4. The Manganese, Iron and Copper Mineralization at Kesebol in Dalsland, Southwestern Sweden

By

Per Geijer

Introduction

The occurrence of manganese minerals in the province of Dalsland, W. of the southwestern part of Lake Vänern, has long been known, but no serious attempts at mining these deposits were made before Sweden's trade isolation during World War I, when almost anything containing manganese was at a premium. Of the half a dozen or so of deposits that were then opened up, most were small and lean, and only one mine, that at Kesebol, survived the end of the war and proved workable also under peace-time conditions. Most of its good ore was taken out in the 1920's; during World War II the mine was reopened and some remaining ore was recovered. The relative importance of the Kesebol mine can be judged from the official statistics, which report for all the other mines (1916–1918) a total production of 5,360 metric tons, averaging 20–28 per cent Mn, while production at Kesebol during the periods of activity between 1918 and 1944 was as follows:

Average percentage of Mn	Metric tons
48	6,313
40	3,588
35	19,600
25–28	6,412
12.5–15.5	5,573

Also there is reported (1927) a quantity of 177 tons of copper ore, averaging 15 per cent Cu.

Scientifically, too, the Kesebol deposit presents most interest. Since very little has been published—and that in part inaccurate—on the small but well-defined metallogenetic province in question, it has appeared desirable to give a brief description of the Kesebol deposit. This account is based on field observations made for Wargöns Aktiebolag during several stages of the mining, and on the study of a set of specimens brought together on these occasions and preserved in the collections of the Royal Institute of Technology, Stockholm. Use has also been made of the official mine map (work chiefly by T. Hallgren), and of an unpublished examination paper by S. V. Sölver, who, on the writer's initiative, undertook a microscopic study of a number of specimens in the collection already referred to (Sölver, 1942). Of special interest in this paper is the identification of jacobsite, not previously noted in the deposit.

The writer wishes to express his gratitude to Wargöns Aktiebolag for permission to publish this description, which is essentially based on work done for that company, and to Professor Frans E. Wickman, curator of the Mineralogical Department of the Swedish Museum of Natural History, Stockholm, where the laboratory work has been carried out.

General Geology

In the part of Dalsland where manganese deposits occur, the bedrock represents two separate units of the Precambrian. The oldest one, referred to the Gothian cycle, is made up of the Åmål supracrustal formation of volcanics (mostly acid to intermediate in composition) and sediments such as quartzite, and further of granites intrusive into this formation; of the granites, only the reddish, salic Kroppefjäll type is represented in the Kesebol area. The other, later unit is the Dalslandian, a supracrustal sequence of arenaceous and argillaceous sediments with subordinate volcanic intercalations; it is separated from the underlying Gothian by a great unconformity. Recent studies (Larsson, 1956) have shown that the Bohus granite, which is represented by some small stocks in the north, is later than the Dalslandian and its deformation. This deformation has taken the form of strong compression, with folding axes running approximately S.–N. and local overthrusts; a final stage has been the development of block movements along fissures that obliquely cut across the folded zone.

The district contains three types of ore deposits, viz. the "copper slate" of Stora Strand, replacement deposits of iron and manganese, and fissure veins with sulfides of copper and lead. The Stora Strand deposit shows no appreciable relation to the others and will not be further considered here. The iron and manganese deposits are numerous, but mostly quite small. Older data on them, and some observations from the 1916–1918 mining, have been compiled by Tegengren (1924). The relative amounts of the two metals show great variations, and there are even reported iron deposits without any associated manganese ore. All occurrences are in shear zones, as a rule in the Gothian rocks but exceptionally in those of the Dalslandian, and are formed by replacement or, more rarely, by fissure filling. The iron mineral is crystalline hematite. The manganese minerals reported are manganite, rhodonite, and rhodocrosite; those reported as forming the gangue are quartz, calcite, chlorite, barite, and rarely fluorite. Pyrolusite has been mentioned by earlier observers but this was believed to be due to a mistake for manganite. The reports of manganite appear to be based on data by Flink (1910), but the arguments for this identification are unsatisfactory. The couple of specimens in the collections of the Mineralogical Department, on which FLINK's study was based, show a black mammillary mineral. A powder photograph was kindly taken by Dr O. GABRIELSON, of the Department; it showed conclusively that the material cannot be manganite. On the other hand, no positive identification could be made. It is clear that this is a supergene product and, since most of the ore mined showed no signs of secondary oxidation, it is probable that it was restricted to the top parts of some deposits.

