Geology, Mineral Deposits and Exploration Potential of the Skeena Group (NTS 093E, L, M; 103I), Central British Columbia

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KEYWORDS: Skeena Group, mid-Cretaceous, Rocky Ridge Formation, basalt, rhyolite, Equity Silver mine, mineral exploration

INTRODUCTION

Extending from Berriasian to Cenomanian time, the Skeena Group is a 3.5 km thick succession of mixed clastic sedimentary rocks with minor intercalated basalt and rhyolite flows that record 50 million years (143–93 Ma) of Early to mid-Cretaceous sedimentation and volcanism in central British Columbia (Fig 1). Volcanic strata are age-equivalent to the Spences Bridge and Crowsnest volcanics in southern BC and to the Mount Nansen and South Fork volcanics in the Yukon (Fig 8 *in* Bassett and Kleinspehn, 1996). Sedimentary strata are age-equivalent with units of the Bowser Lake Group and overlap in time with the generally younger successions of the Kasalka Group of central BC and the Nanaimo Group of Vancouver Island.

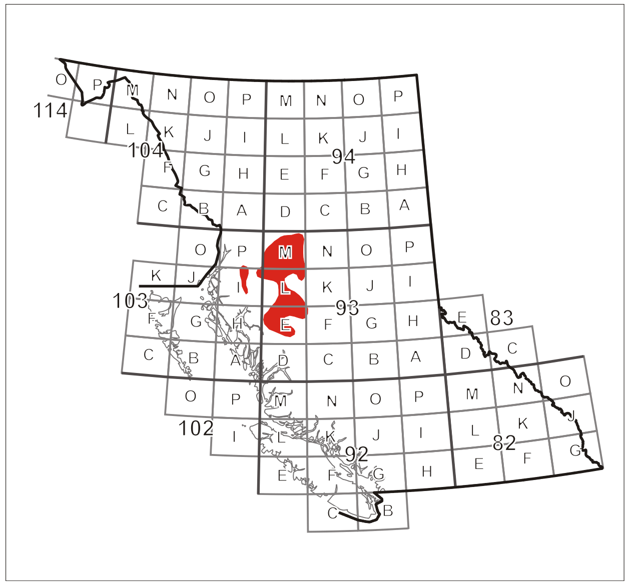

Figure 1. Distribution of Skeena Group rocks in BC.

Previous Geological Work

Skeena Group strata are widely distributed through central BC and have been studied for 125 years as part of regional mapping projects. A comprehensive bibliography is included at the end of this report.

Major steps in the evolution of stratigraphic nomenclature of the Skeena Group are shown in Figure 2. Dawson (1881) first included the strata now recognized as Skeena Group as a part of the larger 'Porphyrite Group'. Leach (1910) divided the Porphyrite Group into two units, the lower Hazelton Group and an upper Skeena series, and Hanson (1924b) and Jones (1925) raised the latter unit to formation status.

The differentiation between Hazelton Group and Skeena Formation strata was challenging because both units are characterized by clastic sedimentary rocks near their contact. Consequently, Armstrong (1944a, 1944b) merged both of these units into a larger Hazelton Group, which combined the clastic sedimentary rocks near the top of the earlier-defined Hazelton Group and the clastic sedimentary rocks of the Skeena Formation, into a single unit called the Upper Sedimentary Division. Sutherland Brown (1960b) continued with this system, formally naming Armstrong's 'Upper Jurassic to Lower Cretaceous Sedimentary Division' the 'Red Rose Formation'.

Following Roddick's (1970) informal usage of the term 'Bowser Group' for a regionally extensive clastic sedimentary succession exposed around Bowser Lake, Duffell and Souther (1964, p 27–33) proposed the name Bowser Group for a thick section of Late Jurassic to Early Cretaceous clastic sedimentary rocks in the Terrace area. This step created a major new unit in the midst of Armstrong's (1944a, 1944b) thickened Early Jurassic to mid-Cretaceous Hazelton Group. Working farther to the east where all rock units are exposed, Tipper and Richards (1976) addressed this problem by redefining the Hazelton Group as an Early to Middle Jurassic sequence, the Bowser Lake Group as a Middle to Late Jurassic sequence and resurrecting the name Skeena Group for the Early to mid-Cretaceous succession of sedimentary and volcanic rocks. Tipper and Richards (1976) also recognized the Late Cretaceous to Eocene Sustut Group as the unit that immediately overlies the northeast part of the Skeena Group strata. In the southeast part of the Skeena Group area, MacIntyre (1985) defined the Late Cretaceous Kasalka Group, which regionally overlies the Skeena Group at an angular unconformity.

Figure 3 presents the evolution of the internal stratigraphic subdivisions of Skeena Group. Leech (1909, p 62) described the Skeena series as a sequence of non-marine shale, sandstone and coal. Armstrong (1944a, 1944b) subdivided this rock sequence into a Sedimentary Division and an overlying Volcanic Division at the top of his larger

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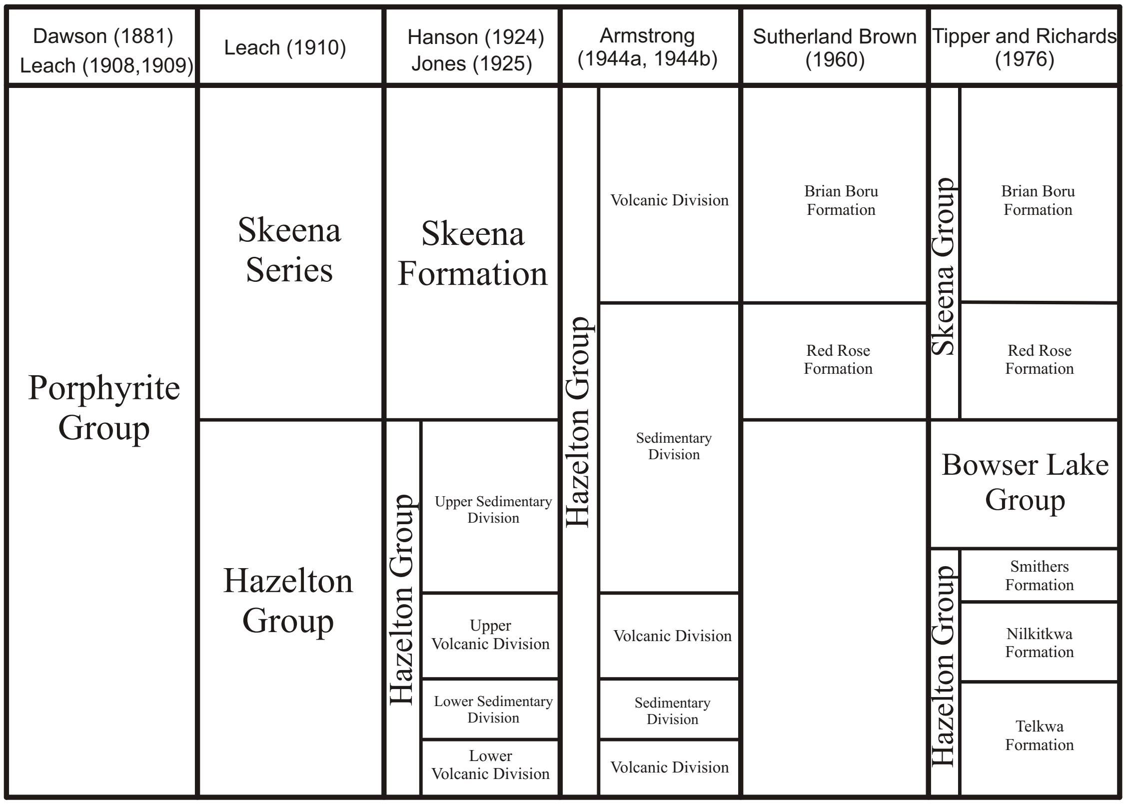

Figure 2. Development of regional stratigraphic subdivisions and nomenclature (*modified from* Ferri *et al.*, 2005).

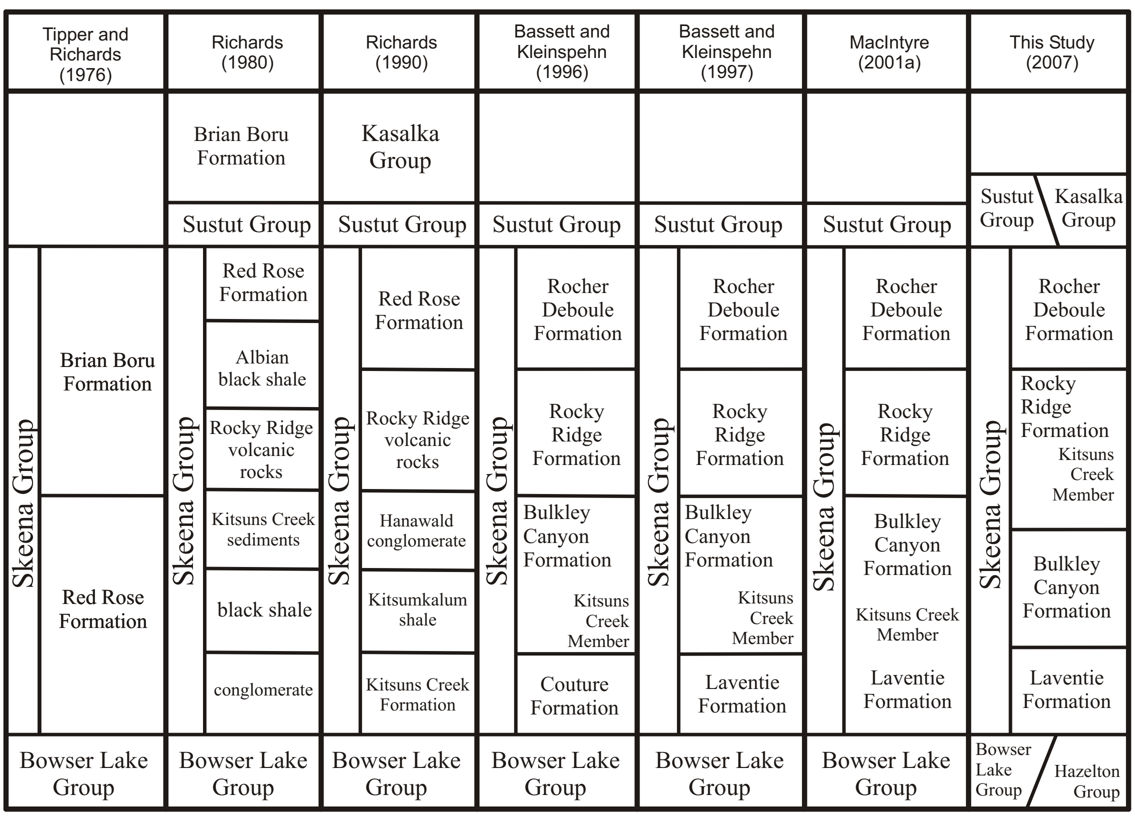

Figure 3. Development of Skeena Group subdivisions and nomenclature.

Hazelton Group succession. Sutherland Brown (1960b) formalized these same two stratigraphic divisions as the Red Rose and Brian Boru formations, respectively. Richards (1980) introduced six subdivisions for the Skeena Group and separated the Brian Boru Formation as a younger unit. Further refinement created five formal subdivisions for the Skeena Group (Richards, 1990). The first study to focus entirely on Skeena Group rocks was the PhD research program of Bassett (1995), which is also available as two publications (Bassett and Kleinspehn, 1996, 1997). They first interpreted Skeena Group stratigraphy as four formations (Bassett and Kleinspehn, 1996), but modified the nomenclature slightly in the second paper (Bassett and Kleinspehn, 1997). Subsequent targeted studies have been completed by Tackaberry (1998), MacIntyre (2001b) and MacIntyre *et al*. (2004). In the latter report, Skeena Group stratigraphy is simplified further into three main formations. In this report, the Skeena Group is divided into the same four formations and one member used by Bassett and Kleinspehn (1997), but the Kitsuns Creek Member is now combined with the Rocky Ridge Formation.

Mineral deposits hosted by Skeena Group rocks are discussed by Fleet Robinson (1911), Malloch (1914), Galloway (1914, 1916), O'Neill (1919), Jones (1925), Lang (1929), Kerr (1936), Kindle (1940, 1954), Stevenson (1947), Sutherland Brown (1960b), Wojdak and Sinclair (1984), Cyr *et al*. (1984), Church (1984, 1986), MacIntyre (1985a, 1985b, 2001b, 2006), Church and Barakso (1990), Leitch *et al*. (1990), Gaba *et al*. (1992), Church and Klein (1998), Wojdak and Ethier (2000), MacIntyre and Villeneuve (2001a), Fingler (2004) and MacIntyre *et al*. (2004) in addition to summary property descriptions available from MINFILE and comprehensive data provided in exploration assessment reports.

Current Project

A new research project was launched to examine the widespread exposures of Skeena Group volcanic units over the full extent of these rocks and to study all the metallic mineral occurrences hosted by Skeena Group strata.

