CHAPTER VI
DISCUSSION

A. GEOLOGICAL HISTORY OF THE KHUDENGTHABI AREA AND ITS RELATIONSHIP TO THE ORE GENESIS:

Our work has covered infinitesimally small area of a mountain range, which runs for thousands of mile from the western China to the south of Andaman-Nicobar islands. It will be even wrong to attempt to decipher the intricate geological history of the mountain range basing on the work upon this small area. Our attempt is to understand the history of the ophiolite belt of Nagaland-Manipur and therefrom to understand its role in the genesis of ore mineral deposits in the Khudengthabi-Moreh area.

The Penrose conference (1972) on the ophiolites, organised by the Geological Society of America has unanimously accepted that the ophiolite complex is represented by a suite of: (1) Ultramafic complex usually with the metamorphic and tectonic fabric, which are more or less serpentinized. (2) Gabbroic complex originally with cumulus peridotite and pyroxenite grading upward to layered gabbro, often containing plagiogranite differentiated at the top. (3) Sheet dyke swarms. (4) Pillow lavas forming carapace on the top of the units and interlayered at the top with pelagic sediments and metaliferous precipitates.

Geologist of Geological Survey of India (Venkataramma, 1985) considers that the sediments in the Nagaland-
Manipur Arakan flysch trough was filled up by between Upper Cretaceous and Middle Eocene age. These sedimentary rocks also contain metamorphic peridotite cumulus complex, which include peridotite, dunite, pyroxenite, chromitite and gabbro. A mafic volcanic suite may contain sulphide minerals. The sedimentary rock comprises of radiolarian chert, pelagic limestone. Duarah et al. (1983) considers that the Nagaland-Manipur Arakan trough was a subduction zone established by late Jurassic—early Cretaceous time. The ultramafics form the barren eugeosynclinal flysch basin. Deep sea pelagic and orogenoclastic sediments were also deposited, which includes radiolarian cherts of the Disang Group. The upliftment of the ocean floor took place during Cretaceous time, where pelagic limestones were deposited. The underthrusting movement of oceanic lithosphere beneath the Burmese block probably commences during early Cretaceous time along a N-S directed trench. The onset of volcanic activity took place in early Cretaceous time. The subduction became well pronounced in the Eocene-Miocene period. As a result of continued underthrusting until Miocene times, the overlying Cretaceous–Tertiary sediments underwent large scale tectonic deformation. Slices of the mafic, ultramafic detached from the disrupted oceanic lithosphere, started to move upward displacing the flysch sediments further west. The rock fragment evolves from time to time during the emplacement of flysch ultramafics were subsequently deposited as 'melange clasts' in between the
thrust sheet parallel to the subduction zone.

S. Ghosh (unpublished report) of Geological Survey of India considers the limestone to be rootless allochthonous blocks.

Our work is too limited to make any categorical statement about the geological history on the regional basis. It is beyond any doubt that the Disang shale and associated sedimentary rocks such as sandy shale, varigated shale, were deposited from the middle to late Cretaceous in a N-S extending geosynclinal trough. The lithochronological column established by us is following:

From the bottom, shale intercalated with limestone lenses; sandy shale with conglomerate; shale with limonite nodule; graywacke; green serpenمينized marble with olivine, magnetite and probable extrusive rock fragments; massive oliving peridotite; layered olivine peridotite with cortlandite; dunite; harzburgite-wehrlite-herzolite; gabbro-bronzite-herzolite; dolerite dyke and quartz vein, is not the complete succession. Radiolarian chert and metamorphosed shale with cherty quartz is found just outside the territory in the northwestern part below the marl and limestone lenses.

a) Geological history of the sedimentary trough:

Radiolarian chert:— The radiolarian chert of greenish grey to reddish brown colour contain radiolarians which are identified
to be Novixitus or Xitus sp., Parvicingula(?) sp., Helocyptocanum sp., Archaeodictyomitra sp., Acanthocircus dicranocanthos, Ceruops sp. indicate an early Cretaceous age (Duarah et al., 1983). As for the sedimentation environment it indicates deep sea trough but from the spatial relationship the sediments should considered to be deposited near the continental mass.

