CHAPTER III MINERALIZATION AND PETROGRAPHY
3.1 MINERALIZATION

Tungsten never occurs in free state in nature, but in combination with other oxides of different elements like iron, manganese, calcium and less frequently with copper and lead.

Present area of study owes its importance for tungsten mineralization, along with fluorite which occurs as fluorite-quartz vein and pockets in granite (Balda Granite) and shear zone areas. The mineralization of tungsten occurs in pneumatolytic and hydrothermal quartz and pegmatite veins, intruding shear zone, granite and in contact zone of schist and granite. These mineralized quartz veins are noticed sporadically over 2 Km strike length with a width of about 500 metres. Since the discovery of tungsten mineralization, exploration work so far carried out by G.S.I., M.E.C.L., and R.S.M.D.C., recognises that sampling and proving the grade and reserves are highly problematic because of erratic nature of 'insitu' mineralization.

MODE OF OCCURRENCE:

Occurrence of quartz veins is very erratic. At places there is a close network of stringers and veins while in other places it is totally absent. Clustering of these mineralized quartz veins is mainly restricted
to shear zone, near by fracture plane and contact zone. On the basis of clustering of the quartz vein, the area is sub-divided into number of zones and named shear zone 1, 2, 3, 4 etc. Shear zones are restricted to very small area and in length, these shear zones vary in between 150 to 500 metres and width varies from 1 to 3 metres.

Apart from these shear zones there exists one Greisenised vein, with a length of 150 metres and width of a metre in SW part of the mineralized area in exacontact zone of schist and granite.

In secondary environment accumulation of tungsten with some other heavy minerals is seen in form of eluvial and colluvial deposit in near by and foot hill areas of mineralized zones. Accumulation of tungsten minerals, 'insitu' and near by foot hill area suggests low solubility and mobility of tungsten and all that small amount of transport that has taken place is under the influence of gravity.

3.1.1 **MINEREOLOGY OF TUNGSTEN ORES**

In nature tungsten is almost exclusively hexavalent in minerals of both primary and secondary origin, though its chemical compounds encompass a wide range of oxidation states. Over 20 minerals are known
(Ford 1949, & Dana 1951) and most of them are oxotungstates or forms of the oxides, only one sulphide (tungstenite) occurs rarely and only one silicate (welinite) in which tungsten may replace a substantial part of Mn.

Out of these reported minerals in present area, tungsten mineral of wolframite group i.e. ferberite Hubnerite and scheelite are of economic importance while all others are minor constituents or merely of mineralogical curiosities.

Wolframite: It is a iron manganese tungstate and it forms solid solution series of iron and manganese. Fe and Mn are replaced by Ca, Mg, REE and Sc while W is replaced by Nb and Ta (sarri 1968). Iron manganese ratios in composition shows both regional changes and zonal distribution within a single vein but regional changes are of greater contrast. MnO/FeO ratio is considered to be a function of temperature and has been discussed in detail (along with previous work) by Taylor and Hosking (1970), Groves and Baker (1972), Singh and Varma (1977) etc. Two end members of wolframite isomorphous series are hubnerite (MnWO₄) & ferberite (FeWO₄).

Hubnerite: It is a manganese tungstate with maximum 20% FeWO₄. It alters to tungstite and pyrolusite. It shows monoclinic symmetry and colour is reddish brown. Crystals
show bladed habit. Sometimes it shows bands of light brown to dark reddish brown colour. It is generally found in high temperature zone.

**Ferberite:** It is a Iron tungstate with maximum of 20% MnO. It shows monoclinic symmetry and colour is black with uneven fracture and sub-metallic lusture. Crystals are commonly wedge shaped, short, prismatic and flattened and occurs in high temperature quartz vein.

**Scheelite:** It is a calcium bearing tungstate. In scheelite Cu and Mo replaces Ca and form an isomorphous series. Occurrence of scheelite is restricted to skarns; high temperature quartz veins; strata bound tungsten deposits; and gold bearing quartz veins. It shows tetragonal symmetry and tabular habit with diagonal striations. Colour is white, tan-grey, yellowish or greenish and streak is white lusture is vitreous to adamantine. In ultraviolet light it luminesces pale blue colour while with increasing molybdenum substitution it changes to, white to yellowish.

Among these, Ferberite is most abundant while scheelite occurs as thin film and is of secondary origin in present Balda tungsten deposit area.
3.1.2 **COUNTRY ROCKS**

In present mineralized area, country rocks are composed of schist and phyllite rocks of Sirohi group (Delhi Supergroup).

