CHAPTER III
ORE
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3.1 INTRODUCTION

Deccan Tholeiitic Basalts of diverse composition have been erupted in different geological periods confined to Cretaceous - Tertiary boundary. This Tholeiitic Basalts has never been considered as a possible host to precious metals and base metal sulphides. This pessimistic regarding the metallogenic potential of the Deccan Traps has possibly been a cumulative outcome of the lack of encouraging surface indications of mineralization in a region characterized by Continental Volcanism and experience of locating workable metallic mineral deposits in India only in Archean-Proterozoic rocks.

In the present attempt a base metal occurrence has been studied and its possible occurrence as hydrothermal deposits related or coeval with Volcanism. Number of workers have reported sporadic occurrence of specks and disseminations of base metals (Mulage 1992), Shrinivasan and Rajkrishnan (1993) and Sabale (1993) mostly in the western part of the Traps. Beside the base metal deposits the suspected gold occurrence in the Deccan
Plateau in Alech hills is reported by Ziauddin and Narayanswami (1974). But considering the vast areal extent of Basaltic flows of the Deccan Trap the mineralization manifestations in the form of specks and disseminations are not impressive, therefore have not been attended by many workers. So it must be pointed out that most of the hydrothermal deposits associated with Deccan Volcanism could be deep seated and their alteration product have been represented by supergene sulphides enrichment zone below water table and oxidized zone above the water table. At some places especially in the west coast of Maharashtra surface indication of mineral deposits at relatively shallow depth could be masked by lateritic cover and weathered Trap.

The area attracted the attention of investigators from the information gathered through historical documentation in Marathi that Brass was extracted from this area so this basin was referred as ‘Pital – Dara’ in fourteenth century (verbal communication). During enquiries some of the local liquor addicts narrated that a “local liquor ‘shindi’ gives a better kick than the branded ones” which triggered our explorationists mind to relate this
phenomenon to higher copper content of the soil on which these trees grown, which now a geochemically proven fact now.

The sulphides ore deposit of the Ladole and adjoining area is situated in Barshi Taluka of Solapur District of Maharashtra. The area falls in Ambenali formation of Wai Subgroup. The sulphide ore predominantly consists of base mental with minor appearance of iron and nickel metals. The locality choosen for present investigation is of interest because of its unique occurrence of ore in Basaltic rocks in the native form. In Ladole area samples were collected from dugwells, road cuttings, nala cuttings, and quarries (Fig. 3.1). Ore microscopic work was carried out using Leitz Laborlux ore microscope on number of (120) polished ore samples. For the identification of the ore minerals chemical etching methods given by Ramdohr 1996, Uytnbogaardt et al 1971 and Craig and Vaughan (1981) were used before the confirmation of ore minerals under microscope. The sections were prepared in various orientations for the study of textures and structures of the ore. From these studies a paragentic sequence has been proposed for the deposit.
FIG. 3.1: SAMPLE LOCATION MAP.
The surface expressions of sulphides are manifested by occurrence of number of malachite leaching (plate 3.1) and gossans in the Ladole and adjoining areas. No ancient or old working is seen from this virgin area except a well in the neighborhood which tempts one due to its depth and features. The sulphides of study area occur in the form cavity fillings and amygdale fillings in the basaltic rocks. Occasionally the sulphides are also found to fill the fractured plane and joint planes of the host rock. A close observation of the mineralization suggest that it is in the form of cavity filing, vug filing, fracture filling in the form of specks and occasionally they are found disseminated in host rock.

3.2 ORE MINERALS

The primary ore minerals in the studied area include Native Copper, Chalcopyrite, Pyrite, Sphalerite, in decreasing abundance while scanty occurrence of Co, Ni, Fe minerals are also observed. The rich ore is in the form of oxide (Cu₂O) which is at shallow depth in the Basaltic rocks. Below the oxide zone the secondary supergene enrichment zone and their minerals are restricted to suitable zones which is diagrammatically represented in Fig.3.2.
FIG. 3.2: SUPERCENE SULPHIDE ENRICHMENT.
Most probably the vesicular and amygdaloidal Basalt are mineralized. The common gangue mineral associated with the ore minerals are Quartz, Calcite, and Apophylite.

