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# A COMPARISON OF THE ORE DEPOSITS OF LÅNGBAN, SWEDEN, WITH THOSE OF FRANKLIN, NEW JERSEY.

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Readers of the *American Mineralogist* will recall that quite recently Dr. Flink (1) published in its pages an account of Långban and its minerals. He gives a description of the geology and ore minerals and a list of the very large number of species found there. However, he makes no attempt to describe the genesis of the ores nor does he segregate the numerous and peculiar minerals into paragenetic groups.

The genetic history of these deposits is the principal theme of a paper by Dr. Magnusson (2) which was made available to American readers in a review by Dr. Geijer (2a) in *Economic Geology*. This review does not, however, reproduce the paragenetic table which is of peculiar interest.

The author had the good fortune to spend two days at Långban a few years since under the guidance of Dr. Magnusson. He desires to briefly summarize the facts concerning the Långban mines in order to bring out their similarities to, and differences from those of Franklin. Geijer's review is so concise and clear that it will be quoted in large part; and by reproducing Magnusson's genetic table the details of the mineralogy will be clearly evident.

"The Långban deposit contains iron ores and manganese ores. Although closely associated they are well separated from each other, there being rarely more than two per cent manganese in the iron ores and the same amount of iron in the manganese ore. The country rock is dolomite. Both kinds of ore are clearly replacement deposits. The iron occurs as specular hematite and magnetite. Brick red jasperoid is associated with the hematite, while the magnetite is accompanied by skarn silicates, as diopside, amphibole, and garnet. The magnetite ore and skarn surround the bodies of hematite and jasperoid. The relations clearly indicate that the former association is developed by a recrystallization and alteration of the hematite-jasperoid combination. An early stage in this is marked by the appearance of porphyroblasts of magnetite in the hematite.

"The manganese ore is braunite and hausmannite. The latter is accompanied by a skarn of manganese silicates, pyroxene, amphibole, garnet, and olivine. The relations between braunite and hausmannite (with skarn) form an exact counterpart to those of hematite and magnetite. The development of hausmannite porphyroblasts is well illustrated.

"The parageneses now shown to belong to two distinct periods are explained as follows. At first iron was deposited as oxide, manganese as oxide and partly carbonate, some of which is also still left. With the iron came the silica of the jasperoid. The geological facts admit of no other explanation than that the iron and manganese ores belong to the same period of mineralization. The salient problem, then, is the explanation of their deposition as separate ore bodies. . . . . The presence of abundant oxygen appears to account for the separate deposition of iron and manganese, the occurrence of manganese oxide and carbonate but no ferrous carbonate, the presence of lead as silicates instead of sulphide, and of arsenic as acid radicals, etc. Later, a rise of temperature has caused the change of hematite to magnetite, of braunite to hausmannite, and the accompanying skarns.

"Lead, arsenic and antimony occur constantly in all the ores of Långban. Of the lead silicates, kentrolite and melanotekite occur with the primary ores, ganomalite and hyalotekite with the skarn ores. Similarly, the primary arsenate, karyinite is replaced by berzeliite. Therefore, also the lead and arsenic minerals can be divided into those of primary deposition and those of the second or skarn period. The same holds true of the antimony.

"Later than the skarn minerals are the 'fissureminerals' representing a third period . . . . regarded as an end phase of the skarn period. In this group is found a great part of the famous Långban minerals, as arsenites, native lead, pyrochroite, thaumasite, tilasite, margarosanite."

With this very clear picture of the general nature of the Långban deposit before us and with Magnusson's detailed paragenetic table it is possible to get some insight into the development of the remarkable complex of minerals found at Långban. The primary

# PARAGENETIC CLASSIFICATION OF LÅNGBAN MINERALS (AFTER MAGNUSSON)

## Ore and Skarn Minerals

### 1st Period

*Iron Ores*

- Hematite $Fe_2O_3$
- Jasper $SiO_2$ with $Fe_2O_3$

*Manganese Ores*

- Braunite $MnO \cdot 3Mn_2O_3 \cdot SiO_2$
- Rhodochrosite $MnO \cdot CO_2$

*In Ores of both Types*

- Kentrolite $2PbO \cdot Mn_2O_3 \cdot 2SiO_2$
- Melanotekite $2PbO \cdot Fe_2O_3 \cdot 2SiO_2$
- Karyinite $3(Ca, Mg, Mn, Pb)O \cdot As_2O_5$
- Langbanite $m(Mn, Ca, Mg)O \cdot n(Fe,Mn)_2O_3 \cdot p(Sb_2O_3) \cdot SiO_2$