These rocks have suffered two major events of magmatic activity. First major activity in this area is represented by intrusion of Erinpura Granite of porphyritic nature and post-magmatic quartz veins while second phase of magmatic activity is represented by intrusion of Balda Granite of leucocratic nature and post-magmatic hydrothermal quartz veins and pneumatolytic activity. Balda Granite is medium to fine grained rock and is responsible for tungsten mineralization.

3.1.3 **HOST ROCK AND GANGUE MINERALS**

Host rocks for tungsten mineralization in this area are quartz veins, greisenised pegmatite vein and leucogranite (Balda Granite), which are genetically related to 'Ind phase' of magmatic activity. This granite is responsible for tungsten mineralization and is of localized type, occurring in form of small lensoidal granite bodies. Post dating this Balda Granite are quartz veins and greisenised pegmatite veins which
are enriched in tungsten minerals like wolframite (ferberite). These veins cut across schist and granite and occupy plane of weakness in shear zone, contact zone, granite and schist.

Main tungsten mineral found in this area is wolframite of ferberite variety and is generally associated with gangue minerals like quartz, tourmaline, books of mica (muscovite), fluorite, feldspar, topaz and some other minerals of pneumatolytic alteration. In contact zone of quartz veins, tourmalinization and darkening of country rock is a main feature and occurrence of of fluorite is in form of pockets and veins while mica books (muscovite) are distributed in uneven fashion, mainly along contact zone.

3.1.4 **SURFACE INDICATION OF MINERALIZATION:**

Mineralization of tungsten, (wolframite) is in quartz veins and occurs in the form of nuggets and crystals ranging in size from microscopic dimensions to a few centimetres. Though it follows a very erratic distribution but a careful study can surely search out few crystals of wolframite impregnated in quartz veins. One such crystal is shown in plate No. 3.1. Author during his field studies has seen and collected samples of such nuggets and crystals of wolframite. Later on these samples were examined microscopically and chemically
Plate No. 3.1: Showing Wolframite Crystal in Mineralized Quartz Vein.
analysed. Apart from this, other indications of tungsten mineralization are altered contact zone rocks, tourmalinization and presence of mica books.

Though, in this area presence of scheelite is rare and is of secondary origin but its presence can be noticed by using ultra-violet portable lamp. On exposure to U.V. light, scheelite luminesces to pale blue and some times yellowish-white, depending upon increasing content of molybdneum.

Presence of scheelite mineralization is also reported in skarns, which occurs approximately 10 km. in northeast of the present area, near Deva-Ka-Dera village. Though this area is not a part of this study, but out of curiosity, author has visited this area and on the basis of very generalised studies, based upon the lithology and general trend of the area, it seems that same types of rocks, like intrusive Balda Granite and related hydrothermal and pneumatolytic activity in calc-silicate rocks, are responsible for scheelite mineralization in this area. This suggests that same type of mineralizing fluids while intruding schist and granite have given rise to mineralization of wolframite and while intruding calc-silicate rock, development of skarn and scheelite mineralization have taken place.
3.2 CONTROL OF MINERALIZATION

All ore bodies are related to some specific geological features and they exercise some kind of control on location and over the shape and size of the ore bodies. Therefore, depending upon the stratigraphic and structural relation, controls of mineralization can be differentiated into 'structural control' and 'stratigraphic control'. Studies of these controls are of great importance in mineral exploration.

3.2.1 STRUCTURAL CONTROL:

Structure play a vital role in localization of ore bodies, they in fact make available room for mineralization and path for movement of mineralizing fluids. Importance of structural features in forming ore bodies structural control of has been emphasised on the basis of different ore bodies in the world by various authors: Wilson (1948); Gilbert (1957); Hosking (1974); O'Driscoll (1981); Jackson et al (1982); and Turner et al. (1982).

In this area mineralization is of hydrothermal and pneumatolytic origin and seen mainly in quartz vein and pegmatite veins and to lesser extent in contact zone of these quartz veins, pegmatite vein and in altered part of granite (Balda Granite). Mineralized veins, (quartz & pegmatite) strictly follows the structural
features of the area. Structural features which show relation and control of mineralization are foliation plane, shear zone and other weak planes which are genetically related with intrusion of Balda granite and second generation of folding ($S_2$), trending NE–SW. Structures showing control of mineralization are the youngest as they cut across all the previous structure and mineralized quartz veins and pegmatite veins are intruded along the weak planes of these structures. Therefore, those structures which are developed along with or later than the intrusion of Balda granite form the important loci for the emplacement of wolframite bearing, mineralized quartz veins. In fact these structures, not only show control of mineralization but also represent preparation of pre-mineralization condition, more specifically ground preparation for mineralization in this area.

