Fireside Deposit: Diagenetic Barite in Strata of the Kechika Group, and Vein Barite Related to Rifting of the Kechika Trough, Northwestern British Columbia (NTS 094M/14)

by P.J. Wojdak

KEYWORDS: barite, Fireside mine, Kechika Trough

INTRODUCTION

Dresser Industries produced barite from the Fireside property from 1983 to 1985 for use in oil and gas exploration. After a twelve-year hiatus, mining was reactivated on a sporadic seasonal basis by Fireside Minerals Inc. from 1997 to the present. Examination by the author of new exposures during this second phase of mining has elucidated the geology of the deposit and led to a better understanding of barite vein formation.

The Fireside mine, located in NTS area 94M/14, is reached from the Alaska Highway 125 km east of Watson Lake, or 11 km west of Fireside, via a 5.5 km gravel road (Fig 1). Realignment of the Alaska Highway in the 1990s north of its former location shortened the length of the access road by 1.5 km. The property is located 5 km north of the Liard River in rolling upland of the Liard Plain, an area dotted with numerous small lakes and blanketed by glacial till. Outcrop is sparse and confined to the tops of low hills and along major streams. Decades ago, an extensive forest fire swept the Fireside district. The area is covered now with dense growth of young spruce and birch. Early exploration at Fireside included many bulldozer-cut lines with unsystematic orientations, spacings and lengths. These are regrown with a tangle of alder. Foot travel away from roads at Fireside is difficult.

History and Production

G.B. Smith of Edmonton, Alberta recorded the first four claims at Fireside in October 1963. The claims were acquired by Magnet Cove Barium Corporation in 1964, and a seismic refraction survey on the Bear, Moose and Wolf claims was filed for assessment by H.C. Bickel (1965). The earliest geological description was by J.W. McCammon (1965). He described a large stripped area and barite showings that, based on topographic and geological relationships, correspond to the Bear West and Bear East veins. A secondary barite showing 300 m to the southwest, also noted by McCammon, does not correspond to the Moose or Beaver showings and is unknown to the writer.

Dresser Minerals Inc., a subsidiary of Dresser Industries and affiliated with Magnet Cove Barium, continued to

This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the BC Ministry of Energy, Mines and Petroleum Resources website at http://www.em.gov.bc.ca/Mining/Geolsurv/Publications/catalog/cat_fldwk.htm

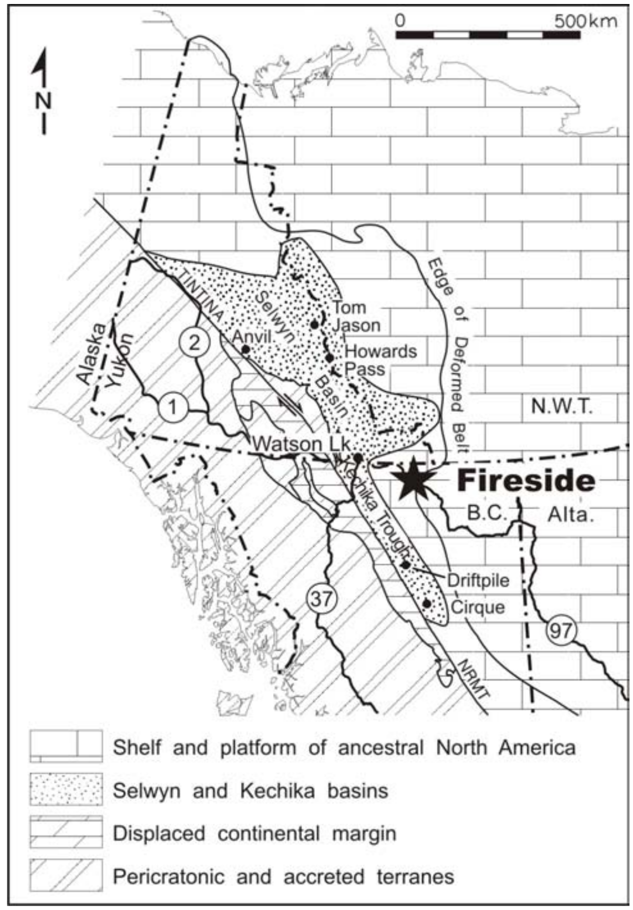

Figure 1. Regional setting of the Fireside barite deposit.

