IRON RANGE DEPOSITS, SOUTHEASTERN BRITISH COLUMBIA (82F/1)

By P. Stinson and D.A. Brown

(Contribution No. 27, Sullivan-Aldridge Project)

KEYWORDS: Economic geology, Proterozoic, Iron Range, albite alteration, breccias, hydrothermal iron oxide deposits.

INTRODUCTION

The Iron Range fault is a steeply dipping north-striking structure in the core of the Goat River anticline, east of Creston. It is characterized by strong alteration along its entire length, and locally, by high concentrations of iron oxide mineralization. Similar alteration was observed along minor subsidiary faults in the northwest and northeast parts of Iron Range Mountain. The main Iron Range deposit consists of the segment of the fault containing the richest iron mineralization and underlies the northern half of the ridge which makes up Iron Range Mountain. This area extends northward onto the Grassy Mountain sheet (82F/8).

The area of most substantial mineralization, where the fault zone runs along the northern part of the crest of Iron Range Mountain, was the focus of a detailed study involving 1:5000 mapping, sample collection, and thin section study of representative samples. The remainder of the Iron Range fault and subsidiary faults with similar alteration were examined and sampled during the course of regional mapping in the Yahk map area (Brown and Stinson, 1995, this volume).

REGIONAL GEOLOGY

Iron Range Mountain is underlain by sediments of the middle Aldridge Formation and several concordant Moyie sills which dip gently to the north and northwest (Figure 1). These rocks comprise the core of the Goat River anticline, a broad, gently north-plunging fold which underlies the west half of the Yahk map area (Brown and Stinson, 1995, this volume). The Iron Range fault is a northerly trending structure which cuts up-section from the International Boundary, in lower Aldridge Formation, to upper Aldridge Formation just north of the Yahk map area; further north it is cut by the Arrow thrust system (Reesor, 1981; Figure 1). It consists of a steeply dipping zone of deformation and mineralization varying in width from about 10 metres near the 49th Parallel to about 150 metres on the northern part of Iron Range Mountain. Net slip on the fault is minor in the main deposit area as sills are offset very little.

However, the amount of deformation and the complex relationships between deformation and mineralization point to a protracted, perhaps multistage history. There is evidence for both west-side-down movement and possibly both directions of strike-slip movement, based on rare kinematic indicators in the mineralized fault, local drag folding, and offsets of marker laminites (D. Anderson, Cominco Ltd., personal communication, 1994). Deformation in the surrounding rocks consists of penetrative cleavage, mainly in silty beds, and local metre-scale folding. Intersection lineations and fold axes in the rocks near the fault have a consistent moderate plunge to the north-northwest. This deformation is strongest near the fault and is probably related to it.

EXPLORATION HISTORY

The Iron Range prospect was discovered and staked in 1897. Over the next five years several shafts, adits, drill holes, and trenches were completed (Blakemore, 1902; Langley, 1922; Young and Uglow, 1926), none of which are preserved. Shafts and drill holes attained a maximum depth of 20 metres below the surface. Cominco Ltd. (then a subsidiary of Canadian Pacific Railways) acquired the main claim block on the northern part of Iron Range Mountain in 1939 and completed a major surface trenching program in 1957. All the exploration activity up to this point was aimed at evaluating the iron resource, which is potentially substantial. The claims remained CPR and Cominco Crown grants until 1994, when they were acquired by Discovery Consultants of Vernon who intend to evaluate the deposit's potential as an Olympic Dam type copper-gold-silver resource.

IRON MINERALIZATION

The intensity and types of mineralization and alteration vary over the length of the Iron Range fault. Mineralized zones can be broadly subdivided into the main deposit (most of the detailed study area), the La Grande zone (the southern part of the detailed study area, named after one of the claims), the Mount Thompson zone (the segment of the fault zone exposed east of the summit of Mount Thompson), and peripheral zones (the