3.2.2 **LITHOLOGICAL CONTROL**

Lithology plays direct or indirect role in localization, type of ore assemblage and mineralogy of ore bodies by influencing upon pH and Eh conditions of mineralizing fluids, which in turn are responsible for mineralization and formation of different mineral assemblages.

Main lithounits in the study area showing
mineralization are rocks of leucocratic nature of Balda Granite and post-magmatic to Balda Granite, quartz veins, pegmatite veins, greisenised vein and contact zone of these veins. Emplacement of Balda Granite and related post magmatic features in phyllite and mica schist of the area show mineralization of tungsten in form of wolframite while same type of granitic bodies intruding impure calcareous (carbonate and quartzite association) metasediments show development of grossularite and vesuvianite bearing skarn in Deva-Ka-Bera area, in north eastern extension, of present area at about 10 km. distance. These skarns show low grade mineralization of tungsten in the form of scheelite. In contrast to Balda Granite, Erinpura Granite of porphyritic nature which is older in age and occupies vast tract of the study area does not show sign of mineralization of tungsten.

Therefore, it is clear that mineralization in Balda area is associated with Balda Granite (leucogranite) and related, post-magmatic rocks and that, lithology shows control over mineralization of wolframite and scheelite, which in this area is seen to occur in same metallogenetic province.

3.3 PETROGRAPHY

In the following megascopic and microscopic petrography of the rocks occurring in the present area is
described briefly. Precise and detailed mineralogy of the rocks is not attempted here.

Broadly speaking there are three types of rocks occurring in this area. They are granites (Erinpura and Balda), quartz veins and schists.

3.3.1 **SCHISTS**:

Megasopic description: These are light to dark grey coloured, fine to medium grained schistose rocks with closely spaced schistosity planes. The minerals identified in specimens are scales and small flakes of silvery shining muscovite and black biotite. Sometimes black striated prismatic crystals of tourmaline of variable dimensions ranging from 0.8 cm to 1 cm in length are observed lying in schistosity planes at random. The specimens present silky lusture like that of phyllite due to the abundance of scaly muscovite (sericite). The schists in contact with quartz veins are relatively rich in colourless quartz and hence assume a hard quartzite like appearance in hand specimen. Occasionally colourless to greyish, short prismatic porphyroblasts of Andalusite form knot like protrusions on schistosity planes.

Microscopic description: Under the microscope the schists of the present area offer medium to coarse grained crystalloblastic schistose texture. Occasionally
porphyroblasts of andalusite (sometimes as sericite pseudomorphs) and tourmaline are noted. Most abundant minerals are quartz, muscovite and biotite followed by tourmaline. Andalusite porphyroblasts and opaques closely associated with biotite are sparse with rare altered topaz.

Schistosity is produced by the abundant closely associated muscovite and biotite. The former occurs as prismatic short needles often penetrating biotite flakes or their bundles arranged in preferred orientation. Occasionally muscovite forms big porphyroblasts like flakes across the schistosity. Biotite is observed as subidioblastic dark reddish brown coloured pleochroic flakes. In microsections normal to schistosity small crenulations in schistosity are observed showing polygonal arrangement of micas enclosing xenoblastic equigranular quartz. The relative proportion of the two micas is variable. Sometimes muscovite is more than biotite or vice-versa. Rarely biotite shows large number of pleochroic haloes and alteration to pale green chlorite.

Generally most abundant xenoblastic quartz forms granoblastic matrix in which oriented biotite and muscovite are embedded. Sometimes quartz is seen as flattened elongated lenticular crystals parallel to schistosity. Rarely big size quartz crystals are noted
around which the schistosity swerves.

Tourmaline content of the schists is variable. The mineral is observed as cross sections or prismatic strongly pleochroic crystals of light to dirty brown colour. In some cross sections zoning with bluish core and brown margin is noted. In general, they are arranged parallel to schistosity. Occasionally tourmaline forms porphyroblasts enclosing small size quartz of the matrix and then occurs across the schistosity. When tourmaline is abundant the rock can be named tourmaline mica-schist.

