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Exhalative-sedimentary manganiferous iron ores from the Gåsborn area, W. Bergslagen, Central Sweden

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Abstract

The Gåsborn metamorphosed manganiferous iron ore horizon consists of Mn-poor (<1 wt% Mn) iron ore-bearing marbles and metavolcanics and manganiferous (5–25 wt% Mn) iron ore-bearing metavolcanics and metacherts, displaying lateral facies transitions. The ore horizon is concordantly intercalated in a pile of felsic metavolcanics. It shows a concentric zoning around two pipe-like structures which consist of extremely Mn-poor (<0.1 wt% Mn) iron ore-bearing Mg-enriched metavolcanics, located directly below the ore horizon. Major- and trace-element analyses suggest that (1) the ore horizon is of exhalative-sedimentary origin and (2) the Mg-enriched metavolcanics mark the top of a (now metamorphosed) conduit zone for hydrothermal fluids from which the ores were deposited.

Introduction

The Gåsborn area is located 10 km E of the famous Långban manganese mines in the western part of the Bergslagen district in central Sweden (Fig. 1). In the area a 0.1–15 m thick metamorphosed manganiferous iron ore horizon occurs intercalated in felsic metavolcanics. The ore horizon consists of manganiferous iron ore bearing felsic metavolcanics and metacherts and Mn-poor iron ore bearing marbles and metavolcanics, which display lateral facies transitions from one type to the other. In the central part of the area extremely Mn-poor iron ores are found in two discordant pipe-like bodies of Mg-enriched metavolcanics underlying the ore horizon. The Gåsborn manganiferous iron ores were briefly described by Tegengren (1924) and Magnusson (1930, 1970), but are not so well known as the other manganiferous iron ore deposits in W. Bergslagen (Långban, Pajsberg, Harstigen, Sjögruvan, Jacobsberg and Slöjdartorp). This paper presents the petrography and facies development of the Gåsborn manganiferous iron ore horizon. From the field evidence, major and trace element analyses of the ores, and data gathered from the literature, a model for the formation of the ore horizon is presented.

Geological setting

The 1.9–1.8 Ga Svecokarelian (Svecofennian) rocks of the Gåsborn area comprise the following lithological units: (1) A volcano-sedimentary sequence of felsic metavolcanics with intercalated marbles, metacherts, metamorphosed basic lavas