In addition to documenting new mineral discoveries, existing mineral deposits will be reassessed and a series of recently proposed metallogenic models for the Skeena Group will be evaluated. The bimodal volcanic units of the Skeena Group have recently been interpreted as evidence for a caldera setting (MacIntyre, 2001a), which is the optimal setting for the formation and preservation of alkaline epithermal mineral deposits (Hedenquist and Sillitoe, 2003; Hedenquist and White, 2005). Previously, these same volcanic rocks were identified as products of rifting (Barrett and Kleinspehn, 1996), which is the optimal setting for the development of subaerial Bonanza-type epithermal deposits and subaqueous exhalitive mineralization (Hedenquist and White, 2005). Overall, the regional depositional environment for the Skeena Group is interpreted as a continental margin or fore arc tectonic setting (Barrett and Kleinspehn, 1997), similar to the interpreted setting for the world's greatest VMS district, the Devonian-Mississippian Iberian Pyrite Belt (White, 1999).

Only one geological setting and metallogenic interpretation can be the best fit. The BC Geological Survey field program was developed to evaluate these contrasting interpretations through study of the volcanic strata and examination of the mineral deposits. Results will identify the model with the best correlation to field and laboratory evidence and will help focus exploration efforts. Work in the 2006 field season concentrated on readily accessible exposures in the Babine Lake, Rocky Ridge and Francois Lake areas adjacent to the Smithers – Houston – Burns Lake corridor (Fig 4).

REGIONAL GEOLOGICAL SETTING AND SKEENA GROUP GEOLOGY

Overall, the regional depositional environment for the Skeena Group is a continental margin setting along western North America. In detail, Skeena Group strata record three distinct paleogeographic stages, reflecting contrasting tectonic phases. The summary below is *modified from* Bassett and Kleinspehn (1997) and Ferri *et al*. (2005).

In the first paleogeographic stage, Berriasian to Aptian (143–115 Ma), Skeena strata is represented as two contrasting rock types that grade laterally (Fig 4, 5). Coal-bearing micaceous sandstone and siltstone of the lower Bulkley Canyon Formation are interpreted as sediment accumulation in a series of coal-swamp deltas. The lower Bulkley Canyon Formation hosts the important Telkwa coalfields. Marine black shale, and lesser siltstone and sandstone, of the lower Laventie Formation are interpreted as deposits accumulated in restricted tidal basins adjacent to the deltas. These Early Cretaceous rock types correlate to the north with the deep basinal deposits of the McEvoy Formation of the Bowser Lake Group, which record the final filling of the Bowser foredeep produced by Jurassic accretion of the Intermontane Belt to North America.

The second paleogeographic stage is recorded by early Albian to early Cenomanian (115–95 Ma) deeper water marine sedimentation and coeval interbasinal volcanism. Southeastward marine transgression is recorded as finer grained sedimentary rocks of the upper Laventie Formation. The upper Bulkley Canyon Formation is preserved at the southern limit of Skeena Group exposures as more micaceous, fossil-poor, coal-absent tidal sandstone–siltstone sequences interpreted as shallow-water delta-front or delta-plain deposits. The contemporaneous Rocky Ridge Formation includes several widely scattered eruptive centres of volcanic rocks that record a period of minor crustal extension in the subsiding basin. Adjacent to the volcanic flows, volcanic detritus is incorporated in the sedimentary stratigraphy. These distinctive sedimentary rocks rich in volcanic clasts comprise the Kitsuns Creek Member of the Rocky Ridge Formation. Individual volcanic centres vary from subaerial to submarine. The peripheral volcaniclastic Kitsuns Creek Member grades laterally outward into either upper Laventie Formation or upper Bulkley Canyon Formation sedimentary strata. These Early to mid-Cretaceous rock types correlate with the magmatism in the Omineca Belt to the east, with ongoing arc volcanism of the upper Gambier group to the west and continued sedimentation of the upper McEvoy Formation of the Bowser Lake Group to the north. The upper McEvoy Formation hosts minor distal volcanic ash.

The third paleogeographic stage records a brief episode (early to mid-Cenomanian; 95–92 Ma) marked by the accumulation of subaerial fluvial and deltaic conglomerate, sandstone and siltstone of the Rocher Deboule Formation. Coarse clastic debris is dominated by chert pebbles, with local volcanic clasts eroded from the underlying Rocky

Ridge Formation. The mid-Cretaceous conglomerate correlates to the north with fluvial chert-pebble conglomerate and sandstone of the Devil's Claw Formation of the Bowser Lake Group. These rocks record the final filling of the Bowser foredeep produced by the Jurassic accretion of the Intermontane Belt to North America. Within the area of the Rocher Deboule Formation, the fluvial conglomerate is conformably overlain by fluvial chert-granite conglomerate, sandstone and mudstone of the Tango Creek Formation of the Sustut Group. To the south, Rocher Deboule strata correlate with the red basal conglomerate of the Kasalka Group, which unconformably overlies lower Skeena Group rocks in the Tahtsa Lake area (MacIntyre, 1985a).

The Devil's Claw Formation (Bowser Lake Group), the lower member of the Tango Creek Formation (Sustut Group), the basal conglomerate of the Kasalka Group and the Rocher Deboule Formation (Skeena Group) are all roughly coeval and are all composed of fluvial chert-clast–rich conglomerate and sandstone. Bassett and Kleinspehn (1997) conclude that all four formations are laterally equivalent units of the same progradational chert-rich unit and predict that these similar, coeval units will ultimately be consolidated into a single formation.

Geology of the Rocky Ridge Formation

The volcanic rocks of the Skeena Group were named the Rocky Ridge volcanics by Richards (1980) and formalized as the Rocky Ridge Formation by Richards (1990). These two maps also recognized the associated volcaniclastic sedimentary strata as the Kitsuns Creek Member (Richards, 1980) and then the Kitsuns Creek Formation (Richards, 1990). All of these strata have been further described in a series of maps and reports, including MacIntyre (1985a, 1998, 2001a, 2001b, 2006), Bassett (1991, 1995), Bassett and Kleinspehn (1996, 1997), Richards *et al*. (1997), Tackaberry (1998), MacIntyre *et al*. (2001a, 2001b, 2004) and MacIntyre and Villeneuve (2007). The most comprehensive studies of this volcanic strata are reports by Bassett and Kleinspehn (1996) and Tackaberry (1998) and the most recent geochronological results for the Rocky Ridge volcanics are tabulated in MacIntyre and Villeneuve (2007).

Rocky Ridge volcanics occur in isolated geographic areas within the otherwise continuous clastic sedimentary deposition of the Skeena Group (Fig 6; Bassett and Kleinspehn, 1996). Prior to 1998, the Rocky Ridge Formation was defined as a sequence of mafic volcanic flows, associated fragmental facies and minor intercalated volcaniclastic sedimentary rocks. In all reports and maps completed from 1998 onwards, the Rocky Ridge Formation is described as a package of bimodal volcanic rocks and related sedimentary facies. New radiometric dates (MacIntyre and Villeneuve, 2007) establish that the felsic and mafic volcanic units differ by 10 million years in age. New fieldwork reveals that felsic and mafic volcanic rocks of the Skeena Group are stratigraphically separated by hundreds of metres of clastic sedimentary rocks. Consequently, these contrasting volcanic units are described separately in this report, although both rock types are still included as parts of the Rocky Ridge Formation.

FELSIC VOLCANIC ROCKS OF THE ROCKY RIDGE FORMATION

Rounded, equidimensional intrusive 'rhyolite plugs' are widespread throughout Skeena Group rocks. These

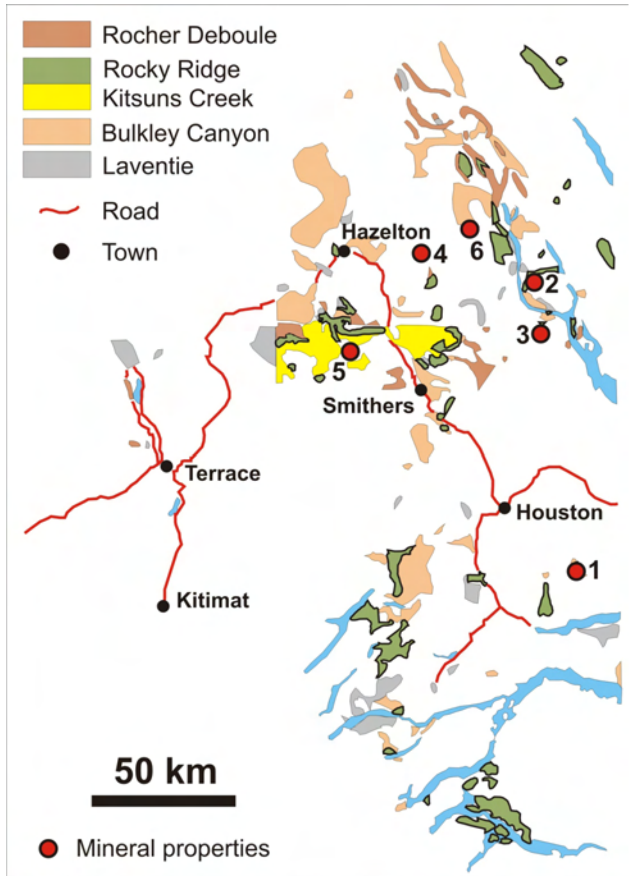

Figure 4. Geology map of the Skeena Group (*modified from* Bassett and Kleinspehn, 1997). Numbers show mineral properties from Table 2.

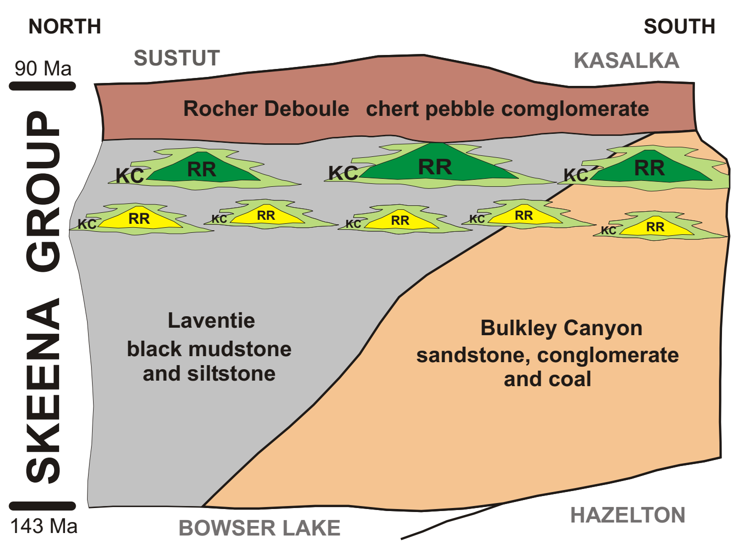

Figure 5. Schematic stratigraphy of Skeena Group (*modified from* Bassett and Kleinspehn, 1997). Abbreviations: RR, Rocky Ridge Formation; KC, Kitsuns Creek Member.

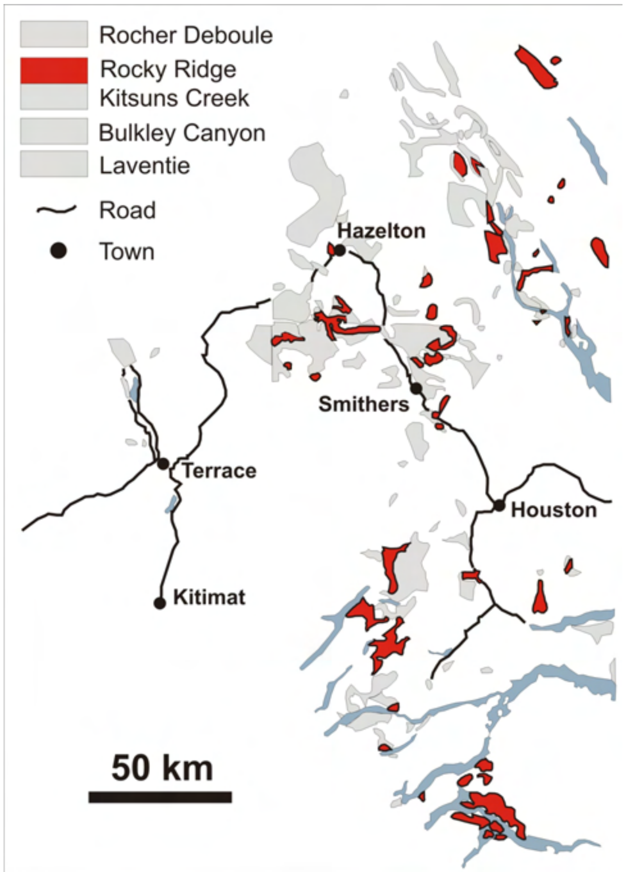

Figure 6. Geological map of volcanic units of the Skeena Group (*modified from* Bassett and Kleinspehn, 1997).

bodies were initially mapped as a series of Eocene stocks ('EBr'; Richards, 1980). Textures and field relationships evident in subsequent mapping by MacIntyre indicated that rhyolite bodies close to the Granisle and Bell mines in central Babine Lake were extrusive rhyolite domes or cryptodomes (MacIntyre, 1998). Subsequent reassessment of the field data (Tackaberry, 1998; MacIntyre, 2001b) lead to the conclusion that the ring of 14 rhyolite domes north and west of Old Fort Mountain were mid-Cretaceous, and therefore also extrusive bodies. New U-Pb dating (MacIntyre and Villeneuve, 2007) shows that felsic volcanic rock exposed along the walls of the main pit road at the Equity Silver mine are also mid-Cretaceous, confirming that the ore-hosting succession of sedimentary and volcanic rocks at the mine are Skeena Group rocks.