Shale intercalated with marl and limestone lenses: - The limestone lenses, which are intimately bedded with the Disang shale have been identified to be pelagic limestone by Duarah et al. (1983) and Venkataramamma (1985), and allochthonous rootless bodies by Ghosh, indicate the gradual shallowing of the basin sometimes in the Upper Cretaceous. Shallowing of the basin is further evidenced by gradual increase of sand percentage in the shale which culminates in the deposition of conglomerate beds. Thereafter again shale has been deposited, which may be an evidence of further deepening of the trough, a structural change evincing beginning orogenic movement. Shale in this period contain sporadic limonite modules indicating a shallow water deposition on the continental shelf. This shale is overlain by the graywacke beds.

Graywacke: - Graywacke as a rock is a definite evidence of mechanical precipitation of feldspar and quartz on or near the continental shelf. To form the graywacke bed, a granitic
or granite gneissic mass must be present on the continent or on an island arc, where from the grains have been carried and deposited without a long transportation. Lack of kaolinization and very little sericitization of the feldspar grain in graywackes indicate that they have been eroded from some unweathered fresh exposures.

Graywackes are the youngest sedimentary rocks observed in the Khudengthabi-Moreh area.

b) Geological history of the igneous intrusion:

The oldest igneous rocks observed in the Khudengthabi area is the serpentinized verd green marble with olivine, pyroxene and magnetite containing small blocks of extrusive rocks.

Extrusive rocks:— Only a few pieces of black cryptocrystalline often rounded extrusive rocks have been observed embedded in the serpentinized green marble. Because of the paucity of sample and extremely disturbed condition of the terrain, it is difficult to ascertain the stratigraphic position of these volcanoclastic rocks. As these rocks contain amygdaloidal feldspathoid and calcite veins, probably the volcanoclastic sediments were deposited interbedded with the pelagic limestone. Subsequent intrusion of ultramafic rocks accompanied by tectonic movements have intermixed the rocks and only remnants of volcanoclastic rocks were left embedded in the
altered green serpentinized marble. In that case, these under­sea volcanoclastic rocks are the first igneous rocks to be formed in the Khudengthabi-Moreh area.

Serpentinized marble with olivine and magnetite:— The ultrama­fies primarily represented by olivine peridotite have intru­ded into the pelagic limestone, thereby altering its physical nature. It is extremely difficult to ascertain the exact nature of the intrusives, but remnant of olivine, pyroxene and magnetite, and the migmatite like structure which has resulted because of the tectonic movement convince us that this is the phase which represent "ultramafic complex with metamorphic tectonic fabric which is more or less completely serpentinized".

Massive olivine peridotite:— There are a few shale beds which have been intruded by the massive olivine peridotite, these beds overlie the serpentinized marble, indicating that there was a time gap between these two intrusives. The massive olivine peridotite has intruded during a period of quiescence as evidenced by their non foliated nature, but the rocks were highly fragmented and jointed, indicating that they were subjected to post hardening tectonic movements.

Layered olivine peridotite:— Layered olivine peridotites are definitely younger that the massive olivine peridotite and progressively they change to a lighter fraction harzburgite­wehrlite­lherzolite. There is no definite boundary between the layered olivine peridotite and pyroxene rich peridotites.
Dunite:- Dunites are a fraction of the layered olivine peridotite rich in chromite grains. There is no distinguishable boundary between the dunite and layered olivine peridotite.

Harzburgite-wehrlite-lherzolite:- The pyroxene rich fraction of the peridotites occupy an elevationwise higher position than the olivine peridotite. These rocks are highly foliated and all the three groups of rocks often gets intermixed. It is interesting to note that the chromite bearing dunites and peridotites are spatially associated with the graywacke beds as most of the chromite deposits are located nearest to the graywacke beds.

Gabbro-bronzitite-lherzolite:- The gabbroic rocks which are located in the northeastern part of the mapped area has got an peculiar association with the lighter fraction of peridotitic rocks. The spatial relationship is probably a tectonic one as the beds between these two groups of rocks are highly disturbed.

The lherzolite, bronzitite and pyroxenite occur as small independent intrusive masses in the central and northern part of the field. These rocks have a crosscutting relationship with the peridotite. These intrusions often envelope patches of sedimentary rocks, thereby inducing highgrade contact metamorphism in these rocks as we see in the formation of idocrase, diopside, grossular garnet and hydrogrossular garnet.
Dolerite dyke:— There is a single dolerite found in the Sibong sector of the Khudengthabi area. This dyke crosscuts the sedimentaries including sandy shale and conglomerate bed. Though the definite relationship between the dolerite dyke and ultramafic could not be achieved, the dyke is probably younger than the ultramafics.