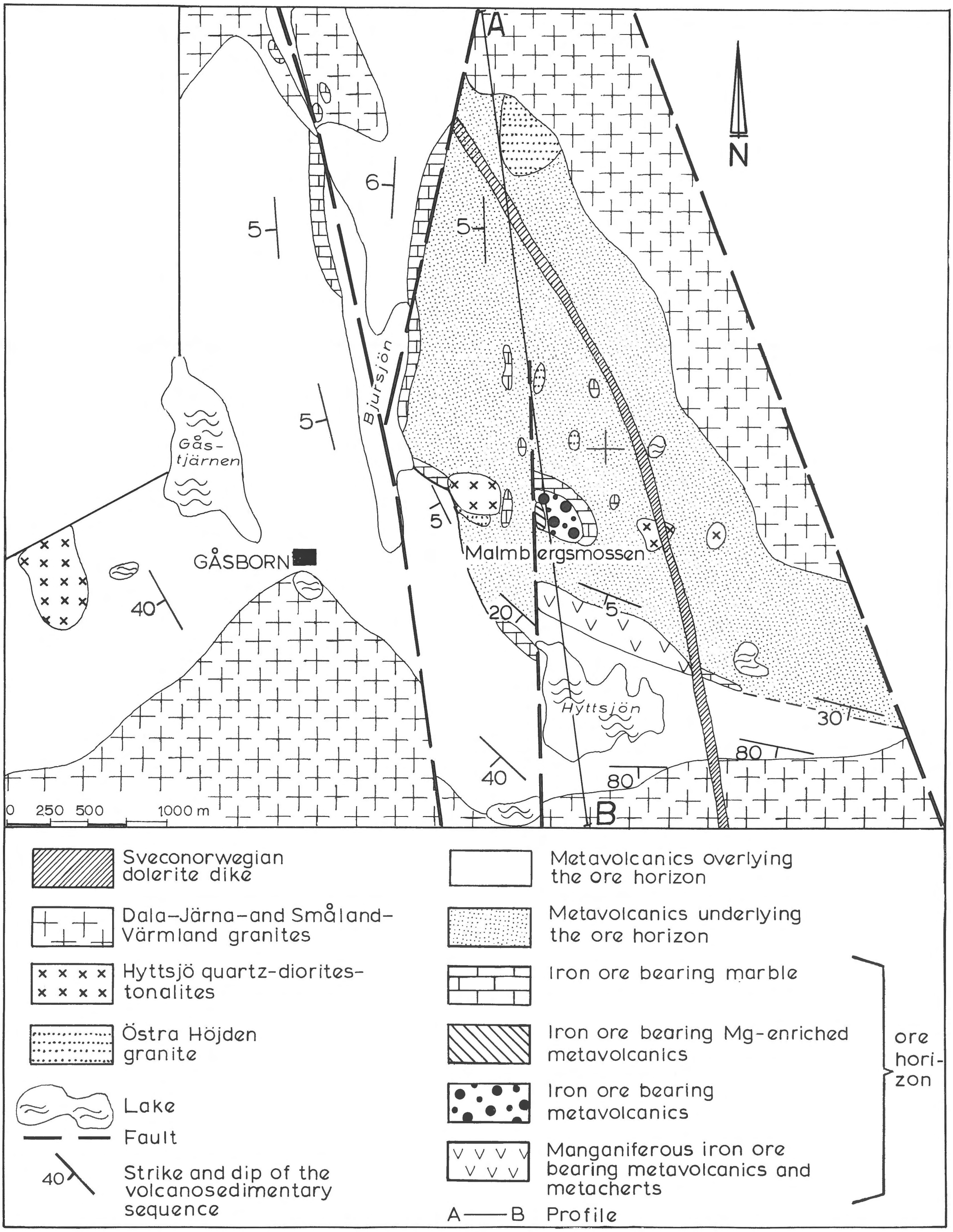

Fig. 1. Geological sketch map of the Gåsborn area, showing the outline of the manganiferous iron ore horizon.

and a metamorphosed manganiferous iron ore horizon (Magnusson 1930; Damman in press), belonging to the Upper Leptite-Hälleflinta and Slate Group of the Bergslagen supracrustal Sequence (Oen et al. 1982; Oen 1987). This volcano-sedimentary sequence is intruded by: (2) basic sills and dykes associated with the basic lavas, (3) a granite (Ostra Höjden granite, Fig. 1) of the group of about 1.87 Ga older granites of the Bergslagen district (Åberg et al. 1983 a, b; Oen et al. 1984, Baker 1985), and (4) gabbros, diorites and tonalites (Fig. 1) belonging to the about 1.84 Ga Hyttsjö gabbro-diorite-tonalite-granite suite (Oen et al. 1982; Oen & Wiklander 1982; Oen 1987). A hydrothermal vein system associated with the granite is characterised by an estimated maximum temperature of 560° C, a lithostatic pressure of maximal 1.5 kbar and a hydrostatic pressure of maximal 4 kbar (Damman in prep.). The gabbros, diorites and tonalites show contact metamorphic aureoles; the maximum temperature and pressure of contact metamorphism are estimated at 750–800° C and less than 3 kbar (Damman unpublished data).

This complex of 1.9–1.8 Ga rocks is intruded in the N, E and S (Fig. 1) by younger, 1.7–1.6 Ga (Welin et al. 1977) granites of the Småland-Vårmland (Filipstad) and Dala-Järna groups and by a 1.2–0.9 Ga (Oen & Verschure 1982) Sveconorwegian dolerite dyke (Fig. 1). No contact metamorphic aureoles of significance were found associated with these intrusives.

Structure and form of the ore horizon

A reconstruction of the structure and form of the ore horizon was made by combining aeromagnetic data (Björk 1986) with field data. The ore horizon varies in thickness between 0.1 and 15 m and is exposed in scattered outcrops and old pits which have been worked for iron and manganese (Magnusson 1930). In the central part of the Gåsborn area (the Malmbergsmossen ore field) the ore horizon is sub-horizontal and outcropping in an area of about 2 km^2 (Fig. 1). To the E and N the sub-horizontal ore horizon is cut off by the 1.7–1.6 Ga younger granites (Fig. 1). To the N the ore horizon can be traced up to the contact with the younger granites; in the granites remnants of the ore horizon are found as scattered, small roof-pendants (Fig. 1). To the E the ore horizon is either eroded away or was probably never deposited since only exposures of the underlying metavolcanics are found. Approximately 1 km W of Malmbergsmossen the ore horizon dips about 15° W, and disappears below the surface under the overlying metavolcanics. South of Malmbergsmossen the dip of the ore horizon increases from 5–7° S to about 80° S, turning to vertical at about 500–1000 m N of the younger granite S of the Gåsborn area (Fig. 1).

Description of ore bearing rock types

Mg-enriched metavolcanics containing Mn poor iron ore are found on the dumps of two mines in the centre of the Malmbergsmossen field (Fig. 1). According to Magnusson (1930) the iron ores in these mines formed 2 irregular bodies in the metavolcanics underlying the ore horizon. Two silicate assemblages are found in these rocks; an older assemblage consisting of fine grained phengite and chlorite enclosing a matrix of albite and quartz, and a younger, overprinting assemblage, consisting of orthoamphibole, biotite and cordierite. The chemistry of biotites and orthoamphiboles developed along the edges of hydrothermal veins associated with the Ostra Höjden granite varies with distance from the veins. This suggests that the replacement of the older assemblage by the younger took place during emplacement of the Ostra Höjden granite (Damman in prep.). In the older assemblage magnetite occurs as small, disseminated grains between phengite and chlorite. In the younger assemblage magnetite frequently shows coronitic rims of hercynite and corundum and small inclusions of chalcopyrite, pyrrhotite and pyrite and is found in irregular aggregates embedded in a matrix of orthoamphibole and biotite. The Mg-enriched nature of these rocks is shown by comparison of their major element chemistry with that of the surrounding metavolcanics (Table 1).