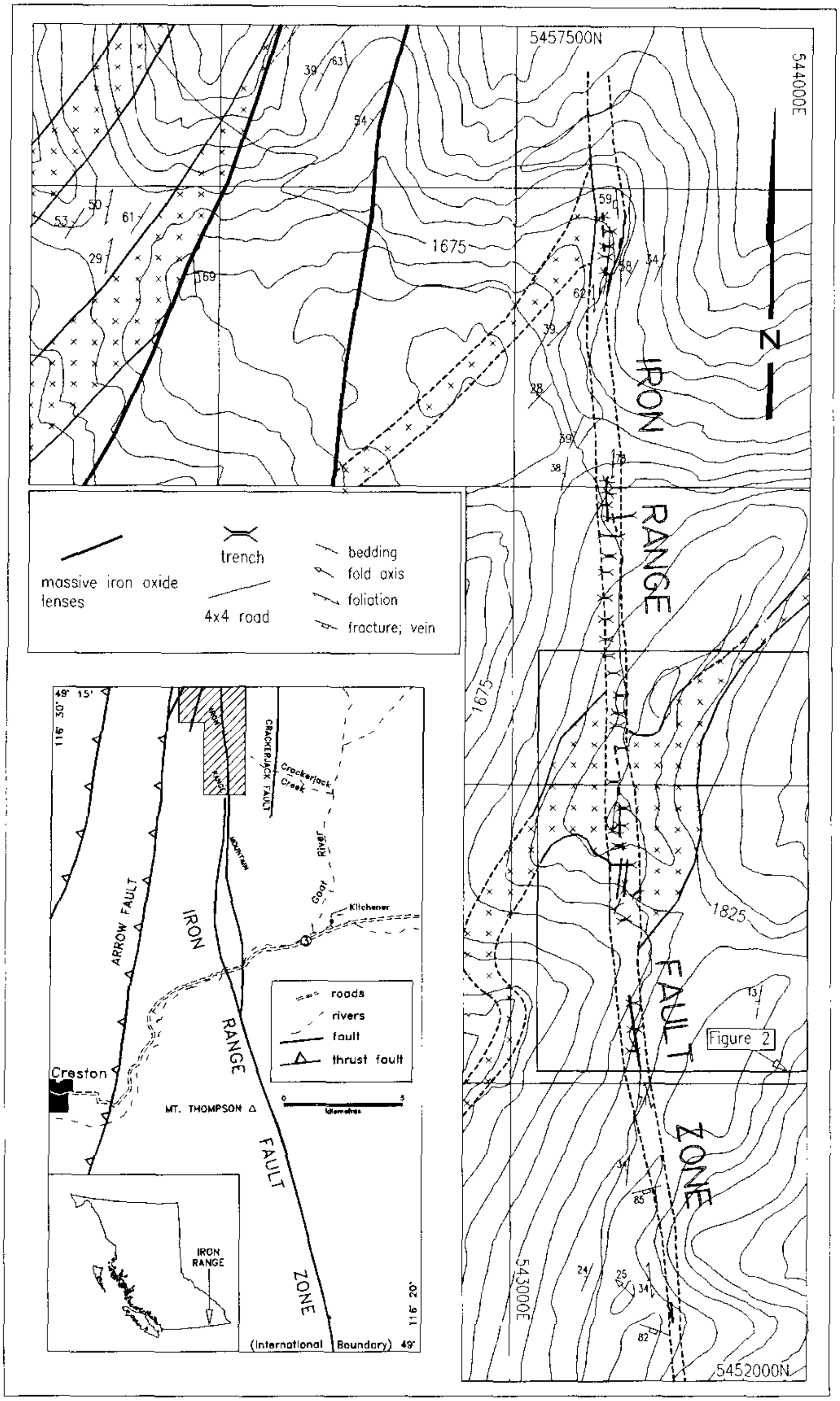

Figure 1. Simplified geological map of the main zone of the Iron Range deposit. Moyie sills are indicated by a cross hatch pattern. The widening of the sills near the fault is mainly a topographic effect. The location of Figure 2 is indicated by the labelled box. The contour interval is 30 metres, and the grid is a 1 kilometre UTM grid. The inset map is the west half of the Yahk map area (simplified from Brown and Stinson, 1995) with the location of the Iron Range map indicated by the hatched area

rest of the Iron Range fault and subsiduary faults). The main deposit produces a continuous, prominent aeromagnetic anomaly (Geological Survey of Canada, 1971).