In the third group of metalliferous deposits, the sulfide-bearing veins (TEGENGREN, 1924), several types are represented, but their close relations are apparent. Thus there are veins with pyrite, chalcopyrite, and galena, others characterized by the presence of bornite (with chalcocite, galena, etc), and a third type with argentiferous tetrahedrite. The amount of sulfides in the veins is small. The fact that copper sulfides have also been found associated with the iron and manganese mineralization has been taken as an indication of a genetic connection between these two types of epigenetic deposits in Dalsland.

The Kesebol Deposit

Local geology

From the Strandhem farm a valley runs northwards for about 1 km, decreasing in width until the rock exposures on the sides almost meet. The eastern side of the valley is a low rock scarp, in which there is a chain of occurrences of manganese minerals: near the southern end is the Klapperud (or Strandhem) mine, which was last worked in 1917–1918, and at the northern end the Kesebol mine. Between these larger concentrations, manganese minerals have been found in small quantities at several places. The valley W. of this ore-bearing zone is eroded along a belt of great weakness. Drilling near the Kesebol mine has disclosed in this belt, even at considerable depths, zones of "sand", which may represent rock comminuted *in situ*, or possibly fillings from above. The rock of the eastern wall frequently exhibits strong shearing.

At the Kesebol mine, the predominant country rock is a hälleflinta of the Åmål formation, a rhyolitic form with phenocrysts of quartz. In its present state it cannot be decided whether it was formed as a flow or a pyroclastic deposit. Kroppefjäll granite forms the western side of the valley, and some tongues of it have been encountered in the mine workings.

Mineralization at Kesebol is chiefly concentrated as three ore bodies, here referred to as the *A*, *B*, and *C* bodies (Fig. 1). The surrounding hälleflinta is much broken up, often with quartz veinlets, but there is no defined zone of crushing. *A* and *B* fit into the S.–N. alignment that marks the ore-bearing zone as such, but the columnar *C* body is oriented at almost right angles to it. Dip is easterly, about 55° to 75°. Small concentrations of ore minerals are found

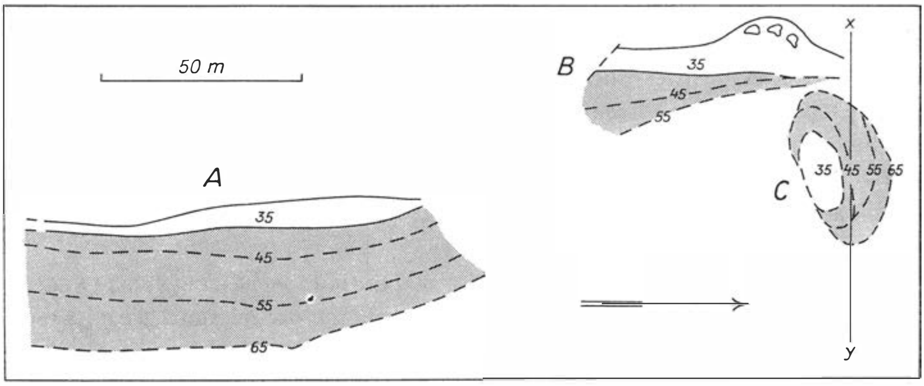

Fig. 1. Horizontal projection of the Kesebol ore bodies between the 35 m and 65 m levels. Scale 1:1200. Constructed from the official mine map.

at many points outside the workable ore bodies. There are three kinds of ore, locally mixed but on the whole separated, although forming part of compound ore bodies. These are: manganese ore, iron ore, and copper ore.