Mn-poor iron ore bearing metavolcanics are found N, E and W of the Mg-enriched, iron ore bearing metavolcanics (Fig. 1). The fine-medium grained metavolcanics show a granoblastic texture and consist of albite (40–60 vol. %), quartz (40–50 vol. %), microcline (5–7 vol. %) and accessory biotite, amphiboles, chlorite, carbonates, zircon, apatite and xenotime. Magnetite forms irregular lenses up to 5 cm thick and several meters long, parallel to the bedding of the metavolcanics. The metavolcanics adjacent to hydrothermal veins related to the Ostra Höjden granite are altered to biotite schists, and contain irregular masses of magnetite with minor chalcopyrite, pyrrhotite and pyrite. Iron ore bearing marbles with intercalated metavolcanite and metachert lenses are found to the N, E and W of the exposures of the iron ore bearing metavolcanics, and to the S of the exposures of the manganiferous iron ore bearing metavolcanics and metacherts (Fig. 1). The lateral transition from metavolcanics to marbles (the only change that is observed in the field; other lateral relationships are inferred from the map) is characterized by a decrease of metavolcanic intercalations in the marbles. Locally, the base of the marbles is brecciated, and irregular marble fragments are found in the underlying metavolcanics. Magnetite, often with thin coronas of hercynite, occurs in lenses parallel to the bedding of the surrounding metavolcanics, a few mm to 3 m thick (Magnusson 1930). A rapid decrease in estimated iron content of the marbles is found with increasing distance from the Mg-enriched metavolcanics (Fig. 3).

Table 1. Major element analyses of Mg-enriched (column 1, $n = 3$) and non-altered metavolcanics (column 2, $n = 3$).

	1($n = 3$)	2($n = 3$)
SiO_2	65.13	78.44
TiO_2	0.30	0.12
Al_2O_3	12.61	10.95
Fe_2O_3	12.50	2.33
MnO	0.12	0.03
MgO	4.50	0.87
CaO	0.55	1.12
Na_2O	1.31	5.10
K_2O	2.48	0.40
Total	99.50	99.36

Where the marble is cut by hydrothermal veins associated with the Ostra Höjden granite a pyroxene garnet skarn is developed in which magnetite occurs in panidiomorphic aggregates. Manganiferous iron ore in metavolcanics and metacherts is found in a small E–W trending zone approximately one kilometer S of the iron ore bearing Mg-enriched metavolcanics (Fig. 1). Magnetite (partly replaced by hematite), Mn-silicates (rhodonite, tefroite, grossularite, rhodochrosite, manganiferous pyroxene, amphibole, mica and epidote) and fluorite occur in up to 70 cm thick and several meters long irregular lenses intercalated between the metavolcanics and the metacherts. Accessory sulfides are locally found in small veins, cross-cutting the ore layers. Several ore layers show up to 3 cm angular metavolcanite fragments in a matrix of magnetite and Mn-silicates. The metavolcanics between the ore also frequently show metavolcanite fragments embedded in a matrix of fine- to medium grained quartz, feldspars, and subordinate magnetite, Mn-silicates and biotite. The above distribution of lithologies suggests a zonal arrangement in the ore horizon with iron ore bearing, Mg-enriched metavolcanics in the centre, followed by iron ore bearing metavolcanics and iron ore bearing marbles at increasing distance from the centre. Manganiferous iron ore bearing metavolcanics and metacherts occur in between the latter rocks to the S (Figs. 1 and 2).

Sample selection and analytical techniques

Samples for chemical analyses were collected from mine dumps and outcrops. Samples showing hydrothermal veining and alteration related to the Ostra Höjden granite were avoided. Samples of iron ore bearing marble, iron ore bearing metavolcanics, and manganiferous iron ores in metavolcanics and metacherts were crushed, ground and analysed for Fe, Mn, Ti, Co, V, P, Zn, Ni and Ba by Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AAS), using a Perkin-Elmer ICP/6500 × R (analyst J. Kist), using stan-

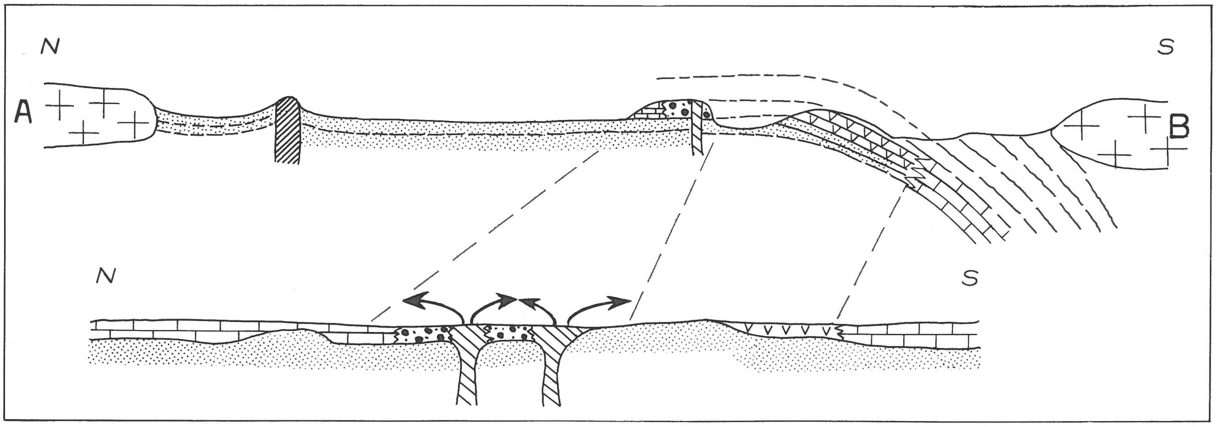

Fig. 2. Upper: Cross-section along line A–B (Fig. 1) through the Gåsborn area. Lower: Idealised N–S cross-section through the Gåsborn manganiferous iron ore horizon. Symbols for rock types as in Fig. 1.

