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## Minerals and their environment of formation

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MINERALS AND THEIR ENVIRONMENT  
OF FORMATION.

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Approved.

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The history of mineralogy began with the development of mining and the use of certain minerals as useful products, such as lime, pigments and precious stones.

In order to know how to distinguish these minerals when found and where they were likely to be found, it was necessary to study the nature, properties and the modes of occurrence. In order to determine all these properties, it was necessary to classify and compare them with the purpose of ascertaining how they resemble each other, and how they differ.

Minerals have been generally classified by their geometrical, physical or chemical properties.

An important branch of scientific mineralogy is the study of the modes and places of occurrence, the origin and the changes to which the minerals are subject. This is valuable in the study of ore deposits.

It is well known that certain minerals are characteristic of certain zones or veins and that they are formed most favorably under certain definite physical conditions.

Recently several classifications of minerals have been made in regard to their mode of origin.

In a paper entitled "The Relations of Ore Deposits to Physical Conditions" by Waldemar Lindgren: the author has traced the relations of certain well known mineral

groupings to the physical conditions which there is reason to assume existed during their genesis.

The paper shows a series of deposits in which the mineral combinations gradually change from pegmatitic and contact metamorphic conditions, as the temperature and depth of the zones decrease, to conditions known to obtain at points where hot springs emerge at the surface.

W.H. Emmons in a paper entitled "A Genetic Classification of Minerals" reaches similar conclusions.

The purpose of this paper is to show that the minerals having the same environment of formation have similar physical or chemical properties.

Data from the articles mentioned have been freely used in the classification of the minerals for this paper.

Lindgren has named one group "persistent minerals", because they are formed under such a wide variety of conditions extending from igneous fusion up to or near the surface.

They are mostly sulphides and oxides, having a high grade of <sup>m</sup>symetry and a high specific gravity.

The sulphides are metallic sulphides.

The minerals formed under the highest temperature and pressure are supposed to be those formed in the molten magma. The magma is regarded as a solution, having all the characteristics of any other solution, but under high pressure and temperature and the minerals are mutually dissolved.

When the magma cools, it may solidify, forming either a glass with no crystals or forming an entire crystalline mass or any gradation between the two. The character depending upon the rate of cooling, the composition of the molten material and the circumstances under which it cools.

The minerals formed from the igneous fusion, aside from the anhydrous common rock making silicates; the oxides of titanium, silica, aluminum, iron and chromium are characteristic. Ferrous sulphide is more common than ferric sulphide. The oxides and fluorides found here are notably hard.

Among the veins formed under high pressure and temperature are the apatite and cassiterite veins and pegmatite dikes.

Cassiterite veins occur in contact with acid eruptions, namely granite, rich in soda and sometimes the rocks of the granite family, such as quartz porphyry, liparite and rhyolite. It is supposed that these veins were connected with the acid eruption and that in their formation the volatile fluorides and boron compounds took part.

These veins were formed immediately after the eruption of the granite, sometimes even before the complete cooling. The metasomatic processes along these veins are intense.

The cassiterite veins are especially characterized by hard minerals.

The apatite veins occur parallel to or following fissures or contraction joints near basic intrusions, namely gabbro.

The cassiterite and apatite veins are similar in many respects. Both types show characteristic pneumatolytic metamorphism of the country rock and abundance of the halogen elements; the tin veins carrying more fluorine; the apatite veins more chlorine.

In the apatite veins the metasomatic action on the country rock produces scapolite, which replaces the soda lime feldspars.

The minerals formed in the apatite veins are chiefly anhydrous silicates, having a hardness about the same as apatite. They are fusible and have a specific gravity near three.

Pegmatite veins contain coarse granular aggregates of quartz and feldspar, generally characterized by simultaneous crystallization. The rarer minerals, such as zircon, apatite, specularite, tourmaline, topaz, beryl and other minerals, containing rare earths are associated with these.

The pegmatite veins formed after the consolidation of the main mass of the igneous rocks and are to be considered as the last result of magmatic differentiations.

