# Exploration and mining in the Kootenay-Boundary Region, British Columbia

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## 1. Introduction

The Kootenay-Boundary Region, in the southeast corner of the province (Fig. 1), offers a variety of mining and exploration opportunities, and is accessible by well-developed infrastructure. Five operating coal mines produce most of Canada's coal exports. The historic lead-zinc-silver Sullivan Mine is in the region, and exploration for base metals and precious metals continues to be a focus. Several mines produce industrial minerals including silica, magnesite, gypsum, and graphite.

In 2014, total exploration spending and drilling increased relative to 2013 (Fig. 2), with about $50.4 million spent on exploration. Exploration drilling (approximately 125,000 m) increased for metals projects relative to 2013, whereas coal exploration drilling was scaled back. With lower coal prices, drill programs in the coal mines were cut, and spending was focused on mine development and mine evaluation projects (Fig. 3), mainly on Environmental Assessment requirements for mine expansions. Coal production increased from 25.6 Mt in 2013, and is expected to be close to 27 Mt for 2014. Highlights for 2014 include:

- approval of the Elk Valley Watershed Management Plan
- continued advances in major mine expansion plans at operating coal mines, with several projects in pre-application of Environmental Assessment (Elkview Baldy Ridge Extension, Line Creek Burnt Ridge Extension, Fording Swift) and the Greenhills Cougar Pit Extension nearing pre-application
- advances in new coal projects such as Crown Mountain (NWP Coal Canada Ltd.), which entered pre-application stages of Environmental Assessment, Coal Mountain Phase II (Teck Coal Limited), which is nearing pre-application, and continued exploration drilling at Michel Creek (CanAus Coal Limited)
- the Kootenay West gypsum mine (CertainTeed Gypsum Canada Inc.) entered pre-application of Environmental Assessment
- base metal exploration in the Belt-Purcell Basin in the East Kootenays (Vine, Sully, Ptarmigan)
- base and precious metal exploration in the West Kootenays (Jersey-Emerald, Jumping Josephine, Swift Katie, Thor, Willa, LH)

## 2. Geological overview

Plate tectonic processes have operated along the western margin of North America for over 2.5 billion years, and the tremendous mineral endowment of British Columbia is intimately linked to these processes (e.g., Nelson et al., 2013). The Canadian Cordillera is a collage of allochthonous terranes, parautochthonous terranes and autochthonous basement, containing diverse rocks and structures, and hence, metallogenic styles.

The Kootenay-Boundary Region (Fig. 1) contains autochthonous and parautochthonous elements of ancestral North America (Laurentia) including: Archean to Mesoproterozoic basement rocks; Proterozoic rift and intracratonic basin successions (Belt-Purcell and Windermere supergroups); Paleozoic to Jurassic passive-margin, shelf, and slope carbonate and siliciclastic successions that were deposited on the western flank of the ancient continent (Kootenay terrane, and North American platform); and Jurassic to Cretaceous foreland basin deposits. It also contains parts of the Slide Mountain terrane, which records mid- to late- Paleozoic back-arc extension that split the western flank of ancestral North America to form the Slide Mountain ocean, and Quesnellia and its basement (Okanagan subterrane) which, entirely exotic to North America, accreted to the continental margin in the middle Jurassic (Nelson et al., 2013).

Historically, the Canadian Cordillera has been divided into five northwest-trending physiographic belts. The Kootenay-Boundary Region includes two of these belts (Fig. 4), the Rocky Mountain Foreland belt, which consists mainly of unmetamorphosed sedimentary successions that were thrust northeastward in thin-skinned sheets, and the Omineca belt, which includes more deformed and higher grade (greenschist to amphibolite) siliciclastic and volcanic rocks, and basement-cored gneiss domes (Monger, 1999). The Omineca belt and the Rocky Mountain Foreland belt are separated by the Southern Rocky Mountain Trench (Fig. 4), which formed during Tertiary transtensional collapse (Monger et al., 1982; Nelson et al.,

