The present chapter deals with the ore peculiarities of the Naraul area. Ore mineralogy has been described mainly on the basis of microscopic examination of the ores under the microscope. Some selected samples were also analysed using XRD. Fluid inclusion studies have been carried out on the cogenetic gangue quartz samples with a view to establish the physico-chemical conditions of ore deposition. The studied ore textures and their deformation reveal paragenesis and the general nature of mineralization besides effects of deformation on the primary textures of the ore.

There are two distinct types of ores occurring in the Naraul area, the polymetallic sulfides and iron oxides. Sulfide ores show bifold syngenetic and epigenetic relations with the host rock, while oxides are syngenetic with the host rock. Syngenetic sulfides which are mostly associated with the volcanic rocks of the area occur as specks, disseminations and cubic crystals in the host rock. At places quartzite belonging to Banjar Group contain pyrite grains, showing syngenetic relation with the host rock. Epigenetic sulfides occur as pockets and veins in the rocks of Larji and Banjar Groups neighbouring the shear zone. Maximum concentration of the ore is observed along the bedding and fracture plane of the calcareous quartzite band of the Naraul Formation. These features are well developed in Lalgi mine. In the quartzites and conglomeratic quartzite, these sulfide ores occur in the
form of specks and disseminations. While volcanic rocks carry epigenetic sulfide ores in amygdules along with the secondary epidote and as cubic crystals of pyrite in association with quartz veins.

Iron oxides, mostly occur parallel to bedding as bands of few mm to few cms alternating with the thick quartzite bands. They form part of the Manikaran Formation and define weak planes responsible for the foliation noticed in these quartzites.

ORE MINERALOGY

On the basis of ore mineralogy three distinct types of ore mineral assemblages have been identified in Naraul area.

SYNGENETIC TYPE: The syngenetic minerals consists of mainly chalcopyrite and pyrite in metavolcanics, pyrite in quartzite and detritus of older fragments eg. pyrite in conglomeratic quartzite containing preserved sulfides.

EPIGENETIC TYPE: The categorised sulfides and oxides include; chalcopyrite, pyrite, hematite, pyrrhotite, bornite, and galena in quartzites, calcareous quartzites, slates and quartz occurring in veins.

SUPERGENE ORE: The primary ore have been altered and oxidised to produce the minerals like covellite, bornite, malachite, azurite, cerrucite and iron hydroxides.

In the following lines mesoscopic and microscopic features of ore minerals observed in the area have been described:

Chalcopyrite: chalcopyrite occurs as specks, small pockets, veins and stringers of few mm to a few cms length, along the bedding and fracture planes. It shows brass yellow colour and
bronze tinge. In polished sections it occurs as fine to medium grained anhedral aggregates, which show brass yellow colour and weak anisotropy to yellowish green. Compared to bornite it shows higher polishing hardness. Replacement and exsolution textures of chalcopyrite with bornite are commonly observed.

**Pyrite**: It is most abundant of the sulfides occurring in the area. It occurs as enhedral cubic crystals in the host rock as well as associated secondary veins. The pyrite cubes occurring in metabasics a kilometer ahead of Raoli on the Jhuni road exhibit penetration twins (Pl.).

In polished sections pyrite occur as enhedral to sub-hedral crystals and irregular masses. It shows various replacement and oxidation textures along with the well developed deformation features. It shows yellowish white colour, internal reflections are not seen. It show higher polishing hardness than chalcopyrite.

**Pyrrhotite**: It is noticed occurring in veins and stringers with chalcopyrite. Under the microscope it shows irregular habit, high reflectivity and pinkish colour. It is isotropic to grey with no internal reflections. It also shows exsolution growth with pyrite (Pl.22b). It is also observed in association with chalcopyrite (Pl.22c).

**Cuprite**: In handspecimens it is difficult to distinguish, but under the microscope, it shows typical grey colour with bluish tinge. In the oil the tint becomes darker and blue hue deepens. The characteristic deep red internal reflections of
this mineral has been observed. It shows higher polishing hardness as compared to that of chalcopyrite and occurs as oxidation product of chalcopyrite (Pl.21e).

**Sphalerite** : Sphalerite has been noticed as irregular mass in association with chalcopyrite, pyrite and hematite. It shows grey colour and internal reflection of brownish colour. Polishing hardness is more than that for chalcopyrite.

