C. SUMMARY AND CONCLUSION

a) Summary:-

Deposition of chromite ore, specially in an orogenic belt is in the heart of controversy from the period when the theory of plate tectonic and associated mineral deposition was proposed in the end of 1950s. The intimate association of chromite deposition in an orogenic belt and emplacement of ophiolite belt has been now universally accepted (Cyprus, Turkey, Japan, Cuba etc.). A typical ophiolite belt with ultramafic metamorphites; massive and layered ultramafic complex comprised of dunite-harzburgite-wehrlite-lherzolite-pyroxenite-gabbroic complex; volcanic complex intimately associated with shale, sandy shale, pelagic limestone, radiolarian chert and graywacke passes over the Indo-Burmese border region, a small part of the massive north-south cordilleria which emerges in western China and ends somewhere in the south of Andaman-Nicobar islands.

A very small section of this belt, around the hamlet Khudengthabi (N 24°17'55", E 94°15'32") situated on the National Highway No. 39 has been selected for our study (area-500 sq.km, latitudes: N 24°15' to N 24°20', longitudes: E 94°15' to E 94°17'25") to understand the association of chromite ore with the ultramafic complex, and the relationships of the ultramafics with the sedimentary rocks of Disang Group (Upper Cretaceous).
Chromite mining was commenced in 1976 by M/S Orissa Industries and the work stopped in 1984 as the near surface ore reserves were exhausted. Our study was conducted primarily to understand inter-relationship between the ultramafic complex and sedimentary rocks; relationship between the chromite ore and ultramafic rocks; genesis of the chromite ore, variation of the chromite ores i.e. disseminated, orbicular, nodular, podiform, and lensoid, massive fine-grained chromite; genetical reasons behind the morphological variation of the chromite ore; temperature pressure regime of chromite ore formation; macro and micro structures and textures of the chromite ore and the significance of these features; process of emplacement of the chromite ore in the crustal region as deciphered from the structure, texture and mineral associations.

As the by-product of this work, investigation on other commercial and noncommercial economic minerals and rocks occurring in the Khudengthabi area has been also studied, but not in much detail.

This work is a part of the general geological study conducted by the geology department of Gauhati University under the supervision of Dr. P.J. Deka to study the metallic and non-metallic mineral occurrences in the Indo-Burma border region, a scheme sponsored by North Eastern Council, Shillong. The present author has started the work from January, 1984, three field trips were made with the total duration of five
months in the field season, on 1984-85, 1985-86, 1986-87. Much of the work has been conducted with the help of geologists of Directorate of Industries, Government of Manipur, and M/S Orissa Industries. Laboratory work has been done in the department of geology, Gauhati University. Chemical analysis were done in the department and also in outside laboratory. Geological works and mechanical works with the serpentinized marble was done in the Gem Testing Laboratory, Jaipur, Gem Testing Laboratory, New Delhi and Arunadaya Rock Cutting Industry, Jaipur.

In the introductory chapter, general information about the location and accessibility, physiography, drainage pattern, short botanical and zoological note, soil type, climate, notes on inhabitants have been given. In the same chapter, the background information on previous geological, geophysical records, previous records on economic minerals, mining and exploration works have been given. In the last part of the introductory chapter, the author has described the geomorphology and the distribution pattern of economic minerals near the Khudengthabi village. A short review on field and laboratory work has been given.

The second chapter deals the geology of the region with a brief report on the geology of Nagaland-Manipur ophiolite belt. Geology of the Khudengthabi area has been described in detail giving the geological outline and geological struc-
ture around Khudengthabi area. Geology of the ultramafic and associated rocks of Khudengthabi area is given with detail. Petrographic descriptions of harzburgite, wehrlite, lherzolite, massive peridotite, layered peridotite, hornblende peridotite, dunite, gabbro, pyroxenite, bronzilite, serpentinized marble and amygdaloidal extrusive rock are studied in detail. Petrology of serpentinite and its distribution is also given in this chapter.

The third chapter is written on economic minerals, divided into two major groups: (1) Chromite ore and (2) Minor economic minerals associated with the chromite ore. While describing the chromite ore, the author has given as far as possible, a detail physical description, mode of occurrence, distribution of the ore, and various types of chromite ore: namely disseminated chromite, orbicular chromite, nodular chromite and massive chromite. The nodular chromite has been further divided into seven types, namely spheroidal, elliptical, ovoid, collapsed, lineated, coalescent and concrescent. The massive chromite has been divided into three major types namely coarse-grained banded massive ore (cumulate), podiform massive ore (residual) and fine-grained massive ore (mobilised).

In the third chapter itself, the geochemistry of the chromite ore and geothermometry have been dealt in.

The second part of the third chapter deals with the minor economic minerals associated with the chromite ore
namely, magnetite, auriferous minerals and nickeliferous minerals. Physical description, mode of occurrence, microstructural relationship between these minerals and the chromite ore have been dealt elaborately especially on the observation made on the polished surface of the ore.