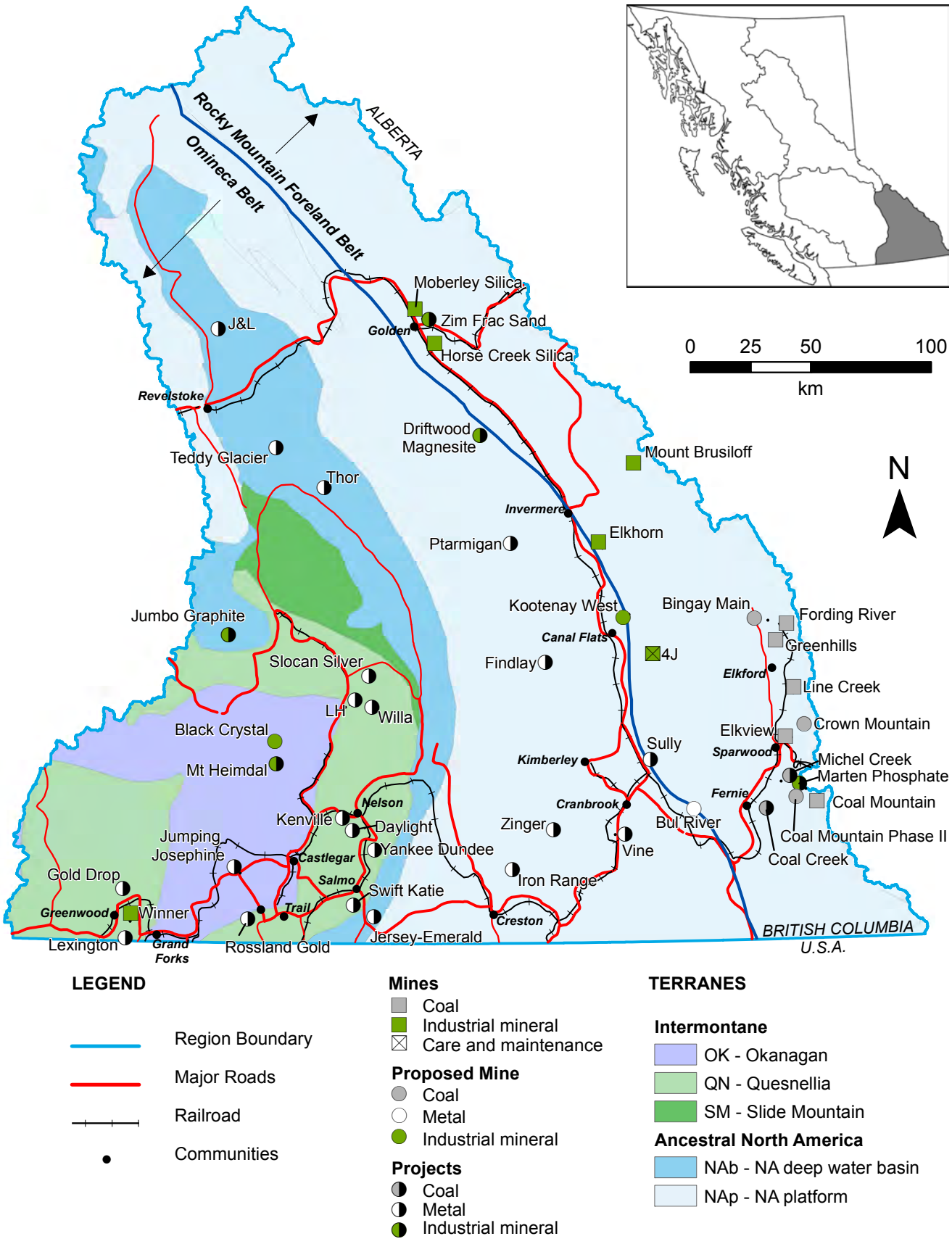


**Fig. 1.** Mines and selected exploration projects, Kootenay-Boundary Region, 2014. Terranes from Nelson et al. (2013).

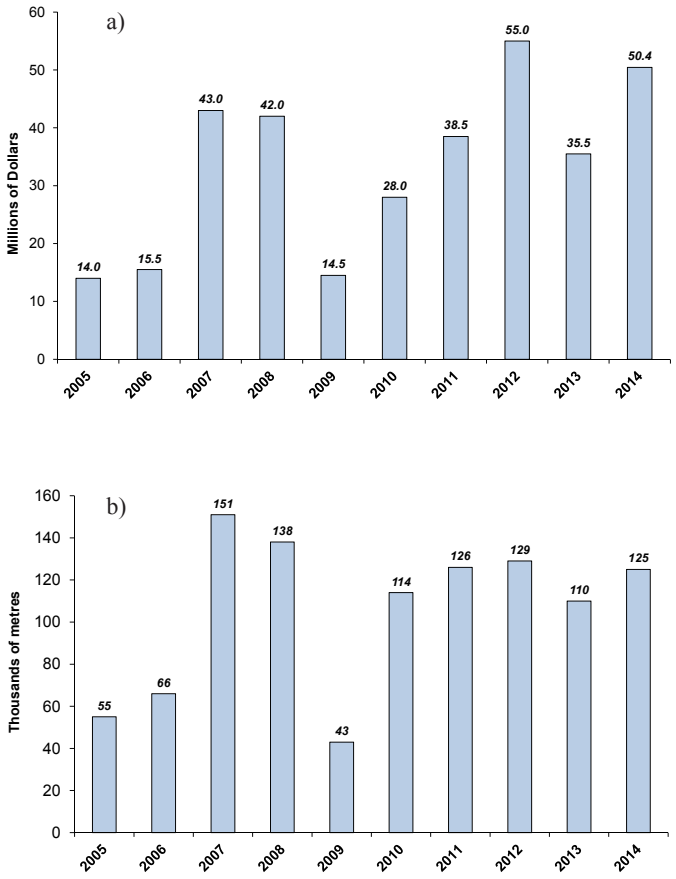


**Fig. 2. a)** Exploration spending and **b)** drilling in the Kootenay-Boundary Region, 2014.

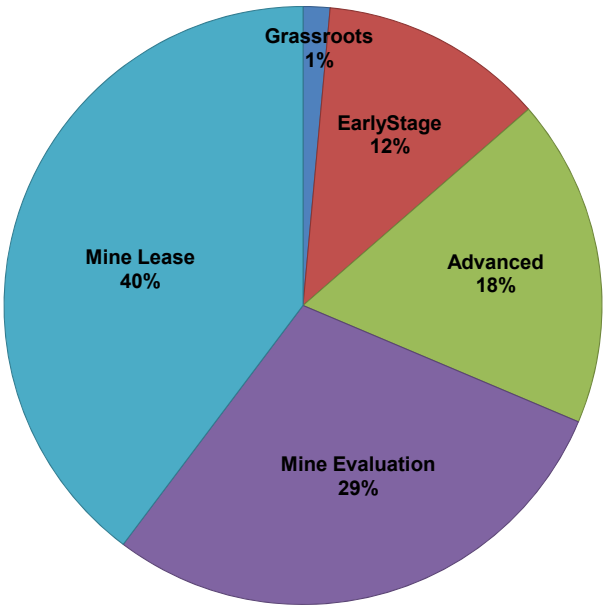


**Fig. 3.** Expenditures by exploration stage, Kootenay-Boundary Region, 2014.

2013). The Rocky Mountain Trench Fault is a normal fault on the eastern edge of the trench, with approximately 5 km of west-side-down displacement.

### 2.1. Tectonostratigraphic elements and terranes

#### 2.1.1. Laurentian basement (ancestral North America)

Archean to Mesoproterozoic Laurentian basement rocks extend beneath the Cordillera west of the southern Rocky Mountain Trench (Fig. 5). Northeast-trending basement structures influenced both Cordilleran tectonism and metallogeny (e.g., McMechan, 2012; Nelson et al., 2013). For example, the Moyie-Dibble Creek fault has been interpreted by Price (1981) and McMechan (2012) as the surface expression of the Vulcan low (Fig. 5). Abrupt changes in thickness and facies in Proterozoic to early Paleozoic strata across northeast-trending structures along this trend suggest periodic reactivation of basement structures. In the West Kootenays, the southwestward shift in trend at the south end of the Kootenay Arc, and other structures indicate a deep structural influence that is also on trend with the basement Vulcan Low.

Although generally deeply buried, crystalline basement is locally exposed in structural culminations such as the Shuswap-Monashee complex (Figs. 4, 5). Located west of the east-dipping Columbia River fault (Fig. 4), the complex is bounded by early Tertiary normal faults, and was exhumed during Tertiary extension (Monger, 1999). Paleoproterozoic granitic and granodiorite gneisses are unconformably overlain by a Neoproterozoic to Paleozoic platformal paragneiss assemblage of calc-silicate gneiss, pelitic gneiss, psammitic gneiss, quartzite and marble. This paragneiss assemblage hosts stratabound lead-zinc deposits, including Ruddock Creek, Jordan River, and Big Ledge (Fyles, 1970; Höy 1982b), and flake graphite deposits.

#### 2.1.2. Proterozoic basins on the western margin of ancestral North America

Following the Hudsonian orogeny (2.0-1.8 Ga), but before the breakup of ancestral North America (780-570 Ma), sedimentary successions accumulated in the Canadian Cordillera (Nelson et al., 2013). In the Kootenay-Boundary region, the Belt-Purcell basin (1.47-1.4 Ga), was a north-northwest trending intracratonic rift that extended into northern Idaho and Montana (Fig. 6). In Canada, the basin includes a 10-12 km section of turbiditic rocks (Aldridge Formation), and tholeiitic sills (Moyie sills; Lydon, 2007). Isopach variations along northeast-striking synsedimentary faults suggest that the basin was also affected by movement along transverse basement structures associated with the Vulcan low. The Belt-Purcell Supergroup hosts the Sullivan Pb-Zn-Ag SEDEX deposit (see Lydon, 2007).

By the end of the Mesoproterozoic (ca. 1.0 Ga), Laurentia was part of the supercontinent Rodinia. Rifting of this supercontinent occurred in at least two main episodes (Colpron et al., 2002). The earlier phase (ca. 723-716 Ma) in southern British Columbia resulted in deposition of the Windermere