dards FeR1, 2, 3 and 4 (Abbey et al. 1983). Relative accuracies are given in Table 2 – only Ti differs from the literature values. These elements were also analysed by ICP-AAS in magnetite separates from marbles, metavolcanics and Mg-enriched metavolcanite. Cu, analysed in 25 samples, was generally very low (1–21 ppm) and too erratically distributed to warrant further consideration. Magnetite separates from marbles, metavolcanics, Mg-enriched metavolcanics as well as 2 whole-rock samples of manganiferous iron ore were analysed for U, Th and REE by Th. v. Meerten with Instrumental Neutron Activation Analyses (INAA) at the Interuniversity Reactor Institute (IRI) facilities at Delft. Analytical procedures and the relative accuracy of the INAA analyses are described in Baker & De Groot (19883). Major elements in whole rock samples of metavolcanics and Mg-enriched metavolcanics were analysed on fused glass beads, using standard XRF techniques (Table 1).

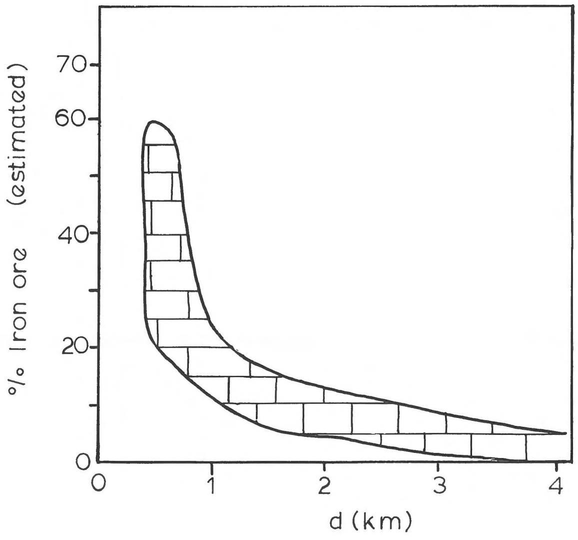

Fig. 3. Estimated iron content of marbles with distance (d) from the Mg-enriched metavolcanics.

Major and trace element chemistry of the ores

Major and trace element analyses of the ores are presented in Table 3. Magnetite separates and whole rock samples from different lithologies in the ore horizon are clearly distinguished by their Mn contents. Magnetite from the Mg-enriched metavolcanics has very low Mn contents (0.04–0.1 wt.%); magnetite and whole rock samples of the iron ore bearing metavolcanics have somewhat higher Mn contents (0.05–0.36 wt.%); magnetite and whole rock samples of iron ore bearing marble have Mn contents between 0.28 and 1.86 wt.%, and manganifeous iron ores show Mn contents between 5 and 25 wt.%. Whole rock metavolcanite and marble samples show higher Mn/Fe ratios but similar Mn contents compared to magnetites separated from them, indicating that Mn is also present in accessory silicates in the metavolcanics and the carbonates of the marble.

The trace element contents of the ores are generally rather low (Table 3), comparable to other Swedish (manganiferous) iron ores (Landergren, 1948; Frietsch, 1970; Loberg & Horndal, 1983). Ti, Co, Ni and Cr are all uniformly distributed over the different lithologies in the horizon. Ba shows low concentrations in most samples analysed, but is strongly enriched in 3 samples of manganiferous iron ore (340, 3500 and 4200 ppm). P and Zn show a slight positive correlation with Mn. V shows a distinct negative correlation with Mn.

U and Th data for six samples from the Gåsborn manganiferous iron ores are presented in Table 4, together with the available data on the Långban manganiferous iron ores (Boström et al. 1979). In several other Gåsborn samples U and Th concentrations were below the detection limit.

The Gåsborn and Långban sampless have similar U and Th contents. U and Th analyses of the Gåsborn manganiferous iron ores plot in the hydrothermal field of Fig. 4 (Bonatti et al. 1972), and provide evidence for the exhalative-sedimentary origin of the ore horizon. Similar U and Th concen-

Table 2. Our analysed concentrations, standard deviations and literature values (Abbey et al. 1983) of elements analysed in FeR−1, −2, −3, −4; Fe and Mn as wt.%, all other elements as ppm.

