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Studies on ore mineralogy of placer ilmenite from parts of east coast of India

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ABSTRACT

Placer ilmenites from three deposits of Andhra Pradesh coast have been investigated for their ore mineralogy. The deposits studied are Kakinada, Bhimunipatnam, and Srikurmam. Standard ore mineralogical methodology adopted for the preparation of polished sections of placer ilmenite grains from the three deposits. The detailed study of these sections under reflected light microscope revealed that the ilmenites from Kakinada are devoid of exsolutions whereas the ilmenites from other two deposits have indicated exsolved phases in the grain level textures, these phases are mainly ilmeno-hematite, hemo-ilmenite and exsolved phases of rutile.

The grain level textures or exsolved phases observed are 1) Homogenous ilmenites, 2) Ilmenites with simple Exsolutions, 3) Ilmenites with complex Exsolutions, 4) Irregular forms, 5) Dispersion or emulsion texture, 6) Lamellar Texture, 7) Skeletal Texture, 8) Worm like lamellae 9) Myrmekitic or Graphic Exsolutions and, 10) Alteration textures. Their presence will have implications for the processing of ilmenites. Because of the fact that the hematite phases in the ilmenite grain will make the ilmenite more iron-rich and thus may result in some processing problems as well as reduced titanium recovery.

Keywords: *Ilmenite, Placer, Ore Mineralogy, Exsolutions, Exolved Phases,*

1. INTRODUCTION

The placer ilmenite is known to occur in a number of deposits along the coastal tracts of Andhra Pradesh. The most important deposits are from South to North located in places like Kakinada, Bhimunipatnam, and Srikurmam, (Fig-1) it is generally believed that the placer ilmenite is derived from the Eastern ghat hinterlands, transported by drainage system and concentrated in the form of beach placers. The mineral ilmenite is economically important because of the valuable titanium metal produced from this mineral. The titanium metal has excellent properties of industrial applicability. These include high-temperature resistance, light weight, high strength and thus it finds its strategic applications in the manufacturing of space accessories, aircraft accessories and defense-related equipment.

Fig-1 Location of the Deposits of Present Study

Within Andhra Pradesh, the ilmenite reserves are in the range of 83 million tons as estimated by Atomic Minerals Division-Government of India. A number of investors are coming forward to invest in these deposits for their mining and processing. The commercial applicability of these ilmenites depends on their geochemical and ore mineralogical properties. Earlier some work on geochemistry has been attempted (Jagannadha Rao, 1985, Jagannadha Rao et .al 2005, 2005a, 2006). However detailed ore mineralogical work is not carried out earlier and hence this work is taken up to study the details of ore-mineralogy.

2. METHODOLOGY

99.9% pure ilmenite grain has been separated and mounted using the industrial araldite This is to enable the polishing of the ilmenite grains, which are in the size range from +80 meshes to -120 meshes (ASTM). After mounting the grains, these are polished using standard polishing techniques, by using the polishing medium carborandum, chrome- rouse and diamond paste. After polishing, these sections are studied under the reflected light microscope (Leica, DMLP).

3. RESULTS

The ilmenites from three deposits investigated are showing excellent grain level micro textures indicating perhaps their diverse ore mineralogy, sources of derivation and variability in paragenesis, the grain level textures, and morphological variations are so significant especially in case of Bhimunipatnam and Srikurmam deposits. The ilmenites from Kakinada deposit are more or less homogeneous and exhibit different ore mineralogy. The most abundant and common textures recorded in this investigation are presented below, in general, five different types of intergrowths have been recorded they are ilmenite-hematite, hematite-ilmenite, hematite-ilmenite-rutile, hematite-rutile and ilmenite-rutile.

The textures present in ilmenites of present investigation are 1) Homogenous ilmenites, 2) Ilmenites with simple Exsolutions, 3) Ilmenites with complex Exsolutions, 4) Irregular forms, 5) Dispersion or emulsion texture, 6) Lamellar Texture, 7) Skeletal Texture, 8) Worm like lamellae 9) Myrmekitic or Graphic Exsolutions and, 10) Alteration textures. The details are presented below.