3.2.1 Native Copper

Native copper is the most abundant ore mineral encountered megascopically as well as microscopically in the studied area. The grain size varies from 0.1mm to 2 mm while submicroscopic grains are also present. The shape of the mineral is generally euhedral to subhedral. The native copper is predominantly distributed throughout the area as disseminations, specks, and interestingly in the form of thin foliation (Plate 3.2). The majority of the native copper is disseminated and as a coarse grained aggregate in the host rock and occasionally as dendritic or spear like crystal associated with other ore mineral. It is characteristically found in the cavities and vesicles of the basalt. Under the ore microscope in the polished section it can easily be identified by its brownish pink color in freshly cut section but turns copper red when tarnishing. Lamellar twinning is visible owing to the etching in suitable solvent. The mineral is difficult to acquire a good polish because of hardness 2.5-3 hence frequent
scratches are observed. Reflectance is very high and the colour is distinctly reddish shows reflectance 60-87 nm in air. Unisotrophism is common. The mineral is always associated with cuprite, chalcopyrite magnetite and hematite.

The only one generation of native copper is observed. The native copper generally occurs as single grain, which euhedral to subhedral and is commonly found associated with cuprite and chalcopyrite. Occasionally 2-7 mm folia of native copper are observed along the joint plane of the host. Most of the grains are found to fill the vesicles of the host rock. The native copper is being replaced by cuprite where chalcopyrite is also found to replace the copper from the periphery (Plate 3.3). Occasionally a fine grained native copper is also observed within the hosts where native copper forms, an inclusion within the cuprite showing deep blood red internal reflection (Plate 3.4).

3.2.2 Chalcopyrite

Chalcopyrite mineral is encountered megascopically and microscopically in the host rock. Chalcopyrite generally exhibits anhedral to subhedral shapes with the grain size vary from 0.1 to 0.5 mm. The chalcopyrite is distributed throughout the area but
found with marked variation in amount. The majority of the chalcopyrite mineral is in the form of disseminations where it is fine to medium grained.

Microscopically the ore mineral in polished sections can be easily identified by its characteristic yellow to brass yellow colour which tarnishes to deep yellow colour owing to the air etching on exposure to the atmosphere. The chalcopyrite mineral gets easily polished and shows reflectivity around 47%. Anisotropic effects and reflection pleochroism are poor and internal reflection is absent. Nitric acid produce, slight darkening while acidified permanganate rapidly etches the surface.

Chalcopyrite is found to be in the form of cavity fillings and vesicle fillings distributed in the host rock (plate 3.5). The chalcopyrite is also observed in association with cuprite and native copper (plate 3.6) where it replaces native copper along the grain boundary. The chalcopyrite and Bornite sometimes showing basket-wave exsolution texture (plate 3.7). The chalcopyrite Bornite exsolution texture indicates that these are formed in supergene enriched zone and at slightly lower temperature. The epigenetic nature of mineralization and deposition along the
suitable cavity is reflected by the growth of chalcopyrite mineral along the fractures (plate 3.8). The chalcopyrite is partially replaced by the silicate mineral exhibiting remnant islands of chalcopyrites (Plate 3.9).

3.2.3 Pyrite

Pyrite is another abundant sulphide mineral observed in the Ladole. Pyrite is commonly 0.1 to 0.5 mm in size with fine microcrystalline masses. Pyrite is in association with Pyrrhotite and magnetite.

In the polished sections pyrite shows yellowish colour, distinctly different from chalcopyrite, high polishing hardness and a high reflectance which is frequently masked by the mottled surface of the grains. The reflectivity values are high as 54%. The highly brittle character of the mineral is reviled by its shape. The shape of the mineral is essentially rounded or globular.

The pyrite is difficult to get polished, hence it shows mottled image. Pyrite of the Ladole generally fills the cavities voids of the host rock. Its epigenetic natures are revealed through its growth along the fracture plane of the grain where it displaces and widens the fractures of the host mineral (Plate 3.10). This
pyrite is associated with sphalerite and chalcopyrite and one of the earliest mineral deposited in the Ladole area.

3.2.4 Cuprite

Cuprite is the dominant oxide phase observed in the study area which fills the vesicle and fracture planes. It exhibits grey-white colour with bluish tint. The bluish tint is apparent especially against the native copper and chalcocite. By slightly uncrossing the Nicol it appears green to blue tint and shows extensive red internal reflection. It shows moderate reflectance and as it is relatively difficult to polish. Cuprite is frequently associated with native copper and chalcopyrite and is seldomly found associated with Scheelite (plate 3.11).