	Fe	Mn	Zn	Co	Ni	Cr	V	Ti	Ba	P
FeR−1										
Our conc.	53.89	0.15	3200	11	–	–	98	120	995	7300
St. dev. (%)	0.90	2.30	9.0	19	–	–	4.6	5.8	3.1	4.8
(*n* =)	5	5	6	5			5	6	6	6
Lit. conc.	53.06	0.17	3500	12	–	7	100	200	1000	6100
FeR−2										
Our conc.	28.01	0.08	37	8	17	39	37	1100	215	1300
St. dev. (%)	0.90	2.80	9.8	16	8.9	10	7.2	4.6	3.6	3.6
(*n* =)	5	5	6	4	5	6	6	6	6	5
Lit. conc.	27.42	0.09	43	7	21	47	37	1100	240	1200
FeR−3										
Our conc.	31.93	0.06	34	–	–	–	4	10	9	300
St. dev. (%)	0.80	1.50	4.1	–	–	–	3.5	8.9	11	7.4
(*n* =)	5	5	6				6	6	6	5
Lit. conc.	31.12	0.06	36	–	–	–	8?	100	11	300
FeR−4										
Our conc.	28.21	0.13	27	3	–	8	8	370	37	570
St. dev. (%)	1.30	1.50	6.1	17	–	19	43	4.5	2.0	2.0
(*n* =)	5	5	6	1		4	6	6	6	4
Lit. conc.	27.92	0.145	27	2	–	9	11	400	43	600

Table 3. Averages of major and trace element contents of the Gåsborn manganiferous iron ore horizon. (1) Magnetite separates from the Mg-enriched metavolcanics; (2) Whole rock samples and (3) magnetite separates of iron ore bearing metavolcanics; (4) whole rock samples and (5) magnetite separates of iron ore bearing marbles; (6) whole rock samples of manganiferous iron ore.

	Mn	Ti	Co	Ni	Cr	Ba	P	Zn	V
1 (*n* = 9)	0.07	1000	20	7	10	15	70	100	300
2 (*n* = 8)	0.24	600	10	2	7	10	80	120	20
3 (*n* = 3)	0.22	1500	20	5	13	20	120	170	60
4 (*n* = 16)	0.70	600	12	2	8	8	100	110	15
5 (*n* = 36)	0.50	1200	20	4	12	22	200	190	50
6 (*n* = 9)	10.0	1000	15	3	15	500	400	400	4

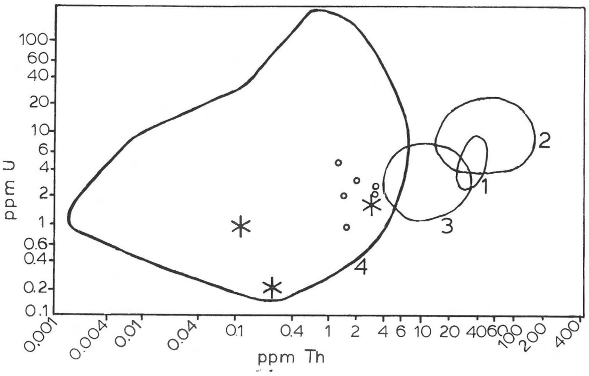

Fig. 4. Plot of Th versus U from the Gåsborn and Långban manganiferous iron ore horizons. Fields: (1) laterites, (2) Mn-nodules, (3) ordinary pelagic sediments, (4) hydrothermal manganiferous iron ores (Boström et al. 1979). (*) Långban manganiferous iron ores (Boström et al. 1979), (o) Gåsborn manganiferous iron ores.

Table 4. U and Th abundances (ppm) in Gåsborn and Långban manganiferous iron ores. (1–6) Gåsborn manganiferous iron ores: (1) whole rock iron ore bearing metavolcanics; (2 + 3) magnetite separates from the Mg-enriched metavolcanics; (4) magnetite separate from iron ore bearing marble; (5 + 6) whole-rock manganiferous iron ore. (7–9) Långban manganiferous iron ores (Boström et al. 1979).

	U	Th
1	3.46	2.267
2	1.80	4.22
3	4.46	1.278
4	0.93	1.759
5	2.00	1.56
6	2.47	3.85
7	1.04	0.11
8	0.20	0.24
9	1.67	3.24

trations in the Långban manganiferous iron ores (Table 4, Fig. 4) indicate that they are neither the products of chemical weathering nor the products of nodule forming processes on the ocean floor, but rather that they have an exhalative-sedimentary origin (Boström et al. 1979).

REE analyses of magnetite separates and whole rock samples from the Gåsborn iron ores, together with the North American Shale Composite (NASC; Haskin et al. 1968) are given in Table 5. NASC normalized REE patterns are shown in Fig. 5. The REE patterns show clear similarities with REE patterns of some recent marine exhalative sedimentary manganiferous iron ores (Fleet 1983). This also supports an exhalative-sedimentary origin for the Gåsborn manganiferous iron ores, and suggests that the behaviour of REE during deposition of proterozoic exhalative-sedimentary Fe- and Mn-ores is similar to that of recent Fe- and Mn-deposits.

Table 5. REE abundances (ppm) of magnetite separates and whole rock samples from the Gåsborn manganiferous iron-ores and the North American shale composite (NASC) (Haskin et al., 1968). (1–11) Gåsborn manganiferous iron ores; (1–3) magnetite separates from Mg-enriched metavolcanics, (4 + 5) magnetite separates from metavolcanics, (6–9) magnetite separates from marbles, (10 + 11) whole rock samples of manganiferous iron ore, (12) NASC.