As already mentioned andalusite is noted in the schists as porphyroblasts of prismatic colourless crystals with good cleavage or their altered pseudomorphs of sericite. The present schistosity constituted by quartz, muscovite and biotite passes through these porphyroblasts or their pseudomorphs uninterrupted as straight or slightly curved trails forming helicitic structure. This indicates the formation of these prophyroblasts after the period of deformation that produced this schistosity. In unaltered porphyroblasts helicitic structure is marked by poikiloblastically enclosed abundant quartz with little micas.

As referred already, rarely colourless relic of a mineral in its alteration to fibrous micaceous aggregate, showing cracks, low relief, first order grey polarisation colour and straight extinction, is observed. This is
tentatively identified as topaz.

From the above description the schists of the present area are biotite-muscovite schists. When andalusite and tourmaline are present, they can be named andalusite-mica schists and tourmaline-mica schists respectively.

3.3.2 ERINPURA GRANITE

Megasopic description: Very coarse to coarse grained greyish white coloured rock having colour index of approximately 10 to 15%. The rock presents a porphyritic texture with phenocrysts of greyish felspar (Plagioclase?) with dimensions of 3 to 4 cm by 2 cm. They are embedded in the groundmass comprising white felspar, vitreous colourless to smoky grey quartz and spangles and flakes of muscovite and black biotite. Micas here have a general tendency to occur in patches and with grey felspar phenocrysts attribute an apparent mesocratic look to the rock. Both the groundmass and phenocryst felspars are subhedral, prismatic or rectangular crystals with well developed cleavages and pearly luster. Quartz crystals are interstitial to felspars.

Microscopic description: Under the microscope the granite is holocrystalline, very coarse to coarse grained with texture varying from porphyritic to hypidiomorphic. Phenocrysts are alkali felspars (predominant microcline and some orthoclase) and plagioclase.
Groundmass is comprised of quartz, muscovite and biotite. Minor accessories are zircon, sphene, opaques and rare orthite (?).

As mentioned above microcline with its typical cross-hatched twinning is most abundant in alkali felspars. Orthoclase when present shows one or two directional cleavages and usual alteration to fine sericite along them and at margins. Fine sericite when formed along both the cleavages presents a criss-cross arrangement of tiny crystals. Alteration at times is also into dusty clay material. Orthoclase rarely shows vein shaped perthitic intergrowth.

Plagioclase content is variable from one slide to the other. That means its relative proportion in Erinpura Granite is variable from place to place. At times it is more than alkali felspar and is enclosed in it. Like alkali felspars, plagioclase prismatic crystals are highly altered into sericite pseudomorphs and occasional rosettes.

Both the above mentioned felspars show strong strain effects as indicated by well developed fractures bending of twin lamellae and wavy extinction. In the fractures quartz, muscovite and biotite are present. They are free from strain effects, hence appear to be later than the deformation in felspars. Sometimes in the fractures the shape of the quartz is vein-like or cuneiform
as found in graphic intergrowth, showing same optic orientation over considerable area.

Muscovite and biotite occur as patches or bands of flakes and in fractures. Biotite is closely associated with opaque ore minerals. Rarely local biotite flakes enclosing small grains of quartz are also noted. Besides its usual brown colour, at times it is light green especially when its alteration to chlorite is incomplete. Green chlorite pseudomorphs are also observed. Pleochroic haloes around zircon inclusions are seen. One colourless squarish crystal with two right angle cleavages and moderate relief is observed enclosed in biotite (Slide EG.4). This mineral shows high order interference colours and high dispersion. From these characters tentatively it is identified as Orthite.

Quartz is wholly anhedral with sutured interlocking margins and interstitial to felspars. It occurs as recrystallised small size crystals when in the fractures of the felspars.

Very rarely apatite and sphene are also observed as minor accessories.
3.3.3 BALDA GRANITE

Megascopic description: This rock in hand specimen appears greyish to pinkish white leucocratic with colour index of 10-15%. It shows fine to medium grained equigranular aplite like texture. The minerals that can be identified are felspars of pink to white colour with interstitial smoky grey or colourless quartz with no cleavage and vitreous lusture. Colourless to silvery muscovite and black biotite flakes, scales and spangles are dispersed throughout the specimens. The former appears to be in greater abundance than the latter. Sometimes they are distributed in crude preferred orientation attributing gneissosity to the specimens.