Cuprite ore mineral is the major oxide found in the investigated area. The ore mineral is occurring as cavity fillings pore space fillings, vug fillings and fracture fillings (plate 3.12) in the host rock. The cuprite is also occurred as isolated grains in association with other ore minerals where it shows deep blood red internal reflection (plate 3.13) while twinning is more common in cuprite grains (plate 3.14). The association of cuprite with the other ore minerals is more common where the native copper is
being replaced by cuprite (Plate 3.15). In the altered zone the flakes of cuprite shows internal green reflection showing its cubic crystal habitat (plate 3.16). In the vesicular and amygdaloidal basalt cuprite is associated with secondary minerals and the percentage of the cuprite ore is found to be increased with alterations and weathering at shallow depth.

3.2.5 Sphalerite

Sphalerite is one of the rarely occurring mineral in association with the mineralization. Under the microscope this is found to be associated with chalcopyrite in minor amount and can be identified by its characteristic colour and texture. In the specimens observed under reflected light sphalerite shows its typical grey colour and very low reflectivity (17.5%) with yellowish brown internal reflection. It turns brownish when treated with HNO₃. It gets easily polished due to its low polishing hardness.

It is one and the rarest zinc sulphide observed in few pockets of the area. The mineral is very fine grained which are associated with iron rich minerals, where it is found replacing
Ileminite completely and sometimes leaving behind remnants in the replacing mineral (plate 3.17)

3.2.6 Iron oxide minerals

The early phase of the mineralization is represented by deposition of number of metallic oxide. This early phase of mineralization is evident mainly by the oxides of iron (plate 3.18) and rarely titanium. The iron oxide minerals, observed are magnetite, Ileminite and hematite found associated with Rutile which is the titanium oxide phase. This ore occurs exhibiting a diffused structure in the host (plate 3.19). Magnetite occurs as euhedral grain showing corroded border and is found later replaced by gangue mineral (plate 3.20). Magnetite can be identified by its brownish gray colour under reflected light microscope. On the other hand Ileminite is identified by its brownish with a pink or violet tinge. Exsolved lamellae of Ileminite in magnetite are more common (plate 3.21) in occurrence. While the oxidation of magnetite results in the replacement by hematite along crystallographic preferred plane which is called as martitization (Plate 3.22). Rutile is the rarest titanium oxide showing yellowish gray colour frequently
associated with hematite. It occurs as euhedral needle like to columnar crystal (plate 3.23).

3.3 TEXTURAL RELATIONS

The textural feature of minerals and the single minerals relation within an assemblage in the host provides the evidence on the nature of depositional processes, depositing sequence, post depositional re-equilibrium and deformations. These textural relations of ore minerals are considered to establish the stages of ore deposition their ore assemblage and characteristics of each stage. Thus the recognition and interpretation of textures is significant step to know the origin and post depositional history of ore deposit. The ore mineral textures exhibited by polymetallic ore assemblage of Ladole and adjoining areas reflect the sequence in their development and depositional history.

The study area under present investigation exhibits different stages of ore mineral deposition which is deduced through the mineral assemblages and their textural evidences. The evidences have suggested that the mineralization in Ladole is represented by the deposition of minerals Fe-Co-Ni rich followed Cu, Pb and Zn rich. Both of these stages reflect the effect of sulphide enrichment
and oxidation during weathering. The established paragenetic sequence which is given in table 3.1 and the notable textures are described below.

3.3.1 Exsolution Texture

Exsolution represent simultaneous crystallization of two minerals from a single parent fluid at static physico-chemical conditions. Many metallic sulphides show wider compositional range at high temperature then at room temperature. Decrease in temperature after initial deposition can thus lead to the separation of one mineral from another as the continuous process of reequilibration occurs. This characteristic process of mineral separation is common among sulphides and oxides. The number of textures apparently resulting from exsolution has been given by Edward (1960) and Ramdohr (1969). The condition like nucleation, diffusion and sufficient rapid crystal growth to form a daughter phases are necessary for exsolution process. The exsolution lamellae of Ileminite in magnetite are observed in the oxide stage of mineralization (plate 21). The Exsolved lamellae of Bornite in chalcopyrite (plate 7) is an indication of slight cooling of ore forming media.
Table No. 3.1.: Paragenetic Sequence of Mineralization in Ladole Area.