1) Homogeneous ilmenites

Homogeneous ilmenites are characteristically found in all the deposits. Their occurrence is most significant in fine and very fine fractions. The high percentage of homogeneous ilmenites within the opaque fraction between –150 to +230 mesh is significant. The shape of ilmenite grains ranging from elongated, irregularly broken and sub rounded. The reflection pleochroism of ilmenites is from rose brown to moderate brown and in general greyishwhite with a brown tint. Some grains with pleochroism from pink to brown are also observed. In general, the homogeneous ilmenites appear more towards derived from coarse grains whereby due to mechanical breakage they are separated from bigger grains.

2) Ilmenites with simple Exsolutions

Niggli called those in which the previously simple solid solution is chemically conceivable by the formation of the important disintegration components. As far as the substance it is to be noted that continuous transition exists between the simple exsolution.

These exsolutions are typical of lamellae of two minerals formed unidirectional and exhibit clear cut demarcation. Thus these are of the very simple form indicating their phases formed from the single melt at one time.

In this group, the simple exsolutions are mainly contributed by phases of ilmenite and hematite. These phases depend on the original composition of the melt. A number of patterns observed in this class. The hematite phases within the host ilmenite indicating the dominant ilmenite phase (more than 50%) which can be considered as "ilmeno-hematite." Similarly, the formation of ilmenite lamellae within the host hematite indicating the dominant hematite phase (more than 50%). This can be termed as "hemo-ilmenite." During the course of the investigation, hundreds of grains showing these patterns were observed. However, the variations can be recorded as mentioned below

i. Wide variation in the width of intergrowth lamellae of both ilmenite and hematite phases mentioned above.

ii. The variations in the grain boundaries, micro-fractures are very significant indicating their differences.

iii. Variations in optical properties such as reflectance, pleochroism, brightness etc. are significant. The Fig-2 presents some of the grains showing the simple exsolution.

On the basis of the width of intergrowth lamellae of ilmenite in hematite, six, groups are made. They are <2μm, 2-10μm, 10-20 μm, 20-40μm, 40-60 μm and >60μm. Grains with all the above types of lamellae are equally abundant. The width of the intergrowth lamella of ilmenite indicates the source rocks of its derivation.

3) Ilmenites with complex Exsolutions

In this group, Exsolutions are contributed by decomposition of the anomalous solid solution, decomposition with scant addition and removal of material and finally with complete re-mineralization. Under this category the hematite phases within ilmenite host and ilmenite phases within hematite host exhibit grain level textures which are of complex nature. The various textures observed are presented below. In general, the detailed investigations indicate the involvement of remixing and crystallization resulting in complex exsolutions. The various textures observed indicate the paragenitic history of their derivation Fig-3 presents complex exsolution formed in more than one paragenetic event

4) Very irregular forms

These are a group of textures whereby ilmenite and hematite phases occur in strange and irregular shapes and forms. These forms cannot be attributed to any standard terminology nor can be given a standard name. They are for the most part products which are the of collection crystallization from all other forms, but they can also originate spontaneously. They occur preferentially with cubic lattice which is closely related in size and bonding and hence is subject to easy change in position. They can hardly be distinguished or not distinguished at all as for shape from some replacement forms or re-crystallization products of former gel precipitate.

The Fig-4 presents the grains with an irregular form of Ilmenite and hematite. These forms mainly indicate the crystallization of ilmenite and hematite phases without any particular orientation or symmetry resulting from these forms.

5) The dispersion or Emulsion texture

As per Ramdohr (1969) dispersions (Emulsions) should be called as textures in which finely divided mineral particles are dusted through the host which is present for the most part in considerable excess. In many cases, the dispersions which are also called emulsions may in one immediate neighborhood be once irregularly distributed or less prominently aligned in strings parallel to certain directions in the host or may form peculiar garlands. In a number of sections observed in the present investigations, the dispersion textures exhibit dispersions or emulsions of a coarser size which are more common. Dispersions and emulsions of hematite in ilmenite and ilmenite in hematite are common (Fig-5).