Manganese Ore

Two different kinds of manganese ore can be discerned, viz. hausmannite ore and silicate–carbonate ore. The former carries hausmannite as its chief constituent, but somewhat mixed with silicates and carbonates, and the distinction is not, in practice, a sharp one. Good hausmannite ore explains the amount of ore with 48 per cent Mn, obtained by hand sorting (compare above). In the silicate–carbonate ore, hausmannite may occur in patches.

Hausmannite is, apart from the rare jacobsite, the only hypogene oxidic manganese mineral identified in the deposit. In the rich ore it forms cloudy masses of a dull black colour, in a subordinate, dense mass of a light grayish-brown colour, made up of silicates and carbonates. The hausmannite is fine-grained,

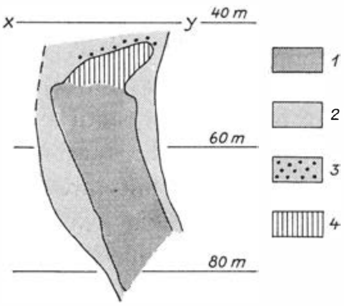

Fig. 2. Vertical section through ore body *C* along *x–y* of Fig. 1. Scale 1:1200. 1 hausmannite ore, 2 silicate–carbonate ore, 3 hematite, 4 copper ore. From the official mine map.

generally about 0.02 mm in grain size, but coarser patches are noted locally, with grains up to 0.60 mm. In the larger grains the typical, plagioclase-like twinning is well brought out.

Jacobsite was tentatively identified by SÖLVER (1942), who found that the mineral in question must be a member of the magnetite–jacobsite series but probably also contained some other metal beside the iron and the manganese, since the sum of the latter, as determined by him in a material estimated to be 90 per cent pure, proved too low (Mn 20.9, Fe 36.6 per cent).

On material separated from the same specimen, an analysis has been made by Mr. A. PARWEL, of the Mineralogical Department. This analysis confirms SÖLVER's identification of the mineral as jacobsite. It also makes it clear that the material analysed by him must have contained more impurities than he suspected. The present writer, too, underestimated the quantity of these impurities, which occur chiefly as fissure fillings in the grains of jacobsite. Identified impurities in the specimen are carbonate and bementite. The amount of RO represented by them can, with fair accuracy, be calculated from the analytical figures for CO_2 and SiO_2. Detracting this amount, one arrives at a proportion $RO:R_2O_3$ of 1.055 : 1.000. The difference is too small to justify the assumption that Mn occurs in part as Mn_2O_3 (which could not be determined because of the presence of FeO). It seems probable, therefore, that this jacobsite, beside the chief components MnO and Fe_2O_3, contains only 1.59 per cent FeO, a little MgO and some CaO, Al_2O_3, and BeO.

Analysis of Kesebol jacobsite.

Oxide	Content, %	Mol. quot.
Fe_2O_3	59.65	0.3735
Al_2O_3	0.17	0.0017
FeO	1.59	0.0221
MnO	28.82	0.4063
MgO	0.98	0.0243
CaO	2.89	0.0515
BeO	0.06[a]	0.0022
ZnO	nil[a]	
CO_2	1.75	0.0398
SiO_2	4.25	0.0708
	100.16	

[a] Spectrochemical determination.

The probability that BeO, too, belongs to the jacobsite is supported by the fact that a spectrochemical determination on a sample of garnet, the non-metallic mineral in the paragenesis which appeared most likely to contain the metal in question, showed only traces of it. The presence of beryllium in the deposit, even in such slight amounts, may be of a certain geochemical interest.