explore and develop the property (Crosby, 1971; McLeish and Baron, 1981) and began in 1984 to prepare the Moose deposit for mining. By 1986, some 70 000 t had been mined (Butrenchuk and Hancock, 1997), from which 41 071 t of barite were produced. Much of the barite was stockpiled and hauled to Watson Lake on a market basis until 1989. By 1997, the original Fireside claims had lapsed and new claims were acquired by Matovich Mining Industries Ltd. Later that year, Fireside Minerals Inc. became operator through an option agreement with Matovich and mined the Moose deposit. The Moose pit was reclaimed and, in 1998, Fireside Minerals developed Bear West. The majority of subsequent barite production has been obtained from that deposit, with a small amount coming from Bear East. An-

TABLE 1. ANNUAL PRODUCTION AT FIRESIDE BARITE MINE (1998–2007). PRODUCTION IN 2002 EXCLUDES 5000 TONNES THAT WERE MINED BUT NOT MILLED. PRODUCTION IN 2003 INCLUDES THE 5000 TONNES MINED IN 2002.

Year	Ore source	Mined (tonnes)	Barite production (tonnes)
1984 1986	Moose, minor Bear East	70000	41071
1997	Moose	15000	9000
1998	Bear West	18000	11500
1999	Bear West	36000	23000
2000		0	0
2001	Bear East & West	15000	10000
2002	Bear East	7500	1500
2003	Bear West	15000	10000
2004	Bear West	14000	9000
2005	Bear West	15000	10000
2006	Bear West	30000	12000
2007		0	4000
Total		**235500**	**141071**

nual barite production at Fireside totals 141 071 t of barite from 235 000 t of ore (Table 1).

Mining leases 361111 and 361112 cover areas of 41.8 ha over the Moose deposit and 82.3 ha over the Bear deposit, respectively, and are owned by D.C. Allan of Red Deer Alberta. The Ram and Lynx claims that adjoin the leases are also owned by Mr. Allan.

Operations Summary — Mining, Beneficiation and Reserves

Dresser Minerals mined primarily the Moose deposit, supplemented by a small amount from Bear East. Fireside Minerals acquired the infrastructure built by Dresser Minerals. This includes a crusher, jigs and large lay-down area near the Moose deposit, plus a grinding and bagging plant in Watson Lake. Fireside Minerals contracts mining and ore hauling to Jedway Enterprises Ltd. Mining (Fig 2) is done with a track drill, a bulldozer and an excavator. Three 30 t

Figure 2. Mining in the Bear West pit, 2005.

Figure 3. Loading haul truck in the Bear West pit, 2006.

trucks transport the ore (Fig 3) on the 4.2 km haul road to a crusher at the Moose site. Crushed raw ore is upgraded by jigs that separate barite, with a specific gravity of 4.48, from lighter rock. Average mine product has a specific gravity of 4.3; a minimum of 4.2 is required to be saleable, equivalent to 90% pure barite (E.W. Craft, pers comm, 2006). The mine normally operates for three months each year, from June to August. Highway trucks are used for the 125 km trip to Watson Lake. Trucking of barite concentrate begins in mid-summer and the Watson Lake plant operates for about three months, from August to October. The operation provides temporary employment for 25 people.

The ground and bagged barite (Fig 4) is sold to the oil and gas drilling industry in northeastern British Columbia and northern Alberta and, during the 1980s, was sold for use in Alaska (S. Butrenchuk, pers comm, 1998). Barite is a component of drilling ‘mud’. It provides a high hydrostatic head that helps prevent ‘gushers’ and consequent environmental impact and oil loss. Environmental regulations require lead content of barite used in oilfield drilling to be less than 10 ppm. Fireside barite is well within the environmental standard; no galena has been found in the Bear vein and occurs rarely near the margin of the Moose vein. Fireside

Figure 4. Bagged barite at the Watson Lake plant, ready for shipment.

barite also meets American Petroleum Institute criteria for low content of soluble alkaline earth metals, such as calcium.