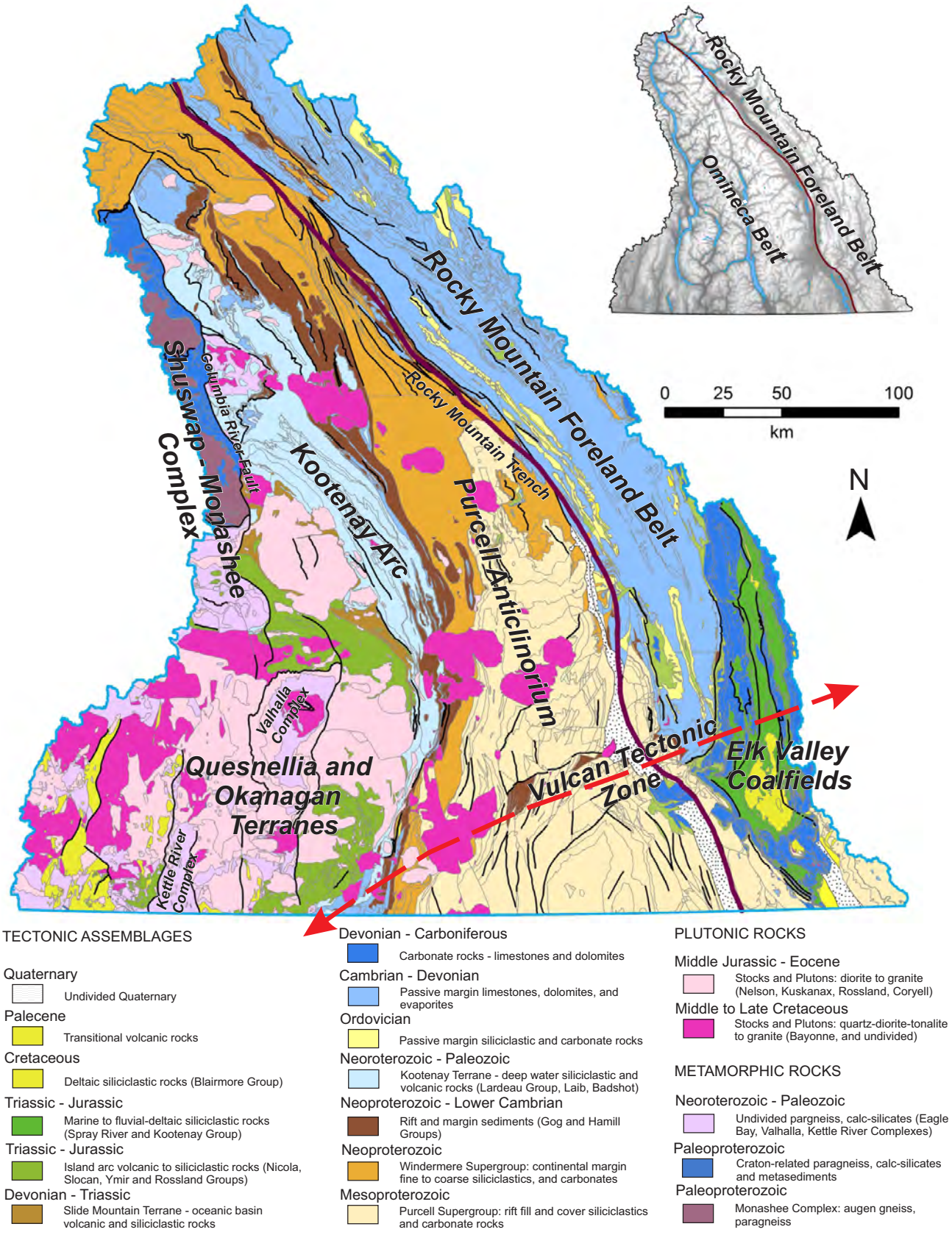


**Fig. 4.** Geology and physiographic belts of the Kootenay-Boundary region.

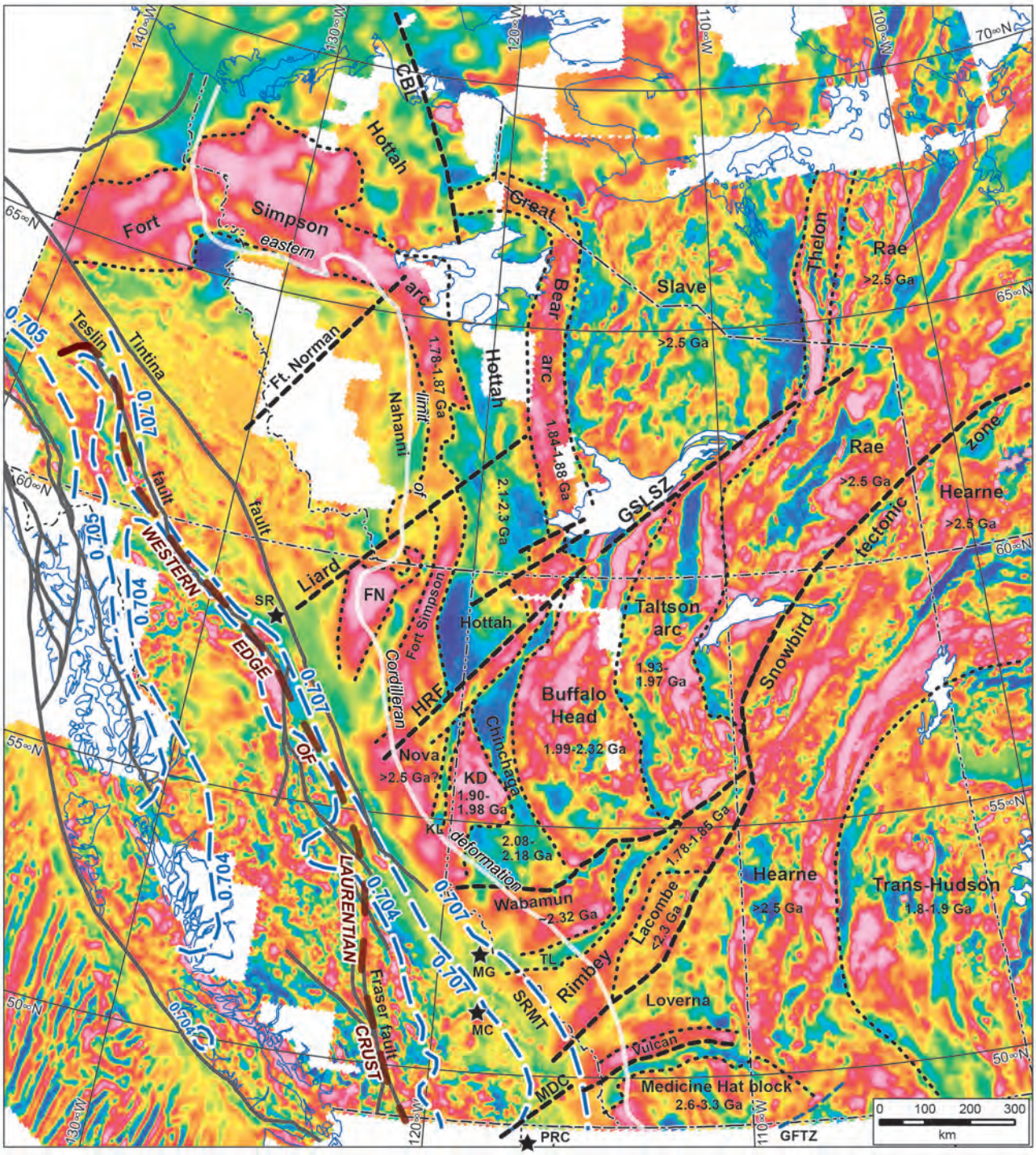


**Fig. 5.** Residual total field aeromagnetic map of western Canada, showing Precambrian basement domains of the western Laurentian craton with respect to the Cordilleran orogen (eastern limit of Cordilleran deformation indicated by white line). Precambrian basement domains are after Hoffman (1988), Ross et al. (1991), Villeneuve et al. (1993), Ross (2002), Hope and Eaton (2002), and Aspler et al. (2003). Precambrian domain boundaries are delineated by dotted lines; major basement structures are shown by short dashed lines. Some major structures extend beneath the Cordillera, including the Moyie-Dibble Creek fault (MDC) and related structures in the south (after McMechan, 2012), and the Liard and Fort Norman lines in the north (after Cecile et al., 1997). Stars show location of Precambrian basement exposures in the Omineca belt: MC = Monashee complex (1.86–2.10 Ga; Crowley, 1999); MG = Malton complex and Gold Creek gneiss (ca. 1.87–2.09 Ga; McDonough and Parrish, 1991; Murphy et al., 1991); PRC = Priest River complex (ca. 2.65 Ga; Doughty et al., 1998); SR = Sifton Ranges (ca. 1.85 Ga; Evenchick et al., 1984). Initial 87Sr/86Sr ratio isopleths for Mesozoic granitic rocks of the Cordillera (dashed blue lines) are after Armstrong (1988). Dashed brown line indicates inferred extent of North American crust beneath the Cordilleran orogen from geophysical, geochemical, and geological. Other abbreviations: CBL = Cape Bathurst line, FN = Fort Nelson high, GFTZ = Great Falls tectonic zone, GSLSZ = Great Slave Lake shear zone, HRF = Hay River fault, KD = Ksituan domain, KL = Kiskatinaw low (1.90–1.98 Ga), LD = Lacombe domain, RDZ = Red Deer zone, SRMT = Southern Rocky Mountain trench, TL = Thorsby low (1.91–2.38 Ga). From Nelson et al. (2013).