Quartz veins:— Minute hydrothermal quartz veins are found all over the field crosscutting the sedimentary rocks and ultramafic complex. These veins are present in the graywacke extent into the hornblende peridotite and in one case, crosscut even a chromite lens. These quartz veins are even younger than the serpentinization phenomena as they crosscut the serpentine veinlets and in some cases even silicify them.

c) Nature of emplacement of the igneous rocks:—

Majority of the workers working in the Nagaland-Manipur ophiolite belt consider that the igneous complex, primarily ultramafics are obducted pieces of the mantle brought to the subduction zone between the India plate and the Burmese plate (Nagaland Directorate of Geology and Mining, 1972-84, Duarah et al. 1983, Geologists of G.S.I., 1985). Dikshit (unpublished report 1985) considers the chromite-bearing ultramafic to be midoceanic diapirs.

After the study of igneous rocks and their relationships with the sedimentary rocks, we can come to an assumption
that there is not one single process of emplacement of the igneous rocks.

**Extrusive complex:** The remnant of the extrusive rocks observed by us embedded in the serpentinized marble makes us believe that the under sea volcanic activity took place sometime in the Upper Cretaceous and volcanic ashes were deposited in the basin to form volcanoclastic sedimentary rocks.

**Graywackes:** Graywackes are definitely a sedimentary rock, but it is also an indirect evidence of granite-andesitic intrusion in the continent or in the island arc region. No granite or plagiogranite intrusive has been reported yet from the region of Nagaland-Manipur ophiolite belt. Still it is clear that there must have been some feldspathic igneous body formed in between the deposition of volcanoclastic rocks and intrusions of ultramafic.

**Serpentinized marble:** Serpentinitized marble containing remnant of olivine, pyroxene and magnetite has been introduced into the limestone bed under a very unusual condition. The rocks have been highly disturbed as evidenced by their migmatite like complex structure. At the same time the temperature of the whole rock mass must have been low enough so that, the calcite grains were not completely dissociated i.e. temperature did not rise above 300°C. This is further supported by unaltered mobilised limestone blocks left within the serpen-
tinized marble. Some of these blocks still retain their sedimentary bedding structure. Such low temperature could have been possible only if the rocks were still under the water and a very quick dissipation of temperature must have taken place. The near complete serpentinization of the rock also indicate that the host rock was extremely rich in water content.

**Massive olivine peridotite:** The massive blocks of olivine peridotite without any foliation, but having a highly jointed nature shows that the introduction must have taken place in a period of comparative quiscence.

**Layered olivine peridotite:** Layered olivine peridotite has been accepted by earlier authors as obducted block of the mantle into highly disturbed sedimentary rocks. Their juxtaposition is considered to be purely tectonic. Our study have shown that the layered olivine peridotite, harzburgite-wehrlite-lherzolite complex have got an intrusive relationship with the country rocks, which is most prominent in the junction of graywacke-hornblende peridotite (cortlandite) and graywacke-harzburgite. Partial assimilation of the graywacke and xenolith of graywacke within the hornblende peridotite indicate that the intrusive magma had suit high temperature.

The graywacke bed into which the ultramafics are definitely intrusive shows the same dip and strike as the
general sedimentary rocks of the Disang Group, indicating the authochthonous nature of the graywacke. The intrusion was gentle enough not to severely disturbed the bedding plane of the sedimentary rocks.

In the northern and central part of the field, a contrast is observed that the sedimentary rocks such as marl, when enveloped by igneous rocks such as gabbro, pyroxenite or bronzitite, severe high temperature contact metamorphic changes are induced in the sedimentary rocks, because of which high temperature metasomatic mineral such as diopside, grossular garnet and hydrogrossular garnet are formed. At the same time, we see there is practically no metasomatic alteration taking place in the graywacke intruded by olivine peridotites. One possible reason of such anomaly is that the earlier fraction of the intrusive magma must have been quite 'dry' in comparison to later fraction as gabbro and pyroxenite. The other reason is that the graywackes are comparatively chemically inert than limestone or marl beds.

d) Ophiolite intrusives in relation to ore genesis:

The major economic minerals observed by us in the Khudengthabi area are chromite, serpentinized marble and idocrase. The minor economic minerals are magnetite, auriferous minerals and nickel-copper minerals.
Chromite:— The relationship between the chromite and ultramafic has been discussed in detail in Chapter No. III. In this chapter, we would like to bring out only the possible physico-chemical relationship between the ultramafic and the chromite mineralization.