DJ Drilling Company Ltd. initiated exploration drilling at Fireside to guide mining by its affiliate, Jedway Enterprises Ltd. (D. Schussler, pers comm, 2005). A series of holes was drilled in the vicinity of the Moose pit in late 2005 and ten holes were drilled in the area of Bear West in early 2006, in both cases on a 30 m grid. The Bear West drillcore was used by E.W. Craft to calculate a mining reserve and to design a five-year plan for mining (Craft, 2006), to begin in 2007. Craft noted that his report is not compliant with National Instrument 43-101. He determined a ‘resource’ of 208 000 t, with 512 000 t of waste rock requiring removal in order to recover barite, giving a strip ratio of 2.46:1. There was no mining at the Fireside property in 2007, but barite was produced from stockpiled material.

GEOLOGICAL SETTING

The Fireside area is underlain by a sequence of siliciclastic sedimentary rocks, limestone and dolomite of Cambrian (or older) to Devonian age, deposited on the ancestral margin of North America (Souther, 1992). These strata form the Selwyn Basin in the Yukon and, in northern British Columbia, a 500 km long embayment known as the Kechika Trough. Fireside is located near the junction between the southern margin of the Selwyn Basin and the northern end of the Kechika Trough (Fig 1). Sedimentary rocks on the Fireside property closely resemble the Kechika Group (Late Cambrian to Early Ordovician) or the overlying lower Road River Group. Ferri et al. (1999) noted the difficulty in distinguishing slate of the upper Kechika Group from overlying strata of the lower Road River Group (Ordovician to Early Silurian). The boundary between the two groups is where tan and light-coloured limy slate and siltstone of the Kechika Group are succeeded upwards by similar rocks, black in colour, of the Road River Group. Accordingly, J. Nelson (pers com., 2007) assigned Fireside strata to the Kechika Group. The upper Road River Group, not seen in the vicinity of the deposit, comprises dolomitic siltstone with minor limestone and chert of Silurian to Late Devonian age. These Paleozoic depositional basins are displaced by the Eocene Tintina fault, which cuts obliquely across the region 60 km south of Fireside.

Important sedimentary exhalitive (SEDEX) zinc-lead-barite deposits occur extensively in the lower Paleozoic strata of the Selwyn Basin and Kechika Trough (Carne and Cathro, 1982; MacIntyre, 1992; Ferri et al., 1999). Barite veins are similarly widespread, crosscutting these strata.

GEOLOGY IN THE VICINITY OF THE BARITE VEINS

The vicinity of the Bear and Moose veins is underlain by thin bedded, limy siltstone and shale (Fig 5). Bedding at-