**Galena** : It is found as specks and pockets in the epigenetic quartz veins. Galena occurs as anhedral masses, which are white in colour and shows high reflectivity in reflected light. Along the cleavage characteristic triangular pits are observed (Pl. 22f). It has been oxidised along cleavage and shows oxidational replacement.

**Hematite** : In handspecimens it occurs as thin layers alternating with the layers of quartzite. At the outcrop layers of hematite also show current bedded structure. It shows grey colour with distinct bluish tint. It is anisotropic to grey and shows abundant deep red internal reflections. In Manikaran Quartzite it is noticed in the form of euhedral to subhedral crystals, which at times form rossatte shaped clusters. It is also found associated with the epigenetic ores of shear zone.

**Magnetite** : It occurs as subhedral grains of grey colour, isotropic and without any internal reflections. It shows polishing hardness less than that of hematite.

**Bornite** : Under the microscope it shows replacement as well as lamellar intergrown with chalcopyrite. It shows pinkish brown colour in freshly polished sections, which tarnishes to
purplish violet after some time. Internal reflection are absent and it shows polishing hardness less than that of chalcopyrite. It occurs in association with pyrite, chalcopyrite, covellite and sphalerite.

Malachite and Azurite: Leachings of these minerals are observed at various places which serves as the indicators for oxidation and secondary enrichment of mineralization. They occur in association with limonite, azurite and goethite. They are more pronounced in fractures.

Covellite: In reflected light it shows characteristic violet-blue colour and anisotropy to brownish tint. Internal reflections are absent. It occurs as alteration product in the form of tiny laths in chalcopyrite and bronite.

Boulangerite - Cerrucite: Under the microscope these minerals occur as weathering products of galena. Cerrucite shows pure grey colour whereas boulangerite is white with grey tinge.

Siderite: In thin section it shows shombhedral cleavage deep brownish colour and is found associated with quartz-carbonate veins in the phyllites of Bhalan Formation.

In order to confirm the presence of above mentioned minerals, some selected samples were analysed by X-ray differection method. The analysis was carried out with the help of Phillips X-ray diffractometer. EDX microanalyser attached to SEM microscope was also used to confirm the presence of certain doubtful minerals.
TEXTURE

Various types of primary and secondary textures are observed in the ores occurring in the area. Which have been discussed in the following lines.

SYN-SEDIMENTARY TEXTURES: The iron oxides are noticed as bands and laminae parallel to bedding in Manikaran quartzite (Pl. 1f). Some of these laminae even define the current bedded structures observed in these rocks.

SYNGENETIC TEXTURE: Chalcopyrite and pyrite are most abundant of the sulfides occurring in the area. They are found as primary ore in the metavolcanics of Larji and Banjar Groups (Pl. 24a). Pyrites in the quartzites of Banjar Group also show syngenetic relation with the quartz veins (Pl. 24f). The pyrite grains are seen disseminated in the quartzite (Pl. 28b,c). At times they exhibit cogenetic grain boundary relation showing mutual boundary texture. Pyrites from the metavolcanics show cogenetic relation with chalcopyrite (31 b).

EPIGENETIC TEXTURE: Various textures indicating the epigenetic nature of chalcopyrite and associated sulfides include:

a) Cavity fillings (Pl. 24c, 28d and 29c)
b) Pore space fillings (Pl. 21a)
c) Chalcopyrite filling fractures of pyrite exhibiting earlier formation of pyrite than chalcopyrite (Pl. 24b).
d) Occurrence of chalcopyrite in amygdules along with
e) Occurrence of pyrite cubes in association with quartz veins (Pl. 16c).

EXSOULATION TEXTURE: The exsolution represents simultaneous crystallization of two minerals at static physical conditions. In the ores studied under the microscope various pairs of minerals showing exsolution textures include, chalcopyrite-bornite and pyrite-pyrrhotite. In chalcopyrite-bornite minerals are along (111) and (110) crystallographic planes (Pl. 23c) and show the characteristic basket weave texture (Rhamdor, 1969). In pyrite-pyrrhotite pair pyrrhotite occurs as an evolved phase in subhedral pyrite grain (Pl. 31a).