6) Lamellar textures

Texture with longer and more continuous lamellae of the guest. The texture differs somewhat with cubic host and cubic guest and cubic host and hexagonal guest or with hexagonal host and cubic guest. They also differ especially high temperature of formation or especial similarity of the lattice bonding.

During slow cooling, the composition of both the host and the lamellae change with temperature as the lamellae increases in size. The width of the lamellae depends on the original crystallization composition and the cooling rate.

These are the most commonly occurring textures whereby long and continuous lamellae guest mineral occurs in the host. These lamellae are of different sizes and with varying width; some of the lamellae are continuous whereas some other lamellae are broken. The lamellae of ilmenite in host hematite and vice-versa are common. However the third mineral lamellae also found to occur in many grains, the most common example for this is the occurrence of ilmenite lamellae within the host hematite and within the lamellae of ilmenite the occurrence of rutile resulting a complex exsolution indicating its paragenitic history (Fig-6).

In the lamellar textures occasionally formation of much more complex lamellae whereby the mineral forming lamellae indicate variable width and form. This perhaps indicates a sudden change of temperature during crystallization. Some of the lamellar textures follow a perfect pattern where the ilmenite in hematite and hematite in ilmenite show an excellent parallel orientation with fixed size and interval.

7) Skeletal textures

Skeletal is a term used to describe the habit of euhedral to subhedral crystals containing crystallographically orientated hollows and gaps. Typically the voids within skeletal crystals are filled with groundmass materials.

Skeletal crystals form under large super cooling and indicate disequilibrium. They form by preferential growth of the corners of crystals, a diffusion controlled growth process. Skeletal morphologies are relatively common in olivine and plagioclase crystals in volcanic rocks. Skeletal olivine crystals are sometimes called hoppers.

Dendrite and parallel growth crystals are other crystal habits associated with large super cooling. Form under large super cooling and indicate disequilibrium. They form by preferential growth of the concerns of crystals a diffusion controlled growth process. They depend first of all on the guest and are dependent on its tendency for idioblastic development. Frequently all of the filigrees are crystallographic ally of uniform orientation. Even convergence may occur with idioblasts of entirely different origin.

Skeletal textures were also observed in a number of grains. These are kind of broken and altered textures formed in grains where the certain position of the material from the grain is removed post-depositionally. In a number of grains, this phenomenon is observed whereby the grain becomes skeletal and fragmented. In some of the grains, the exsolution texture could be seen as the relict where the host material is totally removed. On other words, the phase of a guest mineral seems to weaken the host along with its margins resulting removal of the host leaving the guest as the relict. In some other grains, the micro cracks or fractures act as weak planes along which the removal of material is initiated. In a number of grains, the hematite part is left as relict, whereas the ilmenite body is removed (Fig-7).

8) Worm-like lamellae

In occasionally very fine lamellae of ilmenite within the hematite host which appears to be a group of worm-like lamellae is recorded the very symmetric and systematic orientation of these worm-like lamellae within the host indicate a slow and study crystallization during its paragenesis (Fig-8).

9) Seriate texture

This is a kind of lamellae texture where the guest lamellae form continuous long and parallel lamellae in the host mineral. Seriate texture is seen as blebs of the body in the parent grain. Around the largest of the blebs depletion of the material may be evident.

In this investigation, a number of grains, the seriate texture is observed in ilmenite host where hematite needles exhibit the seriate texture (Fig-9).

10) Myrmekitic or graphic textures

It is called graphic because the exolved or devitrified minerals form lines and shapes. As regards appearance they are more monotonous, they comprise always an interpenetrating growth of large grains of two and on rare occasions more minerals which are present in a variable, but more or less comparable amounts. The grain boundaries are mutually rounded so that in a section the texture resembles finely woven fabric or the paths cut by grabs of woodworms in the sap-wood of trees.

Though these are not very common, in some of the grains this texture is recorded. As per literature, graphic textures are formed when the end members crystallize simultaneously and continuously resulting myrmekitic or graphic texture.