West Morrison Rhyolite

Felsic volcanic rocks within the Skeena Group are exposed in outcrop in a series of 14 small rhyolite domes north and west of Old Fort Mountain and adjacent to north-central Babine Lake.

Eleven discrete outcrop areas of Skeena Group rhyolite are exposed along the West Morrison logging road network, north and west of Old Fort Mountain, northern Babine Lake. These rocks are best described in a BSc thesis by Tackaberry (1998). The white to pale grey rhyolite domes are enveloped in a black matrix lapilli tuff containing clasts of the rhyolite and dacite (Fig 7). Also preserved within this black matrix lapilli tuff are small lenses of fine-grained, dark grey orthoclase and plagioclase-porphyritic dacite. Due to the dark colouring, these outcrops were originally misidentified as basalt, giving rise to the identification of a 'bimodal' basalt-rhyolite succession for the Rocky Ridge volcanics in this area.

Bell Mine Dacite

A similar massive dacite rock collected southeast of the Bell mine yielded a U-Pb age of 107.9 ±0.2 Ma (MacIntyre and Villeneuve, 2001b). A crosscutting basalt dike from this same outcrop, dated by the $^{40}Ar/^{39}Ar$ method at 104.8 ±1.2 Ma, provides a minimum age for the felsic volcanic rock (MacIntyre and Villeneuve, 2001b).

Kitseguecla Lake Rhyolite

A 10 km long rhyolite lens is well exposed as a prominent resistant ridge along the north side of the Kitseguecla Lake road and adjacent logging roads to the north. Initially mapped by Richards (1980) as an Eocene sill, MacIntyre *et al*. (2004) speculated that this rock unit might be another extrusive rhyolite dome, cryptodome or subvolcanic sill, similar to the West Morrison rhyolite domes. Samples from this unit have not yielded enough zircons for a radiometric date (MacIntyre and Villeneuve, 2007).

Knoll Rhyolite

This large mineralized rhyolite dome is correlated to other rhyolite domes that are part of the Rocky Ridge Formation (MacIntyre, 2001b; MacIntyre *et al*., 2004). This unit has not yielded enough zircon for an age determination (MacIntyre and Villeneuve, 2007).

Equity Silver Mine Dacite

Felsic lapilli tuff exposed in the east ramp of the Main Zone pit was collected in 2003 by MacIntyre and Villeneuve as part of a Rocks to Riches–funded project (MacIntyre *et al*., 2004; Villeneuve, 2004; MacIntyre and Villeneuve, 2007). The rock was collected from a stratigraphic package called the Pyroclastic Division, which is described as a sequence of welded to non-welded coarse-grained lapilli tuff and ash tuff, volcanic breccia and minor intercalated, very fine grained tuff or dust tuff (Cyr *et al*., 1984). Rocks of the Pyroclastic Division are primarily dacite. This sample has yielded an age of 113.5 +4.5/–7.2 Ma, which firmly establishes the hostrock succession of interbedded volcanic and sedimentary rocks at the Equity Silver mine as Skeena Group strata.

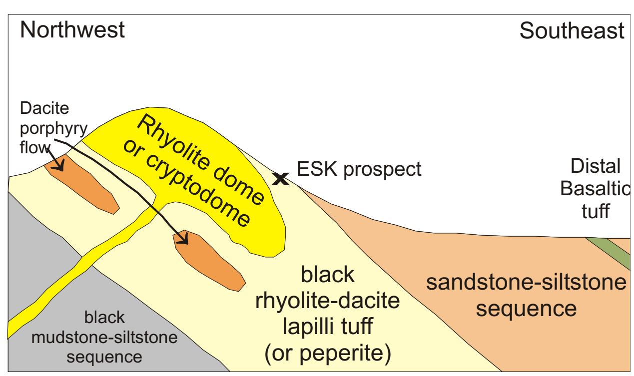

Figure 7. Schematic cross-section through a rhyolite dome along the West Morrison logging road (*modified from* Tackaberry, 1998).

INTERMEDIATE VOLCANIC ROCKS OF THE ROCKY RIDGE FORMATION

Equity Silver Mine Andesite

On the mine property, the fragmental dacite described above is overlain by a succession of andesite and dacite flows called the Volcanic Flow Division (unit 3a on Fig 8; unit 4 of Cyr *et al*., 1984). This demonstrates that volcanic rocks with intermediate composition are also preserved in the Skeena Group. A K-Ar date of 58.5 ±2.0 Ma was obtained from sericite alteration superimposed on these volcanic flow rocks (Wetherell, 1979; Cyr *et al*., 1984); however, this is interpreted as a reset sericite date reflecting the proximity of the multiphase Eocene monzonite-diorite-gabbro intrusion, which crops out a few tens of metres to the east (Cyr *et al*., 1984).

Mount Ney Volcanics

Extensive outcrops of mid-Cretaceous Mount Ney volcanics form scattered mound-like exposures in the forest-covered region of the central and northeast Newcombe Lake map area (NTS 093E/14), where this informal unit was first introduced as unit lKv (Diakow and Drobe, 1989a). The current name appeared first in Geoscience Map 2006-5 (Diakow, 2006). Mount Ney volcanics are predominantly lava flows that range in composition from basaltic andesite to andesite (Diakow and Drobe, 1989b, p 184, *under* 'Lower Cretaceous'). Flows exhibit amygdaloidal and more commonly porphyritic texture defined by felted fine-grained plagioclase laths and pyroxene grains. Except for one large exposure of pillow lava, indicating submarine deposition, they generally form massive unstructured outcrops.

MAFIC VOLCANIC ROCKS OF THE ROCKY RIDGE FORMATION

The Rocky Ridge Formation was defined by Richards (1980, 1990) for the thick succession of porphyritic basalt flows and intercalated volcaniclastic sediments exposed along the length of Rocky Ridge, 25 km northwest of Smithers. Additional basalt units, now correlated with Skeena Group, have been mapped by Woodsworth (1980) in the Morice Lake – Tahtsa Lake – Whitesail Lake – Eutsuk Lake region. North of Rocky Ridge, Richards (1990) mapped small bands of Rocky Ridge basalt within the main Rocher Deboule range. Farther northeast, similar mafic volcanic rocks were mapped through a large region 25 km northwest of Nilkitkwa Lake, and over a similarly large area 25 km north-northwest of Bulkley House at the north end of Takla Lake (Richards, 1990).

All of these mafic volcanic rocks are alkaline and porphyritic (Tackaberry, 1998), although phenocrysts vary between pyroxene, plagioclase and hornblende. Most flows are vesicular, with infillings of calcite or zeolite. Basalt exposures are mainly subaerially deposited; however, outcrops near Tahtsa Lake show a thin accumulation of pillowed flows at the base of a sequence that grades upward into massive flows. Lava flows are interbedded with pyroclastic flows, tuff breccia, siltstone and peperite.

Fossil suites collected from sedimentary units below, above and interbedded with these basalt successions constrain the age of the flows to early Albian (110 Ma) in the south and to mid-Albian to mid-Cenomanian (105–93 Ma) in the north (Bassett and Kleinspehn, 1996). Dating by $^{40}Ar/^{39}Ar$ on hornblende crystals from the uppermost flows exposed on the Rocky Ridge gives an age of 95.6 ±1.6 Ma (Bassett and Kleinspehn, 1996, p 731). A whole rock $^{40}Ar/^{39}Ar$ age of 93.0 ±2.3 Ma was obtained from a basalt flow in the same area (MacIntyre and Villeneuve, 2007). A basalt dike sampled south of the Bell mine (MacIntyre and Villeneuve, 2001b) yields an $^{40}Ar/^{39}Ar$ whole rock age of 104.8 ±1.2 Ma. In summary, combined fossil and geochronology studies constrain the age of the basaltic units of the Rocky Ridge Formation to 110 Ma in the south and from 105 to 93 Ma in the north.

Rocky Ridge Basalt

Bassett and Kleinspehn (1996, p 733) provide the most comprehensive description of this unit at its type area 25 km northwest of Smithers. Strata consist of interbedded alkaline basaltic lava flows and pyroclastic flows averaging 10 to 20 m in thickness. Flows display large (4–8 mm) pyroxene phenocrysts with rare plagioclase or hornblende phenocrysts. Most flows are highly vesicular. The subaerial features of the lava, pyroclastic flows and the presence of vesicular basalt clasts in distal interbedded fluvial deposits indicates that this volcanic complex was emergent, had high relief and was a source of sediment.

Black shale with interbedded sandstone crops out around the coeval volcaniclastic deposits, indicating a tidally dominated shallow-marine setting around the volcanic edifices (Bassett and Kleinspehn, 1996).

GEOLOGY OF THE KITSUNS CREEK MEMBER

Rocks of the Kitsuns Creek Member are fine-grained or medium-grained clastic sedimentary rocks characterized by fine to coarse, monolithic volcanic clasts. They represent volcaniclastic debris shed into medium-grained sedimentary rocks of the deltaic Bulkley Canyon Formation or into black, fine-grained basinal sedimentary rocks of the Laventie Formation. These rocks can only form adjacent to volcanic rock units of the Rocky Ridge Formation. Consequently the Kitsuns Creek Member is classified here as a facies of the Rocky Ridge Formation rather than a facies of the clastic sedimentary formations of the Skeena Group.

There are four contrasting 'end-members' of Kitsuns Creek rock types: massive black mudstone with rhyolite clasts, massive black mudstone with basalt clasts, sandstone or grit with rhyolite clasts and sandstone or grit with basalt clasts. Sedimentary units hosting clasts of intermediate volcanic composition are also described from the Equity mine succession (Cyr *et al*., 1984).

These rock types are important because they may be first field indicators that volcanic units of the Rocky Ridge Formation exist nearby. At the Knoll property, mineralization is hosted by the volcanic unit; but at the ESK property, the sedimentary rocks rich in volcanic clasts or reworked lapilli tuff of the Kitsuns Creek Member host the vein network with elevated base and precious metal values.

The black matrix breccia exposed in many locations along the West Morrison logging road envelopes the ring of 14 prominent rhyolite domes that are exposed in this area. These black matrix breccia form both the immediate footwall and hangingwall rocks to the rhyolite bodies. Initially mapped as basalt conglomerate (with rhyolite clasts), the petrochemical analysis of these rocks by Tackaberry (1998) showed an overall composition of dacite, leading to a classification as dacitic lapilli tuff. An alternative interpretation, based on field textures, is that these rocks are peperite generated by the flow of rhyolite lava, or by the emplacement of a rhyolite cryptodome, into unconsolidated black silt and mud of the Laventie Formation.

GEOLOGICAL AND TECTONIC HISTORY

Skeena Group rocks accumulated on the western continental margin of North America from Early to mid-Cretaceous time. These shallow-water strata grade laterally to the north and northwest into deeper water, basinal sedimentary rocks of the Bowser Lake Group; to the south and southeast, Skeena Group sedimentary rocks pinch out against the subaerially exposed micaceous continental rocks that provided the sediment.

Bassett and Kleinspehn (1996, 1997) describe the evolution of the geological setting of these strata. In the Early Cretaceous, the depositional setting is a series of shallow-water to locally emergent deltas (Bulkley Canyon Formation) adjacent to restricted tidal basins where black shale accumulated (Laventie Formation).

In the mid-Cretaceous, the subsidence of the continental margin was recorded by southeastward marine transgression and more widespread accumulation of the basinal black shale (Laventie Formation). This was accompanied by intermittent volcanism (Rocky Ridge Formation) from widely scattered, subaerial and submarine volcanic centres that evolved over 10 to 15 million years from calcalkaline felsic to alkaline mafic compositions. Bassett and Kleinspehn (1996) conclude that Rocky Ridge volcanic rocks may have accumulated along a rift. MacIntyre (2001a) concluded that the felsic volcanic centres represent caldera complexes.

Toward the end of mid-Cretaceous time, the seafloor rebounded and redbed chert-pebble conglomerate found in a shallow-water to subaerial fluvial environment (Rocher Deboule Formation) prograded northwestward. Northwest of this advancing shoreline, the depositional environments were once again tidal deltas.

Over the 50-million-year span of Skeena Group time, these strata record the evolution from moderately extensional to moderately compressive tectonics affecting the continental margin.