REPLACEMENT TEXTURE: Chalcopyrite is replaced by bornite along the margins (Pl. 23d) culminating into complete replacement of chalcopyrite. At places basket weave structure observed in chalcopyrite is a result of replacement (Pl. 23d), which is supported by the occurrence of bornite in vein fillings in the upper right corner. Bornite is also found to replace sphalerite. At times pyrite is found replacing the chalcopyrite (Pl. 23d) and bornite.

Oxidation of primary sulfides also leads to the formation of a number of secondary sulfides and oxides. These products usually occur rimming around the altered sulfides. Chalcopyrite is found altered to cuprite (Pl. 21e), covellite - azurite - limonite - goethite (Pl. 30d), malachite (Pl. 23b). Occasionally the oxidation is so strong that it has altered nearly whole of the chalcopyrite, leading to the formation of colloform bands (Pl. 21d). These bands often
exhibit chalcopyrite and pyrrhotite cores (Pl. 22c). The oxidation of pyrites has resulted in the formation of goethite – lepidocrocite rims. These bands have been described as colloform bands and at places complete oxidation of pyrite has left no trace of the replaced mineral in the core (Pl. 21d). Oxidation of galena is also observed where boulangerite and cerrucite are formed dominantly along the cleavage planes (Pl. 22f). Covellite is also observed as alteration product in the form of tiny laths in chalcopyrite. Copper sulfides have also been oxidised and altered to malachite and azurite, which are found associated with limonite, and goethite (Pl. 23b). Besides occurring as alteration product of sulfides, goethite also results from the alteration of hematite.

**DEFORMATION TEXTURES**

Syngenetic sulfides and oxides of Banjar Group have suffered all the three phases of deformation, along with the host rocks (Pl. 28b, 29d, e). This is inferred from the development of bedding parallel cleavage due to alignment of hematite flakes as observed near Raoli bridge. This cleavage shows the development of crenulations (Pl. 29d). Which suggests its deformation during second phase of deformation. In thin sections, pyrite cubes occurring in association with folded quartz views (third generation structures) suggest the deformation of sulfides during third phase of deformation (Pl. 16c).

The pyrite reflect complete set of microstructures along with the quartz associated with it. Fragmentation of pyrite (Pl. 101).
27e,f) indicate brittle deformation. Whereas on the other hand its flow is noticed as a result of folding (Pl. 28a,f). In the shear zone, intense fracturing of pyrite (Pl. 19a, 27f) indicates its early formation. Elongation of pyrite is common feature (Pl. 29b) observed besides the distortion of its symmetry (Pl. 24b) and twinning (Pl. 29b). The three stages of deformation, thus, have been suggested by banding, crenulation and folding-fracturing of the primary syngenetic ore. Ores occurring in veins and as fracture fillings are devoid of first two stages of deformation, which reflect their epigenetic nature. But these epigenetic ores have suffered third phase of deformation, as reflected by the folding of ore bearing quartz veins near Raoli bridge and Nagan Nal. The cogenetic nature of quartz of this stage has been confirmed through their boundary texture, which has also been evidenced by homogenization of fluid inclusions. The quartz gangue also shows accumulation in the form of pressure shadows around pyrite crystals (Pl. 29f). Asymmetric nature of these pressure shadows indicate shear component of deformation and its non-coaxial nature.

PARAGENESIS: The microscopic observations of polished section has suggested following assemblages.

Cpy - Bo - Az - Cov
Cpy - Cup
Cpy - Bo - Sph
Py - Cpy - Sph - Gal
Cpy - Bo - Py - Go - Lp - Lm
Cpy - Mal - Az - Lm - Go
The ore mineral in the metavolcanics of Banjar Group represents simple paragenesis. Chalcopyrite exhibit syngenetic relationship with the host rock. Pyrite is cogenetic with chalcopyrite and is also found to replace it. Pyrite itself is replaced by bornite and show exsolution texture with pyrrhotite. Certain pyrite grains show penetration which may be distinguished as second generation of pyrite (Craig & Vaughan, 1981). Bornite show replacement by goethite and lepidocrocite. On the basics of this interrelation following paragenesis is proposed:

Cpy -------------------------
Py --------------------- --------------------------
Pyrr --------------------------
Bo ------------------------------
Go -----------------------------
Lp ------------------------------