### 2nd Period

*Iron Ores*

- Magnetite $FeO \cdot Fe_2O_3$
- Garnet $3(Ca, Mg)O \cdot (Fe, Al)_2O_3 \cdot 3SiO_2$
- Actinolite $(Mg, Ca, Fe)O \cdot SiO_2$
- Malacolite $(Ca, Mg, Fe)O \cdot SiO_2$
- Forsterite $2(Mg, Fe)O \cdot SiO_2$

*Manganese Ores*

- Hausmannite $MnO \cdot Mn_2O_3$
- Mn-Garnet
- Rhodonite $(Mn, Ca)O \cdot SiO_2$
- Schefferite $(Ca, Mg, Mn)O \cdot SiO_2$
- Richterite $(Mg, Ca, Mn, Fe, Na_2, K_2)O \cdot SiO_2$
- Mn-Biotite
- Tephroite $2(Mn, Mg)O \cdot SiO_2$
- Forsterite $2MgO \cdot SiO_2$

*In Ores of both Types*

- Ganomalite $3PbO \cdot 2(Ca, Mn)O \cdot 3SiO_2$
- Hyalotekite $8(Pb, Ba, Ca)O \cdot B_2O_3 \cdot 12SiO_2$
- Molybdophyllite $(Pb, Mg)O \cdot H_2O \cdot SiO_2$
- Trimerite $2(Be, Mn, Ca)O \cdot SiO_2$
- Jakobsite $MnO \cdot Fe_2O_3$
- Plumboferrite $(Pb, Ca, Fe)O \cdot Fe_2O_3$
- Magnetoplumbite $2(Pb, Mn)O \cdot 3Fe_2O_3$
- Manganosite $MnO$
- Periclase $MgO$
- Bromellite $BeO$
- Pinakiolite $3MgO \cdot MnO \cdot Mn_2O_3 \cdot B_2O_3$
- Berzeliite $3(Ca, Mg, Mn)O \cdot As_2O_5$
- Hedyphane $9PbO \cdot PbCl_2 \cdot 3As_2O_5$
- Monimolite $3PbO \cdot Sb_2O_5$
- Atopite $2CaO \cdot Sb_2O_5$
- Weslienite $5(Ca, Fe, Na_2)O \cdot 2Sb_2O_5$
- Swedenborgite $Na_2O \cdot 2Al_2O_3 \cdot Sb_2O_3$
- Molybdenite $MoS_2$
- Galena $PbS$
- Chalcocite $Cu_2S$
- Sphalerite $ZnS$
- Chalcopyrite $CuFeS_2$
- Bornite $Cu_3FeS_3$
- Pyrite $FeS_2$

## Vein Minerals

### 3rd Period

*Both Types of Ore*

- Calcite $CaO \cdot CO_2$
- Aragonite $CaO \cdot CO_2$
- Hydrocerussite $3PbO \cdot 2CO_2 \cdot H_2O$
- Barite $BaO \cdot SO_3$
- Gypsum $CaO \cdot SO_3 \cdot 2H_2O$
- Pyrochroite $MnO \cdot H_2O$
- Bäckstromite $MnO \cdot H_2O$
- Manganite $Mn_2O_3 \cdot H_2O$
- Sphenomanganite $Mn_2O_3 \cdot H_2O$
- Quenselite $2PbO \cdot Mn_2O_3 \cdot H_2O$
- Pyroaurite $6MgO \cdot (Fe, Al)_2O_3 \cdot 15H_2O$
- Barysilite $3PbO \cdot 2SiO_2$
- Pectolite $(Na_2, Ca)O \cdot SiO_2$
- Margarosanite $PbO \cdot 2CaO \cdot 3SiO_2$
- Barylite $2BeO \cdot BaO \cdot 2SiO_2$
- Nasonite $5PbO \cdot 4CaO \cdot PbCl_2 \cdot 6SiO_2$
- Apophyllite $CaO \cdot 2SiO_2 \cdot 2H_2O$
- Inesite $(Mn, Ca)O \cdot SiO_2 \cdot H_2O$
- Thaumasite $3CaO \cdot CO_2 \cdot SO_3 \cdot SiO_2 \cdot 15H_2O$
- Ektropite $12(Mn, Fe, Mg, Ca)O \cdot 8SiO_2 \cdot 7H_2O$
- Dixenite $18MnO \cdot 2FeO \cdot CaO \cdot 4SiO_2 \cdot 4As_2O_3 \cdot 5H_2O$
- Armangite $3MnO \cdot As_2O_3$
- Tilasite $2CaO \cdot MgO \cdot MgF \cdot As_2O_5$
- Ekdemite $9PbO \cdot 2As_2O_3 \cdot 4PbCl$
- Finnemannite $9PbO \cdot 3As_2O_3 \cdot PbCl_2$
- Ochrolite $4PbO \cdot Sb_2O_3 \cdot 2PbCl_2$
- Allactite $7MnO \cdot As_2O_5 \cdot 4H_2O$
- Sarkinite $4MnO \cdot As_2O_5 \cdot H_2O$
- Trigonite $6PbO \cdot 2MnO \cdot 3As_2O_3 \cdot H_2O$
- Acrochordite $4MnO \cdot MgO \cdot As_2O_5 \cdot 6H_2O$
- Pyrobelonite $PbO \cdot MnO \cdot V_2O_5 \cdot H_2O$
- Lead $Pb$
- Copper $Cu$
- Silver $Ag$
- Bismuth $Bi$
- Fluorite $CaF_2$
- Scheelite $CaO \cdot WO_3$