It has been already stated that there are two major schools of thoughts about the emplacement of ophiolite rocks including those which contain Alpine— type chromite deposits. Varma (1986) has mentioned them to be: (1) The older concept which considered that the ophiolite represent the earliest magmatic phase of an ensialic geosyncline. It follows from these that the ophiolites are authochthonous and interlayered with geosynclinal sediments. (2) The currently prevailing view, which regards the ophiolites as oceanic crust generated at midoceanic ridge from where it slowly migrated by ocean floor spreading towards continental margins, there to be subducted into mantle. Further it is also postulated that under special circumstances at plate boundaries, slabs of oceanic lithosphere become detached to over ride the (obduction) continental margin. Miyashiro (1977) recognised three types of ophiolites: Subduction zone ophiolite, island arc ophiolite and obducted ophiolite.

As for the origin of chromite minerals, there are three schools of thought: (1) The classical school (Sampson, 1929; Lindgreen, 1919; Cameron, 1959; Arai, 1980; Winchel,
1941 and others) considers that the chromite grains are just another mineral crystallized from the ultramafic silicate melt having an unusually chromous rich composition. (2) Naldrett and Cabri (1973), Thayer and Jackson (1972) and Thayer (1976) consider the chromite to be the refractory fraction of the remolten crust where the residual part gets concentrated and thereafter emplaced in the crust in the form of hot crystal mush. Singh (1974) considered the introduction of chromite as a 'cold introduction' in the form of diapir. (3) Pavlov et al. (1977) considered the chromites as immiscible oxide magma transported along with the ultramafic magma. It is beyond the scope of our present work to make any categorical statement about the emplacement of chromite in ultramafic magma of Khudengthabi-Moreh region. We can simply state the condition that whatever may be the process of emplacement, it must satisfy the following depositional environment:

1(a). The sedimentary rocks with which the ultramafics have intrusive relationship show only very low grade of metamorphism except in the contact zone indicating that the sedimentary rocks were not subjected to high temperature-pressure environment regionally.

(b). The graywacke beds into which the ultramafics are definitely intrusive show the same dip and strike as the general rocks of Disang Group, indicating their authochthonous nature.
2(a). The intrusive ultramafic magma must have been hot enough to partially assimilate graywacke rocks.

(b). The intrusion was gentle enough not to severely disturb the bedding planes of the sedimentary rocks.

3(a). The intrusive chromite bearing magma was fluid enough to allow settling of chromite grains and nodules in it so that they can form cumulate structures.

(b). Pressure at least in some of the depositional chamber must have been sufficiently low so as not to destroy the nodular structure of the ore.

(c). The pressure regime under which the various types of chromite ores were formed was not uniform.

(d). The magma was well differentiated even before its emplacement as evidenced by layering and crosscutting relationship of different types of ultramafic rocks.

4(a). Neither fractional crystallization of magma in situ, nor 'tectonic emplacement of chromite crystal mush' originated in the mantle can individually explain all the observed structural and textural features in the chromite ore of Khudeng-thabi deposit. Lingering plasticity of chromite nodules till the complete solidification of the qualescing material within the nodules and in the silicate matrix make the nodules vulnerable to deformation, if transported prior to their complete solidification. After solidification of silicate matrix,
transportation of huge solid dunite blocks from the mantle to the crust without disturbing the natural sequence of the chromite ores is difficult to comprehend. Moreover chromite nodules could not have preserved their form in the high static and dynamic pressure regime prevailing in the mantle.

(b). Magma mostly differentiated in the subcrustal region could have carried major part of already crystallized chromite grains mechanically and in the crustal region, which is suffering periodic tectonic disturbances, under normal and expected pressure-temperature regime can form all the known morphological types of ore in an Alpine-type chromite deposits, i.e., banded, disseminated, modular, orbicular, podiform massive and lensoid fine-grained massive ore.

