CHAPTER 3. STRUCTURE AND PROPERTIES OF MINERALS

3.1. The Structure of Crystalline Minerals

The spatial arrangement of atoms, ions or molecules in a crystal determines the structure of crystals. The structure of crystals depends mainly on:

- the types of bonds,
- effective radii of ions,
- Polarizability of the ions.

The flotation properties of minerals are strongly affected by the crystal structures of minerals.

The composition of the surfaces of particles (obtained by the grinding of minerals and subsequent interactions with the reagents) depends on the structures of the crystals. Thus, the direction of the cleavage planes along which the grains are broken during grinding and the final shapes of the grains are governed by the crystalline structure.

The crystals under impact, cleavage, bending, sliding and other mechanical actions generally break along predetermined crystallographic planes, called “planes of cleavage”. These planes are highly reflecting and smooth.

In ionic crystals, which have simple lattice, fracture should occur along planes of greatest separation (Fig. 3.1a) (halite).

For the ionic compounds having more complex lattices, cleavage occurs between parallel networks bordered by anions in the absence of cations between these networks (fluorite) (Fig.3.1b).

For minerals which possess two or more cleavage planes (calcite, Fig.3.1c and barite (Fig. 3.1d) cleavage occurs between the pairs of planes formed only by atoms of oxygen. Barite possesses three systems of cleavage taking place between pairs of atoms of oxygen along planes lacking cations.

In considering the phenomenon of cleavage in crystals with covalent bonds, it is useful to divide the crystals into two groups:

a) In which each atom in the lattice is surrounded by perfectly symmetrical neighbors at equal distances,

b) In which the neighboring atoms are at different distances.

In the first case, the cleavage planes do not separate molecules as in graphite and molybdenite. In graphite (Fig. 3.1e) fracture occurs along planes cutting across long weak bonds. An analogous behaviour is characteristic of molybdenite (Fig. 3.1.f), whose cleavage plane occurs along two parallel planes of sulphur atoms.

In the second case; metallic crystals possessing, as a result of free electrons, an increased plasticity, cleavage occurs with difficulty. However, it does occur and is subject to the same major rules as the cleavage in crystals with covalent bonds.
A somewhat special position with respect to cleavage is occupied by quartz and feldspars. Crystals of SiO$_2$ consist of SiO$_4$ complexes, forming oxygen tetrahedra with centrally located atoms of silicon; the bonds between atoms of silicon with all oxygen atoms is rather strong; however, SiO$_4$ does not form any radicals in quartz. Each atom of oxygen in the quartz structure belongs to two neighboring terahedra. No single plane can pass through the quartz crystal without severing strong bonds between silicon and oxygen. As a result, quartz does not possess any special cleavage. Feldspars, which also consist of terahedra, in addition to Si$^{4+}$, have Al$^{3+}$ of larger dimensions and these two cations form practically perpendicular planes along which fracture of the crystal occurs.
Classification of Minerals According to Their Flotation Properties

In addition to the crystallographic and chemical classifications there is classification of minerals according to their flotation properties.

**Sulphides of Heavy Metals and Native Metals**: This group contains minerals of copper, lead, zinc, mercury, antimony and others. They are characterized by poor wetting if their surfaces are not subjected to oxidation during the mining operations. Xanthates are the most effective collectors for the flotation of these minerals.

**Non-polar, Non-metallic Minerals**: This group contains naturally floatable (poor wettablility by water) minerals, as, for example, graphite, sulphur, coal and talc. Flotation of these minerals requires utilization of extremely weak collectors and sometimes only frothers.

**Oxidized Minerals of Non-ferrous Metals**: These consist of carbonates and sulphates of copper, lead and zinc, and other salts derived from oxygenated acids (cerussite, anglesite, smithsonite, malachite, azurite, etc.). Minerals of this group can be floated by xanthate collectors after their sulphidization and also directly (without sulphidization) by fatty acids and their soaps.

**Polar Salt-type Minerals which Contain Cations of Calcium, Magnesium, Barium and Strontium**: The predominant ionic character of the bonds in the crystalline lattices of these minerals, results in active interaction between their cations with anions of the collectors. Hence, these minerals actively enter into a reaction with anionic collectors. Minerals of this group are floated by fatty acids. Examples to these minerals: scheelite, apatite, phosphorite, fluorite, calcite, barite, magnesite, dolomite, etc.

**Oxides, Silicates and Aluminosilicates**: A large number of minerals of this group possess good floatability when either anionic or cationic collectors are used. However, the floatability of many of these minerals with anionic collectors is directly related to the presence of activating cations in their surfaces. A characteristic feature of the flotation of these minerals is a strong dependence on the conditions under which they formed. The following minerals belong to this group: silica, corundum, diaspore, gibbsite, zircon, rutile, hematite, magnetite, cassiterite, ilmenite, kyanite, andalusite, feldspars, mica, kaolinite asbestos, beryl, etc.

**Soluble Salts of Alkali and Alkaline Earth Metals**: These salts can be floated in their saturated solution, which enables them to maintain more or less complete solid phase under conditions of dynamic equilibrium. Flotation of the salt is carried out either by means of fatty acids or collectors of the cationic type. Minerals of this group amenable to flotation are halite, sylvite, kyanite, hydroboracite, etc.