In several mineral deposits paragenetically related to Kesebol, viz. hydrothermal veins in which sulfides characteristically are accompanied by rhodonite and rhodochrosite, beryllium is known to occur, in the mineral form of helvite. On the other hand, the presence of a number of beryllium minerals in the metamorphosed hydrothermal manganese deposit of Långban has been referred to later contributions from granitic sources (MAGNUSSON, 1930). While this is certainly a plausible explanation, the possibility does not now seem excluded that beryllium instead was among the elements belonging to the original, hydrothermal mineralization, and that the special beryllium minerals are due to the metamorphic rearrangement of such constituents, illustrated, for instance, by the lead.

Jacobsite has been identified at Kesebol only in two specimens. It is associated with silicate–carbonate ore and hematite. In one specimen it frequently encloses crystals of hematite, and even occurs as tabular grains that are partial or complete pseudomorphs after this mineral.

Psilomelane. In a specimen of hausmannite ore there have been noted under the microscope aggregates with a colloform, mamillary structure, which replace the hausmannite ore. There is but little of it, and no closer examination has been undertaken, therefore, the identification as psilomelane is entirely conjectural. In any case it has the appearance of a secondary, supergene product.

Rhodonite and *garnet* are the most important silicates in the ore, at least among the products of the earlier mineralization stages. One frequently sees rose-coloured rhodonite in considerable quantity with little or no admixture of other minerals. Its grain size varies, generally within the range 0.1–10 mm. The garnet is resin yellow to reddish, and yellowish-brown in thin sections. It forms lumps, or isolated crystals only about 0.02–0.04 mm in size. Sometimes the garnet has a dull brownish-red colour. In thin sections it is then found to be replaced by an apparently amorphous substance of lower refraction, probably neotocite. To judge from the colour of the normal garnet it is not a spessartitic one, but probably a somewhat manganiferous andradite or grossularite. Garnet has not previously been reported from any manganese deposit in Dalsland.

In one specimen there have been noted, in calcite veins with some hematite, small crystals, colourless in thin section, of a garnet with anomalous birefringence.

Very common are minerals that apparently are derived from the alteration of earlier silicates, at least of the rhodonite. Most common is one with a light orange colour in thin sections, and forming fibrous aggregates; it belongs to the somewhat varying hydrous manganese silicates known as *bementite*. A variety with a much stronger colour that may be described as carmine yellow is only rarely seen. A frequently occurring form is one that apparently belongs to the *serpentine* group. It is light greenish-gray in thin sections, or almost colourless, and is made up of minute flakes which sometimes, when big enough for their shape to be discerned, are found to be oriented in two perpendicular directions.

Neotocite often is megascopically conspicuous as jet-black lumps, but is quantitatively subordinate.

There are several kinds of *carbonates* in the ore, often intimately mixed. Rhodochrosite is identified from its very high refraction. Other carbonate grains have ω varying slightly around 1.690. This may be either a dolomite with a little Fe or Mn, or a calcite with about 20 molecular per cent of $MnCO_3$. Strong effervescence with cold HCl speaks in favour of the latter alternative. As in the case of most minerals in the manganese ore, separation for analysis is practically impossible because of the fine grain of the mixture. Variations in the composition of carbonates have been reported from several manganese deposits, notably from those of the Olympic Peninsula in Washington, which show great similarity to that of Kesebol (compare p. 48).

Iron Ore

The mineralogical composition is extremely simple, there being, as a rule, almost nothing but hematite, developed as plates that often are grouped in radiating bunches. The length of these plates may be from around 0.02 mm to 0.10–0.20 mm or more; generally there is but little variation within the area of a microscopic section.

Order of mineral deposition in the manganese and iron ores. Determination of the relative ages of the minerals that constitute these ores at Kesebol meets with difficulties. To judge from available observations, the relative age of two mineral species can vary, indicating several successive stages of formation.