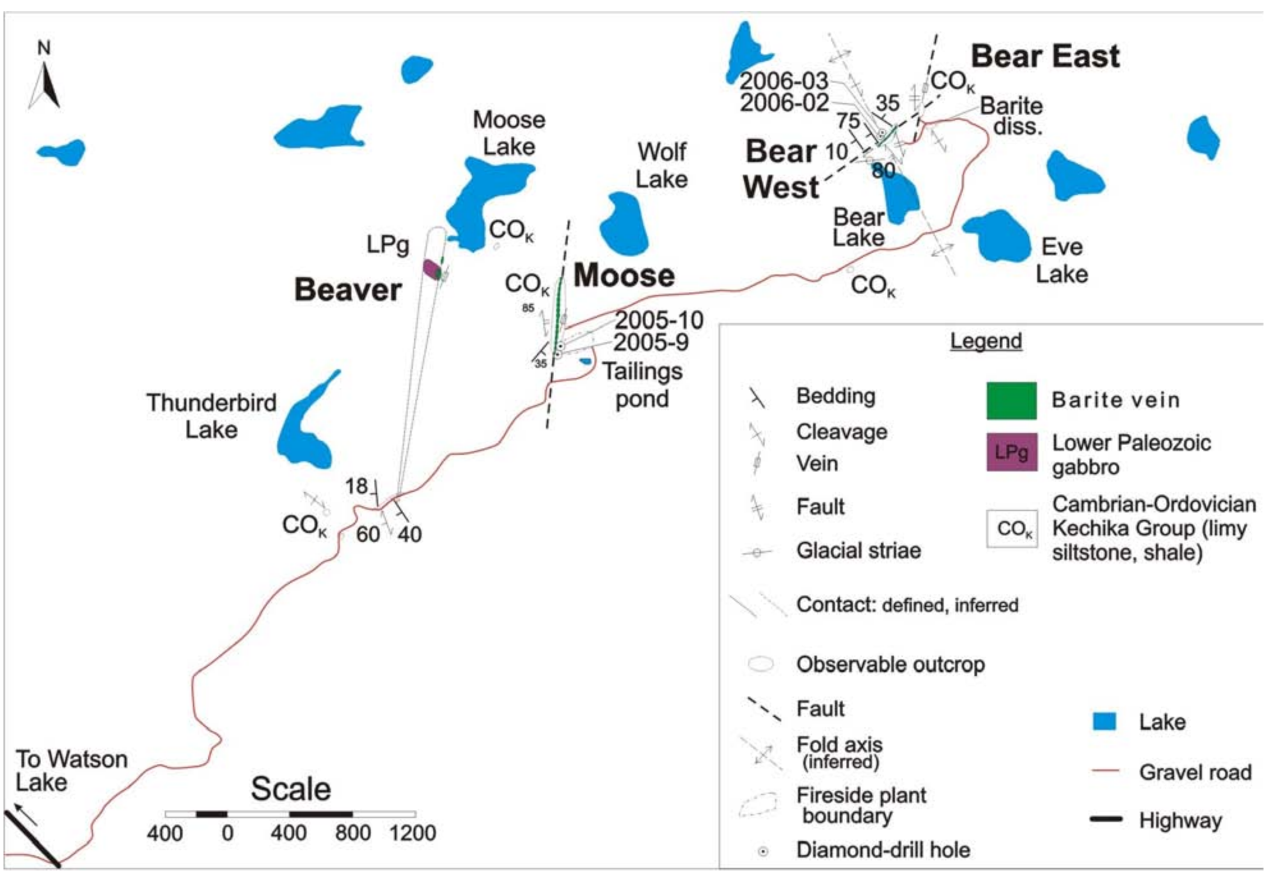

Figure 5. Geology of the Fireside barite minesite.

titudes are variable: the rocks strike northwesterly but the dip ranges from flat to moderate to the northeast and the southwest. A strong fracture cleavage is developed that commonly masks bedding. Open, upright folds about northwesterly axes are inferred from variation in bedding attitudes. Nonweathered rocks are grey, but most near-surface rocks are tan-brown to orange. Quarry exposures show that the transition between the two colours is sharp, occurring within a few centimetres, and cuts across bedding and cleavage in a complex pattern (Fig 6).

Figure 6. Siltstone and shale in the north wall of the Bear Pit, showing bedding, steep fractures and irregular boundary between grey and orange rocks.

Two outcrops in the poorly exposed area near the Bear and Moose veins are particularly interesting. An outcrop where the access road crests a low rise, southeast of Thunderbird Lake, contains very well preserved worm burrows. The same outcrop contains a spotted mafic dike described in detail below. Another road outcrop, just south of the Bear East vein, contains barite as disseminated crystals 0.3 to 0.5 cm in size (Fig 7). Identification of barite was corroborated by X-ray diffraction analysis (J.A. McLeod, pers comm, 2006). The barite crystals occur preferentially in thicker siltstone beds, up to 10 cm thick, and are generally concentrated in the centre of the bed. Barite forms 5 to 20% of receptive siltstone layers and is absent from thin black mudstone layers. The long axis of individual barite crystals is randomly oriented with respect to bedding, indicating that these are not detrital barite grains. Ferri et al. (1999) described authigenic barite in calcareous slate to silty limestone horizons of the lower Road River Group.

Figure 7. Barite crystals in siltstone.

