated. In all the exposed outcrops the surfaces are fresh and clear and indicates lesser impact of weathering. The mineralised diabase is frequently encrusted by malachite and asurite with limonite dust. Veins of caloite and quartz carrying sulfide minerals are invariably exposed in the open mine in the near surface levels (Fig.1.6).

1.7 PREVIOUS WORK:

Ancient mining activity at Thinthini is evidenced in the form of open excavations, shafts and mine dumps. The old workings are situated about 1 km. away from the northern bank of the Krishna river and about 3/4th km. due west of Thinthini village. There are three main old workings near Thinthini. Due to fallen debris the depth of these workings is difficult to gauge, though earlier reports mention that one shaft had reached a depth of 24 mtrs. (Radhakrishna 1967). Dumps are seen at many places of these old workings and few samples indicate the dominance of pyrite and chalcopyrite crystals. This area was examined by Bouward (1891), Captain J.M.Rodus (1894), K.V. Thomas (1899), K.T.Knight (1899), F.W.Gray (1899), and Bosworth Smith (1906) (in Thinthini feasibility Report 1975) of Deccan Mining Company from time to time for proving gold as they happened to be near Hutti Gold Mines. Bouward (op cit.) was the first to notice the old workings and he recorded in his
notes that the workings were in schists and were probably excavated for iron ore. Grey (op. cit.) was the first to point out that the old workings were not for gold but might have been for copper. It was Bosworth Smith (op. cit.), Consulting Engineer for Deccan Gold Field Development Corporation Ltd., who first reported that the old workings at Thinthini were for copper.

Mahadevan (1941) of the Hyderabad Geological Survey gave an account of the geology and mineralisation at Thinthini. He opined that the Thinthini patch of schist was mainly diabasic and highly mineralised with pyrite, chalcopyrite and arsenopyrite.

Krishnamurthy (1963) of Geological Survey of India carried out a preliminary examination of the property. According to him mineralisation is seen over a strike length of 3 kms. within the sheared, brecciated and faulted zone in a thin band of metavolcanic schist inlier of Dharwar age. The ore shoot is stated to pinch easterly while the host rock steeply dips northwards. Assay values of representative samples collected from the dumps ranged in value from 0.099 to 0.62% Cu.

Radhakrishna (1967) has reported the occurrence of copper ores in porphyritic granite and sheared dyke in the vicinity of Thinthini.

Viswanathaiah and Krishna Rao (1973) have given an account
of the geology, mineralogy and structural control of sulfide mineralisation at Thinthini. They have opined that the structurally controlled sulfide mineralisation in diabase dyke is mainly by hydrothermal solutions, which were derived at the later stages of diabase emplacement. They are of the opinion that the associated granitic rocks are of anatectic and metasomatic origin.

Radhakrishna (1974) in his attempt to group copper ore occurrences in Karnataka has opined that the copper mineralisation at Thinthini is associated with major fault zone, cutting across the regional foliation.

Vasudev (1983) while studying the sulfide deposits of Dharwar craton has reviewed the nature of copper mineralisation at Thinthini. He categorises Thinthini sulfide deposit as fracture controlled cavity filling epigenetic hydrothermal type. He further opines that the deposit is younger to the potassic granites (Closepet granites) and the dyke intruding them.

The State Department of Mines and Geology took up drilling of the mineralised zone in the year 1969 as a part of its programme for evaluation of copper deposit in the State. Radhakrishna and Sundararajan (1972) have given a brief account of the exploratory drilling carried out by the Department, to the end of 1972 in which 15 boreholes ranging in depth from 55-273 mtrs. and totalling 1550 mtrs. have been drilled over a strike length of 750 mtrs. Since 1972, 11 more boreholes
have been drilled. Out of these 6 drill holes fall on the western block (the mineralised dyke portion lying west of Lingsugur-Gulbarga Road - Map 3.1) of the mineralised zone. The total strike length covered by these boreholes in the western block is 773 mtrs. All most all the boreholes have intersected a rich but narrow zone of mineralisation within diabase at the mineralised contact with porphyritic granite. All the drill holes intersected an east-west trending dyke showing mineralisation over a width ranging from 4.5-15 mtrs.

1.8 SCOPE OF THE PRESENT WORK:

The present work aims at detailed investigation of sulfide deposit and the associated rocks around Thinthini area. The previous work by earlier investigators was mainly restricted to the mineralised zone and records only the general geology and mineralogical constituents of the rocks of the area. The adjoining area surrounding the mineralised zone has not been studied. Therefore, the scope of the present work is to give a detailed ore microscopic, petrological and geochemical account of the sulfide ores and various lithological units of the mineralised zone and surrounding area. The present study gives a detailed account of the different ore minerals, their mineralogy, texture and paragenesis. The lithological types occurring around the mineralised zone are also subjected for a detailed mineralogical and chemical study. Trace elements have been determined in some of the samples of both ore
minerals and host rocks. Based on these studies inferences have been drawn regarding the nature and origin of ore deposition, temperature of formation, sequence of ore mineralisation, the relationship of the ore minerals to the host rocks etc. The nature of ore mineralisation and possible structural control of ore mineralisation is also discussed. With the aid of a geological map prepared in detail employing appropriate field and laboratory techniques, mutual relationship among the different rock types, is discussed. An attempt is also made to understand the spatial spread of mineralisation in the entire area of about 150 sq. kms.