<table>
<thead>
<tr>
<th>MINERALS</th>
<th>GROUND PREPARATION STAGE</th>
<th>OXIDE STAGE</th>
<th>BASE METAL STAGE</th>
<th>SUPERGENE ENRICHMENT STAGE</th>
<th>OXIDATION STAGE</th>
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<tr>
<td>Silicate Minerals</td>
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<td>Quartz</td>
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<td>Calcite</td>
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<td>Magnetite</td>
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<td>Ilemminite</td>
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<td>Sphalerite</td>
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<td>Chalcopyrite</td>
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<td>Native Copper</td>
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<td>Bornite</td>
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3.3.2 Replacement texture

The process of replacement is chemical which commonly proceeds along the fractures and boundaries of mineral grains. The replacement process is a result of dissolution and subsequent reprecipitation, solid state diffusion and oxidation due to later fluids. Different varieties of replacement geometries highlighting their genetic history have been described by Ramdohr (1969), Bastin (1950) and Amstutz et al, (1980). The two distinct replacement textures are observed in the study of Ladole mineralization which includes the processes of dissolution and redeposition within the same stage of ore crystallization and those resulting from cavity filling and subsequent replacement. Cuprite, chalcopyrite, pyrite and sphalerite show replacement textural relationship. Two types of replacement textures in the study area recognized. The first stage of mineralization is characterized by fracture and pore fillings while the second type is recognized by replacement and redeposition of the new mineral in the same phase. Occasionally the early phase sulphides have been replaced by later ones resulting Remnant Island of replaced sulphides.
Replacement of early formed crystals along the border in the way of corrosion is also observed.

3.3.3 CAVITY FILLING

The cavities or vesicles generated at the time of host rock formation and later developed fractures are found to be filled with mineralization. Native Copper, Chalcopyrite and Pyrite minerals fill the cavities of the host rock whereas cuprite other minerals occupies the fractures and amygdales in the host rock. The cavities which are syngenetic with magma deposition are vesicles, amygdales and space around grain boundaries and growth cracks of phenocrysts or porphyroblasts. While pre or early cavities are represented by fractures due to emplacement breccia formation, agglomerations and cavarnceses in earlier flows. Those cavities formed later are structural joints, mix fault or shears or crushed breccias represent post cavities.

The epigenetic nature of the mineralizing fluids is evident through their relationship with cavities i.e. filling responses on the wall i.e. dissolution or formation of incrustation on the wall surface.
3.4 CONTROLS OF ORE

The ore mineral deposition in the area shows its restricted occurrence. They are deposited in suitable places like cavities, fractures and joints and their richness is also restricted to the particular flow unit of the host rock suggest that there are definite depositional controls.

3.4.1 LITHOLOGICAL CONTROL

Though the area under investigation is composed of only one rock type i.e. the area characterized by Deccan tholeiitic Basaltic flows. These flows are subdivided into different flow units, such as Massive Compact basalt, vesicular basalt and amygdaloidal basalt. The ore mineral richness is observed in the vesicular and amygdaloidal basalts. The vesicles and amygdales are filled with the zeolitic minerals. However the ore minerals are also present in massive basalt sparsely distributed in the form of specks but dominance is observed in amygdaloidal and vesicular basalts. The characteristics occurrence of rich ore in and around amygdales and in associated with zeolitic basalts along contact also supplement lithological controls.
3.4.2 **STRUCTURAL CONTROL**

Though the area under investigation is not representing any major structures like fold and fault, still the joints of various patterns and their sympathetic fractures are more common. Occasionally the mineralization is found to be restricted to joints and fracture planes in the form of thin foliation. The rock structure like amygdales and vesicles comprise the mineral formation in association with quartz calcite and the other zeolitic minerals. The mineralization is also observed as vein fillings which elucidate role of structural control.

3.4.3 **GEOCHEMICAL CONTROL**

The mineralization restricted to zeolitized, silicified and carbonated zones and fractures do indicate role of geochemical control in ore deposition.

3.5 **ALTERATIONS**

The alteration types recognized in the area are Argilitization, Serpentinitiazation, Chloritization, Silicification and Kaolitization. The characteristic minerals suggest their presence in the zone of alteration representing alteration types in the locality. The alteration types can be established as follows;
3.5.1 ARGILITIZATION

Argillic alteration is characterized by kaolinite, commonly replacing plagioclase. The argillic alteration is commonly observed in weathered zone.

3.5.2 SERPENTINIZATION

The well shaped and usually rounded phenocrysts and microphenocrysts of olivine do occur with cracks. These cracks and margins of the olivine phenocrysts shows altered to serpentine and also iddingsite.

3.5.3 CHLORITIZATION

Chlorite is sparsely disseminated in ground mass. The chloritization can be observed near the quartz veinlets near the ore minerals. Zoned pyroxene grains show corrosion and altered to chlorite.

3.5.4 SILICIFICATION

Silicification is found in voids and amygdales in association with ore mineral zone. The addition of silica in the form of zeolites and quartz is commonly observed in the host rock. Recrystallization of silica at the time of mineralization episode is
marked by the increase in the grain size of the host and forming newly zeolitic minerals.