Microscopic description: Balda granite is generally medium to fine grained but occasionally even coarse grained holocrystalline rock showing equigranular hypidiomorphic to allotriomorphic texture. It is comprised of plagioclase, alkali felspars (microcline > orthoclase), quartz as essential minerals and muscovite and biotite as major accessories. Sporadic tourmaline and fлюspar are also observed as minor accessory minerals.

Amongst the felspars, plagioclase which constitutes more than 2/3 of the total felspars, occurs
as subhedral prismatic or rectangular crystals showing occasional well developed zoning and alteration into clay minerals. Sometimes crude directional fabric is formed due to somewhat preferred orientation of plagioclase prismatic crystals (Slide No. BG 9).

Alkali felspars occur also as typical subhedral rectangular crystals with microcline being more abundant than orthoclase. Occasionally patch and vein perthite texture is developed in these alkali felspars and they are altered into dusty clay material. Rarely microcline shows strain effect and is altered into sericite along the cracks. The proportion of microcline relative to the other felspars is variable. As for instance in slide BG 4, marginal part of section has segregations of microcline crystals. At times microcline shows replacement relation with plagioclase.

Quartz is relatively in greater abundance here than Erinpura granite and as usual anhedral and interstitial to felspars. It shows typical wavy extinction and constitutes 30 to 40% of the rocks. It is quite variable in size from fairly large size anhedral crystals to those of small size enclosed in microcline.

Muscovite and biotite flakes are of varying sizes. Sometimes they are observed in intimate association and also as independent aggregates of big
flakes. Biotite prismatic crystals present strong pleochroism in shades of brown. Non-pleochroic basal sections are also observed. Occasionally biotite crystals are completely altered into green chlorite pseudomorphs.

Rarely prismatic crystals of tourmaline showing typical pleochroism in shades of brown and enclosing poikilitically small quartz is observed.

Sporadic flourspar is noted in some microsections as anhedral, colourless, low relief isotropic crystals along the margins of quartz and other minerals.

3.3.4 Comparative Study of Modes of Granites:

Modal analysis of Erinpura and Balda granite samples of the present area with their averages are presented in Table No. (3.1).

Comparative studies of these modes indicate that Erinpura granite has less of quartz and plagioclase and more of alkali felspars than Balda granite. The mica content in Balda grinite is slightly more than in Erinpura with muscovite in greater abundance than biotite, a feature just the opposite of that in Erinpura. Opaques are poorer in Balda compared to Erinpura.
### TABLE NO. 3.1

**MODAL ANALYSIS**

**Modal Analysis of Erinpura Granite:**

<table>
<thead>
<tr>
<th>Mineral%</th>
<th>RR-1</th>
<th>RR-3</th>
<th>RR-5</th>
<th>RR-6</th>
<th>RR-11</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>26.55</td>
<td>31.68</td>
<td>24.63</td>
<td>31.68</td>
<td>29.55</td>
<td>28.78</td>
</tr>
<tr>
<td>Microcline</td>
<td>41.35</td>
<td>37.03</td>
<td>36.45</td>
<td>39.47</td>
<td>35.47</td>
<td>37.74</td>
</tr>
<tr>
<td>Orthoclase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plagioclase</td>
<td>20.54</td>
<td>18.06</td>
<td>22.68</td>
<td>17.66</td>
<td>24.68</td>
<td>20.72</td>
</tr>
<tr>
<td>Muscovite</td>
<td>1.55</td>
<td>1.76</td>
<td>1.20</td>
<td>.51</td>
<td>.96</td>
<td>1.19</td>
</tr>
<tr>
<td>Biotite</td>
<td>8.65</td>
<td>10.50</td>
<td>14.50</td>
<td>9.80</td>
<td>8.10</td>
<td>10.36</td>
</tr>
<tr>
<td>Opaques</td>
<td>1.09</td>
<td>.66</td>
<td>.54</td>
<td>.78</td>
<td>1.25</td>
<td>.86</td>
</tr>
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</table>