Of the manganese minerals, hausmannite, rhodonite, and garnet are the oldest. Their relative ages cannot be stated, but their distribution, with hausmannite chiefly in the central parts of the ore bodies, may indicate that this oxidic mineral was formed before the silicates. Bementite and serpentine are clearly later. It is probable that they formed chiefly at the expense of rhodonite, though the serpentine may possibly be pseudomorphous after tephroite (or picrotephroite), a mineral not identified as such at Kesebol. Closely associated with these hydrous silicates are the various carbonates. Together, hydrous silicates and carbonates brecciate not only the anhydrous silicates but also the hausmannite ore. This illustrates that the bementite cannot be wholly pseudomorphous, but must be in part deposited from solutions. The same conclusion was reached by HAMBERG (1890) in his study of the "caryopilite" (bementite) from Pajsberg. It is noteworthy that there are reported, from the analogous deposits in the state of Washington, cases where rhodonite forms veins in bementite (PARDEE *et al.*, 1921). No similar case has been encountered at Kesebol.

Neotocite was later still, yet in all probability also belongs to the hypogene mineralization. Psilomelane is the only manganese mineral that is probably of supergene origin.

The relations between manganese ore and iron ore are complicated. The distribution of the solid hematite ore, chiefly along the foot-wall of ore body *A* and locally on the margins of *B* and *C*, may be taken as a sign that it was deposited later than the manganese minerals. On the other hand, the relations between jacobsite and hematite give unequivocal evidence of the opposite age relation. Penecontemporaneous deposition of manganese and iron minerals is indicated in some cases, especially by their association in small ore concentrations outside the ore bodies proper, as at the surface NW. of the mine.

Copper Ore

Sulfides of copper have been noted in small amounts at a few places; in one case, galena is associated with them. But the only occurrence that can be called copper ore is as a core in the uppermost part of *C* ore body (Fig. 2). Downwards and sideways it ended with rapid transitions towards underlying and surrounding manganese ore. Since no observations were made by the writer while this small quantity of ore was taken out, the following characteristic is based wholly on the study of specimens selected from the ore pile at the mine.

In part the copper sulfides (chalcocite, bornite, and chalcopyrite) occur in a flinty, dark rock, which in thin sections is found to consist of a fine-grained mosaic of quartz grains, apparently a silicified rock, with minute octahedra of magnetite in streaks and garlands. The rest, certainly comprising most of the rich ore, contains very little gangue and consists of a sulfide matrix enclosing numerous grains of hematite. The most characteristic variety is a high-grade chalcocite ore; of the 177 tons of copper ore recovered, about 12 are said to have belonged to this type (HALLGREN). Chalcopyrite is reported to have been the most common sulfide, but it seems probable that the richer sulfides accounted for more of the copper contained in the ore.

The *chalcocite* ore is massive, bluish in colour. Hematite is present, as in all the copper sulfides, as grains which mostly are rather evenly scattered. In part they are tabular, as in the iron ore, but with a greater average size, about 0.10–0.50 mm. Much more common, however, are grains with an octahedral shape, although for the most part greatly corroded, and generally made up of several individual hematite crystals. They vary in size about 0.15–1.5 mm or so. It is evident that these grains are pseudomorphs after magnetite, but martitization has not followed the usual octahedral pattern.

The chalcocite forms grains commonly about 1 to 2 mm in size, with wavy, moderately complicated boundaries. As a rule it is white in polished sections, and displays, after etching, the typical basal cleavage, rarely combined with cracks along a pyramidal face. It is weakly anisotropic. Some grains, otherwise similar, show a very distinct blue colour, either throughout or in lamellae

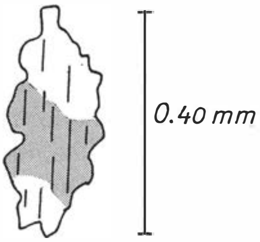

Fig. 3. Grain of chalcocite (white) and covellite (gray). See text.