MAIN ZONE

The main Iron Range deposit is contained within the widest segment of the fault zone. The deposit varies in width from approximately 60 to 150 metres and is at least 3 kilometres long. It runs from the Union Jack claim in the north to the Rhodesia claim in the south (MINFILE 082FSE014-20). This is the area explored by Cominco's 1957 trenching program. Bedrock is exposed in the less-deteriorated trenches; natural outcrop is very rare. Deformation fabrics, veining, and mineralized zones are all strongly aligned in the fault zone and are related to movement across it.

Lenses of massive hematite and magnetite occur along the length of the main zone. They range in width from 0.5 to 3 metres and pinch and swell substantially over their strike length. They are difficult to trace from trench to trench. Where nearly continuous exposure across the fault zone is preserved in trenches on the Maple Leaf claim, there are four parallel lenses spaced from 5 to 40 metres apart (Figure 2).

Most of the massive lenses are surrounded by wider *zones of hematite breccia*. Less commonly, massive iron oxide lenses cut foliated, sericitic sediments or gabbro. Breccia consists of fragments of albitite in a hematite-rich matrix. Contacts between the breccia and the

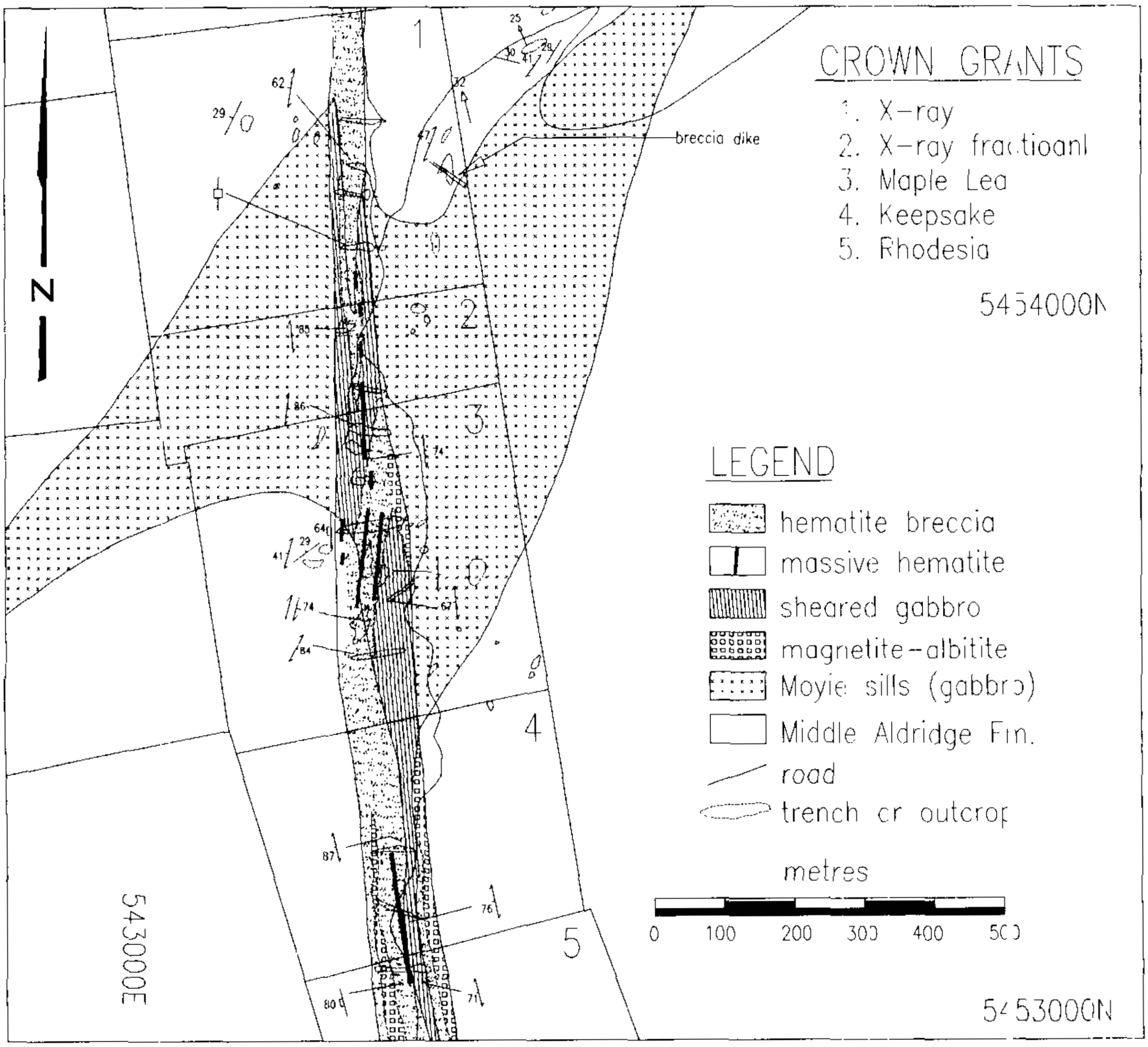

Figure 2. Detailed map of the part of the Iron Range fault and mineralization. See Figure 6 for location.

massive lenses are often gradational as the abundance of clasts diminishes into the lenses. Rare, small, angular fragments of albitite were observed in some of the lenses. Most of the massive lenses have envelopes of microbreccia 2 to 6 metres wide which have 70-80% hematite matrix surrounding angular clasts less than 1 centimetre across. Outward from the hematite-rich zones are wider breccia zones with 30 to 50% hematite as matrix and veins (Photos 1, 2). These breccias have a cataclastic texture. The original matrix is very fine grained fault gouge which is extensively replaced by hematite and minor magnetite. The massive lenses and surrounding breccias constitute the main iron resource of the Iron Range deposit.

The mineralogy of the lenses and breccias is dominantly hematite with variable amounts of magnetite. Thin sections show original magnetite abundances ranging from 5 to 30% as 0.5 to 2-millimetre euhedra. They are strongly pseudomorphed by hematite, with cores of magnetite remaining (Photo 3). The magnetite pseudomorphs sit in a matrix of fine-grained, often radiating, bladed hematite. Parts of the fault zone are occupied by unfractured albitite with disseminated to semimassive magnetite. Large magnetite euhedra (1-5 mm) form local, heavy disseminations, and fine-grained magnetite forms discontinuous veinlets and pods.