	La	Ce	Sm	Eu	Tb	Yb	Lu
1	7.75	10.82	1.63	0.40	0.30	0.96	0.26
2	32.50	37.80	2.78	0.65	0.31	1.57	0.56
3	14.04	27.34	6.03	5.14	1.83	0.60	0.20
4	20.50	33.00	2.68	0.63	0.46	0.60	0.20
5	1.62	2.75	0.93	0.37	0.20	0.47	0.11
6	3.58	0.47	1.10	0.20	0.47	0.54	0.15
7	5.50	8.88	1.46	0.22	0.47	0.65	0.17
8	85.40	93.40	5.59	1.17	1.03	1.77	0.37
9	0.97	2.66	0.38	0.14	0.27	0.25	0.06
10	37.07	58.37	6.00	1.30	2.05	0.32	d.l.
11	145.89	228.10	19.40	2.52	2.07	1.06	0.21
12	32.00	73.00	5.70	1.24	0.85	3.10	0.48

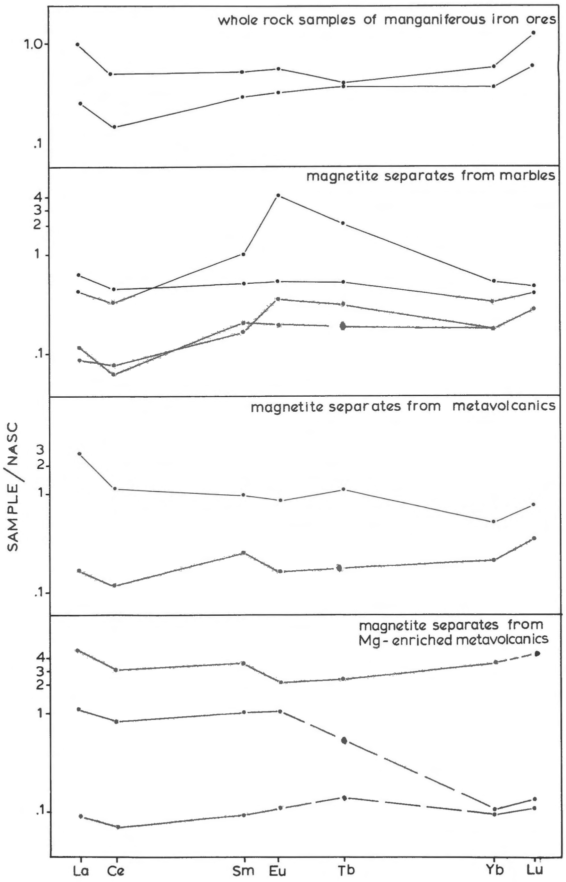

Fig. 5. NASC normalised REE plots of the Gåsborn manganiferous iron ores.

Discussion

The Gåsborn manganiferous iron ores have generally low trace element contents (Table 3), suggesting that they are most probably of exhalative sedimentary origin. Experimental and field studies of such ore deposits (Toth 1981) have shown that fluids from which the ores are deposited have Fe/Tr (trace element) and Mn/Tr ratios of at least 10^2–10^3. The relative rapid accumulation rate of ore deposition (Bonatti et al. 1972; Toth 1981) inhibits the accumulation of minor elements from other sources, leading to general low minor element concentrations in such deposits. Mg-enriched rocks similar to those underlying the Gåsborn ore horizon are often found associated with sulfide deposits in the Bergslagen district (Geijer 1964; Koark 1962, 1973; Karlsson 1986). Studies of various massive sulfide deposits in the world (Vrana 1975; Schermerhorn 1978; Berge 1978) indicate that these rocks may represent metamorphic equivalents of chloritisation and silicification products associated with the sulfide deposits. According to Schermerhorn (1978) the Mg-enriched rocks underlying the Falun sulfide deposit were probably formed along a conduit zone of the fluids from which the sulfides were deposited. Baker & De Groot (1983) described phengite and chlorite bearing rocks similar to the older assemblage in the Gåsborn Mg-enriched metavolcanics associated with exhalative-sedimentary iron ores in the Hjulsjö area of Bergslagen. They suggested that these rocks may represent conduit zones for fluids from which the iron ores were deposited. The above arguments suggest that the Mg-enriched rocks underlying the Gåsborn manganiferous iron ore horizon may also represent a conduit zone of the hydrothermal fluids from which the ores were precipitated as exhalative sedimentary deposits. This suggestion is supported by the zonal arrangement of facies (Figs. 1 and 2) and the distribution of Fe, Mn and V in the ore horizon (Fig. 3, Table 3). The presence of marbles as a chemical precipitate in the ore horizon indicates that the ore-forming fluids had a high fCO_2/fO_2 ratio (Gurvich, 1981). making them relatively acid with respect to seawater. In these relatively acid hydrothermal fluids V is soluble and is transported as V^{3+}, but with increasing pH values V will precipitate insoluble V-hydroxides (Burkhart-Baumann 1972). Fe is soluble at low pH values (Krauskopf 1973), while Mn remains soluble to intermediate pH values (Bonatti et al. 1972, Krauskopf 1973). These differences in solubility suggest that acid hydrothermal solutions that mix with sea-water, will first precipitate V close to the hydrothermal vent; Fe and Mn have higher solubilities and will be deposited farther from the vent. Table 3 shows that the highest V and the lowest Mn concentrations occur in magnetite separates from the Mg-enriched metavolcanics. Going laterally in the ore horizon, away from these Mg-rich rocks (Figs. 1 and 2), an increase in Mn and a decrease in V and Fe content with distance is noticed (Table 3, Fig. 3). The observed zonal distribution pattern of V, Fe and Mn around the Mg-enriched metavolcanics is consistent with what may be expected from the theoretical considerations discussed above. This supports the view that the Mg-enriched metavolcanics mark outflow zones of fluids from which the Gåsborn manganiferous iron ores were deposited. The Gåsborn manganiferous iron ores are not as well known as other manganiferous iron ore deposits in W. Bergslagen (Långban, Pajsberg, Harstigen, Sjögruvan, Jacobsberg and Slöjdartorp), which are often referred to as belonging to the Långban type of manganese deposits (Magnusson 1930, 1970); Tegengren 1924; Geijer & Magnusson 1944; Koark 1970; Roy 1981; Frietsch 1982). The Gåsborn manganiferous iron ores are lacking hausmannite and braunite, minerals regarded as characteristic for Långban type manganiferous iron ores. However the following facts suggest that they belong to this type of deposit (Magnusson 1930, 1970:

(1) The Gåsborn and the Långban deposits occur at approximately the same stratigraphic level within the Bergslagen Supracrustal Sequence (Oen et al. 1982, Oen 1987).
(2) The Gåsborn ores, in common with Långban type ores, are concordantly intercalated in felsic metavolcanics and associated with marbles, showing lateral transitions to manganiferous iron ores. Small amounts of rhodochrosite in the manganiferous iron ores suggests that carbonates were present in these ores prior to metamorphism.
(3) The lateral transition of manganiferous iron ores into manganese poor iron ores is a strikingly similar feature of both the Gåsborn and the Långban manganiferous iron ore deposits and is considered diagnostic for all Långban type deposits (Magnusson 1970).

The model of Mg-metasomatic alteration and local, small scale deposition of Långban type ores presented in this paper differs from that of Frietsch (1982) and Zakrzewski (1982). They suggested that the deposition of all sulfide-, iron-, and manganese-ores in the Bergslagen district took place in large basins in which ore deposition was controlled by water depth and related to changes from K-rich to Na-rich metavolcanics. The presence of brecciated metavolcanics in the ore horizon and debris flows in the overlying metavolcanics is compatible with rift- related basin setting as proposed by Oen et al. (1982) and Oen (1987).

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References

Åberg, G., Bollmark, B., Björk, L. & Wiklander, U. 1983a Radiometric dating of the Horrsjö granite, South Central Sweden – Geol. För. Förh. 105: 78–81

Åberg, G., Levi, B. & Frederiksson, G. 1983b Zircon ages of metavolcanics and synorogenic granitic rocks from the Svardsjö and Yxsjöberg areas, South Central Sweden – Geol. För. Förh. 105: 199–203

Abbey, S., McLeod, C.R. & Guo, W.L. 1983 FeR-1, FeR-2, FeR-3 and FeR-4, four Canadian iron-formation samples as reference materials – Geol. Surv. Can. Pap. 83–19

Baker, J.H. 1985 The petrology and geochemistry of 1.8–1.9 Ga granitic magmatism and related hydrothermal sub-seafloor hydrothermal alteration and ore-forming processes, W. Bergslagen, Sweden-GUA Papers of Geology, Ser. 1, 21: 204 pp

Baker, J.H. & De Groot, P.A. 1983 Proterozoic seawater – felsic volcanics interaction, W. Bergslagen, Sweden. Evidence for high REE mobility and implications for 1.8 Ga seawater compositions – Contrib. Mineral. Petrol. 82: 119–130

Berge, J.W. 1978 A re-examination of the association of magnesium and massive sulfide ores – Geol. För. Förh. 100: 155–170

Björk, L. 1986 Beskrivning till Berggrundskartan Filipstad NV Sver. Geol. Unders. Ser. Af, 147: 110 pp

Bonatti, E., Kraemer, T. & Rydell, H. 1972 Classification and genesis of submarine iron-manganese deposits. In: Horn, D.R. (ed.): Ferromanganese deposits on the oceanfloor – Nat. Sci. Found. Washington: 362 pp

Boström, K., Rydell, H. & Joensuu, O. 1979 Långban, an exhalative sedimentary ore deposit? – Econ. Geol. 74: 1002–1011

Burkhart-Baumann, I. 1972 Vanadium: element and geochemistry. In: Fairbridge, R.W. (ed.): The encyclopedia of geochemistry and environmental sciences-Dowden, Hutchinson and Ross, Inc. (Stroudsburg, Pennsylvania): 1321 pp

Damman, A.H. in press Hydrothermal subsilicic sodium gedrite from the Gåsborn area, W. Bergslagen, C. Sweden – Mineral. Mag.