**Modal Analysis of Balda Granite:**

<table>
<thead>
<tr>
<th>Mineral%</th>
<th>R-20</th>
<th>R-46</th>
<th>R-55</th>
<th>R-28</th>
<th>R-38</th>
<th>Average</th>
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<tr>
<td>Quartz</td>
<td>39.73</td>
<td>42.20</td>
<td>37.46</td>
<td>36.64</td>
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<td>39.77</td>
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<tr>
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<td>17.71</td>
<td>15.95</td>
<td>18.21</td>
<td>15.30</td>
<td>13.65</td>
<td>16.16</td>
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<tr>
<td>Orthoclase</td>
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<td></td>
</tr>
<tr>
<td>Plagioclase</td>
<td>28.14</td>
<td>25.98</td>
<td>29.29</td>
<td>34.03</td>
<td>30.26</td>
<td>29.54</td>
</tr>
<tr>
<td>Muscovite</td>
<td>11.92</td>
<td>13.71</td>
<td>12.83</td>
<td>8.80</td>
<td>10.96</td>
<td>11.64</td>
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<tr>
<td>Biotite</td>
<td>2.48</td>
<td>1.36</td>
<td>2.21</td>
<td>4.80</td>
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<td>2.55</td>
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<tr>
<td>Opaques</td>
<td></td>
<td>.80</td>
<td></td>
<td>.43</td>
<td>.37</td>
<td>.32</td>
</tr>
</tbody>
</table>
FIG. No. 3.1 : Q - A - P Plots of Balda & Erinpura Granites
(After Strekeisen, 1976)
Greater quantity of muscovite and quartz in Balda granite indicates that it is more evolved than Erinpura granite. This may be due to greisingen effect as is evidenced by the sparse occurrence of tourmaline and flourspar in it.

The differences in the modes of these two granites of the present area are clearly depicted by their plots in Q-A-P diagram (Fig. No. 3.1) of Strekeisen (1975). These plots show that Erinpura is a typical granite while Balda has a composition of granodiorite or on the boundary of granite and granodiorite.

3.3.5 QUARTZ VEIN ROCKS

Megascoptic description: These are generally of white colour and massive. Exposed surface of these vein rocks are stained faint brown due to weathering effects. They can be divided into three types viz. (I) Non-mineralized quartz vein; (II) Mineralized quartz vein; and (III) Quartz vein from shear zone. The last type shows at times a lot of tourmalinization. Its prismatic black crystals, form small rosetles or occur randomly. In mineralized types, sparse wolframite crystals are seen.
Microscopic description: All types of quartz vein rocks are nearly wholly made up of quartz anhedral crystals with interlocking sutured margins. Sheared vein rocks contain elongated and flattened quartz crystals parallel to the direction of shearing. They are also lenticular, relatively fine grained and show extreme wavy extinction. In fact the above petrographic features can be used to determine qualitatively the degree of shearing. Besides quartz occasionally muscovite flakes forming flower shaped aggregates and dark brownish biotite are also observed.
3.4: **FLUID INCLUSION STUDIES**:

To determine the physical and chemical nature of mineralization fluid inclusion studies provide an excellent method. In fact fluid inclusions are like fossils preserved in rocks and minerals and reveal the environment of mineralization. At the same time fluid inclusions also help in differentiating genetically related different lithounits.

In Balda tungsten deposit area, fluid inclusion studies are mainly carried out on rock samples of mineralized and non-mineralized quartz veins. Fluid inclusion study comprises of morphological examination of fluid inclusions, their density, types of inclusions (Primary or secondary) and approximate estimation of various phases in fluid inclusions.

3.4.1 **SAMPLE PREPARATION**:

For fluid inclusion study, samples were prepared by two methods (1) Preparation of slide for study by mounting flat small piece of sample to be studied in glycerine (2) Preparation of thin plates polished on both the sides. Keeping the thickness, nearly 0.5 mm, for optimum optical clarity (Roedder 1967). For examination and interpreting results of fluid inclusions, methods
used and information obtained is after Roedder (1967), Helgeson (1969), Panchpakesan & Balasubramaniam (1977).

3.4.2 **INTERPRETATION** :

Table No. 3.2 shows comparison and characters of fluid inclusions of mineralized and nonmineralized quartz veins.

From the study, it is observed that in mineralized quartz vein number of inclusions is low as compared to non mineralized quartz vein, while the inclusions of primary type are more in mineralized quartz vein. In mineralized quartz vein large size fluid inclusions with branching and elliptical shapes are scattered and randomly distributed. Presence of gaseous, liquid and solid phases are seen and daughter minerals identified are sodium chloride and potassium chloride crystals.

In non mineralized quartz veins fluid inclusion are very small in size with circular shape. Phases could not be identified due to small size and arrangement of secondary inclusions in linear fashion along some weak plane representing their secondary nature.