Near the Beaver vein, a body of gabbro is fairly well exposed in outcrop over a 150 m wide area. The Beaver vein is situated at the contact between the gabbro to the west and siltstone to the east. The medium-grained gabbro consists of about 50% feldspar and 50% mafic minerals, and is altered. Feldspar, presumably plagioclase, is altered and the principal mafic mineral, pyroxene or amphibole, is indeterminate, having been replaced by chlorite and secondary amphibole. Interestingly, biotite that appears to be primary is a minor constituent. The gabbro body at the Beaver barite vein is on strike with an exposure on the access road of bedrock rubble of a spotted mafic dike. These exposures are correlated, defining a dike that trends nearly due north. The mafic unit on the access road is more strongly altered than the larger body near the Beaver vein. The spotted texture derives from clots of chlorite of indeterminate origin, either phenocrysts or amygdules. Similar altered mafic dikes occur near the Moose and Bear West veins (*see* below).

Barite Veins

The Bear West, Bear East, Moose and Beaver veins are similar in that they consist of coarse white barite with essentially no other minerals. There are differences between the veins in orientation and wallrock geology. The Bear West vein strikes east-northeast, whereas the other three trend northerly. All four veins dip subvertically. The author selectively examined core from two diamond-drill holes in the south end of the Moose zone and four holes in the Bear zone. Locations of two of the most important drillholes in each zone are shown on Figure 5.

The Bear West vein is known in the most detail, owing to recent mine exposures. It strikes 050 to 055º and dips vertically to steeply north. On the south, the footwall is a quartz-siltstone breccia. The first stage in brecciation is orange carbonate veinlets, each typically less than a centimetre wide, that form a closely spaced subhorizontal sheeted vein network (Fig 8). These are crosscut by second-stage anastomosing silica veinlets, which grade into the breccia that characterizes the footwall of the Bear West vein. The breccia, which consists of quartz-cemented angular black siltstone fragments (Fig 9), forms a zone 8 m wide at one locality. Quartz-siltstone breccia is cut by coarsely crystalline white barite veins. Quartz and barite generally occur in separate veins, but locally they occur in banded veins in which quartz is on the margin and barite in the core of the vein (Fig 8). Within the pit, the Bear West vein ranges from 4 to 10 m wide and splits into two branches. The north (hangingwall) of the Bear West vein is soft phyllite that is problematic to mine: too soft to blast yet too hard to rip with a bulldozer. Bear West has been mined over a 400 m length. Hole 2006-02 (Fig 5) was drilled at a dip of 45º across the Bear vein and intersected two altered igneous dikes. The barite vein has an apparent width in drillcore of 21.7 m (Fig 10) and the two dikes, 4.9 and 2.8 m in core width, are 16 and 25 m wide in the hangingwall of the vein. In hole 2006-03, the Bear vein is an impressive 29.0 m wide (in core length), with a 3 m internal block of quartz-cemented siltstone breccia near the footwall. The hangingwall comprises a 10 m wide fault zone containing a 30 cm mafic dike. Nearby drillholes show similar relationships but without a mafic dike, implying that mafic dikes fill faults in a discontinuous fashion.

The Bear East pit is about 75 m long but, due to sloughing of pit walls, the barite vein is poorly exposed. The vein strikes about 015º, almost perpendicular to Bear West. However, like Bear West, it is characterized by orange carbonate veinlets and quartz breccia on the east (footwall) margin.

Because the Moose pit is reclaimed, the Moose vein is known only from historical descriptions and from exploration core holes drilled in 2005 and 2006. Butrenchuk and Hancock (1997) described the Moose vein as a steeply dipping system within a north-trending braided fault. The barite vein strikes 005º. It pinches and swells up to 3.5 m wide, and was mined over a 400 m length. The author examined the Moose pit in 1997 before it was reclaimed. A metre-wide altered mafic dike was noted in the vein zone. Hesketh (1985), a manager of the Fireside barite mine for Dresser Canada Inc., described the Moose deposit as follows: "Mineralization appears to be directly associated and contacting with an intrusive porphyritic diorite. The intrusive is present at depth and extends, at places, to within 20 feet of the surface on both the hanging and foot walls." The mafic intrusion was not described by Butrenchuk and Hancock (1997). Holes 2005-09 and 2005-10, collared 30 m apart, were drilled at an orientation of 272º/45º to explore for a southerly continuation of the Moose vein (Fig 5). The core is stored in the Jedway Construction Ltd. – DJ Drilling Ltd. yard in Watson Lake and only selected boxes were examined. Both drillholes intersected siltstone and argillite. A portion of a 3.4 m dike in drillhole 2005-9 is shown in Figure 11. Altered feldspar phenocrysts, chloritic 'spots' (probably amygdules) and bright green mariposite are visible. The dike is cut by veins of dolomite, quartz and barite. A second dike, 1 m wide, occurs a few metres deeper in the hole. Both dike/vein intercepts contain sparse clots of base metal sulphides: pyrite, chalcopyrite, sphalerite and galena. Similar altered dike and narrow barite stringers occur in drillhole 2005-10.