Photo 1. A cataclastic breccia from the main Iron Range deposit. The fracture filling is largely hematite and the rest is albitite (hand sample DBR93-220). The large dark spots are lichen. Flare pen for scale.

Sulphide minerals are rare in the Iron Range fault, with the exception of the northernmost trenches. In these trenches there is up to 3 or 4% pyrite as anhedral blebs in the hematite-magnetite lenses and breccias. Traces of chalcopyrite(?) were seen in hand sample but were not found in thin sections. In the remainder of the Iron Range, sulphides were not seen in outcrop or hand sample but some thin sections have tiny blebs of pyrite (<100 μm) within quartz veins. Some pyritic quartz veins with silicic alteration halos occur near the Iron Range fault; their orientations are oblique to the fault. Also, a short distance to the east of the fault on the northern part of Iron Range Mountain, there is an old pit with sulphide-bearing (pyrite-chalcopyrite-galena) quartz vein material in its dump (David Wiklund, Creston, personal communication, 1994). These veins may be related to the pyrite occurrences within the fault.

Foliated gabbro occupies much the width of the fault zone. Mineralization within the gabbro consists of some massive hematite lenses, foliation-parallel veins and zones of disseminated hematite and magnetite, rarer crosscutting breccia veins, and a background level of about 0.5 to 1% disseminated magnetite. The gabbro - iron oxide lens contacts are typically covered by overburden. Where exposed, there are zones of bleaching (albitite?) up to 30 centimetres wide and quartz veins lining the contacts. Crosscutting breccia veins were observed along the margins of the fault zone where strongly foliated gabbro grades into unsheared gabbro of the Moyie sills. The veins are very irregular and contain angular fragments of altered gabbro in a hematitic matrix. Some breccia veins are spatially associated with irregular zones of crosscutting albitic alteration. Disseminated magnetite is ubiquitous in the sheared gabbro, sufficient to be easily detected with a hand magnet. Most of the Moyie sills in the area do not attract a hand magnet and do not register on the regional aeromagnetic map.

Late, white quartz veins cut across all other rock types. The veins are several millimetres to several centimetres wide and most are parallel to the trend of the fault zone. Quartz growth is generally in the plane of the veins and some have several centimetres of shear movement. Some veins contain hematite crystals or angular fragments of massive hematite, apparently plucked from older veins and lenses. Magnetite is present in some quartz veins. These veins are interpreted as having been emplaced late in the deformational history of the fault, representing the last effects of the Iron Range hydrothermal system.