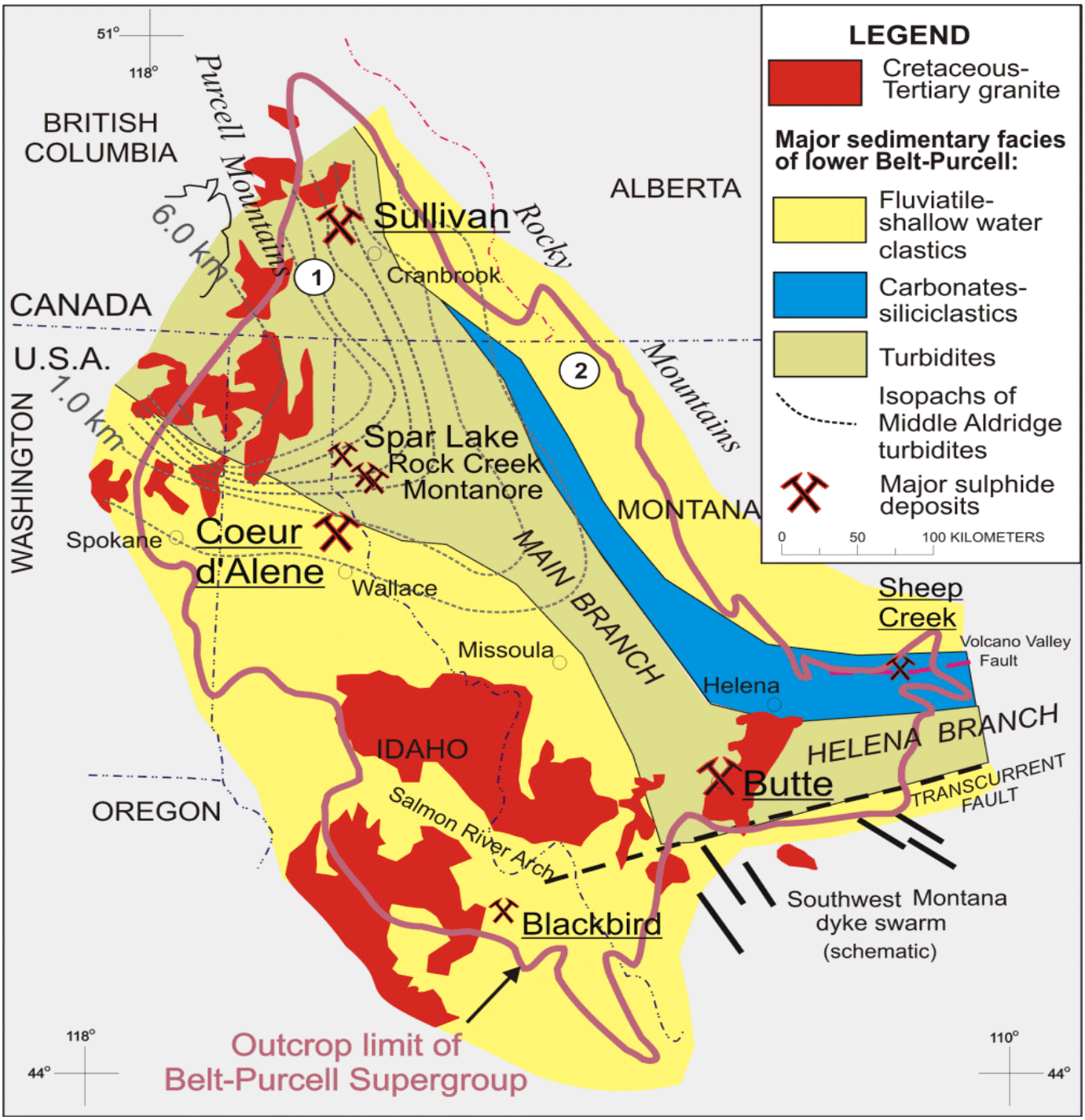


**Fig. 6.** Outcrop extent of the Belt-Purcell Basin, major mineral deposits, and simplified distribution of sedimentary facies in the lower part of the Belt-Purcell Supergroup (Aldridge and Pritchard formations and equivalents). From Lydon (2007).

Supergroup unconformably above the Purcell Supergroup (Fig. 7). Subsidence during the second phase (570-540 Ma) resulted in deposition of the Hamill-Gog Group unconformably over the Windermere Supergroup (e.g., Nelson et al., 2013). The Windermere Supergroup hosts limited syngenetic mineralization, and deposit types are mainly manto-style replacement, Mississippi Valley-type (MVT), and polymetallic veins.

### 2.1.3. Paleozoic to Cretaceous successions on the western margin of ancestral North America

Following the breakup of Rodinia, passive margin successions were deposited on the western flank of ancestral North American (Fig. 7). These rocks consist of Cambrian through Devonian siliciclastic, carbonate, and evaporitic rocks now exposed in the Purcell and Rocky mountains. In the Rocky Mountain Foreland Belt, these rocks host a number of industrial

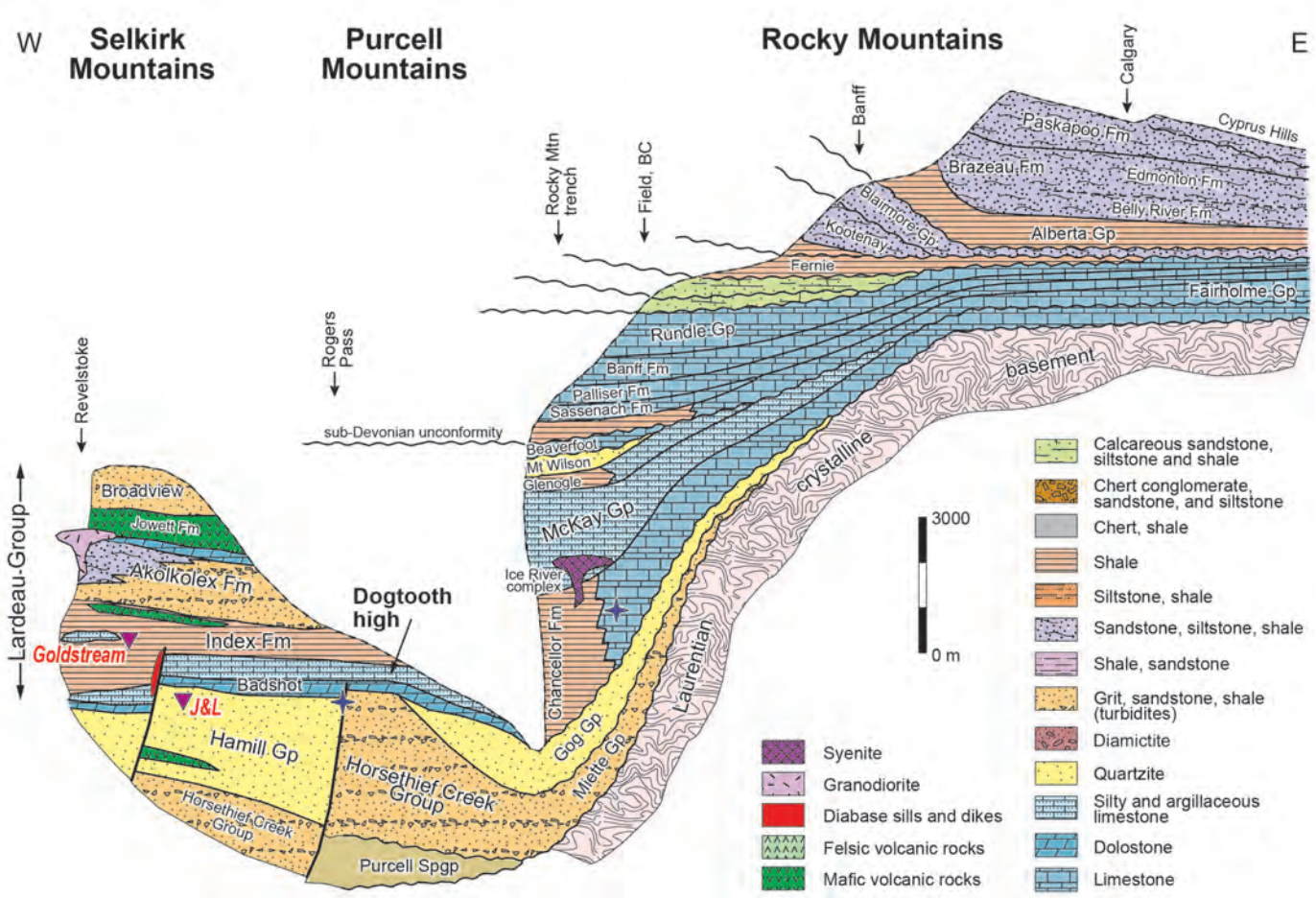


**Fig. 7.** Schematic stratigraphic relationships from the Rocky Mountains to the Selkirk Mountains for Neoproterozoic and younger strata of ancestral North American. Horizontal datum is the transition from marine to nonmarine Jurassic rocks, which is close to the transition from continental margin to foreland basin deposition. After Nelson et al. (2013).

mineral mines and quarries (silica, magnesite, and gypsum). Deep-water equivalents of these successions, now exposed in the Selkirk Mountains, were deposited outboard of the ancestral North American platform (Colpron and Price, 1995). These rocks consist of variably metamorphosed Neoproterozoic and Paleozoic strata, including the Badshot Formation (Lower Cambrian), and the Lardeau Group (Fig. 7; Logan and Colpron, 2006; Nelson, et al., 2013). Eastward subduction beneath the continental margin during the Devonian led to backarc extension and opening of the Slide Mountain ocean in the Pennsylvanian to Early Permian (285-300 Ma). Rocks of the Kootenay terrane represent remnants of the arc that remained on the continental side (Piercy et al., 2006; Nelson et al., 2006). The Badshot Formation hosts stratiform laminated to massive sulphides, and replacement-style mineralization, with characteristics similar to Irish-type deposits. In the Index Formation (Lardeau Group), basaltic and sedimentary units host a variety of Besshi-type, Cu-Zn-rich VMS deposits, and boron-enriched exhalative horizons (Nelson et al., 2013). Latest Devonian to Early Mississippian (ca. 360-340 Ma) carbonatites and associated alkalic intrusions in the western Rockies and Omineca belt are also related to backarc extension, and include the Ice River and Fir showings in the Kootenay-Boundary Region.