1.9 METHOD OF INVESTIGATION:

1.9.1 Field investigation:

The interpretation of various geological features are about based on detailed field study and mapping of 150 sq. kms. of the area for about 3 months spread over in two field seasons. The geological map of the area has been prepared on the enlarged scale of 6 cm: 1 km. and subsequently reduced photographically to the present size. Owing to the isolated distribution of outcrops of different lithological units, at many places, the geological mapping was difficult. The mode of occurrence of ore minerals and their relationship to host rocks is studied at mine sites, where they are well exposed.

Samples representing various lithological units with
mineralogical and textural variations have been collected. Besides, ore samples were collected at regular intervals on the mineralised zone, and also from the ore dumps removed from the underground mine. Core samples were selected from different drill holes, at the mineralisation points. All these samples were subjected to various investigations which are described in the pages to follow.

1.9.2 Laboratory investigation:

a) Petrographic studies: As many as two hundred thin sections from out of the representative rock samples, and nearly hundred polished sections from out of the representative ore samples, collected during the field work, were examined. The rocks were then classified petrographically on the basis of their mineral assemblage and texture.

b) Optical studies of transparent minerals: The refractive indices were determined by immersion method using calibrated liquids. These determinations have been made in sodium light. In case of biaxial minerals only the n\(\beta\) was determined directly by扫描ing out suitable optic axial sections from thin section.

The other optical characters such as 2V, Z\(\alpha\)c, birefringence, anorthite content, twin laws and pleochroism were determined on 4 axes universal stage, according to the methods enumerated by Haidu (1958).
c) Optical studies of ore minerals: Polished ore sections were studied under Meopta and Zeiss ore microscopes. The optical properties like colour, birefringence isotropism/anisotropism were studied along with the physical properties like intergrowth and twinning. Optical properties were determined in air under microscope and also by using oil immersion methods. Etch tests were conducted for the different mineral grains. Quantitative determination of microhardness was done by using Carlszeiss Jena Vicker's microhardness tester. All these investigations were mainly aimed at the correct identification of the ore minerals and their relationship to each other.

d) Modal analyses: All the modes given in this work are determined on Swift's automatic point counter.

e) Chemical analyses: Major element determinations for powdered samples of representative rock types have been done. SiO₂, Al₂O₃, Fe₂O₃ (as total iron), TiO₂, MnO were determined on Beckman Dv-2 spectrophotometer following the procedure detailed by Shapiro & Brannock (1962). FeO was determined by titration method (Vogel 1962). CaO and MgO were determined by EDTA method and Na₂O and K₂O were determined on Carlszeiss Flame photometer.

Trace element analysis for both rocks and ore minerals has been carried out. The representative rock samples were
crushed to -200 mesh and final crushing was made in an agate mortar. The specimen ore mineral samples (chalcopyrite and pyrite) were separated by hand picking, heavy liquid separation and the Frants isodynamic magnetic separation methods. The grain mounts from the chalcopyrite and pyrite fractions were prepared and examined for purity before analysis.

The trace elements were determined spectrographically on a Jarrel Ash 3.4 m Ebert plane grating type. 20-25 mg. of finely crushed (-200 mesh) sample powder was diluted with pure graphite palladium which was used as an internal standard. Arcing time analysis lines were made on the basis of moving plate studies. The concentration of different trace elements was calculated with reference to the synthetic standards (spectrographically pure elements) prepared in the same manner as the unknowns.

1.10 REGIONAL GEOLOGY:

The province of Karnataka which constitute the southern part of Peninsular India, a classical area for the study of Precambrian geology is also the home of well known ancient rocks - the 'Dharwars'. This cratonic portion is a model for Precambrian supracrustal belts and the vast sea of migmatitic gneiswes. The Dharwar system or Dharwar schists, as the supracrustals in Karnataka are called, cover about 1,28,000 sq. kms. and consists of a complex of crystalline schists, with
ultrabasics like amphibolites, peridotites and dunites.