Although the paleotopographic setting is clear, the tectonic setting for this part of the continental margin of North America in Early to mid-Cretaceous time is uncertain. The area of Skeena Group sedimentation and volcanism and Bowser Basin sedimentation immediately to the northwest has been identified by various researchers as a fore arc, back arc, extensional basin or foreland setting (Evenchick and Thorkelson, 2005). The existence of the Gambier arc off to the west throughout the Early and mid-Cretaceous (Souther, 1991) suggests that Skeena Group volcanism could record the onset of back arc extension. MacIntyre *et al*. (2004) interpret the scattered volcanic centres of the Rocky Ridge Formation as a nascent (or incipient) volcanic arc, with the individual volcanic centres representing caldera complexes. Bassett and Kleinspehn (1996, Fig 5) interpret the locus for the Rocky Ridge volcanic centres as a north-northeast-trending rift.

MINERAL DEPOSITS

All mineral occurrences hosted by Skeena Group strata are listed in Table 1, where individual occurrences are sorted into alphabetical order. In Table 2, the ten coal deposits are removed from this initial list, three broad alteration zones that lack elevated base and precious metal values are also removed from the initial list and the Mount Cronin mine is removed from the list because a new radiometric date (MacIntyre and Villeneuve, 2007) reveals that

TABLE 1. MINERAL OCCURRENCES HOSTED BY THE SKEENA GROUP.

Name	Property	MINFILE	Status
1600 Zone	Fireweed	093M 151	deposit
Anomalous Zone	Equity Silver	093L 001	showing
Beamont station			alteration
BQ			prospect
Cabinet Creek			past producer
Chisholm Lake		093L 159	showing
Denys Creek			
East Zone	Fireweed	093M 151	deposit
ESK	Old Fort Mountain		showing
Far East Zone	Fireweed	093M 151	deposit
Far West Zone	Fireweed	093M 151	deposit
Gaul	Equity Silver	093L 001	prospect
Goathorn Creek		093L 156	past producer
Hematite	French Peak	093M 015	past producer
Hope	Equity Silver	093L 001	prospect
Jan	Fireweed	093M 151	deposit
Kathlyn Lake			deposit
Knoll		093M 100	prospect
Main	Equity Silver	093L 001	past producer
MN	Fireweed	093M 151	deposit
Mt. Cronin		093L 127	deposit
North Zone	Equity Silver	093L 001	prospect
Owen Creek			deposit
Rio	French Peak	093M 015	past producer
Seeley Lake		093M 150	
South Zone	Fireweed	093M 151	deposit
Southern Tail	Equity Silver	093L 001	past producer
Sphalerite	Fireweed	093M 151	deposit
Superstition	Equity Silver	093L 001	prospect
Tadinlay	Old Fort Mountain		alteration
Telkwa River		093L 156	past producer
Thautil River		093L 158	showing
Ute	French Peak	093M 015	past producer
Waterline	Equity Silver	093L 001	past producer
West Morrison	Old Fort Mountain		alteration
West Zone	Fireweed	093M 151	deposit
Zest	Equity Silver	093L 001	showing
Zymoetz River		093L 154	
3200 Zone	Fireweed	093M 151	deposit

TABLE 2. METALLIC MINERAL OCCURRENCES HOSTED BY THE SKEENA GROUP, SORTED BY

Map no.	Property	MINFILE	Status
1	Equity Silver	093L 001	past producer
2	Old Fort Mountain		showing
3	Fireweed	093M 151	deposit
4	Knoll	093M 100	prospect
5	BQ		prospect
6	French Peak	093M 015	past producer

the Mount Cronin deposit is hosted by Kasalka Group rocks. All the remaining prospects from Table 1 were then resorted and grouped according to their individual properties in Table 2, revealing that there are just six areas with metallic mineralization within Skeena Group rocks. Four of these areas have been discovered within the last 20 years.

Equity Silver Mine (MINFILE 093L 001)

The Equity Silver mine produced silver, copper, gold, antimony and arsenic from complex sulphide ores between 1980 and 1994. Open pit and underground workings at four adjacent orebodies (Fig 8; North zone, Waterline, Main zone and Southern Tail) yielded a total of 33.8 Mt of ore at an average grade of 64.9 g/t Ag, 0.4% Cu and 0.46 g/t Au. South of the Southern Tail orebody, the Hope, Superstition and Gaul mineral prospects lie along the south-southwest extension of this same trend. Mineralogy of the ore zones and peripheral alteration zones are summarized in Table 3.

The mine property is underlain by a mixed sedimentary-volcanic succession (Cyr *et al*., 1984). Basal conglomerate and minor argillite (Clastic Division; units 1a and 1b on Fig 8) is conformably overlain by a sequence of intercalated subaerial tuff breccia and minor reworked pyroclastic debris (Pyroclastic Division; units 2a and 2b) that hosts the orebodies. This package is conformably overlain by bedded andesite to dacite flows (Volcanic Flow Division; unit 3a) and an onlapping sequence of interbedded volcanic conglomerate, sandstone and tuff (Sedimentary-Volcanic Division; unit 3b).

At different times, these rocks have been correlated with Hazelton Group, Skeena Group and Kasalka Group strata. New U-Pb zircon geochronology results (MacIntyre and Villeneuve, 2007) from a sample of felsic lapilli tuff collected from the east ramp of the Main zone pit give an age of 113.5 +4.5/–7.2 Ma. This confirms that the hostrock volcanic succession (unit 2 on Fig 8) at Equity Silver mine is mid-Cretaceous Skeena Group strata. Underlying chert-pebble conglomerate and carbonaceous siltstone of unit 1 Coarse Clastic Division) may be part of the Bowser Lake Group.

The ore deposits are hosted within rocks of the pyroclastic division and lie between two intrusive stocks. West of the mine, the 58 ±2 Ma quartz monzonite stock has unaltered and altered zones; the eastern kaolin-sericite-chlorite-pyrite–altered portion hosts weak porphyry-style copper-molybdenum mineralization. East of the mine, the 48 ±2 Ma gabbro-monzonite intrusion has five mappable, sequential phases (gabbro, intermediate phase, diorite, monzonite and hypabyssal monzonite) all cut by late felsite dikes termed ‘quartz latite’. Since the orebodies lie between these two intrusions, published genetic models relate ore formation at the Equity Silver Mine to these distinctly different intrusions. Cyr *et al*. (1984) and Wojdak and Sinclair (1984) conclude that the ore is epigenetic and epithermal in character and associated with the emplacement of the older western stock that hosts the porphyry Cu-Mo–style mineralization. Church (1984) and Church and Barakso (1990) conclude that the multiple ore zones are epigenetic and associated with intrusion of the younger eastern polyphase intrusion (Fig 9).

In addition to the two main genetic models summarized above, Wojdak and Sinclair (1984) discussed the possibility that the ore may have formed penecontemporaneously with its host volcanic rocks, as a late-stage epithermal vein system (Fig 9). Panteleyev (1995) proposes similar timing for the formation of the Equity Silver ores as a ‘transitional’ ore deposit, which form at moderate depths

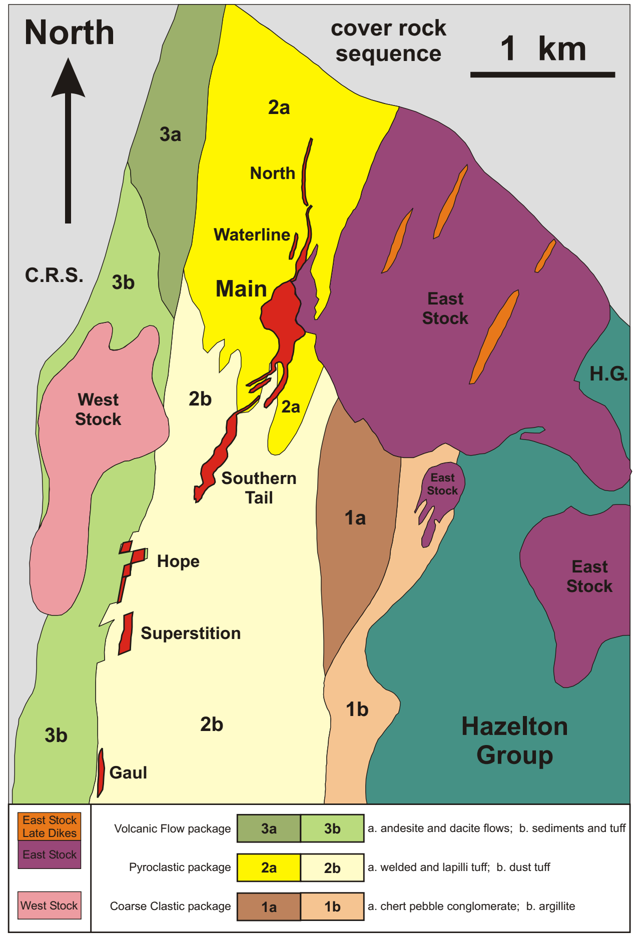

Figure 8. Geology map of the Equity Silver mine area (*modified from* company plans). Abbreviation: C.R.S., cover rock sequence.

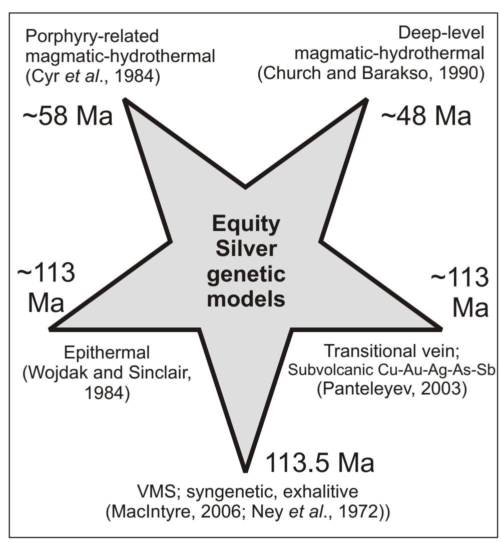

Figure 9. Schematic summary of five genetic models for ore formation at the Equity Silver mine.

(2–3 km), shallower than the setting for conventional porphyry copper deposits, but deeper than the setting for epithermal ore deposits (Fig 9).

In contrast, Ney *et al.* (1972) initially regarded the deposits as syngenetic volcanogenic massive sulphide deposits that were later deformed and recrystallized by the gabbro-monzonite intrusion (Fig 9). As an evolution from this early genetic model, MacIntyre (2001b) considered the largest individual ore zone (Main zone, 22 Mt) as the remains of an initially larger syngenetic, exhalitive volcanogenic massive sulphide lens, which accumulated within the 113.5 Ma dacitic pyroclastic volcanic facies (Fig 10a). A portion of the syngenetic sulphide minerals of the Main zone were intruded by the western edge of the gabbro-monzonite intrusive complex and the sulphide minerals were remobilized and extensively redistributed both northward and southward along a north-northeast-trending fault zone that is parallel to the orientation of the late, planar, hypabyssal monzonite intrusive phase of the younger gabbro-monzonite intrusive complex (Fig 10b).

The following list restates all these proposed genetic models in light of the mid-Cretaceous age now established for the hostrocks volcanics at the mine (*see also* Fig 9):

- synvolcanic exhalitive mineralization related to mid-Cretaceous volcanism, with later recrystallization and remobilization caused by the intrusion of the eastern Eocene stock;
- penecontemporaneous epithermal mineralization related to mid-Cretaceous volcanism, with later recrystallization and remobilization caused by the intrusion of the eastern Eocene stock;
- penecontemporaneous transitional (porphyry-epithermal transition) mineralization related to mid-Cretaceous volcanism, with later recrystallization and remobilization caused by the intrusion of the eastern Eocene stock;
- Eocene epigenetic mineralization related to the emplacement of the 58 Ma western quartz monzonite stock; and
- Eocene epigenetic mineralization related to the emplacement of the 48 Ma eastern gabbro-monzonite stock.

TABLE 3. MINERALOGY OF EQUITY SILVER ORE AND ALTERATION ZONES (*FROM* CYR *ET AL.*, 1984).

