3. Origin of Ore-Minerals from Residual Liquid of Magma

The residual liquids, which result as end phase of crystallisation-differentiation of magma, constitute hydrothermal solution. If the external pressure i.e. rock pressure is less than the vapour pressure of the residual liquid and the confining rock is permeable to the high penetrating power of the vapour under pressure, a vapour phase results, later to condense to a liquid phase. But if the external pressure is greater than the vapour pressure of the residual liquid, no vapour phase will result, and the mother liquors will be alkaline liquids, which may be expelled as such to form rising hydrothermal metallization solutions. The external pressure is high under deep seated conditions and so over there a vapour phase may be absent.

Thus, there are two methods of deposition of ore minerals from hydrothermal solutions :

(i) The hydrothermal solutions leave magma as gaseous emanations that later condense to hydrothermal liquids from which ores are deposited. This is a simple and likely method for transport of valuable constituents from the magma and their deposition.

(ii) The hydrothermal solutions, which leave the magma as attenuated alkaline liquids, carry with them ingredients of mineral deposits and deposit them at suitable sites under favourable conditions.

It seems likely that the ore-genesis took place in both the ways.

Brown, J.S. (1950) gave somewhat different views regarding ore-genesis. According to him ore deposits could not possibly have originated through the agency of water and water played only a minor part in the process. The fundamental reason for this is that the ore-fluid has to travel for many thousands of feet through solid rocks, having a porosity only between one and two per cent and average openings of 0.0005 mm or half microns. Further, hydrothermal theory would require accumulation of enormous volume of water at great depth in the heated crust of the earth to bring the metal to the surface, which seems decidedly difficult. He considers vapour as a major vehicle for these mineral substances to be deposited and entitled it a metallurgical interpretation of ore-genesis.

He advocates for several independent source magmas rather than one. Indications are that these various source magmas accumulate at different depths dependent, in main, on relative density, the lighter ones at the highest level, the heavier ones successively deeper. Outstanding in importance are :

Relation to Intrusives

The composition, size, form and depth of formation of the intrusive body play important role in formation of contact metasomatic mineral deposits. In general, intrusives of silicic and intermediate composition, such as quartz-monzonite, monzonite, granodiorite or quartz-diorite, yield mineral deposits. It is because they contain higher water content compared to that in basic rocks, and water in the magma is the chief collector and transporter of metals.

Intrusive bodies of the size of batholiths, stocks and those with gentle dips offer wider zones of reaction and, hence, are more favourable for contact metasomatic deposits. Irregular forms of cupolas and roof pendants also expose greater areas for reaction. Greater the depth of intrusion, lesser is the loss of magmatic emanations and more chances for formation of mineral deposits.

Relation to Invaded Rocks

The composition and structure of invaded rocks determine the nature and the extent of their alteration. Sedimentary rocks particularly carbonate rocks are the most susceptible to changes. They show recrystallization and recombination with foreign materials. The carbonate rock in the contact of the intrusive may be converted to garnet rock, silicate and ore. The shale and slate alter to hornfels with andalusite, sillimanite and staurolite. The sandstone recrystallizes to quartzite with sparse dissemination of ore minerals. The invaded igneous rock is the least affected, especially when the intrusive is also of the same composition. Metamorphic rocks are also not favourable for further alteration and ore localisation.

The structures like bedding, laminations, faults etc. serve as good channel ways for escaping emanations and may produce larger and more widely distributed ore deposits. Bedding planes in contrast to directions across it are more favourable for the magmatic emanations to yield better ore deposits.

Resulting Mineral Deposits

The resulting mineral deposits are found scattered irregularly within the contact aureole or close to the intrusive contacts, having tendency to concentrate towards the gentler dip of the intrusive, e.g. barytes occurs in limestones of Vempalle formation (Cuddapah), Andhra Pradesh, near the contact with basic sills or in the sills themselves. The graphite deposits in Orissa are found along the contact zones of khondalite with granite-gneiss associated with pegmatitic bodies.

The contact metasomatic deposits are mostly small in size, consist of several disconnected bodies and have abrupt terminations. The outlines are irregular with ramifying tongues, projecting outward. The ores are generally coarse in texture. They lack crystal outlines except with a few exceptions like pyrite, arsenopyrite etc. The deposits are characterised by an unusual assemblage of ore and gangue minerals, characteristic of high surface water and produce solvent that dissolves other minerals and carries them down the ground water table. The leaching solution as proceeds downward loses a part of their metallic content within the zone of oxidation as oxidised ore. The secondary or supergene sulphide enrichment takes place when the down trickling solution reaches below the water table and its metallic contents are precipitated as secondary sulphides. Below this zone is the primary or hypogene zone which remains altogether unaffected. The process in ideal situation gives rise to a zone of gossan in the topmost part of the oxidation zone, followed by a supergene enrichment zone and then a primary zone (Fig. 2.1).