The relations of ores occurring in the shear zone are more complex. Pyrite show syngenetic relation with the host rock. Where as chalcopyrite and sphalerite occur as pore space filling and cavity fillings (Pl. 21a), which are indicative of their epigenetic nature. Pyrite have developed cracks as a result of deformation (Pl. 24b), which have acted as
channelways for the migration of second phase fluid. Solution activity seems to have taken place in pulses. Two major pulses have been identified. Earlier of these is responsible for the migration of chalcopyrite and sphalerite while later, cross cutting the earlier one is responsible for the deposition of second phase sulfides. Bornite usually occurs as alteration product of chalcopyrite (Pl. 23a), alteration being restricted to margin or (111) and (110) cleavage planes (Pl. 23d). Bornite itself show alteration to limonite - goethite or covellite. Along with bornite, chalcopyrite also show alteration to chalcocite or malachite - azurite (Pl. 2a, 23b). Exsolution textures are observed for chalcopyrite - bornite and sphalarite - galena. Galena also show alteration leading to cerrucite and boulangarite. These inter relations suggest following paragenetic sequence :

\[ \text{Py} \rightarrow \text{Cpy} \rightarrow \text{Bo} \rightarrow \text{Sph} \rightarrow \text{Cov} \rightarrow \text{Cup} \rightarrow \text{Mal-Az} \rightarrow \text{Lm-Go} \rightarrow \text{Gal} \rightarrow \text{Bo} \rightarrow \text{Cer} \]

In case of iron ores occurring in Manikaran quartzite, hematite and magnatite show syn-sedimentary characters (Pl. 1f). At
places pyrite crystals are also observed along with these minerals so the simple paragenesis for these minerals is:

\[
\begin{align*}
\text{Mg} & \quad -
\text{He} & \quad -
\text{Py} & \quad -
\end{align*}
\]

**Sulfide Mineral Intergrowth**: Intergrowth of pyrite and chalcopyrite occurring as syngenetic sulfides in metavolcanics suggest a temperature range between 170°-550°C (Barton & Skinner, 1979) and presence of bornite, along with this association at places, suggests copper rich nature of the solution phase. Pyrite - Pyrrhotite exsolution observed in one polished sample suggests their stability range between 500° - 750°C in highly enriched iron phase of the system Fe-Cu-S. (Barton & Skinner, 1979).

In the shear zone assemblages are discussed within the framework of somewhat speculative temperature-composition projection of the sulfur rich part of the Cu-Fe-S system after (Barton and Skinner, 1979) chalcopyrite - bornite assemblage falls in the copper rich part of the diagram and indicate temperature below 200°C.

Exsolution of chalcopyrite - bornite suggest a temperature 195 ± 5°C (Bretl, 1963). In the sulfide - carbonate - silica paragenesis at f CO2 = 10 atm, f S2 = 10-20 atm and fO2 below 10-45 atm, pyrrhotite - galena - sphalerite will recrystallise at about 250°C without siderite (Oen et al, 1975). On cooling pyrrhotite is replaced by Pyrite and marcasite, so Galena - sphalerite exsolution observed in calcareous
quartzite might indicate these conditions but sphalerite-chalcopyrite assemblage in the Cu-Fe-S-Zn system suggest low temperature and is stable up to 500 ± 10°C.

Deformational aspect of texture: Brittle deformation of pyrite (Pl. 24d, 27e,f) resulting from cataclasis indicate temperature below 400°C and confining pressure up to 600 MPa (Atkinson, 1975). But in certain circumstances pyrite shows ductile deformation under these conditions (Mookherjee, 1971) as observed near the shear zone (Pl. 28a). McClay and Ellis (1983) point out that at geological strain rates in low grade metamorphic environment, which is same in the present case, pressure solution and cataclastic flow are dominant operative mechanisms. Considerable brecciation (Pl. 24b) indicate moderate deformation (Craig and Vaughan, 1984). In the shear zone minor brecciation grades into complex cataclasis with an increasing degree of fragmentation and disorientation and has eventually resulted into durchbewegung texture (Pl. 24f), which according to Vokes (1969) indicate intense deformation.