The Beaver vein is well exposed in an early exploration trench; no work has been done by Fireside Minerals. The vein strikes about 010º. It is 4 m wide and occurs at the sharp contact between a body of gabbro, interpreted to be a dike, and grey shale. Description of mafic-rich grit by Butrenchuk and Hancock (1997) is erroneous. The subvertically dipping barite vein can be traced about 50 m north in a series of overgrown, shallow trenches. A swamp masks exposure to the south.

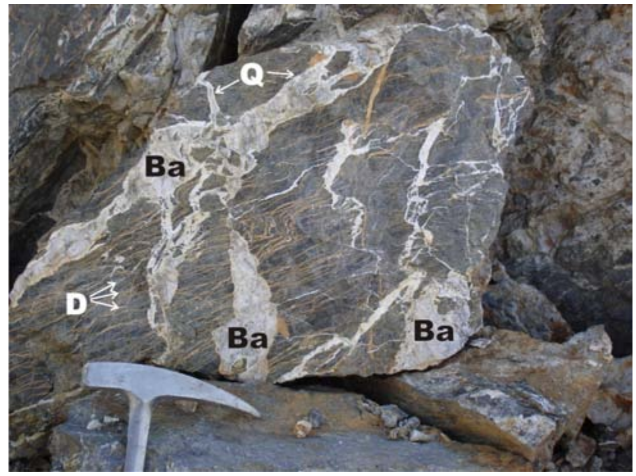

Figure 8. Narrow, orange dolomite veinlets (D) cut by quartz (Q, bright white) and barite (Ba, dull white) in the Bear East pit.

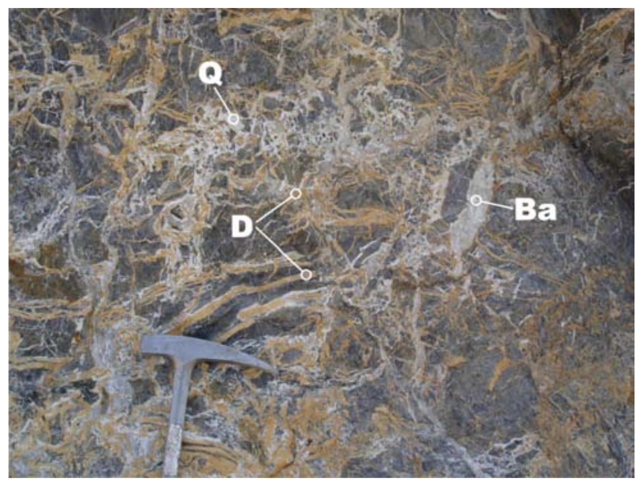

Figure 9. Quartz (Q) and barite (Ba) veins cut disrupted network of dolomite veinlets (D).


Figure 10. Barite vein intercept below the Bear West pit in diamond-drill hole 2006-02; black footwall breccia is also visible.

ORIGIN OF THE FIRESIDE BARITE DEPOSIT

Disseminated barite in siltstone described near the Bear East vein is interpreted to be diagenetic. Its characteristics are inconsistent with a detrital origin. The presence of vertical worm burrows suggests shallow water during sedimentation, possibly an intertidal environment. Following deposition but prior to lithification, siltstone beds were more permeable than the adjoining shale to infiltration of ocean water below the seabed. The Selwyn Basin – Kechika Trough is renowned for syngenetic barite deposits, particularly in Devonian rocks but also in older rocks, including the Kechika and Road River groups (Ferri et al., 1999). It is inferred that Selwyn Basin – Kechika Trough seawater was, at least episodically, enriched in barium. Incursion of barium-enriched seawater, perhaps in a sabkha environment, might produce the observed diagenetic barite horizons. The quartz breccia that characterizes the footwall of the Bear West and Bear East veins is reminiscent of an epithermal emplacement, and is consistent with a continental shelf to subaerial environment.