Serpentinized marble:— Serpentinitized marbles are of common occurrence in many of the ophiolite belts as in Seychelles, Italy, California and Japan. They are formed due to introduction of the ultramafic magma into the pelagic limestone in an under sea condition. The presence of water in excess prevents the rise of temperature, thereby preventing the dissociation of calcite. Magnetite may be formed due to serpentinization of olivine and pyroxene grains and they can be also present as magnetic elements in the intrusive magma.

Idocrase:— Idocrase or vesuvianite though a rare mineral, their formation may be important from different genetical process.
Vesuvianite can be igneous, metamorphic, metasomatic and hydrothermal. In the Khudengthabi region, the vesuvianite associated with diopside, orthopyroxene, grossular garnet and hydrogrossular garnet represent a typical high temperature contact metamorphometasomatic phase. These rocks have been further affected by hydrothermal solution as evidence by formation of minute, transparent accicular idocrase crystal in the vugs of metamorphosed calc silicate rocks. However, the majority of the idocrase in the Khudengthabi area is found in the form of cryptocrystalline, massive, translucent rock of light green colour intermixed with grossular and hydrogrossular garnet. In the idocrase itself, there are large percentage of hydrogrossular molecules indicating their metamorphometasomatic origin.

Magnetite: Magnetite ore subordinates in the Khudengthabi region accompanying the chromite ore and do not have any commercial value of its own. Magnetite are seen to be formed by the following genetical processes: (1) Magnetite grains crystallizing directly from the melt occurring mostly as disseminated crystals in the pyroxenite and gabbro. Few grains of magnetite and stringers were also observed in the harzburgite-wehrlite-lherzolite complex, and serpentinized marble. (2) Magnetite found as stringers in the serpentinized olivine peridotite, harzburgite-wehrlite-lherzolite complex, bronzite-tite and green serpentinized marble. Stringers of magnetite
according to Ramdohr (1969) are originated due to process of serpentinization, when FeO was released from the olivine and pyroxene minerals during their alteration to serpentine. Some idiomorphic crystals of magnetite were also observed associated with these stringers indicating that some magnetite may have been formed by direct crystallization. (3) Magnetite grains are also observed associated with chromite grains developing in the edges and also in the cracks of chromite crystals. Such magnetite according to Ramdohr (1969), Thayer (1964), indicate hydrothermal effect on the chromite grains. But as we observed exsolution texture in the chromite ore of massive podiform type. This magnetite also could have been formed due to sudden release from high temperature and pressure.

Auriferous minerals:- Auriferous namely Au-Cu amalgam and auricupride grains are more a geological curiosity than of any commercial value. Au-Cu amalgam occur as blebs within the chromite grains directly crystallizing from the melt as they have been released by the chromite during its solidification. Auricupride grains occur in the minute serpentine veins cross-cutting the massive fine-grained chromite ore bodies. The Au and Cu have been leached out from the chromite grains by the high temperature hydrothermal solution generated due to heating up of the connate water in the surrounding country rock and were subsequently precipitated in the serpentine veinlets.
Nickel and Copper:

Nickel:- Ni as an element is an integral part of the ultramafic rocks, though this part may be counted in millionth fraction. In the Khudengthabi area, we have observed nickel only in the form of nickel bearing serpentine-garnierite. Presence of nickel in the soil is too little in the Khudengthabi area to have any commercial value.

Copper:- Cu occurs in the gold as Au-Cu amalgam associated with the chromite ore. In the copper enriched podiform chromite ore, this copper has been leached out of the ore and deposited on the surface forming an encrustation of malachite showing a pleasant green colour on the rock surface. Chemical analysis of this encrustation is the following: Cu- 1.04%, Ni- trace and S- nil. This copper does not appear to have any commercial value. Copper was introduced with the chromite ore as magmatic melt and subsequently leached out by the hydrothermal solution rich in carbolic acid and sulphur was absent.
B. MINERALO-ECONOMIC POTENTIAL OF THE KHUDENGTHABI AREA:

a) Economic significance of the chromite ore:-

Today probably more than half of the world's production of chromite is consumed by the metallurgical industry, about 40 percent for refractories and the remainder in chemical manufacturing industries.