From these characters of fluid inclusions it is inferred that presence of uniform gas/liquid phase in all
### Table No. 3.2

**CHARACTERS OF FLUID INCLUSION IN MINERALIZED AND NONMINERALIZED QUARTZ VEINS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mineralized quartz vein</th>
<th>Non mineralized quartz vein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density of fluid Inclusions</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Types: Primary</td>
<td>Maximum</td>
<td>Few</td>
</tr>
<tr>
<td>: Secondary</td>
<td>Few</td>
<td>Maximum</td>
</tr>
<tr>
<td>or pseudo-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>secondary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phases:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gaseous</td>
<td>40-50%</td>
<td>Mainly liquid or</td>
</tr>
<tr>
<td>Liquid</td>
<td>30-40%</td>
<td>gaseous and could not</td>
</tr>
<tr>
<td>Solid</td>
<td>15-25%</td>
<td>detected well due to small size.</td>
</tr>
<tr>
<td>Size</td>
<td>Coarse</td>
<td>Small (fine)</td>
</tr>
<tr>
<td>Shape</td>
<td>Elliptical</td>
<td>Rounded</td>
</tr>
<tr>
<td></td>
<td>with branches</td>
<td></td>
</tr>
<tr>
<td>Arrangement</td>
<td>Scattered</td>
<td>Linear distribution,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>arranged along some</td>
</tr>
<tr>
<td></td>
<td></td>
<td>weak planes</td>
</tr>
<tr>
<td>Daughter minerals</td>
<td>Halite (NaCl)</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>and sylvite</td>
<td>(KCl)</td>
</tr>
</tbody>
</table>
FIG. No. 3.2: Trilinear Co-ordinate diagram of \( \text{H}_2\text{O} - \text{NaCl} - \text{KCl} \) system 'after Roedder, 1976'
inclusions of samples of mineralized quartz vein indicate the homogenous fluid phase of mineralizing solution.

Daughter minerals are of two types, halite and sylvite. They are identified by their isotropic nature and shapes. Halite (NaCl) forms perfect cubes and is isotropic while sylvite is isotropic but shows blunt edges. Presence of these two minerals in fluid inclusions, in fairly good amount (approx 20 to 30%) indicates the mineralizing solutions were highly saline.

Proportion of Halite (NaCl) - Sylvite (KCl) - water (H₂O-Liquid Phase) is calculated and found to be 40:10:50. These values are plotted in trilinear diagram (Figure No. 3.2) constructed by Roedder (1976). The plots indicate that the temperature of mineralizing fluids during the time of entrapment of inclusions was high, approximately above 300°C.

In non-mineralized quartz veins presence of only liquid and gaseous phase in inclusions indicates low temperature and lower salinity of fluids. Linear arrangement suggests that inclusions are aligned along some weak plane, through which mineralising fluids were in circulation. This character indicates that inclusions are of secondary nature.

Different characters of both types of quartz veins are given in Table No. 3.2. for the purpose of
comparison. It shows that these quartz veins are genetically different. Therefore, on the basis of characters of fluid inclusions, different quartz veins of this area can be differentiated and identified as mineralized or nonmineralized quartz veins.
3.5 CHEMICAL ANALYSIS OF WOLFRAMITE:

Mineralization of tungsten in this area is in the form of wolframite and it occurs as chunks, crystals and specks, in quartz veins and pegmatite veins of late phase, post-magmatic origin. These mineralised quartz veins are intrusive in schistose rocks, granite (Balda granite), shear zone and greisened zone.

In wolframite (FeMnWO$_4$), iron and manganese combine in different proportions with tungsten and form a complete isomorphous series, from hubnerite (MnWO$_4$) to ferberite (FeWO$_4$) and with wolframite as intermediate member, on the basis of existing physico-chemical conditions during mineralization. Inferences of environmental conditions of deposition from MnO/FeO ratio have been discussed by various authors like Groves and Baker (1972); Taylor and Hosking (1976); Singh and Varma (1977). On the basis of previous work to study the significance of FeO and MnO in wolframites of Balda tungsten deposit, samples of wolframite crystals and chunks as collected from different types of rocks and from different locations of this area are chemically analysed for various elements. Results of analyses are given in Table No. 3.3 and these are presented in figure No. 3.3 & 3.4.
**TABLE NO. 3.3**

