

THE AMERICAN MINERALOGIST

JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA

VOL. 14

FEBRUARY, 1929

No. 2

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	VEIN MINERALS
1st Period	2nd Period	3rd Period
<i>Iron Ores</i>	<i>Iron Ores</i>	<i>Both Types of Ore</i>
Hematite Fe_2O_3	Magnetite $\text{FeO} \cdot \text{Fe}_2\text{O}_3$	Calcite $\text{CaO} \cdot \text{CO}_2$
Jasper SiO_2 with Fe_2O_3	Garnet $3(\text{Ca}, \text{Mg})\text{O} \cdot (\text{Fe}, \text{Al})_2\text{O}_3 \cdot 3\text{SiO}_2$	Aragonite $\text{CaO} \cdot \text{CO}_2$
	Actinolite $(\text{Mg}, \text{Ca}, \text{Fe})\text{O} \cdot \text{SiO}_2$	Hydrocerussite $3\text{PbO} \cdot 2\text{CO}_2 \cdot \text{H}_2\text{O}$
	Malacolite $(\text{Ca}, \text{Mg}, \text{Fe})\text{O} \cdot \text{SiO}_2$	Barite $\text{BaO} \cdot \text{SO}_3$
	Forsterite $2(\text{Mg}, \text{Fe})\text{O} \cdot \text{SiO}_2$	Gypsum $\text{CaO} \cdot \text{SO}_3 \cdot 2\text{H}_2\text{O}$
<i>Manganese Ores</i>	<i>Manganese Ores</i>	Pyrochroite $\text{MnO} \cdot \text{H}_2\text{O}$
Braunite $\text{MnO} \cdot 3\text{Mn}_2\text{O}_3 \cdot \text{SiO}_2$	Hausmannite $\text{MnO} \cdot \text{Mn}_2\text{O}_3$	Bäckstromite $\text{MnO} \cdot \text{H}_2\text{O}$
Rhodochrosite $\text{MnO} \cdot \text{CO}_2$	Mn-Garnet	Manganite $\text{Mn}_2\text{O}_3 \cdot \text{H}_2\text{O}$
	Rhodonite $(\text{Mn}, \text{Ca})\text{O} \cdot \text{SiO}_2$	Sphenomanganite $\text{Mn}_2\text{O}_3 \cdot \text{H}_2\text{O}$
	Schefferite $(\text{Ca}, \text{Mg}, \text{Mn})\text{O} \cdot \text{SiO}_2$	Quenselite $2\text{PbO} \cdot \text{Mn}_2\text{O}_3 \cdot \text{H}_2\text{O}$
	Richterite $(\text{Mg}, \text{Ca}, \text{Mn}, \text{Fe}, \text{Na}_2, \text{K}_2)\text{O} \cdot \text{SiO}_2$	Pyroaurite $6\text{MgO} \cdot (\text{Fe}, \text{Al})_2\text{O}_3 \cdot 15\text{H}_2\text{O}$
	Mn-Biotite	Barysilite $3\text{PbO} \cdot 2\text{SiO}_2$
	Tephroite $2(\text{Mn}, \text{Mg})\text{O} \cdot \text{SiO}_2$	Pectolite $(\text{Na}_2, \text{Ca})\text{O} \cdot \text{SiO}_2$
	Forsterite $2\text{MgO} \cdot \text{SiO}_2$	Margarosanite $\text{PbO} \cdot 2\text{CaO} \cdot 3\text{SiO}_2$
		Barylite $2\text{BeO} \cdot \text{BaO} \cdot 2\text{SiO}_2$
<i>In Ores of both Types</i>	<i>In Ores of both Types</i>	Nasonite $5\text{PbO} \cdot 4\text{CaO} \cdot \text{PbCl}_2 \cdot 6\text{SiO}_2$
Kentrolite $2\text{PbO} \cdot \text{Mn}_2\text{O}_3 \cdot 2\text{SiO}_2$	Ganomalite $3\text{PbO} \cdot 2(\text{Ca}, \text{Mn})\text{O} \cdot 3\text{SiO}_2$	Apophyllite $\text{CaO} \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$
Melanotekite $2\text{PbO} \cdot \text{Fe}_2\text{O}_3 \cdot 2\text{SiO}_2$	Hyalotekite $8(\text{Pb}, \text{Ba}, \text{Ca})\text{O} \cdot \text{B}_2\text{O}_3 \cdot 12\text{SiO}_2$	Inesite $(\text{Mn}, \text{Ca})\text{O} \cdot \text{SiO}_2 \cdot \text{H}_2\text{O}$