Photo 2. Hematite-filled breccia veins cutting albitite. The veins are parallel to the fault zone. Hematite fillings and veins are interpreted to postdate the initial brecciation. (PST94-I.R.23)

LA GRANDE ZONE

The La Grande zone is the segment of the Iron Range fault in the detailed study area south of the main zone (corresponding to MINFILE 082SE021-028). There the fault zone runs about 250 metres east of the ridge top and is not trenched; it is only exposed where it crosses side ridges. The fault zone appears to be 20 to 40 metres wide but the full width is not exposed. The fault in this area is a zone of quartz veining with variable iron oxide content in a more diffuse zone of grey quartz-hematite alteration. Iron content locally reaches grades approaching that of the massive lenses in the main deposit but over narrower widths (<1 m). This quartz-hematite mineralization is crosscut by late white quartz veins, as in the main deposit. In the La Grande zone the late veins are more common but are less often characterized by shear textures. Locally these veins contain up to 4% hematite, sometimes as 1 to 2-millimetre, platy euhedra.

MOUNT THOMPSON ZONE

South of Highway 3, a magnetite-rich zone crops out on a ridge top approximately 1.5 kilometres south-southeast of Mount Thompson. A zone of albitite, 1 to 2 metres wide, with disseminated to semimassive magnetite, cuts north-south through nearly flat-lying sediments. A wider surrounding zone has irregular hematite-filled fractures. In this area the fault changes from a single wide zone, as on Iron Range Mountain, to an anastamosing set of faults that are locally intruded by gabbro dikes. The individual faults are difficult to trace southward as outcrop becomes very scarce.

CRACKERJACK FAULT

A fault to the east of the main zone (Crackerjack fault; inset map in Figure 1) has a narrow zone (>5 m wide) of hematite-albitite breccia in one location, immediately to the north of Crackerjack Creek (Dean Barron, personal communication, 1994). One grab sample of the richest mineralization assayed [illegible]4% Fe_2O_3. The width of this zone and its extent along the fault are unknown due to poor exposure.

ALTERATION

Several alteration types are associated with the Iron Range deposit. Albite alteration is associated with the highest iron grades. In the main deposit, fine-grained, sugary albite alteration extends over most of the width of the fault zone. Albite alteration is confined to the fault

Photo 3. Photomicrograph showing euhedral magnetite grains in a matrix of bladed hematite. The magnetite grains are almost entirely pseudomorphed by hematite. The slightly darker core of the larger grain is residual magnetite. The field of view is approximately 0.75 by 1.25 mm. Reflected light, plane polarized. (PST94-I.R.11)

zone, except for rare apophyses which extend 1 to 2 metres into poorly foliated gabbro at the eastern contact of the main deposit. Although this alteration primarily affects sedimentary rocks in the fault zone, it is locally well developed in gabbro and, over the length of the fault, is only strongly developed near gabbro. Elsewhere early alteration in the fault zone is silicic.

Gabbro bodies within the fault zone are strongly foliated parallel to strike and are characterized by very strong chlorite alteration formed prior to, or during, shearing. The deformation fabric, seen in thin section, has porphyroclasts of plagioclase wrapped in fine-grained, commonly foliated chlorite. Weak S-C fabrics (Lister and Snoke, 1984) in foliated chlorite indicate west-side-down dip-slip movement. This contrasts with the completely brittle deformation of the albitite and may be attributable to the different competencies and response to stress of the lithologies during deformation. Locally the gabbro is bleached white by albitic alteration.

Sericitic alteration extends outward from the fault zone for about 500 to 1000 metres. The sericitic overprint is best developed in silty beds and is associated with the locally well developed cleavage. In addition to sericite, irregular veins and knots of quartz, epidote, and chlorite were observed in several outcrops of sandstone 100 metres to west of the trenches on the X-ray claim. Sericitic alteration was noted in only one locality in the fault zone, at its western edge on the Maple Leaf claim. There it is associated with a very strong, slaty cleavage developed parallel to the fault. This sericitic slate encloses the westernmost massive hematite lens (Figure 2).