FLUID INCLUSION THERMOMETRY
Fluid inclusions are microscopic isolated droplets trapped in minerals during its formation or afterwards by one of several processes. It thus represents the parent fluid from which the mineral was formed or in which it bathed after its formation during the geological past. The data obtained from fluid inclusions have been used for many purposes but more commonly for solving ore genetical and petrogenetical problems. As a result of advances made in the study of fluid inclusions
during the last two decades (Roedder, 1962, 1976, 1979, 1984; Potter 1977; Potter et al., 1978) now it is considered a potential tool to gain information regarding physico-chemical nature of ore forming fluids. The study in the present case was carried out to find the nature of ore fluids associated with the metavolcanics in Banjar Group and those reposable for the deposition of the ore within the shear zone.

Studies are based on some assumptions which has been given and justified by Roedder (1976). They include:

a) Crystal of an ore mineral (or a gangue mineral cogenetic with ore) grows from a fluid medium, irregularities in the growth process occur which usually cause the trapping of small amount of this medium within the crystal.

b) The fluid trap is representative sample of the ore fluid present at the moment of trapping.

c) Significant quantities of the material are neither lost nor gained from the inclusions after this trapping.

Sample Selection: Transparent mineral are best suited for fluid inclusion study. For the present study cogenetic gangue quartz was used to find the relevant data from the fluid inclusion. Its selection was made through the study in transmitted and reflected light. Though translucent sphalerite also occurs in the shear zone but its fineness and indistinct nature do not permit it to be studied for fluid inclusions.

Sample Preparation: For the study doubly polished wafers of
the selected samples were prepared. Wafers were cut using a thin diamond cutter with profused supply of water coolant. Fluid inclusion petrography was carried out on the wafers fixed on glass slide. While for heating studies these wafers were removed from the slide and balsam was washed away using the appropriate solvent.

Heating stage: Homogenization studies of the doubly polished wafers were carried out on commercially available percalibrated Lietz 1350 heating stage fitted on Lietz Orthoplan microscope within the inherent thermodynamic and optical limitations of the system for the heating purpose. Temperature was increased 2–4° min. through autotransformer while the temperature were recorded through the thermocouple thermometer. The low rate of heating helped in removing the temperature gradient within the chamber. Stage was cooled by circulating water system. The inclusions which occur near fracture and those with doubtful genetic nature were avoided. The readings were rechecked to avoid leakage if any in the inclusion.

The homogenization temperature was taken as the temperature at which bubble disappears and inclusion becomes one phase and homogeneous. This temperature may represent minimum temperature of formation (Craig and Vaughan, 1984). In few cases where daughter crystal did not match at liquid–vapour homogenization, temperature of homogenization is taken as halite dissolution.

Selection of inclusion: Primary and pseudo secondary inclusions were used for thermometric studies. These
inclusions were distinguished on the basis of criteria described by Roedder (1976). Moreover inclusions consisting of different phase ratio were checked for their genetic values indicating primary or secondary nature. As suggested by Roedder (1976) secondary inclusions showing leakage, latter refilling and necking down were carefully avoided.

Fluid inclusion observations: The studies have indicated presence of at least four types of inclusions in the samples which exists to primary and secondary inclusions. Secondary inclusions occur as planar groups and trails along healed fracture and grain boundaries. This classification is based on Roedder (1977). For the heating purpose temperature was increased 2-4°C/min. through autotransformar, while the temperature was measured through thermocouple thermometer. The slow rate of heating helped in removing temperature gradient within the chamber. Stage was cooled by circulating water system. The inclusion which occur along fractures and those with doubtful genetic position were avoided. The readings were rechecked to avoid leakage if any in the inclusions. The fluid inclusion data of the categorised types of inclusions is given in table 4 and their characteristic features are as follows:

Type-I inclusions are three phase halite bearing saline fluid inclusions (Pl. 27a). They contain 70-80% liquid, 10-20% gas and small cubic halite crystal. They are sparsely populated. Their size varies from 10-20μm. They are irregular to regular in shape (Pl. 25b, c, 27b). They are noticed in quartz vein
samples from. Gas bubble in these inclusions is dark in colour and always stationary while liquid is light transparent. The halite daughter crystal is identified by its refraction (RI=1.54) and cubic nature (Pl. 26a). It is mostly detached from the margin. On heating these inclusions show typical behavior where gas bubble gradually disappear at a temperature of 205° - 210° C. Interestingly the halite dissolution temperature forms the temperature of homogenization at a temperature 250°C. Thus they represent high saturation of salts in the parent fluid.