During Mesozoic to Tertiary terrane accretion, strata of the passive margin were shortened and displaced northeastward, to create a classical thin-skinned fold-thrust belt, with eastward-vergent, eastward migrating, piggyback thrusts detaching along a basement-cover décollement (Fig. 8; e.g., Price and Fermor, 1985). Thrust loading led to foreland basin subsidence and synorogenic sedimentation of material derived from emerging thrust sheets. These Jurassic to Cretaceous foreland basin deposits include the coal-bearing successions that are mined in the region. Siliciclastic, carbonate, and evaporitic sequences in the Foreland Belt also host relatively easily mined industrial minerals such as gypsum, magnesite, and silica.

### 2.1.4. Slide Mountain terrane

Eastward subduction beneath the western flank of ancestral North America during the Devonian-Mississippian led to backarc extension and opening of the Slide Mountain marginal ocean basin (e.g., Nelson et al., 2006). In the Kootenay-Boundary Region, interbedded mid-ocean ridge basalts, cherts,

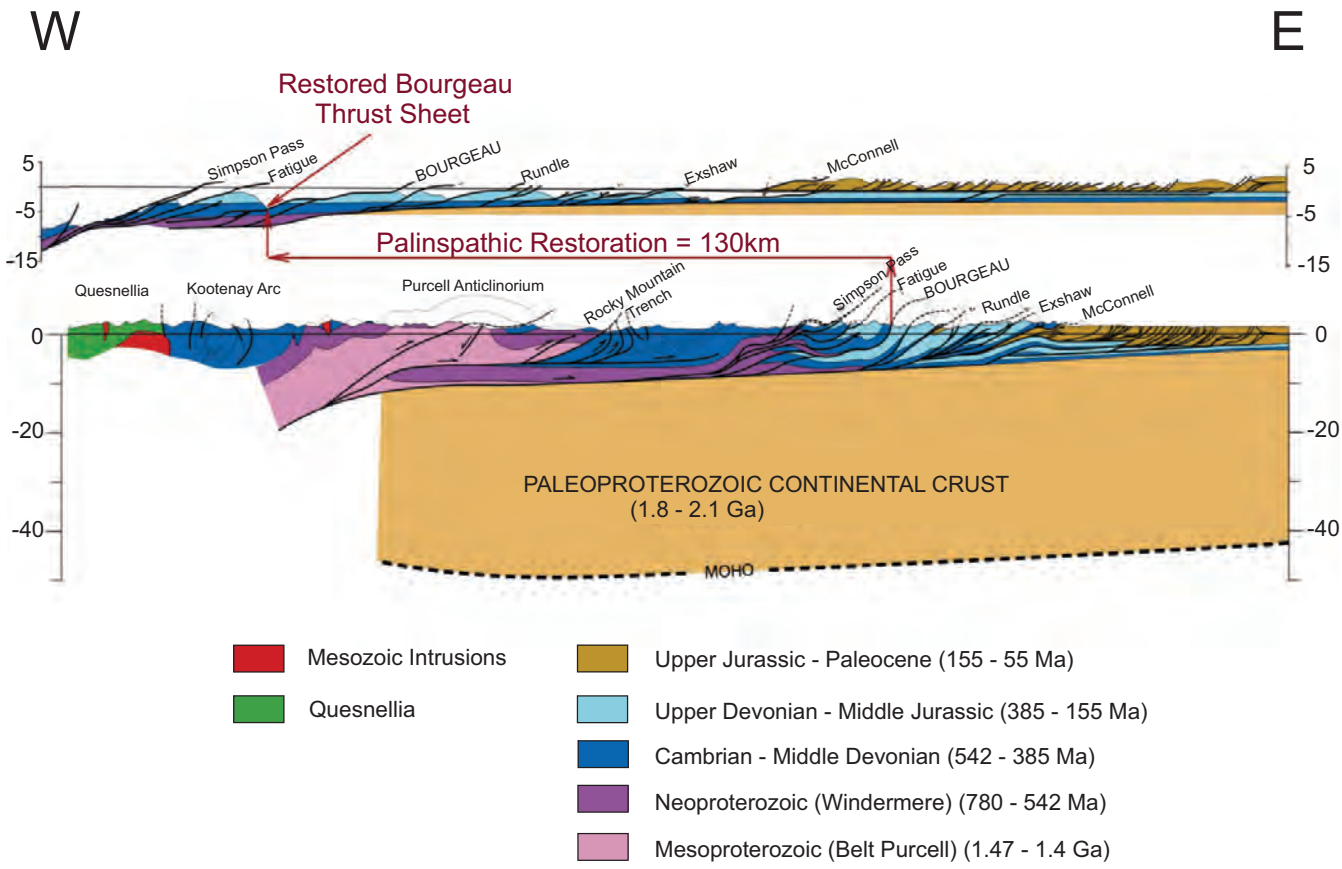


**Fig. 8.** Palinspastic restoration of the Rocky Mountain fold and thrust belt, southern British Columbia. Modified from Price and Fermor (1985).

sandstones and conglomerates imbricated between Quesnellia and ancestral North America represent remnants of the Slide Mountain ocean.

### 2.1.5. Quesnel terrane

By early to middle Permian, westward subduction beneath terranes outboard of North America consumed crust of the Slide mountain ocean, which closed by the end of the Triassic. Closing of the Slide Mountain ocean led to accretion of exotic arc terranes such as Quesnellia to the continental margin. Quesnel terrane consists of upper Devonian to Permian cherts, siliciclastic rocks, and basalts (Harper Ranch and Attwood Groups), coeval volcaniclastic rocks, pelites, and carbonates; and Upper Triassic to Lower Jurassic volcanic arc rocks (Nicola Group). Synorogenic siliciclastic rocks (Triassic Slocan Group) unconformably overlap the Slide Mountain and Quesnellia terranes, and were likely derived from uplift during accretion.

In southeastern British Columbia, Devonian and older units of southern Quesnellia differ significantly from coeval units to the north, and have been referred to as the Okanagan subterrane (Monger et al., 1991). These rocks form a roughly east-west trending belt, and constitute basement to Late Devonian and younger sequences of southern Quesnellia (Nelson and Colpron, 2009). Fragmentary evidence suggests that these rocks may originated in the Arctic realm (Massey et al., 2013; Nelson et al., 2013). The Trail gneiss complex (paragneiss and orthogneiss), Knob Hill complex (chert, greenstone, and ultramafic ophiolitic rocks), and Anarchist group (argillite-phyllite, chert, carbonate, and greenstones) rocks may represent a primitive arc to back-arc assemblage, with MORB, island arc tholeiites, and associated facies (Nelson and Colpron, 2009).

### 2.1.6. Mesozoic to Tertiary magmatism

Renewed eastward subduction upon closing of the Slide Mountain ocean and terrane accretion led to Late Triassic to early Jurassic magmatism. By mid-Jurassic, the emerging Canadian Cordillera had been fundamentally transformed from a set of loosely connected arc and pericratonic terranes, to a progressively thickening and complexly structured accretionary wedge. During the Eocene, the tectonic framework was one of dextral transtension accompanied by extensional collapse of previously thickened crust. Exhumation of the Shuswap-Monashee and Valhalla metamorphic complexes (Fig. 4) is related to this regional extension (Vanderhaeghe, et al., 2003).

Metallogenic episodes in the Late Jurassic-Early Cretaceous, mid-Cretaceous, Late Cretaceous, and Paleocene-Eocene, and Late Eocene can be related to changing convergence rates, subduction geometries, and convective heat transfer. Shearing and deformation also created pathways for pluton emplacement, and mineralization. The metallogenic importance of this

is found in the suite of epigenetic deposits with increasing influence of continental sources of metals (eg. Mo, W), and increased precious metal enrichment (Nelson, et al., 2013). Major deposit types include porphyry Cu-Mo (±Au) and Mo, intrusion-related gold, Ag-Pb-Zn, tungsten, and structurally controlled epithermal and orogenic Au veins.