replacements were composed of few minerals, the chief ones of very simple composition. The rise of temperature which followed their deposition caused widespread chemical interactions of the original minerals with a great increase in the mineral complexity of the resulting aggregate. Magnusson believes that nothing of importance was added to the deposit after the primary mineralization. Nevertheless several elements appear in the skarn period which were not found in the earlier minerals. Boron in hyalotekite and pinakiolite; beryllium in trimerite and bromellite; chlorine in hedyphane; are suggestive of magmatic additions. The sulphides, too, found in nests in skarn and magnetite appear to be additions. Manganosite and periclase are interpreted as resulting from the breakdown of rhodochrosite and dolomite, respectively.

The third period, that of vein formation, is marked by still greater mineral diversity. The veins are for the most part small gash veins, often with open vugs and generally containing abundant calcite. They are found in skarn, in both types of ore, and especially in the narrow spaces separating iron and manganese ore bodies, so they contain materials drawn from both sources. The author's impression gained during his brief visit to the mine and from the study of many specimens was that the vein material had not travelled far. Many of the minerals have been found in but a single vein or small group of them and Flink's description of the hundreds of specimens which have been preserved for study, in each of which occurs a single mineral or even a single crystal, indicates very local chemical reactions.

There is a noteworthy development of hydrous minerals which is in agreement with the lower temperature assumed by Magnusson to have prevailed during their formation. Barite is abundant and fluorine appears in fluorite and tilasite. Reducing conditions are indicated by the occurrence of native metals, lead especially being found in masses as great as fifty pounds in weight; and by the presence of arsenites like armangite and manganites like quenselite. The multiplicity of lead compounds and of arsenates and silicoarsenates of manganese is the chief feature of the mineralogy of the veins.

The idea has frequently found expression that the Långban deposits have much in common with those of Franklin. It is based on the fact that not only do both deposits consist largely of iron and manganese ores but that a number of rather complex minerals are common to both and are practically unknown elsewhere. Such minerals are shown in the list that follows.

Schefferite = Mn-pyroxene
Manganophyllite = Mn-biotite
Tephroite = Mn-olivine
Manganosite
Pyrochroite
Hedyphane
Barysilite
Margarosanite
Nasonite
Allactite
Dixenite, Långban, close to Mcgovernite, Sterling Hill

If we include with Långban in this comparison the closely similar deposits of manganese ore at Harstigen, Pajsberg and Jacobsberg we may add to this list:

Hyalophane
Caryopilite = bementite of Franklin
Ectropite = bementite of Franklin, probably
Friedelite
Ganophyllite

Those minerals then, common to both deposits, include manganese silicates, oxides, and arsenates; and lead silicates. The list is not impressive. The principal ore minerals of the two localities are different. And there is the important difference that zinc is wholly absent from the Långban ores.

The geological history of the Franklin deposits is more diversified. There is, however, the striking analogy between the two that manganese-rich skarn has formed in great quantity at both, due to an increase in temperature after the primary minerals were implaced; at Långban this rise was apparently regional while at Franklin it was due to contact metamorphism of a local sort. At Långban the rarer elements whose presence led to the formation of a host of minerals, lead, arsenic and antimony, seem to have been introduced with the ore; at Franklin on the other hand the comparable elements, lead, arsenic, chlorine and sulphur, came in with the later pegmatite. If the mineralogical complexity of the two ore deposits is based on the length of the respective mineral lists, there is no great difference between them unless we include the as yet undescribed minerals from Långban in which case the balance lies heavily in favor of the latter. It is of course to be remembered that the deposits in New Jersey are vastly more extensive than those of Sweden so that the mineral richness of Långban is proportionately much more remarkable.

## REFERENCES

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This paper which is in English gives much additional material on the geology of the mines, with a map.

Discussion of the foregoing paper would be welcomed by the author and editor and any comments or criticisms received will be printed in a future number of the Journal. The Editor.