Mineral[1]	Main	Southern Tail	Waterline	Cu-Mo Porphyry	Tourmaline
Pyrite	XXXXX	XXXXX	XXXXX	XXXX	XXXXX
Rutile	X	X	X	X	
Ilmenite	X	X			
Magnetite	XXXX	XXX	XXX	X	XX
Pyrrhotite	XXXX		XX		
Molybdenite		X	X	XXX	X
Specular hematite	XXXX	XX	XXX		X
Arsenopyrite	XX	XXXXX	X		
Sphalerite	XXX	XXX	XXX		XX
Chalcopyrite	XXXXX	XXXX	XXXX	XX	XX
Tetrahedrite	XXXX	XXXXX	XX	X	X
Gold	XX	X	XX		
Galena	XX	XX	XX		XX
Sulfosalts	XX	XX	X		
Marcasite	XXX		X		
Chalcocite	X	X		X	
Covellite	X	X			
Scheelite			X		
Wolframite		X			
Stibnite	X				
Corundum	XX				
Andalusite	XX	XX	XX		
Tourmaline	XXXX	X	XX	X	XXXXX
Dumortierite	XX				X
Scorzalite	XXX	X	XX		
Spinel	XX				
Chlorite	XXXX	XXXX	XXX	XX	XX

[1] listed in approximate order or paragenesis

XXXXX, very abundant; XXXX, abundant; XXX, moderate; XX, minor; X, trace

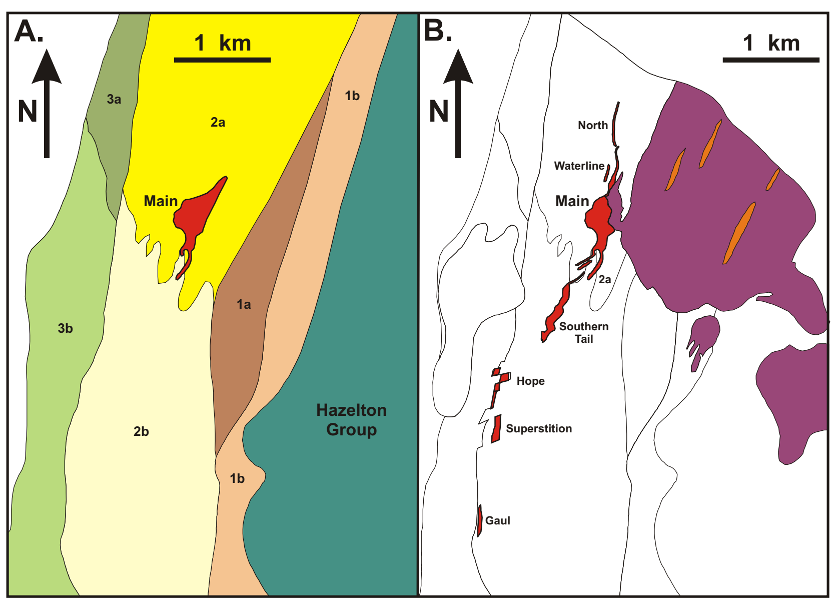

Figure 10. Two-stage genetic model for the formation of the Equity Silver deposits; a) mid-Cretaceous VMS deposit formed at Main zone; b) Eocene pluton intrudes, recrystallizes and remobilizes Main zone sulphide minerals along one of a series of fracture zones; *see* legend for Fig 8.

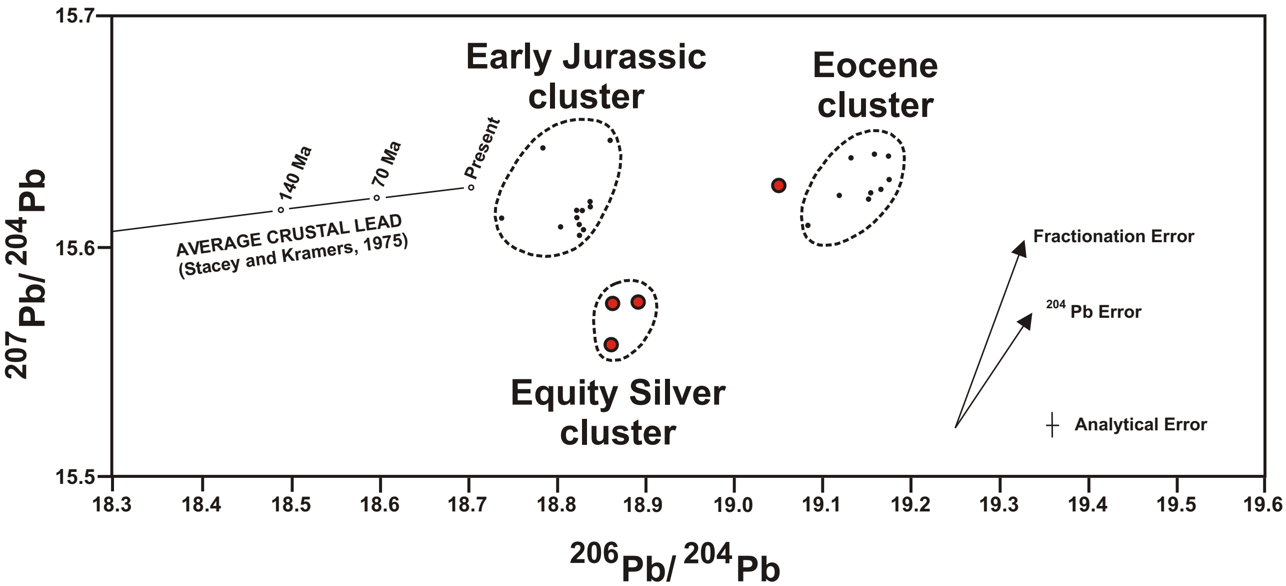

Figure 11. Galena Pb isotope data from the Equity Silver mine (data *from* Godwin *et al*., 1988; chart *from* Alldrick, 1993).

Galena Pb isotope analyses of seven samples collected from different ore zones at the Equity Silver mine show a tight cluster of lead isotope ratios from three samples (Fig 11). This 'Equity Silver' cluster represents significantly older lead than the well-established lead analyses from several types of Eocene ore deposits (Fig 11; Alldrick, 1993). It is also younger than the lead isotope signatures obtained from many Early Jurassic ore deposits hosted by Hazelton Group island arc rocks (Fig 11; Alldrick, 1993). Since only Early Jurassic, mid-Cretaceous and Eocene rocks are present in the mine area, the data cluster from the three Equity Silver samples is interpreted as a mid-Cretaceous age. This means the lead initially crystallized in galena that was syngenetic with, or penecontemporaneous with, the mid-Cretaceous Skeena Group volcanic hostrocks (genetic models 1, 2 or 3 above). A single data point lies in the direction of the younger Eocene-age data cluster (Fig 11). This result suggests that, for this sample only, the primary mid-Cretaceous mineralization was likely remobilized by a later magmatic, hydrothermal and structural event that contributed some new lead to the mid-Cretaceous galena crystals in two of the analysis samples. This later event was most likely the intrusion of the large multiphase gabbro-monzonite intrusion that intrudes and displaces the Main zone orebody along its northeastern margin (Fig 10b). Remobilized sulphide minerals were displaced into north-northeast-trending fractures and/or faults that accompanied the later hypabyssal monzonite stage of emplacement of the multistage intrusion (Fig 10b).

Cyr *et al*. (1984) recognized that different parts of the Equity Silver ore zones and their different associated alteration suites have chemistry, mineralogy and textures that are characteristic of either epithermal or exhalitive styles of ore deposits (Table 3). This is a consequence of sulphide deposition in and around a shallow-water volcanic edifice constructed on sediments of a deltaic sedimentary succession. Historically, epithermal and exhalitive deposit types have been regarded as mutually exclusive mineralizing systems, but many years of detailed studies at the Eskay Creek gold mine (Roth, 2002) reveal that epithermal, exhalitive and even clastic sedimentary ore deposits can be deposited around the same long-lived hydrothermal system as the structural controls and the depositional environment change with time.

Fireweed (MINFILE 093M 151)

Sulphide minerals were discovered in outcrop at the Mn (manganese) and sphalerite (zinc) showings in 1987. Ongoing exploration work has defined 10 mineralized zones (Table 1) with a drill-indicated resource at the West Zone of 580 544 t grading 342 g/t silver, 2.22% zinc and 1.34% lead. The property geology is described in a recent comprehensive report by Price (2006).

Bedrock exposures are limited on the property. Extensive drilling reveals that the host strata is a succession of mudstone, siltstone and fine to coarse sandstone. Conglomerate and volcanic units are conspicuously absent. In this report, these strata are correlated with the Bulkley Canyon Formation of the Skeena Group.

Sedimentary rocks are cut by dikes or sills of felsic volcanic rock, variously termed 'latite', 'quartz latite' and 'rhyolite' in earlier reports. The dikes are light grey, fine-grained rhyolite porphyry with fine plagioclase phenocrysts and quartz eyes (Howell, pers comm, 2006). These intrusive rocks have previously been correlated with Eocene biotite-feldspar porphyritic intrusions and andesitic volcanic rocks of the Mount Newman Formation that crop out along the southern edge of the property (Price, 2006; MacIntyre, 2001a). MacIntyre *et al*. (2004) reinterpreted these felsic dike rocks as possible feeders to the mid-Cretaceous Rocky Ridge rhyolite domes mapped to the north. Three kilometres north of the Fireweed property, a large dome of Rocky Ridge rhyolite underlies the eastern half of McKendrick Island. A new age determination from a rhyolite dike collected from drillcore at the Fireweed property gives an age of 103.4 ±0.4 Ma, confirming this correlation (MacIntyre and Villeneuve, 2007).

On the Fireweed property, the presence of these mid-Cretaceous subvolcanic rhyolite feeder dikes, the absence of rhyolite domes and flows of the Rocky Ridge Formation and the absence of volcaniclastic conglomerate of the Kitsuns Creek Member, all support the interpretation that the sedimentary strata on the property are a section of the Bulkley Canyon Formation lying somewhere stratigraphically below the time-horizon of Rocky Ridge volcanics and Kitsuns Creek Member conglomerate of the upper Skeena Group.

Mineralization is polymetallic with variable amounts of silver, lead, zinc, copper and gold. The zones also have anomalous concentrations of manganese, cadmium, arsenic, tungsten and antimony. In order of abundance, sulphide minerals identified on the property are pyrite, pyrrhotite, sphalerite, chalcopyrite, galena, marcasite and tetrahedrite. The three main types of mineralization are

- breccia zones: fractured or brecciated sedimentary rock infilled with fine to coarse-grained massive pyrite-pyrrhotite and lesser sphalerite, chalcopyrite and galena.
- disseminated sulphide minerals: fine to very fine grains of pyrite, marcasite, sphalerite, galena and minor tetrahedrite are interstitial to sand grains in coarser-grained sandstone.
- massive sulphide minerals: fine-grained, commonly banded, massive sulphide minerals contain rounded quartz grains and fine fragments of sedimentary rocks, and form distinct bands within fine-grained sedimentary rocks. Composed of alternating bands of pyrite and pyrrhotite, with minor chalcopyrite, sphalerite and galena, these bands are typically associated with the breccia zones and are commonly sandwiched between the altered dikes. The term ‘massive sulphide’ does not imply any genetic process, *i.e.*, this style of mineralization does not necessarily indicate syngenetic or exhalitive volcanogenic massive sulphide mineralization.

Knoll (MINFILE 093M 100)

The Knoll prospect is located 60 km north of Smithers, along the east bank of Harold Price Creek. Massive to flow-banded rhyolite crops out as a prominent dome (Wojdak and Ethier, 2000; MacIntyre, 2001b). This unit is locally spherulitic and is intercalated with rhyolite breccia and volcaniclastic conglomerate. Beyond this resistant dome, the surrounding strata is a sequence of feldspathic sandstone, carbonaceous mudstone and siltstone and thinly bedded felsic ash tuff. All these units are interpreted as part of the Skeena Group; the rhyolite is interpreted as Rocky Ridge Formation and is similar to the rhyolite domes exposed along the West Morrison logging road, north of Old Fort Mountain.

Discovered in 1983, mineralization consists of disseminations and veinlets of pyrite, sphalerite and galena hosted by the massive rhyolite, rhyolite breccia and lapilli tuff. Disseminated pyrite is widespread in the rocks of the rhyolite dome. Grab samples collected from outcrop returned high assays for lead, zinc and arsenic, elevated silver and cadmium, and anomalous levels of gold and copper. Seven holes were drilled on induced polarization targets in 1988. The best intersection was 1 m grading 0.51% Pb, 1.32% Zn, 9.58% As, 30 ppm Ag and 1610 ppb Au. In 2006, a soil sampling program was completed over the property.

ESK

ESK is a new sulphide discovery hosted by the black felsic fragmental unit that envelops the series of prominent rhyolite domes near the West Morrison logging road, northern Babine Lake. At this showing on the south side of the rhyolite ring, the distinctive black-matrix, white-rhyolite-clast volcanic breccia stratigraphically overlies the massive white rhyolite domes (Fig 7). The same breccia texture is also well exposed, stratigraphically underlying the same rhyolite domes, along the north side of the ring of rhyolite domes. Mineralization consists of 2 to 4% fine disseminated sulphide minerals in clast-rich rhyolite breccia to crackle breccia of flow-banded rhyolite. Best assays are 172 ppm Zn, 14 ppm Pb, 5 ppm Cu, 278 ppb Ag, 6 ppb Au, 77 ppm As and 1116 ppb Hg.

BQ

BQ was discovered by prospecting in 1994, but saw little work until 2006 when trenching, geophysical surveying (induced polarization) and two drill programs were completed. Sediment-hosted sulphide mineralization is localized along steep fractures adjacent to dikes of locally flow-banded quartz-feldspar porphyritic rhyolite and aphanitic rhyolite (Watkins, 2005). Sedimentary strata exposed in the local area include micaceous sandstone and grit, black carbonaceous siltstone and shale. Sulphide minerals form individual veins, vein networks, replacement zones and scattered blebs of pyrite, arsenopyrite, pyrrhotite, sphalerite and chalcopyrite distributed over a 400 m long zone of fracturing, adjacent to a prominent rhyolite dike. A broad sericite-quartz-carbonate-clay alteration zone is overprinted on the fractured to locally brecciated sedimentary hostrock. Best assay intervals from 11 drillholes completed to date include 7.31 g/t Au over 1.3 m, 0.776 g/t Au over 233.05 m and 4.18% Zn over 1.0 m.