Fleet, A.J. 1983 Hydrothermal and hydrogenous ferro-manganese deposits: do they form a continuum? The rare earth element evidence. In: Rona, P.R., Böstrom, K., Laubier, L. & Smith, K.L. Jr. (eds): Hydrothermal processes at seafloor spreading centres – Nato Conf. Ser. IV: Marine sciences: 796 pp

Frietsch, R. 1970 Trace elements in magnetite and hematite, mainly from N. Sweden – Sver. Geol. Unders. Ser. C. 646: 136 pp

Frietsch, R. 1982 A model for the formation of the non-apatitic iron ores, manganese ores and sulfide ores of C. Sweden – Sver. Geol. Unders. Ser. C. 795: 43 pp

Geyer, P. 1964 On the origin of Falu type of sulfide mineralization – Geol. För. Förh. 86: 3–27

Geyer, P. & Magnusson, N.H. 1944 De mellansvenska järnmalmernas geologi – Sver. Geol. Unders. Ser. Ca. 35: 654 pp

Gurvich, Y.M. 1981 The carbonaceous manganiferous association – Int. Geol. Rev. 23: 584–590

Haskin, L.A., Haskin, M.A., Frey, F.A. & Wildeman, J.R. 1968 Relative and absolute terrestrial abundancies of the rare earths. In: Ahrens, H. (ed): Origin and distribution of the elements – Pergamon (New York): 909 pp

Karlsson, K.L. 1986 Corundum bearing assemblages from the Proterozoic Zn-Pb-Cu deposits of Saxberget, central Sweden – Geol. För. Förh. 107: 233–241

Koark, H.J. 1962 Zur Alterstellung und Entstehen der Sulfiderze vom Typus Falun – Geol. Rundsch. 52: 133–145

Koark, H.J. 1970 Zur Geologie des neuentdeckten Braunit-Hämatit- Mangansilikat- Lagers Slöjdartorp im Nybergfeldet der Zentralschweden – Geol. För. Förh. 92: 388–401

Koark, H.J. 1973 Zur Entstehung der tektonischen Stengelbaus and präkambrischen Eisen- und Sulfiderzkorpern der Zentralschwedischen Leptitserie – Mineral. Dep. 8: 19–34

Krauskopf, K.B. 1973 Introduction to geochemistry – Mc. Graw Hill Book Cy (New York, St. Louis, San Francisco, Toronto, London, Sydney): 721 pp

Landergren, S. 1948 On the geochemistry of Swedish iron ores and associated rocks – Sver. Geol. Unders. Ser. C. 496: 182 pp

Loberg, B.E. & Horndal, A.K. 1983 Ferride geochemistry of Swedish precambrian iron ores – Mineral. Dep. 18: 487–504

Magnusson, N.H. 1930 Långbans malmtrakt – Sver. Geol. Unders. Ser. Ca. 23: 111 pp

Magnusson, N.H. 1970 The origin of the iron ores in Central Sweden and the history of their alteration – Sver. Geol. Unders. Ser. Ca. 643: 364 pp

Oen, I.S. 1987 Rift related igneous activity and metallogenesis in SW Bergslagen, Sweden – Precambr. Res. 35: 367–382

Oen, I.S. & Verschure, R. 1982 Isotopic age determinations in Bergslagen, Sweden I: Introduction – Geol. Mijnbouw 61: 301–304

Oen, I.S. & Wiklander, U. 1982 Isotopic age determinations in Bergslagen, Sweden III: The Hyttsjö suite of gabbro-diorites and tonalite granites, Filipstad area – Geol. Mijnbouw 61: 309–312

Oen, I.S., Helmers, H., Verschure, R. & Wiklander, U. 1982 Ore deposition in a Proterozoic incipient riftzone environment – a tentative model for the Filipstad – Grythyttan – Hjulsjö region, Bergslagen, Sweden – Geol. Rundsch. 71: 182–194

Oen, I.S., Verschure, R. & Wiklander, U. 1984 Isotopic age determinations in Bergslagen, Sweden V: The Horrsjö granite – Geol. Mijnbouw 63: 85–88

Roy, S. 1981 Manganese deposits on the ocean floor – Academic press (London – New York – Toronto – Sydney): 458 pp

Schermerhorn, L.J.G. 1978 Epigenetic magnesium metasomatism or syngenetic chlorite metamorphism at Falun and Orijarvi – Trans. Instn. Min. Metall. Sect. B.: Appl. Earth Sci. 87: B162–167

Tegengren, E. 1924 Sveriges adlare malmer och bergverk – Sver. Geol. Unders. Ser. Ca. 17: 406 pp

Toth, J.R., 1981 Deposition of submarine crusts rich in manganese and iron – Geol. Soc. Amer. Bull. 91: 44–54

Vrana, S. 1975 Magnesian – aluminous rocks, the associated ore mineralizations and the problem of magnesium metasomatism – Krystallinikum 11: 101–114

Welin, E., Gorbatschev, R. & Lundegårdh, P.H. 1977 Rb-Sr dating of the rocks in the Värmland granite group of Sweden – Geol. För. Förh. 99: 363–367

Zakrzewski, M.A. 1982 Geochemical facies model of ore formation in the Grythyttan-Hallefors area, Bergslagen, central Sweden – Geol. Rundsch. 71: 195–205