Other alteration associated with the Iron Range fault is minor. Weak, rusty surface stain is present throughout the area, but this is a regional characteristic of the middle and upper Aldridge rocks, due to ubiquitous disseminated pyrrhotite (Höy, 1993). Mafic minerals within the gabbro sills near the fault zone have some chlorite overprint, but it is much weaker than within the fault zone.

Away from the parts of the Iron Range fault and subsidiary faults which have significant iron mineralization in surface exposures, the faults are characterized by a zone of cataclasis and silicic and/or albitic alteration 10 to 20 metres wide. Chloritic alteration was noted in several locations, all near intersections with Moyie sills. Examples are near the International Boundary, and on two faults on the northeast flank of Iron Range Mountain (in 82F/8).

PARAGENESIS AND RELATIONSHIP OF MINERALIZATION TO DEFORMATION

The origin of the Iron Range deposits is strongly linked to deformation in the Iron Range fault zone. Deformation can be separated into three episodes which may represent three stages of a continuous deformation. These are related to different stages in the evolution of the iron oxide mineralization. This is summarized in a paragenetic diagram (Figure 3).

The timing of the first movements on the Iron Range fault is difficult to determine. It is possible that it was originally a growth fault and served as a conduit for feeder dikes to the Moyie sills. The basis for this interpretation is the thick accumulation of sills in this part of the basin (Brown and Stinson, 1995, this volume). Also, much of the deformed material in the fault zone is gabbro, forming long narrow bodies. These have been interpreted as dikes (Blakemore, 1902; Langley, 1922; Young and Uglow, 1926). Within the main deposit, however, at least some of the gabbro bodies are sills that have been stretched into the plane of the fault zone, forming large drag folds and possibly sheath folds (Figure 2). The apparent thickening of the sills near the fault in the detail map area is mainly an effect of topography, but may be partly due to minor shearing along the margins of the main fault zone. If the sheared gabbros are deformed sills, then motion on the Iron Range fault probably began well after the deposition and burial of the Aldridge Formation. Pre-mineralization movement on the fault is inferred from the initial localization of albitite alteration along a narrow, crosscutting zone in the Aldridge sediments.

Albite alteration in the Aldridge Formation is usually the result of hydrothermal activity related to the intrusion of Moyie sills into relatively unconsolidated, water-saturated sediments at shallow levels below the sea-floor (Höy, 1993). The very strong albite alteration in

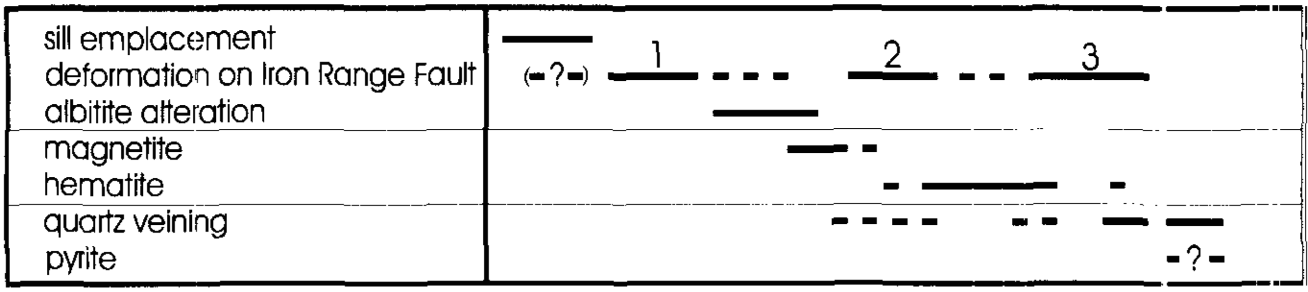

Figure 3. Diagram illustrating paragenetic sequence for the Iron Range deposit. Numbers refer to deformational episodes: (1) Initiation of the Iron Range fault and formation of hydrothermal conduit; (2) Cataclasis of albitite and shearing of gabbro; (3) Further cataclasis and shearing of iron ore.

the main Iron Range deposit is confined to the fault zone, although it is only developed in and around gabbro bodies. Initial magnetite mineralization is interpreted to have occurred with the albitic alteration, perhaps late in this episode. This mineralization is only well developed where subsequent brecciation is weak and shear fabrics are lacking. Magnetite precipitation continued into the next recognizable stage in the evolution of the Iron Range fault.