The age of this fracture-hosted mineralization and the adjacent felsic dike has not been determined; a sample collected by MacIntyre and Villeneuve (2007) produced insufficient zircons for dating. The dike is texturally similar to a 10 km long rhyolite sill that crops out as a prominent ridge along the north side of the Kitseguecla Lake Road. The northern edge of this sill crops out just 500 m south of the main roadside showing on the BQ prospect. This large sill locally displays tiny quartz eyes, hosts minor very fine disseminated pyrite, shows distinctive flow-banding along its northern margin that trends north (perpendicular to the east-west trend of the main sill) and closely resembles the rhyolite exposed in the string of rhyolite domes along the West Morrison logging road.

French Peak (MINFILE 093M 015)

The French Peak deposits include the Ute, Rio, Mud and Hematite prospects. Mineralization consists of quartz-siderite veins and mineralized shear zones hosting tetrahedrite, galena, chalcopyrite, sphalerite and pyrite. A resource of 2630 t grading 411 g/t Ag, 2.4 g/t Au, 14% Pb and 5% Cu was calculated for the property. The 2006 exploration program completed 11 drillholes totalling 1445 m on the Ute and Rio showings.

The rhyolite, dacite, andesite and basalt hostrocks, termed ‘French Peak volcanics’, have previously been classified as Kasalka Group rocks, but a new $^{40}Ar/^{39}Ar$ date of 99.3 ±2.3 Ma (MacIntyre and Villeneuve, 2007) on augitephyric basalt shows that these rocks are volcanics of the Rocky Ridge Formation, Skeena Group.

CURRENT EXPLORATION

Exploration programs within Skeena Group volcanic rocks during 2006 included initial drilling on the BQ claims northeast of Kitseguecla Lake, follow-up drilling on the Fireweed property southeast of Smithers Landing and on the French Peak property west-northwest of Fort Babine, a soil sampling grid over the Knoll property and prospecting on the ESK claims northwest of Old Fort Mountain (Fig 4). The Superstition Creek prospect, just south of the Equity Silver mine (Fig 8), was drilled in 2004.

METALLOGENIC MODELS

The bimodal volcanic units of the Skeena Group have recently been interpreted as evidence for a caldera setting (MacIntyre, 2001b), which is the optimal setting for the formation and preservation of alkaline epithermal mineral deposits (Fig 12; Hedenquist and White, 2005). Previously, these same volcanic rocks were identified as products of rifting (Barrett and Kleinspehn, 1996), which is the optimal setting for the development of subaerial Bonanza-type epithermal deposits and subaqueous exhalitive mineralization (Sillitoe, 2002; Sillitoe and Hedenquist, 2003; Hedenquist and White, 2005). On a larger scale, the tectonic setting for the Skeena Group was interpreted as an active continental margin (fore arc) tectonic setting (Barrett and Kleinspehn, 1997), similar to the world's greatest VMS district, the Devonian-Mississippian Iberian Pyrite Belt (White, 1999). These contrasting metallogenic models are summarized in Table 4.

DISCUSSION

A bimodal volcanic succession must display a simple or complex alternating sequence of basalt and rhyolite flows in close association. Andesite and dacite units should be conspicuously absent. There is no exposure of bimodal volcanic rocks *sensu stricto* in any of the Rocky Ridge volcanic sections examined in the field this season or presented in the literature. This term may have evolved when the black, carbonaceous dacitic lapilli tuff that envelops the rhyolite domes along West Morrison logging road were misidentified as 'basalt' during the initial mapping program (unit lKvb *in* MacIntyre *et al*., 1997a). A close spatial association between rhyolite and basalt flows is exposed in outcrops southeast of the pit at the Bell mine, but the rhyolite and basalt units are juxtaposed across a major fault break. There are basalt flows and tuff exposed several hundred metres stratigraphically above the rhyolite 'domes' exposed along the West Morrison (Fig 7) and Kitseguecla Lake roads. However, the intervening strata are thick successions of fine to coarse clastic sedimentary rocks of the upper Skeena Group, indicating a substantial passage of time between volcanic eruptions.

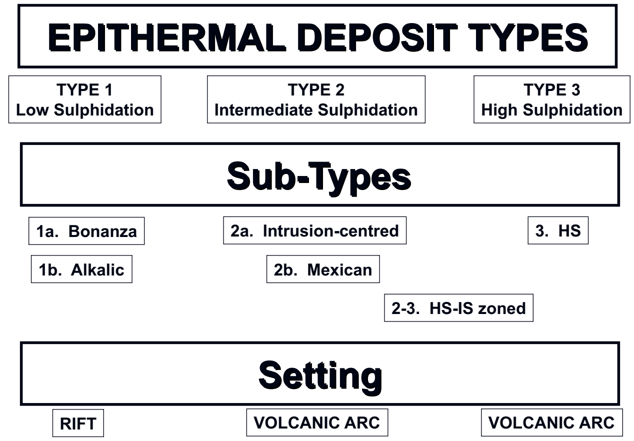

Figure 12. Classification system for epithermal ore deposits (Hedenquist and White, 2005).

Volcanic rocks that accumulate in caldera settings are characteristically bimodal and alkaline, while the upper, younger, basalt units of the Rocky Ridge Formation are alkaline, underlying rhyolite, andesite and dacite units are consistently calcalkaline (Tackaberry, 1998). Taken together, these points indicate that none of Rocky Ridge volcanism erupted in a caldera setting.

Volcanic rocks that accumulate in rift settings are also characteristically bimodal (Sillitoe, 2002) and are usually preserved as thick successions of complexly interlayered basalt, rhyolite and siltstone. There are no volcanic intervals anywhere within Skeena Group strata that resemble typical rift-fill successions or distribution patterns (thick, linear, volcanic-filled troughs).

The points above indicate that it is unlikely that the geological setting for the deposition of the volcanic rocks within the Skeena Group is either a caldera or rift structure.

Other possible settings are within a fore arc, in a back arc rift (marginal basin) or within an intracratonic rift. Fore arc volcanism is extremely rare and is characterized by linear arrays of volcanic centres (Cees van Staal, pers comm, 2006). Intercontinental rifts are characterized by bimodal volcanic rocks and often provide the setting for abundant exhalitive (volcanogenic massive sulphide) mineralization (*e.g*., the Iberian Pyrite Belt). Since these characteristic features are not in evidence in the volcanic strata of the Rocky Ridge Formation, these two tectonic settings are also considered unlikely.

In contrast to the above models, the concept of a nascent, continental margin volcanic arc that does not fully develop (MacIntyre *et al*., 2004) is a good fit with the documented features of Rocky Ridge volcanism. The early onset of differentiated calcalkaline andesite, dacite and rhyolite volcanism from widely scattered volcanic centres was fol-

TABLE 4. METALLOGENIC MODELS PROPOSED FOR THE SKEENA GROUP.

Tectonic model	Proposed by	Associated deposit types	Reference
Caldera	MacIntyre, 2001b	Alkaline epithermal	Hedenquist and White (2005)
Rift	Bassett and Kleinspehn, 1996	Epitheral and VMS	Sillitoe (2002)
Continental margin, fore arc	Bassett and Kleinspehn, 1996	VMS	White (1999)

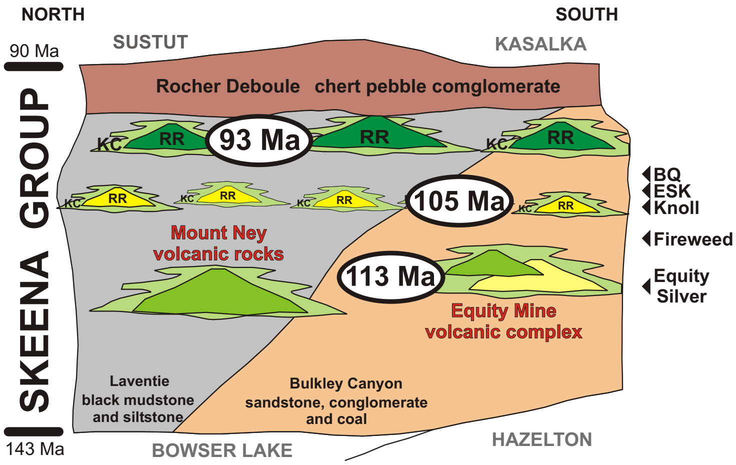

Figure 13. Schematic stratigraphy of Skeena Group (*modified from* Bassett and Kleinspehn, 1997), showing the relative position of the Equity Mine and Mount Ney volcanic complexes and relative stratigraphy position of key mineral prospects. Abbreviations: RR, Rocky Ridge Formation; KC, Kitsuns Creek Member.

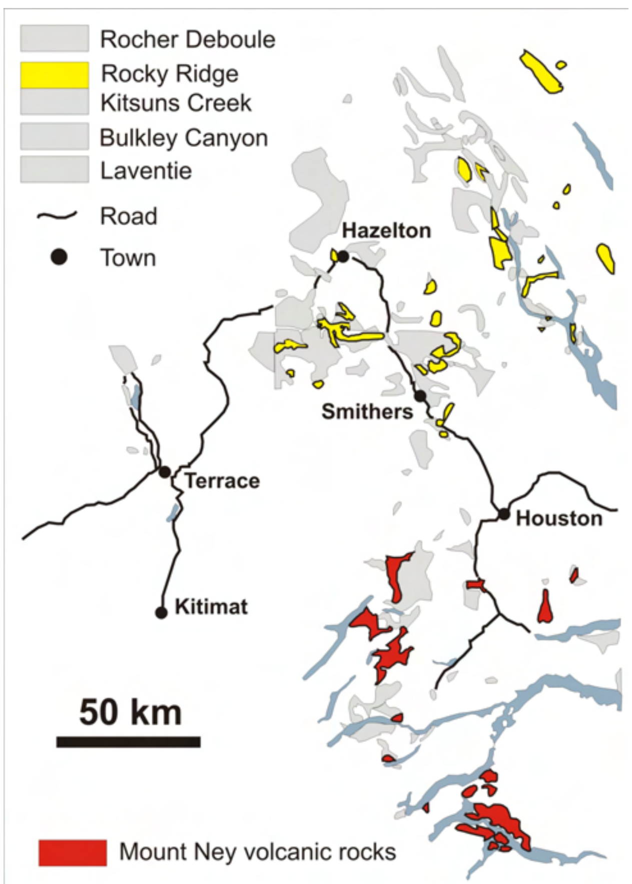

Figure 14. Distribution of the younger Rocky Ridge (rhyolite-basalt) and older Mount Ney (andesite-dacite) volcanic packages of the Skeena Group (*modified from* Bassett and Kleinspehn, 1997; Diakow, 2006).

lowed by an episode of alkaline basaltic volcanism. Then, all volcanic activity terminated during the period of deposition of the Rocher Deboule Formation. In the Late Devonian volcanic succession of the Finlayson Lake district of the Yukon Territory, Piercey *et al*. (2002) attribute the change from initial felsic calcalkaline to younger mafic alkaline volcanism to the interruption of an initial period of typical subduction by subduction hinge roll-back, which triggered back arc rifting. Within the Skeena Group, the onset of alkaline basalt volcanism near the end of Rocky Ridge Formation time may have marked the initiation of back arc rifting, but further rifting and its associated volcanism ceased abruptly about 93 Ma.

The other tectonic and metallogenic model that may apply puts the entire mid-Cretaceous Rocky Ridge volcanic succession in an incipient back arc rift setting, lying east of the Gambier volcanic arc, which remained active throughout the Early and mid-Cretaceous.

CONCLUSIONS

Toward the end of Skeena Group sedimentation, a 20-million-year period (113–93 Ma) of intermittent volcanism evolved from intermediate to felsic to alkaline mafic composition. Most volcanic piles were built on deltaic alluvial fans and were locally emergent, with the base of each volcano submerged and the surrounding volcaniclastic debris apron deposited in shallow marine settings. The youngest (93 Ma) mafic volcanic units have no associated mineralization (Fig 13). The intermediate age (108–104 Ma) rhyolite volcanic rocks have minor to significant mineralization associated with subvolcanic feeder dikes, sills and cryptodomes. The oldest (113 Ma) andesitic to dacitic volcanic piles have associated economic concentrations of silver, copper and gold.

The Equity Silver deposit is poorly exposed in outcrop. Its discovery was the result of the follow-up of multiphase geochemical surveys and boulder tracing (Ney *et al*., 1972). Within the Skeena Group, the Mount Ney volcanics are a broad expanse of intermediate composition volcanic sequences with similar age as the Equity Silver mine volcanics (Fig 14). A strategy committed to systematic, sequential reconnaissance and follow-up exploration programs through this region would be necessary to zero in on a similar target.

BIBLIOGRAPHY

Alldrick, D.J. (1993): Geology and metallogeny of the Stewart mining camp, northwestern BC; *BC Ministry of Energy, Mines and Petroleum Resources*, Bulletin 85, 105 pages.

Armstrong, J.E. (1944a): Preliminary map, Smithers, British Columbia; *Geological Survey of Canada*, Paper 44-23, scale 1:126 720.