These dikes rarely contain deposits of economic importance except for tin and the rare metals.

The metasomatic action on the country rock is slight. The solution has a tendency to take up substance from the country rock, which may become part of the pegmatite and crystallize as garnet, zorsite, andalusite, stanrolite and feldspars.

The large group of hard anhydrous silicates and hard oxides especially characterize this environment.

Contact deposits are characterized by heavy anhydrous silicates and hard oxides. The sulphides present belong to the "persistent class."

These deposits are limited to the deposits formed at the contact of igneous intrusives with sedimentary rocks. They generally follow the contact irregularly and never extend far from the contact. The minerals generally occur in the limestone or calcareous rock. The sedimentaries usually undergo a more or less intense metasomatic alteration, due to the replacement of calcareous rock by hot gaseous solutions given off from the cooling magma. Limestone seems to be a substance especially favorable for causing the deposition of the minerals from this gaseous solution.

Among the deposits formed at shallow depths, but having some characteristic features which distinguish them from corresponding gold and silver deposits are the "Zeolitic Copper Veins" and copper deposits in amygdaloidal basalt.

The deposits of the Lake Superior region are typical of these two classes, where native copper is found associated with the zeolites.

The most important gangue minerals for both kinds of deposits is calcite. The common association of native silver and entire absence of gold is characteristic. The

presence of epidote, prehnite and some green earth minerals is also quite characteristic of these deposits. All of the minerals mentioned are characteristic alteration minerals of the basaltic rocks. The deposits in the Lake Superior region occur in the Cambrian.

The presence of hydrous silicates and their absence in the other veins is characteristic.

Other deposits at shallow depths are formed in the belt of weathering, belt of cementation and zone of secondary enrichment.

In the belt of weathering the minerals are characterized by the absence of sulphides and anhydrites. They are soft, have a low specific gravity and low symmetry.

This belt extends from the surface to the ground water level. The chief processes are the breaking down of the complex minerals into simpler minerals. Its reactions are mainly those of oxidation, carbonation, hydration and losses of material by leaching. Also it is a region of low pressure, relatively low temperature and great porosity. Solution is greater than deposition. These processes cause a decrease in volume, disintegration and softening.

At the ground water level is the lower oxidizing zone or the zone of secondary enrichment.

In the belt of weathering the oxidation of the sulphides produces sulphates.

These are transported downward and react upon the



sulphides, producing richer sulphurets in the lower oxidizing zone.

The minerals of this zone are the soft, rich, heavy ores of copper and silver.

Below the belt of weathering extending from the ground water level to the zone of flowage is the belt of cementation. Here the rocks are more or less porous and fractured. Its temperature is not very high, but the pressure is high enough to play an important part in the reconsolidation of sedimentary material. Redeposition is the rule here.

The minerals are harder than in the upper belt and are likewise characterized by the absence of sulphides and anhydrites and have a low symmetry.

Cinnabar and rich, heavy sulphides and native metals are formed in veins of shallow depth.

In many places veins containing gold, silver and metallic minerals are found in flows of volcanic origin which were at a few hundred to several thousand feet in depth at the time of the mineral deposition.

There is more silver and the gold is more finely divided here than in the deeper seated veins. They have been called "propylitic," "gold and silver veins," "fluoritic gold and silver veins." and by Vogt "younger veins."

Veins at the surface are characteristic of the filling of open cavities. Hot solutions at the surface seldom form deposits of economic importance.

Sulphides and oxides are characteristic. There are practically no minerals formed rich in water and the zeolites are almost unknown.

Haloids, nitrates and sulphates are the characteristic minerals of the desert and salt lakes. They are mostly soft, easily fusible, have a low specific gravity and a vitreous luster.

These lakes are found on all large continents in isolated areas from which the drainage never reaches the sea. The waters gather in the depressions and by concentration of their salts by evaporation become salt lakes or form dry beds of solid residue. These lakes are numerous in the desert region in western United States.

During the dry season the water in these lakes evaporates and the material held in solution is deposited. Vast amounts of alkaline material is deposited in this manner.