Chromite is the most widely used of all the steel-alloying elements because of its ability to impart additional strength, hardness and resistance to corrosion. By varying the quantity of chromium, by the addition of other elements, particularly nickel, tungsten, molybdenum, vanadium and manganese and by suitable heat treatments, a bewildering variety of different steels are made.

The chromates and dichromates of sodium and potassium together with many other salts of the elements such as chromic alum and chromium sulphates, are important industrial chemicals, particularly in the tanning and dyeing trades. The chromates of zinc and barium are employed extensively for colouring paints, linoleum, rubber and ceramics. Chromium oxides besides, being a source of the pure metal, is a valuable green pigment and a number of hydrated oxides are obtainable in commerce under various names. Chromic acid solutions are used in chromium plating, in the anodizing of aluminium and in the protection of magnesium base alloys. Chromium salts are used in photography, in the manufacture of safety matches,
in the bleaching of oils and fats, in some types of electrical batteries and as catalysts in the preparation of aviation petrol, methanol and industrial alcohol.

Chromite is a valuable refractory material. The Orissa Industries has been exploiting the chromite ore of Manipur for last ten years for refractory purpose.

The following are the important brands of Orissa Industries (ORINO) in which the chromite is used as refractory mineral:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Brand</th>
<th>( \text{Cr}_2\text{O}_3 ) %</th>
<th>Characteristics and uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>ORICHROME-I</td>
<td>40</td>
<td>Ceramic banded chrome base ramming mass used in high pressure boilers and as neutral layers between basic and acidic bricks.</td>
</tr>
<tr>
<td>2.</td>
<td>ORICHROME-AII</td>
<td>33</td>
<td>Air setting chrome base ramming mass, having excellent dry strength and maintains the strength at intermediate temperature, chemically resistant to slag attack.</td>
</tr>
<tr>
<td>3.</td>
<td>MAGCHROME-I</td>
<td>4.32</td>
<td>Chemically setting magchrome ramming mass for construction and repair both cold and hot steel, and other metallurgical furnaces operating on basic slag.</td>
</tr>
<tr>
<td>4.</td>
<td>INDUCTRAM</td>
<td>8</td>
<td>Specially meant for bottom ramming of electric-arc furnace and open-hearth furnace bottoms.</td>
</tr>
<tr>
<td>5.</td>
<td>ORICASTCHA-I</td>
<td>30</td>
<td>Chrome base castable having excellent strength of 450</td>
</tr>
</tbody>
</table>
kg. cm²/min at 1000°C used for cyclones duct, piping and chutes of petro-chemical and mineral processing industries.

6. ORICASTCHA-II 35 Chrome base castable, resistant to chemical attack of basic fluxes, slag and fumes, good volume stability and resistance to thermal shock. Used in paper industry and non-ferrous furnace.

7. ORICAST CHA-III 28 Having good strength with abrasion resistance, and resistance to chemical attack and thermal spalling. Used in reheating furnace hearth, recovery boilers, aluminium furnace below metal line.

8. ORICAST MC-I 23 Magchrome castable for general use.

9. ORICAST CM-I 25 Chromemag castable for general purpose.

10. MORTAR MAGCHROME 20 Basic mortars.

11. MORTAR CHROMEMAG 33 Basic mortars.

12. GUNCHROME 35 Basic gunning materials.

b) Economic significance of idocrase:-

(i) Uses of idocrase as semiprecious and decorative raw materials:-

The famous gemologist Herbert Smith (1977) recognises idocrase or vesuvianite as a semiprecious gemstone when the crystals are clear olive green or yellowish-brown colour and not facetting. The compact form is termed as 'Californite'
No. 41
Beads and statue made from pale green idocrase of Khudengthabi by the lapidary of Jaipur.

No. 42
Olive-green idocrase of gem quality cut in cabochon form.
No. 43
Statue cut from light green translucent idocrase of Khudengthabi by the lapidary of Jaipur.