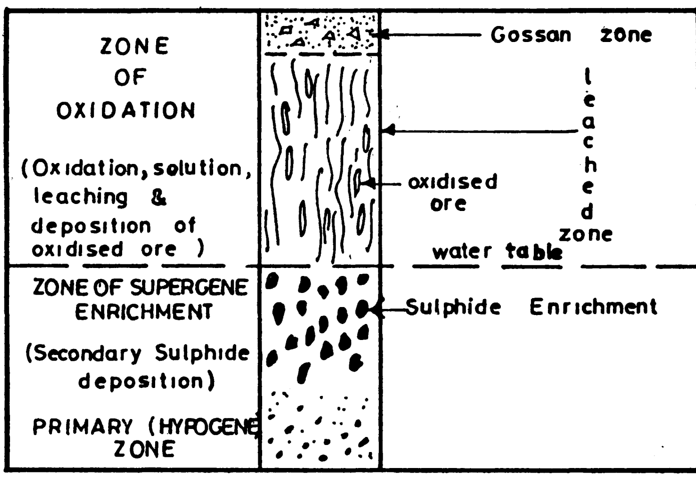

Fig. 2.1. Zones of oxidation and supergene enrichment.

Zones of Oxidation

Gossan : Gossan is the cap-rock of an ore deposit in the form of cellular mass of limonite and gangue formed due to oxidation of an ore and points to the nature of underlying hidden deposits.

Limonite : The limonite which is ubiquitous in the Gossan of the oxidised zone occurs in a variety of colours and structures, each of which is significant. It may have formed from iron-bearing sulphides or iron-bearing rock silicates. The former is distinguished from the latter by its solubility in dilute hydrochloric acid. The limonite so formed may be indigenous or transported. The free acid generated in the oxidation zone, transports iron in ferrous state and deposits it elsewhere, while the indigenous limonite occupies the voids left by former sulphides. In general, seal brown, maroon and orange colours of limonite in the cappings signify copper, while yellow and brick red indicate pyrite. Ocherous orange is suggestive of galena, tan to brown of sphalerite and tan to maroon of molybdenite.

(iv) long continued crustal stability to facilitate residual concentration and prevent destruction of deposits by erosion.

Under the above conditions a limestone deposit with ferruginous impurities may give rise to workable iron-ore deposit by removal of limestone in solution and accumulation of iron-oxides as insoluble residues. The weathering process may also result in new mineral deposit, like felspar of syenite decomposed to form bauxite, while the other constituents go into solution and removed. Likewise residual deposits of manganese, clay, nickel, phosphate, kyanite, barytes, ochre, tin, gold etc. may be formed. The source material, chemical changes and other details of formation may, however, in each case differ considerably. For example, the source material for the kyanite of Lapsaburu, Singhbhum, Bihar is the precambrian kyanite-quartz-granulite rock which by weathering under the warm humid climate caused removal of undesired materials to result a high quality kaynite deposit in the form of massive residual boulders.

B. Mechanical Concentration

Mechanical concentration is a process by which heavy minerals are separated from light ones by moving water or air and concentrated in the form of placer deposits. It, thus, includes two steps :

(i) separation of heavy and stable minerals from mother rock by the process of weathering, and

(ii) their accumulation at suitable site.

The source materials of the placer deposits may be lode deposits including veins and stringers, disseminated ore minerals, rock forming minerals and earlier placer deposits such as buried placers or bench stream gravels. A continuous supply of placer minerals is essential for mechanical concentration. The placer minerals have high specific gravity, and are durable and resistant to weathering.

Process

The placer minerals after release from the source materials by weathering are washed downslope to the nearest stream or to the seashore. The moving stream water takes away the lighter matrix to the farthest distance, while the heavies sink to the bottom and lag behind in their travel. The short currents and waves also separate heavy minerals from light ones. The heavies, thus, concentrate in the stream or beach gravels in sufficient amounts to form placer deposits. The process of concentration is dependent upon the difference in specific gravity, size and shape of particles. A heavier mineral sinks more rapidly than a lighter one of the same size. The shape and size of particles determine their specific surfaces which decide the rate of settling in water. Lesser specific surface means lesser friction and causes rapid settling, the weights of particles remaining the same. For example, a spherical body having less specific surface compared to a thin platy disc of the same weight, sinks more quickly. Velocity of moving water is the added factor which affects mechanical concentration. With the increase in velocity of water, the transporting power is increased and the