The last part of the third chapter deals the genetic inferences made on chromite ore based on ore microscopic studies, ore petrology and geochemistry of the chromite ore. The problem of genesis of chromite ore of Khudengthabi has been postulated basing upon the structure and texture of the ore: gravity settling of chromite grains and nodules; formation of chromite nodules; origin of coarse-grained massive banded ore, formation of massive podiform ore and emplacement of massive fine grained ore.

A new hypothesis is forwarded to explain the formation of chromite nodules and this has been correlated with the intrusion of chromite bearing magma.

A section has been added on the significance of the proposed ore genesis and its use in chromite ore prospecting in an ophiolite belt.

The fourth chapter deals with the problem of idocrase occurrences discovered by the workers of Gauhati University in the Khudengthabi-Moreh region. Distribution of the idocrase mineral has been described with the physical description as colour, form, petrological association and mineralogy.
In the fifth chapter, the author has described a valuable commercial decorative rock namely serpentinized marble reported for the first time in the Manipur-Nagaland ophiolite belt. Apart from distribution and mode of occurrence, the industrial potential has been dealt in detail giving information about raw material, machineries, electricity, water, labour, commercial viabilities and possible industrial centre along with transport and marketing. The serpentinized dunite, commercially known as the Madras Black Stone has been dealt briefly.

The sixth chapter discusses briefly the geological history of the Khudengthabi area and its influence to the ore genesis.

Mineral economic potential of the Khudengthabi area with the economic significance of idocrase and chromite has been dealt in detail.

b) Conclusion:

The present work has shown that the Disang Group of the sedimentary rocks of the Upper Cretaceous age has been deposited in a N-S lying trough, which has been variously identified as eugeosynclinal trough, or as a subduction zone. The change of sedimentation pattern starting with radiolarian chert and shale at the bottom, pelagic limestone, sandy shale, conglomerate, and graywackes signifies a gradual shallowing
of the trough towards the uppermost Cretaceous age. Volcanogenic sedimentary rocks are extrusive rocks embedded with the limestone, which formed the green serpentinitized marble, after the introduction of ultramafics indicate igneous activities prior to the major orogenic upheaval. After a period of quiescence, olivine peridotite followed by dunite-harzburgite-wehrlite-lherzolite has been introduced into the sedimentary rocks. Most of the workers working in the area after 1960s have accepted that the ultramafics have been tectonically emplaced within slightly metamorphosed sedimentary rocks. Our observation is that though the contacts are often highly tectonized and the ultramafics have been often truncated, sliced, faulted and even thrust, at some less disturbed area, the distinct intrusive character can be recognised by partially assimilated graywacke rocks within the ultramafics similarly fingers and lenses of ultramafic within the slightly metamorphosed and disturbed sedimentary rocks. There was a time interval between the intrusion of peridotitic rocks and gabbro. Marl beds enveloped by the gabbroic and pyroxenite rocks has been metamorphically and metasomatically affected which resulted in the formation of idocrase, diopside, grossular garnet and hydrogrossular garnet.

The chromite ore, as we understand, has been introduced into the crustal region along with the highly mobile peridotitic magma probably in the form of already crystalli-
zed grains. The magma was hot enough to assimilate graywacks, but in a single introduction their volume was little so as not to bring in regional metamorphism. There must be a number of introduction of already differentiated magma from the mantle into the crust.

The chromite grains in a fluid magma were precipitated to form banded massive chromite showing cumulate structures. In an upwelling magma flowing from chamber to chamber through naturally expected constraint will have an intermittent flow as a result of which a number of eddies will be formed and chromite grains congregated in the vertex will form nodules.

If the magma flow is stopped due to clogging of the channel, a high pressure regime will be locally formed and the ore will change to a massive podiform ore-body. If the pressure become extremely high, the constraint will be broken and ore will be pushed out like 'tooth-paste from a tube' and they will form the fine-grained massive chromite ore.

In the Khudengthhabi region, that is in an Alpine-type chromite-deposit, one can get four genetical varieties of ore i.e., cumulus (coarse-grained banded massive, nodular) residual (podiform massive), mobilised (fine-grained massive) and late—formed ore (disseminated grains).

The chromite deposits of ophiolite belt in Manipur, structurally, texturally and by mineral assemblage are typical
Alpine-type deposit.

Our present work is too limited in scope to ascertain any definite mode of emplacement of the chromite ore into the crust, but not any single processes proposed by different authors i.e. magmatic sedimentation, fractional crystalization from the magma in situ, mobilisation of crystal mush, introduction of cool diapirs can explain all the observed structures, textures and spatial relationships of the chromite ore with the igneous and sedimentary rocks. The author considers that the introduction of ultramafic chromite bearing magma in an erogenic belt suffering from intermittent tectonic movements during their introduction will give rise to physico-chemical regime where chromite will be deposited as magmatic sediments, banded ore, nodules and orbicules; and they will also form podiform ore and fine-grained massive lensoid ore bodies.

Formation of idocrase and serpentinized green marble deposits are result of introduction of ultramafic magma into pelagic limestone and marl beds.

Our present work scratches only the surface of the great geological mystery of the ephiolite belt.