No. 44
Statue cut from light green translucent idocrase of Khudengthabi by the lapidary of Jaipur.
and in the trade, it passes under the name of 'Californite Jade' or 'American Jade'. A leaf-green, olive green or yellowish green idocrase is often sold as gem variety of diopside. The 'Californite' or 'American Jade' is the dominant variety in Pumbung valley of the Khudengthabi area. The light green or white coloured idocrase with green strips closely resembles the jadeite mass, which is sold in the market under the commercial name of 'Chinese Jade' or 'Burmese Jade’. A layman or a trader not having expertise in jade trade confuses these two minerals because of having similar specific gravity (specific gravity—Jadeite 3.33, Idocrase 3.3-3.45), hardness (Jadeite 6-6.5, Idocrase 6-6.5), lustre (Jadeite—waxy, Idocrase waxy), excellent polishing qualities or both the minerals. Only a gemological laboratory can differentiate these two minerals because of low refractive indices of idocrase (extraordinary 1.7000 to 1.721 and the ordinary 1.717 to 1.712). The crystalline idocrase has got a vitreous lustre, but such crystals are extremely rare and found in very small sizes (1-2 mm) in the vugs (Photo plate No. 38) of the Khudengthabi area.

Rarity of crystalline variety of idocrase shows that all the compact idocrase masses can be termed commercially as 'California Jade', 'American Jade' or 'Californite.' Our investigation has shown that the massive idocrase can become an excellent commercial raw material for the lapidary industry or for curving high priced arts good for domestic and export market. Three samples of massive idocrase has been
send to Jaipur for cutting and polishing purpose and the results obtained are following:

(1) River born flat boulder from the Pumbung river weighing 1.5 kg. The colour of the sample is light green, in which a number of dark olive green patches are present. The sample was cut in the lapidary Training Institute in Jaipur and three dark green cabochon gemstones pieces were obtained suitable to be checked in the ring or other ornaments (Photo Plate No. 4). The weight of the pieces varies from 2.5 to 3 carat. Commercial pricing in the Jaipur gem market is nearly Rs. 30 per carat. The light green part of the boulder was also cut into cabochon pieces but these were not found commercially valuable.

(2) A piece of massive idocrase having watery green colour weighing 750 gm. has been collected from in situ position of the exposed surface in the upper Pumbung valley and was cut into ornamental beads. The beads can be easily cut into proper shape, polished and the holes can be bored through them using ultrasonic boring apparatus. These beads take good polish (Photo Plate No. 4), but because of the colour which closely resemble to the cheap glass and plastic beads, did not attract much attention of the gem dealers of Jaipur. No attempt has been made to cut stone figure rings and bracelet from these rings.
(3) A massive watery green or colourless idocrase boulders collected from the Pumbung weighing nearly 1.5 kg. has been given to Jaipur artisans to curve stones statue and art goods from the stone. The result obtained was excellent (Photo Plate No. 43, 44) and commercial interest was shown on the massive variety of idocrase as a suitable raw material for curving statues and art goods suitable to be sold in the local and export market.

Our enquiry in the Jaipur gem market has shown that the traders are ready to pay upto Rs. 100 per kg. of massive idocrase, if the sample weighs more than 1 kg and have got no visible flow. A translucent piece (quite rare) can fetch a much higher price. A price upto Rs. 50 per kg. is offered for unsorted massive light green and colourless idocrase boulders in the Jaipur gemstone market.

John Sinkankas (1969, p. 265) states that North American idocrase (californite) has made with considerable successful in the ease of massive types, but less sold for the faceting material. Attempt to sell 'Californite' to the Chinese as a substitute for jade was unsuccessful as nephrite and jadeite products fetch a better price and the precious varieties of serpentine-bowenite and retinalite commercially known as 'Soo Chow' or 'New Jade' and can be supplied at a much cheaper rate.
Reserve:— It is not possible to indicate the reserve of the commercially exploitable idocrase at present as even the preliminary geological survey has not been completed. A number of pits have been dug by us in the field season during 1984-85 in the Pumbunglok and Namchufut river valleys to determine the distribution pattern of idocrase boulders. It has been found that maximum concentration takes place at the stretch between 1½ km. to a distance of 3 km. down the source. The available data are not sufficient to give even a rough estimate of the placer deposits.

The indicator boulders near the source were counted and nearly 120 boulders were found to be above (30x50) cm. size each. Some of the boulders are of (9x1) m. size or above. Considering that a minimum of 30 per cent of the boulders will be economically viable for handicraft units to use, a rough estimate of the exposed reserve of massive idocrase (Sp. gr. 3.4) may be placed at about 1100 tons.

The reserve will much higher, if other exposures around the village Kwatha is taken into account.