Karyinite $3(\text{Ca}, \text{Mg}, \text{Mn}, \text{Pb})\text{O} \cdot \text{As}_2\text{O}_5$	Molybdophyllite $(\text{Pb}, \text{Mg})\text{O} \cdot \text{H}_2\text{O} \cdot \text{SiO}_2$	Thaumasite $3\text{CaO} \cdot \text{CO}_2 \cdot \text{SO}_3 \cdot \text{SiO}_2 \cdot 15\text{H}_2\text{O}$
Langbanite $m(\text{Mn}, \text{Ca}, \text{Mg})\text{O} \cdot n(\text{Fe}, \text{Mn})_2\text{O}_3 \cdot p(\text{Sb}_2\text{O}_3) \cdot \text{SiO}_2$	Trimerite $2(\text{Be}, \text{Mn}, \text{Ca})\text{O} \cdot \text{SiO}_2$	Ektropite $12(\text{Mn}, \text{Fe}, \text{Mg}, \text{Ca})\text{O} \cdot 8\text{SiO}_2 \cdot 7\text{H}_2\text{O}$
	Jakobsite $\text{MnO} \cdot \text{Fe}_2\text{O}_3$	Dixenite $18\text{MnO} \cdot 2\text{FeO} \cdot \text{CaO} \cdot 4\text{SiO}_2 \cdot 4\text{As}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$
	Plumboferrite $(\text{Pb}, \text{Ca}, \text{Fe})\text{O} \cdot \text{Fe}_2\text{O}_3$	Armangite $3\text{MnO} \cdot \text{As}_2\text{O}_3$
	Magnetoplumbite $2(\text{Pb}, \text{Mn})\text{O} \cdot 3\text{Fe}_2\text{O}_3$	Tilasite $2\text{CaO} \cdot \text{MgO} \cdot \text{MgF} \cdot \text{As}_2\text{O}_5$
	Manganosite MnO	Ekdemite $9\text{PbO} \cdot 2\text{As}_2\text{O}_3 \cdot 4\text{PbCl}$
	Periclase MgO	Finnemannite $9\text{PbO} \cdot 3\text{As}_2\text{O}_3 \cdot \text{PbCl}_2$
	Bromellite BeO	Ochrolite $4\text{PbO} \cdot \text{Sb}_2\text{O}_3 \cdot 2\text{PbCl}_2$
	Pinakiolite $3\text{MgO} \cdot \text{MnO} \cdot \text{Mn}_2\text{O}_3 \cdot \text{B}_2\text{O}_3$	Allactite $7\text{MnO} \cdot \text{As}_2\text{O}_5 \cdot 4\text{H}_2\text{O}$
	Berzeliite $3(\text{Ca}, \text{Mg}, \text{Mn})\text{O} \cdot \text{As}_2\text{O}_5$	Sarkinite $4\text{MnO} \cdot \text{As}_2\text{O}_5 \cdot \text{H}_2\text{O}$
	Hedyphane $9\text{PbO} \cdot \text{PbCl}_2 \cdot 3\text{As}_2\text{O}_5$	Trigonite $6\text{PbO} \cdot 2\text{MnO} \cdot 3\text{As}_2\text{O}_3 \cdot \text{H}_2\text{O}$
	Monimolite $3\text{PbO} \cdot \text{Sb}_2\text{O}_5$	Acrochordite $4\text{MnO} \cdot \text{MgO} \cdot \text{As}_2\text{O}_5 \cdot 6\text{H}_2\text{O}$
	Atopite $2\text{CaO} \cdot \text{Sb}_2\text{O}_5$	Pyrobelonite $\text{PbO} \cdot \text{MnO} \cdot \text{V}_2\text{O}_5 \cdot \text{H}_2\text{O}$
	Weslienite $5(\text{Ca}, \text{Fe}, \text{Na}_2)\text{O} \cdot 2\text{Sb}_2\text{O}_5$	Lead Pb
	Swedenborgite $\text{Na}_2\text{O} \cdot 2\text{Al}_2\text{O}_3 \cdot \text{Sb}_2\text{O}_3$	Copper Cu
	Molybdenite MoS_2	Silver Ag
	Galena PbS	Bismuth Bi
	Chalcocite Cu_2S	Fluorite CaF_2
	Sphalerite ZnS	Scheelite $\text{CaO} \cdot \text{WO}_3$
	Chalcopyrite CuFeS_2	
	Bornite Cu_3FeS_3	
	Pyrite FeS_2	

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 silico-arsenates 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	Barysilite
Manganophyllite = Mn-biotite	Margarosanite
Tephroite = Mn-olivine	Nasonite
Manganosite	Allactite
Pyrochroite	Dixenite, Långban, close to Mcgovernite,
Hedyphane	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.

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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.