## 3. Coal

Coal is produced at five operating mines in the Elk Valley (Figs. 1, 9). These mines, operated by Teck Coal Limited, produce approximately 70% of Canada's total annual coal exports. Coal mining in southeastern British Columbia dates back to the 1800s, with reports of coal discoveries in the Elk Valley around 1845. The first underground mine, at Coal Creek, opened in 1897 and operated until 1958. In the early 1900s, and into the 1960s, several other underground mines operated intermittently. These included mines at Morrissey, Hosmer, Michel/Natal, and Corbin. All produced industrial steam coals and coke for the smelting industry. The Balmer mine was the first open pit strip mine in the Elk Valley. It opened in 1968, and was encompassed by the currently operating Elkview mine.

The main coal deposits in southeastern British Columbia are in the Rocky Mountain Fold and Thrust Belt, and extend along strike for 175 km, following the northwest-southeast trend of the Rocky Mountain Front Ranges. The coal seams are in sedimentary rocks of the Kootenay Group where structurally thickened and exposed sections permit open-pit mining. The Fernie Formation and Kootenay Group (Figs. 9, 10) consist of sandstones, shales, and coals that were deposited in the foreland basin adjacent to the uprising Canadian Cordillera, in the Jurassic to early Cretaceous. The foreland basin contains a series of clastic wedges that are genetically linked to terrane docking on the western margin of North America (Cant and Stockmal, 1989). Episodic thrusting and isostatic subsidence resulted in pulses of erosion, transport and deposition. Deposition of the Fernie-Kootenay coarsening-upward clastic wedge was the first of a series of these clastic wedges derived from uplift (Poulton, 1988; Stott 1984). Mineable coal seams are in the Mist Mountain Formation, and are considered to have been deposited in a coastal plain depositional system in which delta and interdelta deposits in the lower part of the section grade upward to fluvial deposits (Fig. 11).

The East Kootenay coalfields comprise three structurally separated fields (Fig. 9) including the Elk Valley, Crowsnest, and Flathead. The Elk Valley Coalfield is in the Alexander Creek and Greenhills synclines, and includes the **Fording River**, **Greenhills** and **Line Creek** operations, and the proposed **Crown Mountain** and **Bingay Main** projects. The Crowsnest Coalfield coincides with Fernie Basin, a broad north-trending synclinorium, and includes the current **Elkview** and **Coal Mountain** operations and the Michel Creek, **Coal Mountain Phase II** (Marten Wheeler), and **Coal Creek** projects. The Flathead Coalfield consists of four relatively small, isolated exposures of Kootenay Group rocks in the extreme southeast corner of the region. Provincial legislation prohibits subsurface resource exploration and development in the Flathead Valley, so the Flathead Coalfield and part of the Crowsnest Coalfield are excluded from coal mining activity.

### 3.1. Operating mines

Mining operations, coal production, and expansion plans continued at all five mines in the Elk Valley and Crowsnest Coalfields (Table 1, Fig. 9). The main product is metallurgical coal (85%), with some thermal and pulverized coal injection (PCI) coal (15% combined). Total clean coal production from the Elk Valley in 2013 was approximately 25.3 Mt. Based on Teck's Q3 2014 forecasts, volumes for 2014 are expected to increase to almost 27 Mt. The mines directly employ over 4,500 people full-time.

In recent years, Environmental Assessment approval of major mine projects in the Elk Valley has been conditional on developing a regional watershed management plan. In November, 2014, Teck received approval from the British Columbia Ministry of Environment for the Elk Valley Water Quality Plan which addresses the management of selenium and other substances released by mining activities. It is a public policy document that will guide future regulatory decision making with respect to all water quality and mining in the Elk Valley. It includes water diversion and treatment, and establishes water quality targets for selenium, nitrate, sulphate, cadmium, and calcite.

The plan was developed with scientific advice from a Technical Advisory committee chaired by the British Columbia Ministry of Environment, and included representatives from Teck, the Ktunaxa Nation, the US Environmental Protection Agency, the State of Montana, Environment Canada and other agencies. Public consultation was also part of the process. A water treatment facility at Line Creek Operations is currently being commissioned, and is expected to be fully operational in 2015. The West Line Creek water-treatment facility is the first of six that Teck plans for the Elk Valley, including one at Fording River Operations for 2018. Together they are part of a selenium management plan that will cost a projected $600 million over the next five years, and $40 million to operate annually.

#### 3.1.1. Fording River Operations

**Fording River Operations** produces mainly metallurgical coal from their Eagle Mountain, Turnbull, and Henretta Pits (Fig. 12). Exploration drilling was conducted in active pits, with plans for highwall pushback in Eagle and Turnbull pits. Henretta South drilling also revealed thick coal seams extending into the north side of Turnbull Mountain. Proven and Probable reserves are projected to support a 74-year mine life at the current production rate, and mine expansion plans are currently underway at both their **Henretta** and **Swift** areas. East of the current Henretta Pit footwall exploration drilling on the eastern limb of the Alexander Creek syncline is intended to demonstrate mineable coal reserves down section from the current footwall limit, and coals with standard Fording River