The main deformation episode followed the albite alteration. In the wide fault zone this consisted of extensive cataclastic brecciation of albitite, foliation development in gabbro, and local development of slaty cleavage in sericitized sediments. The albitite microbreccias are cataclasite (>50% matrix), the breccias are protocataclasite (<50% matrix), and gabbro within the fault zone is locally mylonitic, according to the definitions of Sibson (1977). This variation in deformational style between the different lithologies indicates that this episode occurred at several kilometres depth; cataclastic deformation can occur at depths up to about 5 kilometres (Ramsay and Huber, 1987, p. 584)

This deformation acted as ground preparation for hematite mineralization, although these events may have overlapped to some extent. Fine-grained hematite formed large, fault-parallel lenses and replaced fault gouge in the breccias. This episode began with magnetite deposition, but hematite replaced magnetite and is far more abundant. This change indicates that the fluids became increasingly oxidizing early in this main stage of iron mineralization.

Deformation continued after the main mineralizing episode, resulting in the formation of fractures, shear veins, and local ductile deformation of hematite-rich rocks. Quartz-filled shear veins, with vein-parallel mineral growth and offsets across them, are common along the length of the fault. They crosscut all other lithologies, including early silicified rocks in the La Grande area. Rare extension veins with mineral growth perpendicular to the vein walls were also observed. These vein textures resemble the vein associations in mesothermal, shear zone hosted gold deposits (Roberts, 1987), and may have formed in similar conditions. The iron oxide content of these veins is low. Local, well developed S-C fabrics in hematite breccias are associated with shear veins. Locally, hematite veins are brecciated and filled by quartz. Sulphide-bearing quartz veins, although not shear veins, may have been emplaced during this stage in the deposit evolution or they may be later and unrelated to the iron oxide mineralization.

The deformation style and alteration of the Iron Range fault and subsidiary faults is unusual compared to other faults in the surrounding area (Brown and Stinson, 1995, this volume). These characteristics, and the possible connection to the Moyie sills, indicate that the fault is old, maybe Proterozoic, and perhaps contemporaneous with early movements on the Moyie and St. Mary faults. The source of the large volume of iron contained in the Iron Range deposit is unknown. Potential sources include the Moyie sills and the basement of the Aldridge Formation.

COMPARISON TO OTHER MINERAL DEPOSITS

Hydrothermal iron deposits have received particular attention over the last few years, mainly due to the results of recent work on the Olympic Dam deposit in Australia. Early studies of the Olympic Dam, based on limited drilling information, interpreted the deposit as sedimentary breccias with mineralization and alteration largely due to diagenetic processes (Roberts and Hudson, 1983). Recent studies, based on extensive core logging and underground mapping, have established the hydrothermal nature of the breccias and described the evidence for near-surface hydrothermal brecciation within the host granitic batholith (Oreskes and Einaudi, 1990; Reeve *et al.*, 1990). Copper, gold, silver, uranium, and rare earth elements were deposited late in the evolution of the breccias, after significant iron metasomatism, and were enriched by supergene processes (Oreskes and Einaudi, 1990). These studies note that the core zone of the breccias is broadly associated with a topographic lineament which may reflect an underlying fault zone.

Recent studies propose that the Olympic Dam deposit has important similarities with certain other mineral deposits. This has resulted in the definition of a class of deposits; Olympic Dam type, or Proterozoic iron oxide (Cu-U-Au-REE; Hitzman *et al.*, 1992;

Lefeburc,1995, this volume). Canadian deposits included in this classification by these workers include the Wernecke breccias in Yukon Territory and deposits of the Great Bear magmatic zone in the Northwest Territories. One aspect of the deposit class is the alteration zoning, a summary of which is presented by Hitzman *et al.* (1992). They propose a typical pattern of albite-magnetite-actinolite grading upward and outward through a potassic zone to an outer hematite-sericite zone, with an intermediate zone of albite-sericite-magnetite alteration in sediment-hosted deposits. The Iron Range has an inner core zone of albite alteration and an outer envelope of sericite alteration corresponding to the deeper sodic alteration zone of this deposit class.