**Type-II** inclusions are biphase liquid-gas inclusions which are most widely present in the studied area (Pl. 25c, 26e). They are large 5-30μm in size, irregular to subrounded in shape and at times they are elongated, indicating necking down phenomenon (Pl. 25e). Metastability is also reflected by strong movement of gas bubble in most of these inclusions. Their wide homogenization range from 100° - 250°C leading to liquid phase and varied ratios of content indicate long process of hydrothermal activity during geological past. These inclusions are entrapped both in primary and pseudosecondary modes of origin (Pl. 25f). Pseudosecondary inclusions are smaller in size and comparatively round in shape (Pl. 25f). The liquid is colourless and gas is dark coloured. The variation in ratio of content may be because of release in pressure and long distance covered by parent fluid through structural voids. These inclusions also show negative crystal cavities suggesting slow rate of cooling (Pl. 26a).

**Type III** : These inclusions represent glass bearing liquid-
gas inclusions (Pl. 26b). They are irregular, large in size 20-25 μm. They exhibit vitrified glass compressing gas bubble (Pl. 26c). The glass covers as much as 50-60% of volume while liquid and gas is 30-40% and 5-10% respectively. Glass is identified by its typical cracks, vitrified nature and reflectance (RI=1.5). They are homogenized into liquid at temperature of 160 - 240°C. Glass probably indicate sudden cooling of ore fluid which has been substantiated by wide range of homogenization temperature.

Type IV: These inclusions are biphase secondary in nature. They form trails and arrays of liquid + gas inclusions (Pl. 26d). They consist of 80-90% liquid and 10-20% dark coloured gas phase. They are subrounded to elongate in shape and their size varies from 10-15 μm. They indicate low range of homogenization 105 - 115°C.

Fluid inclusion aspects in relation with ore mineralization

a) Homogenization temperature: Fluid inclusion are considered the only tool which can provide the temperature of entrapment and thus temperature of formation of ore minerals. Fluid inclusion on heating provides temperature of homogenization at which the heterogeneous phase of inclusion becomes homogeneous. This temperature is the minimum temperature of the formation of ore mineral (Roedder, 1976). The study on selected cogenetic gangue quartz (Pl. 21a, b) samples suggest a temperature range of 105-240°C. For type II biphase inclusions where two maxima at 140 - 150°C and 230 - 240°C
are obtained, the rise in temperature in these ranges suggest the ascending hydrothermal fluid activities giving rise to ore mineralization. More over the comparatively high temperature of homogenization in veins within metavolcanics exposed away from the thrust zone suggests that the evolution of the fluid is not from the thrust zone. These inclusions are highly populated near thrust zone. The three phase and biphase inclusions have been correlated with the two phases of mineralisation. The biphase inclusions represent second phase of mineralisation indicating minimum temperature of its formation in the range of 105-150°C. On the other hand first phase of mineralisation represented by three phased inclusions exhibit 140-240°C range of temperature.

**Salinity**: It has been evidenced that saline solutions have more affinity in the transportation of metallic ions. At the same time salinity derived from inclusions study in many cases have been correlated with the enrichment of ore. The present study indicate presence of two types of primary inclusions. Those which are undersaturated have salinity less than 26.3 wt.percent NaCl and three phase saturated inclusions which exhibit salinity range 32.5 - 34.6 wt percent NaCl derived from the dissolution temperature (Fig. 22) of halite daughter crystal (210 - 240°C). It is worth to notice that inclusions near the thrust are enriched in salt contents than those occurring further away. It can be taken to suggest that crystallization of first phase of ore from hot unsaturated solution while the thrusting was followed by saline rich hydrothermal activity, depositing second phase
ore minerals.

Density: Density of entrapped parent play vital role in establishing the transportation and enrichment of ore fluid. It has been derived using the graphical relation between degree of fill, salinity and density (Sepherd et al., 1985) (Fig. 23, 25). The density for Type I inclusions vary between 1.15 - 1.25 gm/cm while for Type II inclusions it ranges from 0.7 - 0.9 gm/cm. This represent the highly dense nature of second phase hydrothermal solution than the first phase parent solution which have migrated through larger distance depositing the small occurrences of ore at various places.