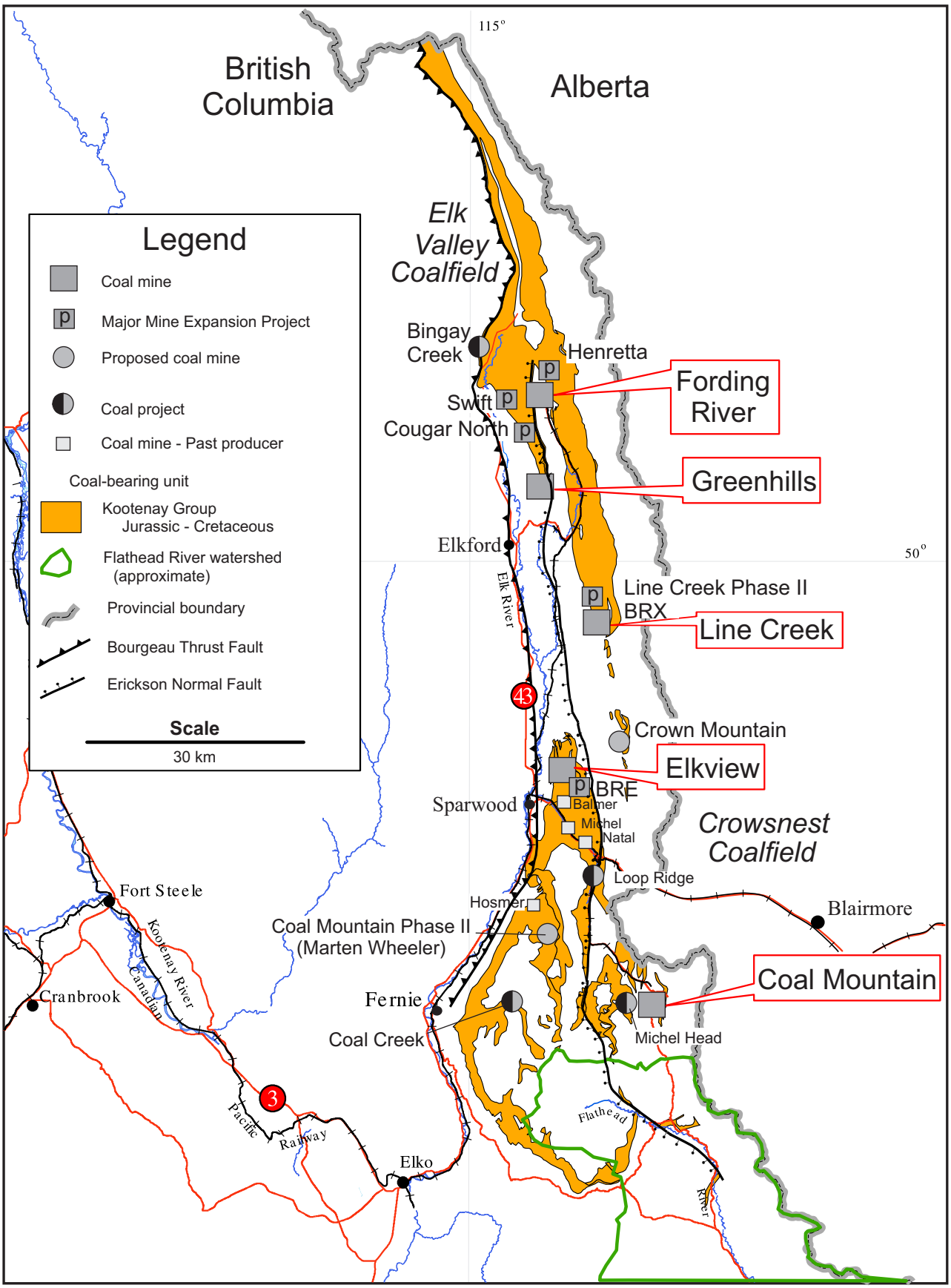


**Fig. 9.** Major mines and projects in the East Kootenay Coalfields.

**Table 1.** Operating coal mines, Kootenay-Boundary Region, 2014.

| Mine | Operator; and Partners | Coal; Major Product | Forecast Production (based on Q1-Q3) | Proven + Probable Reserves of Clean Coal (as of December 31, 2013) | Resource (Meas. & Ind.) | Near-mine exploration; project highlights | Major Mine Expansion Projects | Website |
|---|---|---|---|---|---|---|---|---|
| Fording River | Teck Coal Limited (100%) | HCC, Thermal | 8.97 Mt | 628.6 Mt HCC; 4.6 Mt Thermal | 1098 Mt HCC; 8.0 Mt Thermal | Drilling (24,295 m) at Eagle, Henretta, Turnbull; geological model for highwall pushback at Eagle and Turnbull pits | Swift entered pre-application stage of EA (2011); baseline and environmental studies | www.teck.com/coal |
| Greenhills | Teck Coal Limited (80%); POSCAN (20%) | HCC, PCI, Thermal | 5.15 Mt | 53.3 Mt HCC; 3.04 Mt PCI; 0.96 Mt Thermal | 262.6 Mt HCC; 10.2 Mt PCI; 3.6 Mt Thermal | Drilling at Cougar pit (4,936 m); geological model; baseline studies | West Spoil Expansion approval (2014); Cougar Pit Extension (CPX) preparing to enter pre-application of EA (2015) | www.teck.com/coal |
| Line Creek | Teck Coal Limited (100%) | HCC, PCI, Thermal | 3.40 Mt | 55.7 Mt HCC; 3.4 Mt PCI; 8.3 Mt Thermal | 761.7 Mt HCC; 0.5 Mt PCI; 9.2 Mt Thermal | Drilling (3,214 m) at Burnt Ridge Extension and North Line Creek Extension; geological model | Line Creek Phase II approval (2013); pre-stripping on Mt Michael and Burnt Ridge North; Burnt Ridge Extension (BRX) pre-application of EA (2014) | www.teck.com/coal |
| Elkview | Teck Coal Limited (95%); Nippon Steel & Sumimoto Metal Corp. (2.5%), POSCO (2.5%) | HCC | 5.45 Mt | 176.3 Mt HCC | 731.8 Mt HCC | Drilling at BR1, NP1, BR2, NP2 | Baldy Ridge Extension (BRE) entered pre-application of EA(2014) | www.teck.com/coal |
| Coal Mountain | Teck Coal Limited (100%) | PCI, Thermal | 2.54 Mt | 9.5 Mt PCI; 0.7 Mt Thermal | 80.7 Mt PCI; 2.6 Mt Thermal | Drilling (2,445 m) at 37-pit and 6-pit; geological mapping | Possible pit extension of 6-pit | www.teck.com/coal |

| | | SW Alberta and SE British Columbia | | Lithology |
|---|---|---|---|---|
| Cretaceous | Lower | Blairmore Group | Upper Blairmore | Massive bedded sandstones and conglomerates (chert pebble) |
| | | | Cadomin | |
| | | Kootenay Group | Elk Formation | Sandstone, siltstone, shale, mudstone, chert perbble conglomerate and minor coal seams |
| Jurassic | Upper | | Mist Mountain Formation | Interbedded sandstone, siltstone, shale, mudstone, and thick coal seams |
| | | | Morissey Fm. | Medium to coarse-grained, slightly ferruginous quartz-chert sandstone |
| | Upper / Middle | Fernie Formation | Passage Beds / Upper Fernie Shale / Green Beds | Shale, siltstone, fine-grained sandstone |
| | Middle | | Grey Beds / Highwood | |
| | Lower | | Poker Chip Shale | Shale, siltstone, fine-grained sandstone; Basal phosphorite unit |
| Triassic | | | | |

**Fig. 10.** Jurassic – Lower Cretaceous stratigraphy of the Fernie and Kootenay groups. Modified from Poulton, et al (2012).

**Fig. 11.** Dinosaur tracks on a bedding plane, Mist Mountain Formation.

**Fig. 12.** Fording River mine, looking toward Turnbull Mountain.

quality characteristics.

In September, 2011, the **Swift** project entered pre-application stages of Environmental Assessment for an open-pit project that is expected to produce 175 Mt of clean coal over 25 years. Located west of the Fording River in the northern part of the Greenhills Range, the project comprises both previously mined and unmined zones of the Fording property. The Swift Project expansion will be based on mining multiple coal seams on both limbs of the Greenhills Syncline. Mine development will

progress to the west from previous open pits. The project is along strike and directly north of the **Greenhills Cougar North** project (Fig. 13); and together, the two will become the **Swift**.

### 3.1.2. Greenhills Operations

**Greenhills Operations** is on the west limb of the Greenhills syncline (Fig. 13). Coal seams generally grade in rank from medium-volatile bituminous in the lower parts of the section, to high-volatile-A bituminous at higher intervals. Proven and Probable reserves are projected to support another 14 years of mining from current pits at the current rate. The **Cougar Pit Extension (CPX)** project is the proposed expansion area for Greenhills Operations, and lies immediately north of the existing operations. At full development, the **Cougar North Extension** will merge with the Fording River Operations expansion. In 2014, Teck conducted further baseline work and mine planning to prepare to enter pre-application of Environmental Assessment in 2015. Exploration drilling (4,936 m) focused mainly on the active Cougar pit.

### 3.1.3. Line Creek operations

**Line Creek Operations** produces from the Burnt Ridge South, North Line Creek, and Horseshoe Pits (Fig. 14). Expansion plans are well underway with the **Line Creek Phase II**, which received conditional Environmental Assessment approval in 2013. This expansion will extend operations at Line Creek northward, and encompass the **Mount Michael** and **Burnt Ridge North** areas, adding approximately 59 Mt of clean coal, and 18 years of mine life to the mine. Coal seams are predominantly medium-volatile bituminous in rank, with some high volatile-A bituminous coals near the top of the section. In June, 2014, the **Burnt Ridge Extension (BRX)** project entered pre-application of Environmental Assessment. The project will connect the current Phase I operating area at **Line Creek Operations** to the recently approved **Phase II** area by pushing back the highwall of Burnt Ridge South pit to the north. It will add 8.3 Mt of clean coal to the mine. Drilling in 2014 focused on the Burnt Ridge and North Line Creek extension areas to update geological and geotechnical models. Pre-stripping on Mount Michael began, with pre-stripping on Burnt Ridge North to begin pending approval.

**Fig. 14.** Line Creek mine, Alexander syncline.

**Fig. 13.** Greenhills mine, looking north toward Cougar Ridge North.

### 3.1.4. Elkview Operations

**Elkview Operations** produces mainly high-quality mid-volatile hard coking coal, and has a remaining reserve life of approximately 34 years at the current production rate. Production is mainly from their Baldy Ridge BR1 and Natal PH1 Pit. The mine received approval for expansion at **Baldy Ridge** in 2012, which is within their current mining area, and also for the Natal Phase 1 Pit Extension in 2013. Environmental baseline and other studies are being submitted to satisfy permit conditions. Exploration drilling in 2014 was directed at planning for the next phases of mining in the active Baldy and Natal pits. The **Baldy Ridge Extension (BRE)** entered pre-application of Environmental Assessment in June, 2014. The project will include expansion of their current permit boundary, mining of Baldy Ridge BR3, BR4, BR6, and BR7 pits, expansion of Adit Ridge AR1 pit, and Natal Ridge NP2 pit, dump and tailings facility expansions.

### 3.1.5. Coal Mountain Operations

**Coal Mountain Operations** produces mainly PCI and thermal coal, with Proven and Probable reserves expected to support another 6 years of production at current rates. Coal is mainly produced from seams at **37-Pit** and **6-Pit**. Drilling in 2014 was focused on active pits to update geological modeling, with plans to expand **6-Pit** to the south. Additional geological mapping was conducted on the property, to expand the current mapping of the Mist Mountain Formation on the property.