alternating, parallel to the basal cleavage, with those of white chalcocite. Entirely analogous chalcocite has been described by SCHERBINA (1941) from copper deposits in Glava, about 60 km N. of Kesebol but related to the sulfide-bearing veins of the same metallogenetic province. In spite of recent progress in the understanding of the Cu_2S minerals, due especially to N. BUERGER (1941), this form of chalcocite still remains enigmatic. Thus RAMDOHR writes (1950, p. 290): "Einige rhombische Kupferglanze, meist solche nicht ausgesprochen cementativer Natur, zeigen dutzendfach abwechselnd blaue isotrope, die vielleicht auf Teiloxydation zu $Cu_2(S, O)_5$ beruhen, und weisse anisotrope basale Lamellen, deren Erklärung schwierig ist. Es scheint hier ein abwechselnder CuS-Gehalt vorzuliegen, denn gerade die blauen Lamellen sind oft mit Covellintäfelchen vergesellschaftet."

The obvious probability that the blue colour is due to CuS is, in fact, strengthened by the way in which the *covellite* occurs in the Kesebol ore. There have been observed no signs of covellite in the ordinary development of supergene origin, apart from an insignificant veinlet in bornite. The covellite is regularly associated with chalcocite, never forming veins in it or peripheral replacements but rather as parts of the chalcocite grains; its basal cleavage is parallel to that of the chalcocite. An example is shown in Fig. 3. In this case, the white chalcocite contains clouds of minute specks of covellite. Always the covellite shows the characteristic anomaly that the blue colour observed in air remains unchanged when the section is viewed in immersion oil (the "blaubleibender" covellite of German authors). From the relations here described, it seems probable that the covellite formed penecontemporaneously with the chalcocite, or in part through ex-solution from the latter. The material from Kesebol does not furnish sufficient ground for any further speculations about the apparently complicated mineral relations between Cu_2S and CuS.

As to the relations between the various copper sulfides, apart from the covellite, the following facts have been noted. Chalcocite and chalcopyrite have not been found in contact. Bornite is seen to penetrate chalcopyrite in a typical replacement pattern, but locally has gashes filled with chalcopyrite, presumably segregations. Bornite and chalcocite are observed in contact with "mutual" boundaries, but in one sample the chalcocite has irregular veinlets of bornite.

The corroded shape of the martite grains indicates partial replacement by the copper sulfides. The lamellar hematite does not show quite decisive evidence of the same process. It is not clear whether martitization took place during the introduction of the sulfides, or earlier. The forming of primary hematite, and concomitant martitization of earlier magnetite, in connection with the development of chalcocite and bornite has been observed in several other mineral deposits (GEIJER, 1924).

It is concluded that the copper mineralization is hypogene, in all its aspects. Already the position of the copper ore precludes the possibility that it has been materially affected by supergene processes. The relations between bornite and chalcocite argue in favour of the same view. The chalcocite does not in itself give any unequivocal evidence of a hypogene origin but shows several features which all point in this direction. In the case of the strikingly similar chalcocite from Glava, SCHERBINA (1941) has, from its relation to certain tellurides, found that it must have formed at a temperature above 150°. While this conclusion obviously cannot be extended to the Kesebol chalcocite, it seems clear that the latter, like that at Glava, was in any case deposited as the hexagonal form above 105°.

The Ore Bodies

It remains to give a brief account of the different ore bodies (Figs. 1 and 2).

The *A* ore body is tabular in the plane of the whole ore zone, with an eastward dip of 55°. It has been followed from the surface, where it outcropped about 22 m below datum point, down to the 92 m level, where it petered out, much mixed with country rock. There is a slip plane along the foot-wall contact, and similar ones turn off towards ore body *B*, but as far as it has been possible to ascertain, these movements appear to have been post-mineral. For considerable depth, there was hematite ore along the foot-wall of *A*, and such has also been found locally at the hanging wall. Next to the hematite ore followed a band of good hausmannite ore, but the rest of the ore body contained only silicate–carbonate ore with subordinate hausmannite concentrations.