Pressure: The homogenization temperature obtained from heating experiments needs pressure correction to get temperature of formation (Roedder and Bodnar, 1980). These barometric informations can be had from regional geology, coexisting mineral pair, overhead burden, boiling point curve etc. The pressure may vary between lithostatic pressure and vapour pressure. The common depth of hydrothermal ore formation i.e. 5 - 6 km suggest the entrapment under a lithostatic pressure of about 1200 - 1500 bars but for these ore mineralizations, which exhibit mineralization in fractures and veins the pressure will be hydrostatic varying between 500 - 600 bars. Indirect measurement of pressure suggests even lower values (Fig. 24). For type I inclusions pressure falls in the range of 15 - 30 bars while that for type II inclusions varies from 3 - 8 bars (Fig. 24). Accordingly temperature correction for both the types of
inclusions is negligible.

Structural control: All the members of the Largi Group have been folded isoclinaly as observed from Bara Thach. Two sets of fractures, one parallel and the other oblique to the bedding plane and open spaces in the rocks in the vicinity of Banjar Thrust provided channels for solutions of first phase. Early nature of these solutions is indicated by abrupt termination of fracture fillings by over riding Banjar Group. Veins of this first phase are composed of both quartz and carbonate minerals. This phase is followed by thrusting of Banjar Group over the Larji Group. This thrusting was responsible for generating voids which served as pathways for second phase of solution activity in the area. The minerals of second phase include chalcopyrite – pyrite and galena with associated quartz gangue, however they are devoid of carbonate minerals. These minerals are noticed occurring in complex vein system which is intimately associated with the thrusting event.

Based on the foregoing discussion following arguments interrelating the ore minerals are worth commenting upon.

a) Metavolcanics and quartzites of the Banjar Group provided the source of primary sulfides.

b) The cracks resulted from the thrusting at the contact of Banjar and Larji Groups have acted as channelways for the migration of hot ascending ore fluid associated with the volcanic activity of Bhalan Group.

c) It is established that there were at least three phases
of solution activity responsible for ore mineralization. The solutions of these activity migrated through weak zones however last phase preceded the F deformation event.

d) The first phase of ore deposition has given rise chalcopyrite and pyrite which were formed from hot, saline moderately dense ore fluid at a temperature range of 230 - 240°C. While the second phase which also include galena besides chalcopyrite - pyrite evolved from saline dense ascending hydrothermal solution at a minimum temperature of 140 - 150°C.
Fig. 21a Homogenization temperature for fluid inclusion from the vicinity of Banjar Thrust.
Fig. 21b Homogenization temperature for fluid inclusions for the quartz cogenetic with sulphides occurring in metabasics.
Fig. 22 Halite dissolution temperature curve for Naraul Type I inclusions
Fig. 23 Degree of fill vs density plots for aqueous inclusions (Naraul).
Fig. 24 Vapor pressure calculated from inferred salinities and observed homogenization temperature for inclusions from Naraul Sulfide Belt.
Fig. 25 Temperature-density-composition diagram exhibiting position of inclusions from Naraul area.
<table>
<thead>
<tr>
<th>Type of Inclusions</th>
<th>Contents</th>
<th>Ratio (%)</th>
<th>Size (µm)</th>
<th>Temperature of homogenization</th>
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<tbody>
<tr>
<td>Type I Primary</td>
<td>L+G+H</td>
<td>L 70-80</td>
<td>10-20</td>
<td>140-150 °C &amp; 230-240 °C</td>
</tr>
<tr>
<td></td>
<td>L+G</td>
<td>G 10-20</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>L+H</td>
<td>H 5-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type II Primary</td>
<td>L+G</td>
<td>L 50-60</td>
<td>20-35</td>
<td>105-240 °C</td>
</tr>
<tr>
<td>Pseudo- secondary</td>
<td>L+G</td>
<td>G 50-30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type III Primary</td>
<td>L+G+GL</td>
<td>L 5-10</td>
<td>20-25</td>
<td>210-240 °C</td>
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<td></td>
<td>GL</td>
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<td></td>
<td>GL</td>
<td>GL 50-60</td>
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<tr>
<td>Type IV Secondary</td>
<td>L+G</td>
<td>L 80-90</td>
<td>10-15</td>
<td>105-110 °C</td>
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<tr>
<td></td>
<td>G</td>
<td>G 10-20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

L = Liquid, G = Gas, H = Halite, GL = Glass