**ANALYSES OF WOLFRAMITES SAMPLES**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>WO$_3$ in %</th>
<th>MnO in %</th>
<th>FeO in %</th>
<th>CaO in %</th>
<th>MnO / FeO</th>
<th>Samples types</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(3)</td>
<td>69.80</td>
<td>2.10</td>
<td>20.25</td>
<td>0.48</td>
<td>0.103</td>
<td>Quartz vein</td>
</tr>
<tr>
<td>2(4)</td>
<td>72.30</td>
<td>2.46</td>
<td>19.48</td>
<td>0.24</td>
<td>0.126</td>
<td>Pegmatite vein</td>
</tr>
<tr>
<td>3(3)</td>
<td>69.30</td>
<td>1.92</td>
<td>19.96</td>
<td>0.50</td>
<td>0.096</td>
<td>Greisened zone</td>
</tr>
<tr>
<td>4(3)</td>
<td>68.70</td>
<td>1.58</td>
<td>21.24</td>
<td>0.64</td>
<td>0.079</td>
<td>Contact zone</td>
</tr>
<tr>
<td>5(4)</td>
<td>71.40</td>
<td>2.54</td>
<td>19.52</td>
<td>0.38</td>
<td>0.130</td>
<td>Quartz vein from depth of 40 metres from surface</td>
</tr>
</tbody>
</table>

**Average**

<table>
<thead>
<tr>
<th></th>
<th>WO$_3$</th>
<th>MnO</th>
<th>FeO</th>
<th>CaO</th>
<th>MnO / FeO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70.30</td>
<td>2.14</td>
<td>20.08</td>
<td>0.48</td>
<td>0.107</td>
</tr>
</tbody>
</table>

Standard deviation of values of MnO / FeO = 0.0245.
3.5.1 **INTERPRETATION** :

From Table No 3.3 and Figures No 3.3 & 3.4, significant inferences obtained are as follows:

1. **Iron Vs Manganese content of wolframite**
   - designate these wolframites to be of Ferberite variety.

2. **MnO shows positive correlation and FeO shows negative correlation** while CaO shows similar trend as FeO, with rising WO₃ content (Fig. No. 3.4). Content of CaO in wolframite samples of present area is not of much significance, moreover, this little amount can be considered as a result of contact of mineralizing solution with the country rock.

3. **Plots of Iron/Manganese ratios of wolframite**
   - of this area, on the curve given by Singh & Verma (1977), as shown in Fig. No. 3.3, shows that prevailing temperatures during the time of mineralization were in the range of 250° to 400°C, with lower temperature of formation in contact zone, intermediate in greisened zone and high in quartz vein, pegmatite and in depth.

4. **Temperature range of 250° to 400°C of mineralization shows** that in this area mineralization is of mesothermal to hypothermal type.

5. **Environmental conditions in total area during depositional period were same** because variation in magnitude of MnO/FeO ratio is not of high order.
FIG. No. 3.3
Plots of $\text{MnO}/\text{FeO}$ ratios in Wolframites of Balda Tungsten on the curve, after Singh and Varma (1977)

FIG. No. 3.4
Relation of $\text{WO}_3$ with $\text{MnO}$, $\text{FeO}$ and $\text{CaO}$
MICROSCOPIC STUDIES OF POLISHED SECTION

To study the mineral constituents, texture and paragenesis of tungsten and associated minerals, polished section of available, limited number of samples are prepared and studied using 'Leitz's Laborlux II polar' ore microscope. From these studies, result obtained are as follows.

Identification and study of tungsten and associated minerals show that ore minerals occurring in quartz veins of this area comprises following minerals in decreasing order of abundance.

Wolframite (Ferberite)
Scheelite
Pyrite
Molybdenite
Chalcopyrite (?)

Wolframite is of ferberity variety (Iron rich) and occurs in form of cluster of coarse grained subhedral crystals. It is most abundant ore mineral and show yellowish grey colour and distinct isotropism.

Scheelite occurs as granular mass and specks along the fracture planes of wolframite and seems to be a replacement or alteration product of Wolframite. Other associated ore minerals are very scanty and found as
inclusion. In high power (500X) one can easily distinguish them as anhedral grains of pyrite, pitted molybdenite with a distinct property of internal reflection and chalcopyrite (?).

In most of the polished section studied, the texture looks like replacement type and the mineral assemblage points to a mesothermal conditions of formation. The paragenetic sequence deciphered from the mutual relationship of mineral is as follows.

Pyrite

Chalcopyrite

Molybdenite

Wolframite

Scheelite