Greater part of the State covering about 1,48,000 sq.kms. is made up of rock formations belonging to archean complex. The schistose rocks which are mainly green stones are found as long and narrow bands of various dimensions running usually NW-SE or NNE-SSW in gneissic rocks (Map 1). These schistose rocks are grouped into 7 or 8 main belts (Rama Rao 1962). The most striking feature of Dharwar schists is their remarkably uniform dip and strike. The schistose rocks in this region are named after the places around where they are well exposed. The gneissic complex which surrounds the Dharwar schists cover a much larger portion of the archean complex of Karnataka and consists of several types of granitic rocks varying in structure, texture, colour and other characters. This gneissic complex has been grouped into four successive epochs of igneous intrusion as 1) Champion gneiss, 2) Peninsular gneiss, 3) Charnockite and 4) Closepet granite (Smith 1916). Some parts of the State comprises succession of several sedimentary and eruptive rocks which have undergone repeated tectonic disturbances.

Regionally the area of present study forms a greenstone granite complex in the Karnataka craton. The prominent greenstone belt adjoining to the present study area is Hutti-Muski schist belt. This constitutes two different bands - the northern band which is north of Krishna river, forms the Shorapur band and the southern band which is south of Krishna
MAP 1. GEOLOGICAL MAP OF KARNATAKA CRATON SHOWING THE DISTRIBUTION OF THE SCHISTS AND GNEISES. THESIS AREA IS SHOWN IN THE INSET.
river constituting HuttI band. The northern band is about 40 kms. in length with an average width of about 10 kms. The southern - HuttI-Muski band runs for about 80 kms. attaining its greatest width/about 9 kms. in its northern section. In both these bands hornblende schists predominate over the chlorite schists. There are several old workings for gold in both the bands, particularly in the lower or HuttI band around the HuttI Gold Mines, now being worked. The granite complex of the area according to the regional classification by earlier workers forms an integral part of the Closepet granite. Closepet granites in the region form a well defined band/about 16 kms. wide running N-S for more than 325 kms. from Molakalmur in the north to Closepet in the south. In the area of present investigation it (Closepet granite) comprises a wide range of coarse grained pink porphyritic granite, granitic gneiss and migmatites and forms a back drop to the schist belts (Map 1). Though earlier workers assigned Closepet granites for a single magmatic event, it is the present view that it comprises granites of all ages.

Noting the importance of their (schists and gneiss) evolution in understanding the stratigraphy, structure and metallogenetetic aspects, the author feels to briefly review the status of greenstone-granite complex in the Karnataka craton. BrucefOrte (1888) was the first to name the schistose rocks as 'Dharwars' assigning them to a system. It was the
earlier views that the schistose bands are the remnants of a great formation which probably covered a large part of the gneissic complex and which have escaped denudation. However, Pichamuthu (1953) and Radhakrishna (1968) felt that the schist belts did not extend much beyond their present margins. Radhakrishna (1976) was able to recognise two groups of greenstone belts during his study of Muggihalli, Kolar, Ramgiri and Hutti schist belts. According to him the older group to which Hutti schist belt belong, occur as lensoid bodies with limited extensions and has been invaded by acidic rocks of tonalitic composition resulting in the widespread development of migmatitic gneisses, whereas the younger group occur in well defined NNW-SSE trending belts traceable continuously for over 500 kms. along their strike. This younger group is predominantly composed of sediments with volcanic intercalations in concentrated/the base.

The two greenstone groups are also characterised by distinctive mineralisation episodes. The older sequence (Arechana) is found to host chromium, nickel, gold, copper, iron, vanadium and titanium mineralisation. As distinct from this older sequence with its characteristic metal associations, the younger greenstones sequence (proterozoic) is marked by the presence of orthoquartzites and conglomerate at the base carrying gold, uranium and copper of detrital origin. The two sequences are separated by a period (2900 m.y.) of granitic activity which resulted in wide spread migmatisation of the
older group of greenstones. While the gneissic rocks show intrusive relationship with the older greenstones they form the basement for the overlying younger sequence of greenstones. Though intrusive model is proposed by earlier workers for gneissic complex in the region, it is evidently shown by recent workers (Suryanarayana 1960, Naik 1965, Devaraju 1968, Ekramuddin 1968, Mahabaleswar 1970) in many parts of the gneissic complex, particularly in Closepet granite areas, that they have been formed by metamorphic and metasomatic processes.

Inspite of the immense work done on the greenstone granite complex of the craton, their relative stratigraphic position and the evolution is still a matter of great controversy. At present the schistose rocks which were once assigned to a single system as 'Dharwars' have been grouped into two groups as 1) Sargur Group representing high grade schists and 2) Dharwar Super Group representing typical greenstone belts. In the recent classification of cratonic rocks by Swaminathan and Ramakrishnan (1981), the relative position of the different schists and their gneissic counterparts are as shown in Table 1.
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<td>~3000-2600 m.y.</td>
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<tr>
<td>Late Archaean (Kenovan)</td>
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A view of Thinthini village. Open mines in the foreground and granitic hillocks in the background are seen.

Photographs showing Krishna river valley. A long stretch of mounds of porphyritic granite to the south of the river and isolated small hillocks to the north are seen.
1.4 Small hillocks of porphyritic granite covered by boulders.

1.5 Ore bearing veins in the surface levels of fractured diabase.