Barite veins at Fireside are spatially associated with gabbro dikes. The association may be accidental, veins and dikes coincidentally occupying the same structural openings, or causative (i.e., there may be a genetic link between igneous activity and the hydrothermal veins). Significantly, the gabbro intrusions and barite veins fill northerly-trending structures, not northwesterly ones related to folding. A regional perspective may give further insight into the age and genesis of the gabbro.

Geological mapping by Ferri et al (1999) found several northerly-elongated bodies of gabbro 30 km southwest of Fireside in the Hare-Gemini Lakes area. Composition and texture closely resemble the Fireside gabbro, including the presence of biotite, a rather uncommon mineral to be found in a mafic intrusion. One hypothesis is that the gabbro dikes fill dilational structures generated during Eocene movement along the Tintina fault (J. Nelson, pers comm, 2007). However, Eocene lamprophyre dikes are generally fresh, whereas the Fireside gabbro is altered and located 60 km distant from the Tintina – northern Rocky Mountain megalineament. Furthermore, as noted by Ferri et al. (1999) and previously by Gabrielse (1962), these gabbro intrusions (dikes and sills) are never found cutting rocks younger than Kechika age. Three features strongly suggest that these igneous bodies are related to inception of rifting of the Kechika Trough: 1) their mafic composition; 2) their northerly orientation; and 3) their age, which must be immediately post-Kechika and correspond to initiation of deep-water sedimentation. The evidence is not conclusive but, on balance, is persuasive that the Fireside gabbro is Paleozoic in age. If this interpretation is correct, and because Fireside is located off the axis of the trough (Fig 1), it must be located on a failed splay of the rift system.

The deduced age of the gabbro intrusions links them with regional mafic volcanism. Souther (1992) provided a compilation of the many localities in the Selwyn Basin and Kechika Trough where basalt occurs within the Kechika and Road River groups. In addition to age and stratigraphic position, similarities between these basalts and the Fireside – Gemini Lake gabbro bodies include the presence of primary biotite.

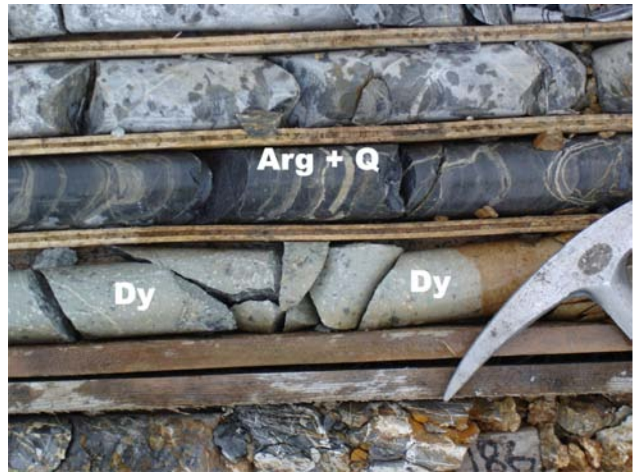

Figure 11. Altered mafic dike (D) and veined argillite (A) in diamond-drill hole 2005-09.

CONCLUSIONS AND RECOMMENDATIONS

The close association of mafic intrusions and barite veins that was observed first by Hesketh (1985) has been corroborated. The barite veins at Fireside are interpreted to have a two-stage origin. The origin of early diagenetic barite is uncertain, possibly related to prior, basin-scale enrichment in barium. The second stage involved remobilization of hydrothermal fluids generated by high-level mafic intrusions. A heat source is necessary to initiate a seafloor hydrothermal system. By the model presented in this paper, the heat source was a high-level mafic magma that resulted in intrusion of gabbro dikes and extrusion of basalt. The resultant circulation of heated seawater caused the formation of marginally younger, crosscutting barite veins at Fireside. Barite was deposited in fault zones near the apex of gabbro dikes. The sequence of mineral deposition was dolomite, then quartz and finally barite. Episodes of brecciation punctuated the mineralizing process.