11) Alteration textures

Alteration of Ilmenite was observed rarely and occasionally. The alteration resulted along the grain boundaries and fractures resulting in the crypto or microcrystalline mass most likely the leucoxene. The intensity, type, and mode of alteration were different from grain to grain (Fig-10). Similarly, the alteration pattern of Kakinada ilmenite is different from the ilmenites of the other two deposits.

Dissolution and /or oxidation of iron from ilmenite in natural water or in acidic water lead to an enrichment of titanium and other elements in the residue, which may be the main cause for ilmenite alteration (Dimanche and Bartholome, 1976). Though ilmenite alteration is neither uniform nor continuous, the weathering mechanism is illustrated as a two-stage process and/or a multi-stage process (Hugo and Cornell, 1991).

4. CONCLUSION

The study clearly demonstrates that the ilmenites from Bhimunipatnam and Srikurmam have excellent grain level ore mineralogy with the availability of exsolved phases within the ilmenite grain. These are phases of hematite with in ilmenite, the phase of ilmenite with in hematite and minute rutile exsolution. Whereas the ilmenites of Kakinada are homogeneous. The reason behind this can be attributed to the source of their derivation. It is well established that the ilmenites of Kakinada are having parentage from basaltic terrain whereas the ilmenites from other deposits are derived from Khondalite percentage. This explains the variation in ore mineralogy of these ilmenites.

The extensive exsolved phase within the ilmenite may have some implications on the processing of their ilmenites. The process plan needs to be designed considering the fact, the complex exsolved phases which may influence the composition of ilmenite by increasing iron content in form of hematite this will not only increase more acid consumption but also results in lower titanium yields.

The Textures Reported:

Fig-1. Simple exsolution

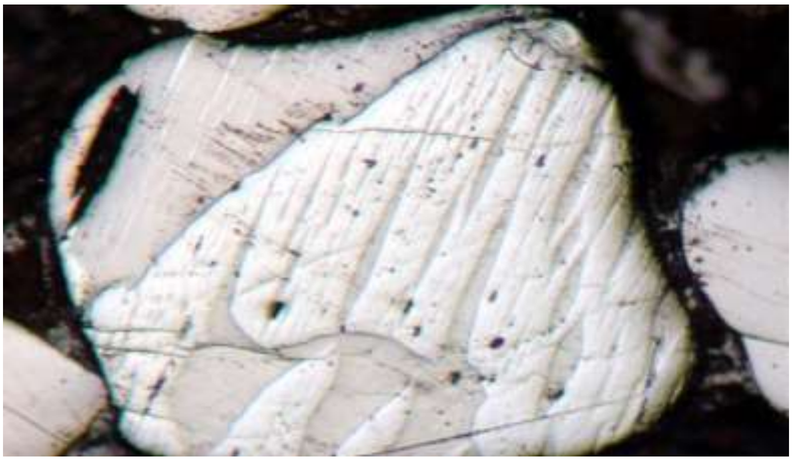

Fig-2.Complex Exsolution formed in more than one paragenetic event

Fig-3.Very Irregular form of Ilmenite and Hematite exolved phases

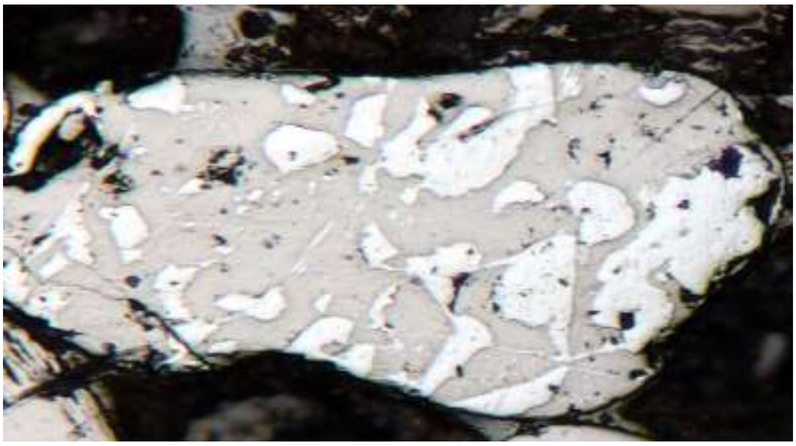

Fig-4.Emulsion texture

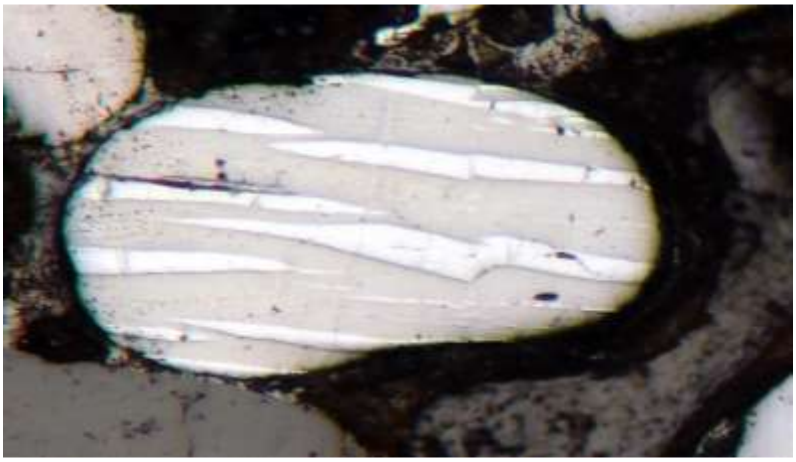

Fig-5. Lamellar texture

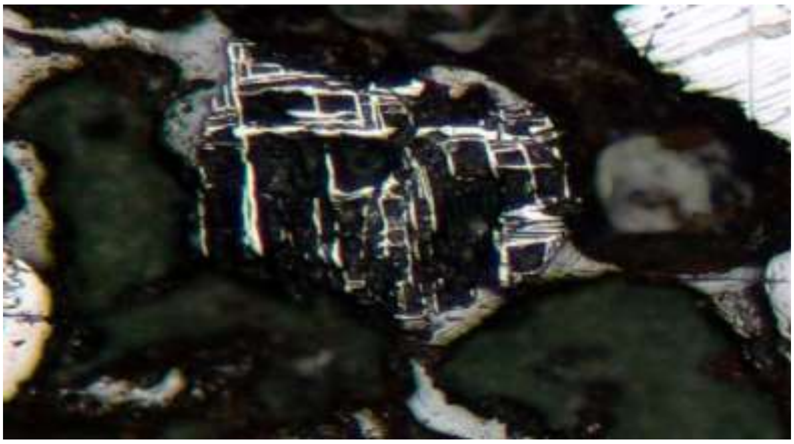

Fig-6. Skeletal Texture formed after all the Ilmenite is removed leaving Hematite skeleton

Fig-7. Worm/needle or Rod like hematite within the Ilmenite matrix (Myrmekitic Texture)

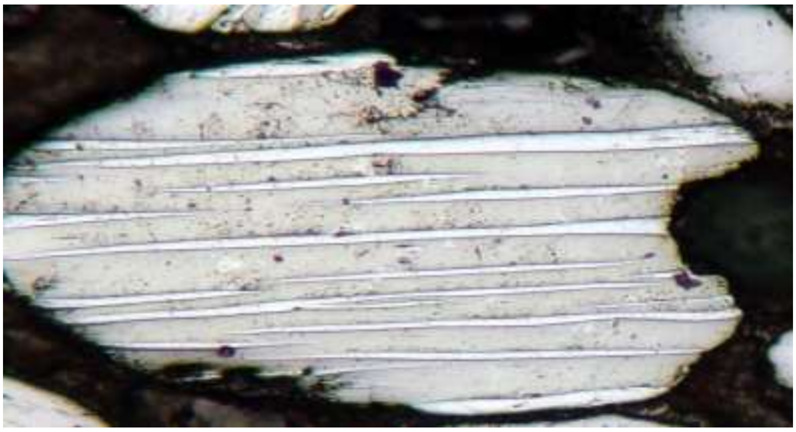

Fig-8. Seriate texture

Fig-9. Alteration of Ilmenite along grain boundaries

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