Armstrong, J.E. (1944b): Preliminary map, Hazelton, British Columbia; *Geological Survey of Canada*, Paper 44-24, scale 1:126 720.

Armstrong, J.E. and Kindle, K.D. (1952): Preliminary map, Hazelton, British Columbia; *Geological Survey of Canada*, Paper 44–24 (revised), scale 1:126 720.

Bassett, K.N. (1991): Preliminary results of the sedimentology of the Skeena Group in west-central British Columbia; *in* Current Research, Part A, *Geological Survey of Canada*, Paper 91-1A, pages 131–141.

Bassett, K.N. (1995): A basin analysis of the lower to mid-Cretaceous Skeena Group, west-central British Columbia – implications for regional tectonics and terrane accretion; *University of Minnesota*, unpublished PhD thesis, 413 pages.

Bassett, K.N. and Kleinspehn, K.L. (1996): Mid-Cretaceous transtension in the Canadian Cordillera – evidence from the Rocky Ridge volcanics of the Skeena Group; *Tectonics*, Volume 15, pages 727–746.

Bassett, K.N. and Kleinspehn, K.L. (1997): Early to middle Cretaceous paleogeography of north-central British Columbia – stratigraphy and basin analysis of the Skeena Group; *Canadian Journal of Earth Sciences*, Volume 34, pages 1664–1669.

Church, B.N. (1973): Geology of the Owen Lake, Parrott Lakes, Goosly Lake area, Omineca Mining Division, British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, Preliminary Map No. 13A, scale 1:50 000.

Church, B.N. (1984): Update on the geology and mineralization in the Buck Creek area – the Equity Silver mine revisited; *in* Geological Fieldwork 1984, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1985-1, pages 175–188.

Church, B.N. (1986): The Bob Creek gold-silver prospect (93L); *in* Geological Fieldwork 1985, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1986-1, pages 121–124.

Church, B.N. (1990): Geology of the Buck Creek Tertiary outlier; *BC Ministry of Energy, Mines and Petroleum Resources*, coloured map included in Paper 1990-2, scale 1:100 000.

Church, B.N. and Barakso, J.J. (1990): Geology, lithogeochemistry and mineralization in the Buck Creek area, British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1990-2, 95 pages.

Church, B.N. and Klein. G.H. (1998): The Allin property and Equity-type mineralization, central British Columbia; *in* Geological Fieldwork 1997, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1998-1, pages 23-1–23-10.

Cook, S., Levson, V., Jackaman, W., Law, D. and Douville, M. (2000): Regional geochemical compilation – Babine porphyry belt (NTS 104O/13); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 2000-24, 9 map sheets, scale 1:100 000.

Cyr, J.B., Pease, R.B. and Schroeter, T. (1984): Geology and mineralization at Equity Silver mine; *Economic Geology*, Volume 79, pages 947–968.

Dawson, G.M. (1881): On the geology of the region between the 54th and 56th parallels, from the Pacific Coast to Edmonton; *in* Report on an Exploration from Port Simpson on the Pacific Coast, to Edmonton on the Saskatchewan, Embracing a Portion of the Northern Part of British Columbia, and the Peace River country; *Geological Survey of Canada*, Report on Progress 1879–1880, pages 99B–142B.

Desjardins, P. and Arksey, R. (1991): Geology of the Lamprey Creek area; *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 1991-1, scale 1:50 000.

Desjardins, P., Arksey, R.L. and MacIntyre, D.G. (1991): Geology of the Lamprey Creek mapsheet (NTS 93L/03); *in* Geological Fieldwork 1990, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1991-1, pages 111–119.

Desjardins, P., Lyons, L., Pattenden, S., MacIntyre, D.G. and Hunt, J. (1990a): Geology of the Thautil River area; *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 1990-5, scale 1:50 000.

Desjardins, P., MacIntyre, D.G., Hunt, J., Lyons, L. and Pattenden, S. (1990b): Geology of the Thautil River map area (NTS 93L/06); *in* Geological Fieldwork 1989, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1990-1, pages 91–99.

Diakow, L.J. (1990): Geology of Nanika Lake map area (NTS 93E/13); *in* Geological Fieldwork 1989, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1990-1, pages 83–89.

Diakow, L.J. (2006): Geology of the Tahtsa Ranges between Eutsuk Lake and Morice Lake, Whitesail Lake map area, west-central British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, Geoscience Map 2006-5, scale 1:150 000.

Diakow, L.J. and Drobe, J. (1989a): Geology and mineral occurrences in north Newcombe Lake mapsheet; *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 1989-1, scale 1:50 000.

Diakow, L.J. and Drobe, J. (1989b): Geology and mineral occurrences in north Newcombe Lake mapsheet (NTS 93E/14); *in* Geological Fieldwork 1988, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1989-1, pages 183–188.

Diakow, L.J. and Koyanagi, V. (1988): Stratigraphy and mineral occurrences of the Chikamin Mountain and Whitesail Reach map areas (NTS 93E/06, 10); *in* Geological Fieldwork 1987, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1988-1, pages 155–168.

Diakow, L.J. and Mihalynuk, M. (1987): Geology of Whitesail Reach and Troitsa Lake map areas (NTS 93E/10W, 11E); *in* Geological Fieldwork 1986, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1987-1, pages 171–179.

Duffell, S. and Souther, J.G. (1964): Geology of Terrace map area, British Columbia (NTS 103I east half); *Geological Survey of Canada*, Memoir 329, 117 pages.

Evenchick, C.A., Mustard, P.S., Woodsworth, G.J. and Ferri, F. (2004): Compilation of geology of Bowser and Sustut Basins draped on shaded relief map, north-central British Columbia; *Geological Survey of Canada*, Open File 4638, scale 1:500 000.

Evenchick, C.A. and Thorkelson, D.J. (2005): Geology of the Spatsizi River map area, north-central British Columbia; *Geological Survey of Canada*, Bulletin 577, 276 pages.

Ferri, F., Mustard, P.S., McMechan, M., Ritcey, D., Smith, G.T., Boddy, M. and Evenchick, C.A. (2005): Skeena and Bowser Lake Groups, west half Hazelton map area (NTS 93M); *in* Summary of Activities 2005, *BC Ministry of Energy, Mines and Petroleum Resources*, URL <http://www.em.gov.bc.ca/subwebs/oilandgas/pub/reports/summary2005.htm>, pages 113–131.

Fingler, J. (2004): Silver Hope project surface geology map; *in* Report on the 2004 diamond drilling program–Silver Hope property; *BC Ministry of Energy, Mines and Petroleum Resources*, AR27862, scale 1:10 000.

Gaba, R.G., Desjardins, P. and MacIntyre, D.G. (1992): Mineral potential investigations in the Babine mountains recreation area (NTS 93L/14E, 15W; 93M/2W); *in* Geological Fieldwork 1991, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1992-1, pages 93–101.

Galloway, J.D. (1914): Rocher Deboule camp; *BC Ministry of Energy, Mines and Petroleum Resources*, Minister of Mines Annual Report, pages 184–193.

Galloway, J.D. (1916): Rocher Deboule camp; *BC Ministry of Energy, Mines and Petroleum Resources*, Minister of Mines Annual Report, pages 106–119.

Godwin, C.I., Gabites, J.E. and Andrew, A. (1988): Leadtable – a galena lead isotope database for the Canadian Cordillera; *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1988-4, 188 pages.

Hanson, G. (1924a): Driftwood Creek map area, Babine Mountains; *Geological Survey of Canada*, Summary Report 1924, Part A, pages 19–37.

Hanson, G. (1924b): Prince Rupert to Burns Lake; *Geological Survey of Canada*, Summary Report 1924, Part A, pages 38–43.

Hanson, G. (1925): Reconnaissance in the Zymoetz River area; *Geological Survey of Canada,* Summary Report 1925, Part A, pages 100–119.

Hedenquist, J.W. and White, N.C. (2005): Epithermal gold-silver ore deposits – characteristics, interpretation and exploration; *Prospectors and Developers Association of Canada*, Short course notes, March 2005, 378 pages.

Hedenquist, J.W. and Sillitoe, R.H. (2003): Alteration, degradation, and slope failure of volcanoes; abstract, *Geological Society of America* Annual Meeting, Seattle, Washington, 2–5 November 2003, Program with Abstracts, Volume 33.

Hunt, J.A. (1992): Stratigraphy, maturation and source rock potential of Cretaceous strata in the Chilcotin – Nechako region of British Columbia; *The University of British Columbia*, unpublished MSc thesis, 447 pages.

Jones, R.H.B. (1925): Geology and ore deposits of Hudson Bay Mountain; *Geological Survey of Canada,* Summary Report 1925, Part A, pages 120–143.

Kerr, F.A. (1936): Mineral resources along the Canadian National Railway between Prince Rupert and Prince George; *Geological Survey of Canada*, Paper 36–20.

Kindle, K.D. (1954): Mineral resources, Hazelton and Smithers areas, Cassiar and Coast districts, British Columbia; *Geological Survey of Canada*, Memoir 223, 148 pages.

Koo, J. (1984): Telkwa coalfield, west-central British Columbia (NTS 93L); *in* Geological Fieldwork 1982, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1983-1, pages 113–121.

Koo, J. (1984): The Telkwa, Red Rose and Klappan coal measures in northwestern British Columbia (NTS 93L, 93M, 104H); *in* Geological Fieldwork 1983, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1984-1, pages 81–90.

Lang, A.H. (1929): Owen Lake mining camp, British Columbia; *Geological Survey of Canada,* Summary Report 1928, Part A, pages 62A–93A.

Lang, A.H. (1940): Houston map area, British Columbia; *Geological Survey of Canada,* Paper 40–18.

Lang, A.H. (1942): Houston area, British Columbia; *Geological Survey of Canada,* Map 671A.

Leech, W.W. (1907): The Telkwa River and vicinity, British Columbia; *Geological Survey of Canada,* Publication 988.

Leech, W.W. (1909): Bulkley valley and vicinity; *Geological Survey of Canada,* Summary Report 1908, pages 41–45.

Leech, W.W. (1910): Skeena River District; *Geological Survey of Canada,* Summary Report 1909, pages 61–68.

Leech, W.W. (1911): Skeena River District; *Geological Survey of Canada,* Summary Report 1910, pages 91–101.

Leitch, C.H.B., Hood, C.T., Cheng, X. and Sinclair, A.J. (1990): Geology of the Silver Queen mine area, Owen Lake, central British Columbia (NTS 93L); *in* Geological Fieldwork 1989, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1990-1, pages 287–295.

Levson, V.M., Cook, S.J., Hobday, J., Huntley, D.H., O'Brien, E.K., Stumpf, A.J. and Weary, G.W. (1997): Till geochemistry of the Old Fort Mountain map area, north central British Columbia (NTS 93M/011); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 1997-10a, 3 data tables.

MacIntyre, D.G. (1985a): Geology and mineral deposits of the Tahtsa Lake district, west-central British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, Bulletin 75, 82 pages.

MacIntyre, D.G. (1985b): Geology of the Dome Mountain gold camp; *in* Geological Fieldwork 1984, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1985-1, pages 193–213.

MacIntyre, D.G. (1998): Babine porphyry belt project – bedrock geology of the Nakinilerak Lake map sheet (93M/8), British Columbia; *in* Geological Fieldwork 1997, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1998-1, pages 2-1–2-18.

MacIntyre, D.G. (2001a): Geological compilation map – Babine porphyry copper district, central British Columbia (NTS 93L/09,16; 93M/01,02E,07E,08); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 2001-3, scale 1:100 000.

MacIntyre, D.G. (2001b): The mid-Cretaceous Rocky Ridge Formation – a new target for subaqueous hot-spring deposits (Eskay Creek type) in central British Columbia; *in* Geological Fieldwork 2000, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2001-1, pages 253–268.

MacIntyre, D.G. (2006): Geology and mineral deposits of the Skeena arch, west-central British Columbia – a Geoscience BC digital data compilation project; *in* Geological Fieldwork 2005, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2006-1, pages 303–312.

MacIntyre, D.G., Ash, C.H., Britton, J.B., Kilby, W. and Grunsky, E. (1995): Mineral potential assessment of the Skeena-Nass area (NTS 93E, 93L, 93M, 94D, 103G, 103H, 103I, 103J, 103O, 103P, 104A, 104B); *in* Geological Fieldwork 1994, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-1, pages 459–468.

MacIntyre, D.G., Brown, D., Desjardins, P. and Mallett, P. (1987a): Geology of the Dome Mountain area (NTS 93L10/15); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 1987-1, scale 1:20 000.

MacIntyre, D.G., Brown, D., Desjardins, P. and Mallett, P. (1987b): Babine project; *in* Geological Fieldwork 1986, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1987-1, pages 201–222.

MacIntyre, D.G. and Desjardins, P. (1988a): Geology of the Silver King – Mount Cronin area, Babine Range, west-central British Columbia (NTS 93L15); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 1988-20, scale 1:20 000.

MacIntyre, D.G. and Desjardins, P. (1988b): Babine project; *in* Geological Fieldwork 1987, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1988-1, pages 181–193.