Mafic magmatism is deduced to have originated during an episode of rifting of the Kechika Trough. The inferred early Paleozoic age of the gabbro dikes should be established by radiometric dating. Whole-rock and minor-element chemical analyses are prime topics for future investigation, to test for a common fingerprint between the gabbro intrusions and the Kechika – Road River basalt. Such data could indicate a common origin that is independent of radiometric dating evidence.

The occurrence of base metal sulphides in the Moose vein, though very minor, suggests a link between the Fireside barite veins and base metal – barite (SEDEX) deposits. The epithermal character of the Fireside veins is consistent with low hydrostatic pressure in a shallow-water shelf environment that is consistent with a failed rift on the continental margin. Formation of a hydrothermal fluid is attributed to high-level mafic magmatism. Considerations of the composition of the ore fluid and mechanism of barite precipitation, from both a theoretical perspective and from investigation of fluid inclusions, are additional topics worthy of further study.

Exploration potential of the Fireside district for additional barite veins is excellent. The Bear West vein is a significant source of barite, and is associated with a west-northwest fault and a very narrow mafic dike. This structure is nearly orthogonal to the northerly trend of the much larger mafic intrusions and other barite veins. Future exploration in this area should use these associations as search parameters, as they are more refined compared with early exploration models.

ACKNOWLEDGMENTS

People associated with the Fireside mine provided open access to the site and, in visits over a 10-year period, were generous with their time in describing and explaining the operation. They include Gordon Webster (President of Fireside Minerals Inc.), Keith Macleod (General Manager of Fireside Minerals), David Schussler (President of Jedway Enterprises Ltd.), Ed Craft (Mine Manager in 2006), Al Matovich and Steve Butrenchuk (Mine Manager in 1998). Frances Sharpe assisted with property and pit mapping in 2006, and expertly prepared the Fireside geology map. And, finally, this paper has benefited considerably from critical review by Jo-Anne Nelson and George Simandl, for which the author is very appreciative. Kirk Hancock kindly assisted with preparation of the figures.

REFERENCES

Butrenchuk, S.B. and K.D. Hancock (1997): Barite in British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources,* Open File 1997-16, pages 87–90.

Bickel, H.C. (1965): Geophysical report on refraction survey, Bear, Beaver and Moose claims; *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 767, 8 pages.

Carne, R.C. and Cathro, R.J. (1982): Sedimentary exhalative (Sedex) zinc-lead-silver deposits, northern Canadian Cordillera; *Canadian Institute of Mining and Metallurgy Bulletin*, Volume 75, pages 66–78.

Craft, E.W. (2006): Fireside Minerals Ltd., pit design and production forecast; unpublished report prepared for *Fireside Minerals Ltd*.

Crosby, R.O. (1971): Airborne geophysical survey, Wolf claim group; *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 2880, 2 pages.

Ferri, F., Rees, C., Nelson, J. and Legun, A. (1999): Geology and mineral deposits of the northern Kechika Trough between Gataga River and the 60th Parallel; *BC Ministry of Energy, Mines and Petroleum Resources*, Bulletin 107, 122 pages.

Gabrielse, H. (1962); Geology, Kechika, BC; *Geological Survey of Canada*, Preliminary Map 42-1962, scale 1:253 440.

Hesketh, J. (1985): Fireside barite mine, Fireside BC; unpublished report prepared for *Dresser Canada Inc.*, Magcobar Minerals Division.

MacIntyre, D.G. (1992): Geological setting and genesis of sedimentary exhalative barite and barite-sulpide deposits, Gataga district, northeastern British Columbia; *Exploration and Mining Geology*, Volume 1, Number 1, pages 1–20.

McCammon, J.W. (1965): Bear, Moose, Beaver groups; *BC Ministry of Energy, Mines and Petroleum Resources*, Annual Report, 1965, pages 257–258.

McLeish, C.A. and Baron, R. (1981): Fireside project, project cost estimate by Canadian Mine Services Ltd for Dresser Industries Inc.; *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 9052, 78 pages.

Souther, J.G. (1992): Volcanic regimes; *in* Geology of the Cordilleran Orogen in Canada, H. Gabrielse and C.J. Yorath, Editors, Geological Survey of Canada, Geology of Canada, Number 4, pages 459–490.