The Iron Range deposit has similarities to this broad class of mineral deposits and could reasonably be included in it. With respect to the Olympic Dam iron breccias, the main genetic differences appear to be the structural style, the origin of the brecciated hostrocks, and the greater depth of formation of the Iron Range deposit. However, enrichment in base and precious metals at Olympic Dam do not have a demonstrated corollary at Iron Range. It is interesting to note the possible fault control at depth at Olympic Dam (Oreskes and Einaudi, 1990), and to speculate that if this fault, or fault system, controlled the upward migration of hydrothermal fluids and metals, it might resemble the present level of exposure on Iron Range Mountain.

ACKNOWLEDGMENTS

We thank Dean Barron and Gavin Manson for assistance in the field. Discussions with Paul Ransom and David Lefebure were useful. The manuscript was greatly improved by critical reviews by Kirk Hancock and John Newell.

REFERENCES

Blakemore, M.E. (1902): The Iron Ore Deposits near Kitchener, B.C.; *Journal of the Canadian Mining Institute*, Volume 5, pages 75-81.

Brown, D.A. and Stinson, P. (1995): Geologic Mapping of the Yahk Map Area, Southeastern British Columbia (82F/1): An update; *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines, and Petroleum Resources*, Paper 1995-1, this volume.

Geological Survey of Canada (1971): Aeromagnetic Map 8471G, Yahk, British Columbia (NTS 82F/1); *Geological Survey of Canada* and *B.C. Ministry of Energy, Mines and Petroleum Resources.*

Hitzman, M.W., Oreskes, N. and Einaudi, M.T. (1992): Geological Characteristics and Tectonic Setting of Proterozoic Iron Oxide (Cu-U-Au-REE) Deposits; *Precambrian Research*, Volume 58, pages 1-47.

Höy, T. (1993): Geology of the Purcell Supergroup in the Fernie West-half Map Area, Southeastern British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Bulletin 84.

Langley, A.G. (1922): Kitchener Iron-deposits, Eastern District (No. 5); *in* Minister of Mines Annual Report 1921, *B.C. Ministry of Energy, Mines and Petroleum Resources*, pages G145-G149.

Lefebure, D.V. (1995): Two Intriguing Mineral Deposit Profiles for British Columbia; *in* Geological Fieldwork 1994, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-1, this volume.

Lister, G.S. and Snoke, A.W. (1984): S-C Mylonites; *Journal of Structural Geology*, Volume 6, pages 617-638.

Oreskes, N. and Einaudi, M.T. (1990): Origin of Rare Element-enriched Hematite Breccias at the Olympic Dam Cu-U-Au-Ag Deposit, Roxby Downs, South Australia; *Economic Geology*, Volume 85, pages 1-28.

Ramsay, J.G. and Huber, M.I. (1987): The Techniques of Modern Structural Geology, Volume 2: Folds and Fractures; *Academic Press*, 700 pages.

Reesor, J.E. (1981): Grassy Mountain, Kootenay Land District, British Columbia (82F/8); *Geological Survey of Canada*, Open File 820.

Reeve, J.S., Cross, K.C., Smith, R.N. and Oreskes, N. (1990): The Olympic Dam Copper-Uranuim-Gold-Silver Deposit, South Australia; *in* Geology of Mineral Deposits of Australia and Papua New Guinea, Hughes, F., Editor; *Australian Institute of Mining and Metallurgy*, Monograph 14, pages 1009-1035.

Roberts, D.E. and Hudson, G.R.T. (1983): The Olympic Dam Copper-Uranium-Gold-Silver Deposit, Roxby Downs, South Australia; *Economic Geology*, Volume 78, pages 799-822.

Roberts, R.G. (1987): Archean Lode Gold Deposits, *in* Ore Deposit Models; Roberts, R.G. and Sheahan, P.A., Editors, *Geological Association of Canada*,Geoscience Canada Reprint Series 3, pages 1-20.

Sibson, R.H. (1977): Fault Rocks and Fault Mechanisms; *Journal of the Geological Society of London*, Volume 133, pages 191-213.

Young, G.A. and Uglow, W.L. (1926): Iron Ores in Canada, Volume I, British Columbia and Yukon; *Geological Survey of Canada*, Economic Geology Series, No. 3, pages 132-142.