The outcrop of ore body *B* is soil-covered. Exposures immediately W. of it show silicified rock with hematite and a little hausmannite. *B* is known from mining between the levels 25 m (about 7 m below the surface) and 56 m; below the latter level there are only patches of ore. The eastward dip is 72°. The ore body was made up of silicate–carbonate ore with some concentrations of hausmannite, the largest having its longer axis obliquely across the strike and pointing towards ore body *C*. On the margins of *B* there was some hematite ore. The eastern (hanging-wall) contact of *B* has been studied in detail and was found to show a gradual but rapid transition to the country rock, in a way indicating replacement. *B* contained more inclusions of the country rock than either *A* or *C*.

Ore body *C* is probably connected with the northern end of *B*, but mineralization there has not proved sufficient for mining, and so definite proofs are lacking. As seen from Fig. 2, the main part of *C* was a columnar concentration of hausmannite ore (somewhat brecciated by bementite and carbonates), surrounded by a mantle of silicate-carbonate ore. Downwards such ore took the place also of the hausmannite. On the bottom level of the mine (105 m) only small tongues of silicate-carbonate ore remain. Upwards, again, from the hausmannite column followed the copper ore. Hematite occurred on the periphery in the upper parts of *C*, and was especially concentrated in the sulfide ore. Since stoping ended about 20 m below the surface, the nature of the uppermost part of *C* is unknown. The change in character towards the top of the known extension, however, makes it probable that mineralization was declining upwards, above the top of the copper ore.

Origin of the Deposit

It is evident from the facts related here that the Kesebol ores were formed by hot, ascending solutions which replaced the shattered country rock. Although there are scattered concentrations of ore minerals also outside the three ore bodies, the concentration of the mineralization to the latter is striking. Apparently the ore-bearing solutions chiefly followed certain channels. In the case of the *A* and *B* ore bodies these were along planes in the general direction of deformation in the zone, but the *C* ore body, by its shape and the relative position of the various forms of ore, indicates the probability that the solutions there worked outwards from a central, roughly cylindrical conduit. It is clear that the solutions have varied in the course of the process, both in composition and in temperature. The replacement of anhydrous silicates by hydrous ones was probably connected with a drop in temperature, but it is quite possible that the variations were more complicated. The frequent brecciation of the products of an earlier phase by those of a later one illustrates that the tectonic movements which have localized the mineralization continued during the process. The fine grain of the replacement products, and the limited depth of the ore bodies, both indicate that the deposition probably took place at a rather shallow depth.

The results of this investigation have also given further support to the view of earlier observers that there has been a genetical connection between the iron–manganese mineralization in Dalsland and the sulfide-bearing veins. It is clear that we have here a well-defined metallogenetic province, co-extensive with the Dalslandian orogeny. Since mechanical disturbances alone cannot produce such geochemically characteristic concentrations of metal, one must look for some other factor connected with the orogeny as the common cause of the various forms of mineralization. The relations between the Bohus granite and the orogeny that have been proved by LARSSON (1956) offer a most plausible explanation, though the connection between igneous and hydrothermal activity may not have been a simple one.

Similar Manganese Deposits

Ore deposits strikingly similar to that at Kesebol are reported from the Olympic Peninsula in the state of Washington (PARDEE, 1927; PARK, 1942). Their chief minerals are bementite, hausmannite, and a manganiferous carbonate. Garnet is not reported, but possibly tephroite. Some deposits contain much barite. Usually, the ore bodies are made up of two parts, one consisting of manganese minerals and the other of hematite and quartz in varying proportions. Sulfides, too, are reported, among them chalcocite. With these paragenetical analogies it is noteworthy that the Olympic Peninsula deposits replace limestone, while that at Kesebol occurs in a rhyolitic rock. Apparently the chemical and mineralogical character of the deposits has been wholly determined by the nature of the hydrothermal solutions, the country rock having had but little influence upon it, or none at all.