MacIntyre, D.G., Desjardins, P. and Tercier, P. (1989a): Jurassic stratigraphic relationships in the Babine and Telkwa ranges (NTS 93L/10, 11, 14, 15); *in* Geological Fieldwork 1988, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1989-1, pages 195–208.

MacIntyre, D.G., Desjardins, P., Tercier, P. and Koo, J. (1989b): Geology of the Telkwa River area (NTS 93L/11); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 1989-16, scale 1:50 000.

MacIntyre, D.G., McMillan, R.H. and Villeneuve, M.E. (2004): The mid-Cretaceous Rocky Ridge Formation – important host rocks for VMS and related deposits in central British Columbia; *in* Geological Fieldwork 2003, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2004-1, pages 231–247.

MacIntyre, D.G., Schiarizza, P. and Struik L.C. (1998): Preliminary bedrock geology of the Tochcha Lake map area, British Columbia (NTS 93K/13); *in* Geological Fieldwork 1997, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1998-1, pages 3-1–3-13.

MacIntyre, D.G. and Struik, L.C. (1997): Nechako Natmap Project – 1996; *in* Geological Fieldwork 1996, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1997-1, pages 39–45.

MacIntyre, D.G. and Struik, L.C. (1999): Nechako NATMAP project, central British Columbia – 1998 overview; *in* Geological Fieldwork 1998, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1999-1, pages 1–13.

MacIntyre, D.G. and Struik, L.C. (2000): Nechako NATMAP project, central British Columbia – 1999 overview; *in* Geological Fieldwork 1999, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2000-1, pages 7–13.

MacIntyre, D.G. and Villeneuve, M.E. (2001): Geochronology of mid-Cretaceous to Eocene magmatism, Babine porphyry copper district, central British Columbia; *Canadian Journal of Earth Sciences*, Volume 38, pages 639–655.

MacIntyre, D.G. and Villeneuve, M.E. (2007): Geochronology of the Rocky Ridge volcanics, Skeena Group, British Columbia; *BC Ministry of Energy Mines and Petroleum Resources*, Geofile 2007-4.

MacIntyre, D.G., Villeneuve, M.E. and Schiarizza, P. (2001a): Timing and tectonic setting of Stikine Terrane magmatism, Babine – Takla lakes area, central British Columbia; *Canadian Journal of Earth Sciences*, Volume 38, pages 579–601.

MacIntyre, D.G., Webster, I.C.L. and Bellefontaine, K.A. (1996a): Babine porphyry belt project – bedrock geology of the Fulton Lake map area, north-central British Columbia (NTS 93L/16); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 1996-29, scale 1:50 000.

MacIntyre, D.G., Webster, I.C.L. and Bellefontaine, K.A. (1996b): Babine porphyry belt project – bedrock geology of the Fulton Lake map area, British Columbia (NTS 93L/16); *in* Geological Fieldwork 1995, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1996-1, pages 11–35.

MacIntyre, D.G., Webster, I.C.L. and Desjardins, P. (1997a): Bedrock geology of the Old Fort Mountain area, northwestern British Columbia (NTS 93M/1); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 1997-10, scale 1:50 000.

MacIntyre, D.G., Webster, I.C.L. and Villeneuve, M. (1997b): Babine porphyry belt project – bedrock geology of the Old Fort Mountain area (93M/1), British Columbia; *in* Geological Fieldwork 1996, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1997-1, pages 47–67.

Malloch, G.S. (1914): Metalliferous deposits in the vicinity of Hazelton; *Geological Survey of Canada*, Summary Report 1912, pages 102–107.

McConnell, R.G. (1914): Geological section along the Grand Trunk Pacific Railway from Prince Rupert to Aldermere, British Columbia; *Geological Survey of Canada*, Summary Report 1912, pages 55–62.

MINFILE (2005): MINFILE BC mineral deposits database; *BC Ministry of Energy, Mines and Petroleum Resources*, URL <http://www.em.gov.bc.ca/Mining/Geolsurv/Minfile/> [December 2006].

Ney, C.S., Anderson, J.M. and Panteleyev, A. (1972): Discovery, geological setting and style of mineralization, Sam Goosly deposit, British Columbia; *Canadian Institute of Mining and Metallurgy Bulletin*, Volume 65, Number 723, pages 53–64.

O'Neill, J.J. (1919): Preliminary report on the economic geology of Hazelton district, British Columbia; *Geological Survey of Canada*, Memoir 110, 50 pages.

Palsgrove R.J. and Bustin, R.M. (1990): Stratigraphy and sedimentology of the lower Skeena Group, Telkwa coalfield, central British Columbia (NTS 93L/11); *in* Geological Fieldwork 1989, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1990-1, pages 449–454.

Panteleyev, A. (1995): Subvolcanic Cu-Au-Ag-As-Sb; *BC Ministry of Energy, Mines and Petroleum Resources*, Mineral Deposit Profiles, Number L01, 4 pages.

Piercey, S.J., Mortensen, J.K., Murphy, D.C., Paradis, S. and Creaser, R.A. (2002): Geochemistry and tectonic significance of alkalic mafic magmatism in the Yukon-Tanana Terrane in the Finlayson Lake region, Yukon, Canada; *Canadian Journal of Earth Sciences*, Volume 40, pages 77–97.

Piercey, S.J., Paradis, S., Murphy, D.C. and Mortensen, J.K. (2001): Geochemistry and paleotectonic setting of felsic volcanic rocks in the Finlayson Lake volcanic-hosted massive sulphide district, Yukon, Canada; *Economic Geology*, Volume 96, pages 1877–1905.

Price, B.J. (2006): Technical report on the Fireweed silver-lead-zinc deposit; *BC Ministry of Energy, Mines and Petroleum Resources*, AR28161, 71 pages.

Richards, T.A. (1980): Geology of Smithers map area (NTS 93L); *Geological Survey of Canada*, Open File 351, scale 1:126 720.

Richards, T.A. (1990): Geology of Hazelton map area (NTS 93M); *Geological Survey of Canada*, Open File 2322, scale 1:250 000.

Richards, T.A., Woodsworth, G.J. and Tipper, H.W. (1997): Geology of Hazelton map area (NTS 93M), British Columbia; *Geological Survey of Canada*, Map 1852A (unpublished), scale 1:250 000.

Robertson, W.F. (1911): Mineral claims in the Hazelton district; *BC Ministry of Energy, Mines and Petroleum Resources*, Minister of Mines Annual Report, pages 95–99.

Roddick, J.A. (1970): Douglas Channel – Hecate Strait map area (103H, 103G E half), British Columbia; *Geological Survey of Canada,* Paper 70-41.

Roth, T. (1993): Geology, alteration and mineralization in the Eskay Creek 21A zone, northwestern British Columbia, Canada; *The University of British Columbia*, unpublished MSc thesis, 230 pages.

Roth, T. (2002): Physical and chemical constraints on mineralization in the Eskay Creek deposit, northwestern British Columbia – evidence from petrography, mineral chemistry and sulfur isotopes; *The University of British Columbia*, unpublished PhD thesis, 401 pages.

Ryan, B.D. (1991): Deposits of coal from the Telkwa coal property, northwestern British Columbia (NTS 93L/11); *in* Geological Fieldwork 1990, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1991-1, pages 399–406.

Ryan, B.D. (1992): Coal rank variations in the Telkwa coalfield, central British Columbia (NTS 93L/11); *in* Geological Fieldwork 1991, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1992-1, pages 451–460.

Ryan, B.D. (1993): Geology of the Telkwa coalfield, British Columbia (NTS 93L/11,14); *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 1993-21, scale 1:20 000.

Ryan, B.D. and Dawson, M.F. (1994): Potential coal and coalbed methane resource of the Telkwa coalfield, central British Columbia (NTS 93L/11); *in* Geological Fieldwork 1993, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1994-1, pages 225–243.

Schiarizza, P. and MacIntyre, D.G. (1999): Geology of the Babine Lake – Takla Lake area, central British Columbia (NTS 93K/11, 12, 13, 14; 93N/03,04,05,06); *in* Geological Fieldwork 1998, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1999-1, pages 33–68.

Sillitoe, R.H. (1999): Styles of high-sulphidation gold, silver and copper mineralization in the porphyry and epithermal environments; *in* PacRim '99 Congress Proceedings, Bali, Indonesia, Weber, G., Editor, *Australasian Institute of Mining and Metallurgy*, pages 29–44.

Sillitoe, R.H. (2002): Rifting, bimodal volcanism, and bonanza gold veins; *Society of Economic Geologists*, Newsletter, Number 48, pages 24–26.

Sillitoe, R.H. and Hedenquist, J.W. (2003): Linkages between volcanotectonic settings, ore-fluid compositions, and epithermal precious-metal deposits; *in* Understanding Crustal Fluids – Roles and Witnesses of Processes Deep within the Earth, Giggenbach Memorial Volume, Simmons, S.F., Editor, *Society of Economic Geologists and Geochemical Society*, Special Publication 10, pages 315–343.

Smith, G.T. and Mustard, P.S. (2005): The southern contact of the Bowser Lake and Skeena Groups – unconformity or transition?; *in* Summary of Activities 2005, *BC Ministry of Energy, Mines and Petroleum Resources*, URL <http://www.em.gov.bc.ca./subwebs/oilandgas/pub/reports/summary2005.htm>, pages 152–156.

Souther, J.G. (1991): Volcanic Regimes; Chapter 14; *in* Geology of the Cordilleran Orogen in Canada, Gabrielse, H. and Yorath, C.J., Editors, *Geological Survey of Canada*, Geology of Canada, Number 4, pages 457–490.

Stacey, J.S. and Kramers, J.D. (1975): Approximation of terrestrial lead isotope evolution by a two-stage model: *Earth and Planetary Science Letters*, Volume 26, pages 207-221.

Stevenson, J.S. (1947): Red Rose mine; *Economic Geology*, Volume 42, pages 433–464.

Struik, L.C., MacIntyre, D.G. and Hastings, N.L. (2001a): Geochemistry data – Nechako NATMAP project; *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 2001-9.

Struik, L.C. and MacIntyre, D.G. (2001b): Introduction to the special issue of the Canadian Journal of Earth Sciences – the Nechako NATMAP project of the central Canadian Cordillera; *Canadian Journal of Earth Sciences*, Volume 38, pages 485–494.

Sutherland Brown, A. (1960a): Geological map of the Rocher de Boule range, Hazelton Mountains, British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, coloured map to accompany Bulletin 43, scale 1:63 360.

Sutherland Brown, A. (1960b): Geological map of the Rocher de Boule range, Hazelton Mountains, British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, Bulletin 43, 86 pages.

Tackaberry, D.M. (1998): Petrography, lithogeochemistry and VMS potential of mid-Cretaceous Rocky Ridge volcanics, Babine Lake area, central British Columbia; unpublished BSc thesis, *University of Victoria, School of Earth and Ocean Sciences*, 73 pages.

Tipper, H.W. (1976): Smithers, British Columbia (NTS 93L); *Geological Survey of Canada*, Open File 35.

Tipper, H.W. and Richards, T.A. (1976): Jurassic stratigraphy and history of north-central British Columbia; *Geological Survey of Canada*, Bulletin 270, 73 pages.

Villeneuve, M.E. (2004): Preliminary report – $^{40}Ar/^{39}Ar$ and U-Pb geochronology for Rocky Ridge volcanics, British Columbia; unpublished report prepared for D. MacIntyre, November 2004, 17 pages.

Watkins, J.J. (2005): Evaluation report of the mineral potential of the BQ property, Omineca mining district; *BC Ministry of Energy, Mines and Petroleum Resources*, AR27943, 45 pages.

Wetherell, D.G. (1979): Geology and ore genesis of the Sam Goosly copper-silver-antimony deposits, British Columbia; unpublished MSc thesis, *The University of British Columbia*, 208 pages.

White, N.C. (1999): Convergent evolution and ore deposits; *Society of Economic Geologists*, SEG Video/DVD Series, Thayer Lindsay Lecture Number 4B.

Woodsworth, G.J. (1979): Geology of Whitesail Lake map area, British Columbia; *Geological Survey of Canada*, Current Research–Part A, Paper 79-1A, pages 25–29.

Woodsworth, G.J. (1980): Geology of Whitesail Lake map area, British Columbia (NTS 93E); *Geological Survey of Canada*, Open File 708, scale 1:250 000.

Woodsworth, G.J., Hill, M.L. and van der Heyden, P. (1985): Preliminary geologic map of Terrace map area, British Columbia (NTS 103I east half); *Geological Survey of Canada*, Open File 1136, scale 1:250 000.

Wojdak, P.J. and Ethier, D. (2000): Geologic setting of the Knoll property – an Eskay Creek target in Cretaceous rhyolite; *in* Exploration and Mining in BC 1999, *BC Ministry of Energy, Mines and Petroleum Resources*, pages 79–84.

Wojdak, P.J. and Sinclair, A.J. (1984): Equity Silver silver-copper-gold deposit – alteration and fluid inclusion studies; *Economic Geology*, Volume 79, pages 969–990.