Conjugated Manganese and Iron Ores

The term conjugated deposits was used by H. E. JOHANSSON (in TEGENGREN, 1924) for the associated manganese and iron ores of Långban, and seems a practical one to characterize cases in which ores of the two metals occur separately but in the closest spatial relation, often as parts of one and the same ore body. It is of interest to note that Kesebol and other deposits in Dalsland exhibit the same kind of "conjugated" mineralization, and likewise the metallogenetic province of the Olympic Peninsula. All of these largely oxidic deposits have been interpreted as having been formed by hydrothermal replacement. Wholly carbonatic replacement deposits of the two metals, on the other hand, never exhibit this phenomenon. The same combination of main elements as in the conjugated deposits (manganese, iron, and silica) is met with in certain sedimentary deposits in Central Sweden (GEIJER, 1925, 1939). In these, iron and manganese compounds have been precipitated alternately (the iron in the ferric state, the manganese largely bivalent) in a fine stratification. This difference furnishes an argument for the view (MAGNUSSON, 1930) that the Långban deposits were formed by replacement (of dolomite) and not by sedimentation.

References

BUERGER, NEWTON W., 1941: The chalcocite problem. *Econ. Geol.*, 36, 19–44. Lancaster, Pa.

FLINK, GUST., 1910: Bidrag till Sveriges mineralogi, II. *Ark. kemi*, 3:6. Stockholm.

GEIJER, PER, 1924: Some Swedish occurrences of bornite and chalcocite. *Sverig. Geol. Unders.*, ser. C, no. 321.

— 1925: Om några skiktade mangansilikatmalmer i Bergslagen. *Ibid.*, no. 326.

— 1939: Kentrolite in a metamorphic manganese-iron ore of sedimentary origin. *Geol. Fören. Stockh. Förh.*, 61, 204–208.

HALLGREN, TOMAS, 1925–1930: Karta över Kesebolsgruvan. (Official mine map, archives of Kommerskollegium, Stockholm.)

HAMBERG, AXEL, 1890: Mineralogische Studien. 12. Über die Habitusveränderung der Rhodonitkrystalle bei der Umwandlung in Karyopilit. *Geol. Fören. Stockh. Förh.*, 12, 609–617.

LARSSON, WALTER, 1956: *In* Kartbladet Vårvik. *Sverig. Geol. Unders.*, ser. Aa, no. 187.

MAGNUSSON, NILS H., 1930: Långbans malmtrakt (summary in English). *Ibid.*, ser. Ca, no. 23.

PARK, CHARLES F., JR., 1942: Manganese resources of the Olympic Peninsula, Washington. *U.S. Geol. Survey Bull.*, 931–R, 435–457. Washington.

PARDEE, J. T., LARSEN, E. S., JR, & STEIGER, GEORGE, 1921: Bementite and neotocite from western Washington, with conclusions as to the identity of bementite and caryopilite. *J. Wash. Acad. Sci.*, 11, 25–32. Washington.

PARDEE, J. T., 1927: Manganese-bearing deposits near Lake Crescent and Humptulips, Washington. *U.S. Geol. Survey Bull.* 795, I A, 2–24. Washington.

RAMDOHR, PAUL, 1950: Die Erzmineralien und ihre Verwachsungen. Berlin.

SCHERBINA, ALEXANDER S., 1941: Die goldreichen Kupferglanz-Bornit-Lagerstätte von Glava in Vermland, Schweden, und ihre geologische Stellung. *Neues Jahrb. f. Min.*, etc., Abt. A, Beil., Bd. 76, 377–458. Stuttgart.

SÖLVER, S. V., 1942: Undersökning av en stuffsamling från Kesebol i Dalsland (Unpubl. exam. paper in mining geology, Royal Institute of Technology, Stockholm).

TEGENGREN, F. R., 1924: Sveriges ädlare malmer och bergverk. *Sverig. Geol. Unders.*, ser. Ca, no. 17.