## 3.2. Proposed coal mines and major projects

In addition to Teck Coal, four companies explored for reserves of hard coking coal in the East Kootenay coalfields in 2014: CanAus Coal Limited, NWP Coal Canada Ltd. (Jameson Resources Limited), CrowsNest Pass Coal Mining Ltd., and Centermount Coal Limited (Table 2, Fig. 9).

### 3.2.1. Crown Mountain

The **Crown Mountain** property (NWP Coal Canada Ltd., a wholly owned subsidiary of Jameson Resources Ltd.) is along strike with Line Creek Operations, and is considered an erosional outlier of the Mist Mountain Formation. The property contains seven major coal seams, with combined average thicknesses of 15 to 35 m. In October 2014, the project advanced to pre-application stages of Environmental Assessment. The project is for an open pit mine with an estimated production capacity of 1.7 Mt per year of clean coal and a 16-year mine life, with proposed construction beginning in 2016. NWP Coal completed a prefeasibility study; and updated coal resource estimates 74.9 Mt (Measured + Indicated). Coal quality test work indicates coal quality characteristics that are similar to the Elk Valley coking coals.

### 3.2.2. Coal Mountain Phase II

At Teck Coal's **Coal Mountain Phase II** (Marten Wheeler) project (MINFILE 082GNE006), the Mist Mountain Formation contains up to 15 coal seams, 1-8 m thick, with a cumulative average thickness of 75 m on Marten and Wheeler Ridges. The seams range in rank from medium- to high-volatile bituminous coal. The project entered pre-application stages of Environmental Assessment in September, 2014. The mine will use infrastructure at the **Coal Mountain Operations**, and produce 76.5 Mt of clean coal over an estimated 34-year mine life, at a production rate of approximately 2.25 Mt per year. In 2014, Teck focused on environmental baseline, geotechnical, and mine design work.

### 3.2.3. Michel Creek

CanAus Coal Ltd., a wholly owned subsidiary of CoalMont Pty Ltd., drilled at their Michel Creek project (MINFILE 082GSE050), which consists of licenses at **Loop Ridge**, **Tent Mountain**, and **Michel Head**. Drilling identified twenty coal seams with an average cumulative thickness of 70 m in a 504 m section of Mist Mountain Formation. Geological modelling and correlation of drill data and coal quality data is currently underway to better define stratigraphic and structural relationships and define a NI 43-101 Resource. Initial raw coal tonnage estimates from historic and current data indicate potential resources between 120 and 140 Mt of high quality, mineable coking coal. Drilling in 2014 focused on the Loop Ridge, Loop Ridge Phase 2, and Michel Head licenses.

### 3.2.4. Coal Creek

CrowsNest Pass Coal mining Ltd. continued geological modelling, resource, and pre-feasibility work at their **Coal Creek** property (MINFILE 082GSE035). The company has been testing the down-dip extensions of the uppermost coal seams of the historical underground Elk River and Coal Creek collieries, the latter of which closed in 1958. The project is underlain by 11 coal zones 2- >20 m thick. The company is evaluating three seams in the uppermost part of the Mist Mountain Formation for underground room-and-pillar mining potential. Drilling in 2012 indicated high-quality hard coking and PCI coal. Although the project remained on hold in 2014, environmental baseline studies, including water quality surveys, are ongoing.

### 3.2.5. Bingay Creek

Centermount Coal Ltd.'s **Bingay Main** is a proposal for an open-pit and underground coal mine on the **Bingay Creek** property (MINFILE 082JSE011). It entered pre-application of Environmental Assessment in early 2013, but the project was suspended on account of low coal prices, and remained on hold in 2014. The mine would produce 2 Mt of coal annually, and have a mine life of approximately 20 years, with a total resource of approximately 39 Mt of clean coal. At **Bingay Creek**, the coal-bearing Mist Mountain Formation is preserved in a tight, asymmetric syncline in the immediate footwall of the west-dipping Bourgeau thrust fault. Based on previous exploration results, coals at Bingay Creek are medium-volatile and high volatile-A bituminous in rank.

## 4. Industrial minerals

The Kootenay-Boundary Region continues to be an important source of industrial minerals such as gypsum, magnesite, silica sand, mineral wool, dolomite, limestone, graphite, tufa, flagstone, railroad ballast, rip rap, smelter slag, and aggregate (Table 3). The largest mines are on the western edge of the Rocky Mountain Fold and Thrust Belt, in Paleozoic carbonate and siliciclastic successions that were deposited on the passive margin of ancestral North America (Figs. 7, 8). Uplifting along thrust faults has exposed these deposits, enabling them to be easily mined.

## 4.1. Operating mines

### 4.1.1. Magnesite

Baymag Inc. produces high-quality magnesite throughout the year from its open-pit mine at **Mount Brussilof** (MINFILE 082JNW001). The deposit was discovered in 1966, and the mine has been in production since 1982. The Mount Brussilof

**Table 2.** Proposed coal mines and major coal projects, Kootenay-Boundary Region, 2014.

| Mine | Operator | Commodity; deposit type | Reserves | Resource (Meas. & Ind.) | Work program | Significant results | Website |
|---|---|---|---|---|---|---|---|
| Crown Mountain (open-pit) | NWP Coal Canada Ltd. (Jameson Resources Limited) | Coal (HCC and PCI) | HCC: 42.60 Mt Proven + 4.91 Mt Probable; PCI: 7.13 Mt Proven + 1.19 Mt Probable (2014) | HCC + PCI: 68.9 Mt Measured + 6.0 Mt Indicated (2014) | Prefeasibility studies; environmental and baseline work; mine design; permitting | Pre-application of EA (2014); 16-year mine life; 1.7 Mt/yr | www.jamesonresources.com.au |
| Coal Mountain Phase II (Marten Wheeler) | Teck Coal Limited | Coal (PCI and Thermal) | N/A | PCI + Thermal: 117.09 Mt Measured + 100.97 Mt Indicated (2014) | Environmental and baseline work; mine design; permitting | Pre-application of EA (2014); total of 76.5 Mt; 34-year mine life; 2.25 Mt/yr | www.teck.com |
| Coal Creek (underground) | CrowsNest Pass Coal Mining Ltd. | Coal (HCC and PCI) | N/A | HCC + PCI: 616 Mt in the upper seams (2014) | Prefeasibility Study (PFS); geological modeling; resource evaluation; baseline studies | Optimization of the PFS; geological modeling | www.crowsnestpasscoal.com |
| Michel Creek (open pit) | CanAus Coal Limited | Coal (HCC and PCI) | N/A | 120-140 Mt estimated | Drilling (RC: 18,892 m; 17 LD: 1,404 m; 12 DDH: 2,537 m; 2 LDRF: 237 m) at Loop Ridge, Loop Ridge Phase 2, and Michel Head; sampling; coal quality | Coal quality results; updated geological model; drilling has identified 20 coal seams with cumulative thickness of 70 m (14% of a 504 m section in Mist Mountain Fm) | www.coalmont.com.au |
| Bingay Main (open pit and underground) | Centremount Coal Limited | Coal (HCC) | N/A | 42.43 Mt Measured + 52.9 Mt Indicated (2012) | On hold | Pre-application of EA (2012); 20-year mine life; 2 Mt/yr; total of 39 Mt HCC | www.centerpointcanada.com |

**Table 3.** Industrial minerals, Kootenay-Boundary Region, 2014.

| Mine | Operator | Commodity; deposit type | Production | Reserves (Proven + Probable | Resource (Meas. & Ind.) | Near-mine exploration and project highlights | Website |
|---|---|---|---|---|---|---|---|
| Mount Brussilof | Baymag Inc. | Magnesite | 180 Kt (MgO and MgOH) | 50 Mt Proven | N/A | - | www.baymag.com |
| Moberly Silica | Heemskirk Canada Limited | Silica; industrial use silica and frac sand | - | 20 to 140 mesh frac sand (dry): Proved 8.9 Mt @ 64% frac sand + Probable 4.6 Mt @ 64% frac sand; OR Silica for industrial (dry): 12.8 Mt Proved + 0.7 Mt Probable (Updated June 2014) | 20 to 140 mesh frac sand (dry): 32.4 Mt @ 64% frac sand Measured and Indicated + 11.7 Mt silica as frac sand residues; OR Silica for industrial (dry): 43.2 Mt Measured + Indicated | $26M capital cost for plant construction and upgrades to existing facility (for frac sand operation); 300,000 tonne per year capacity; Construction started on frac sand processing plant (2014) | www.heemskirkcanada.com |
| Horse Creek Silica | HiTest Sand Inc. | Silica; industrial use and aggregate | - | - | - | Variety of aggregate and industrial use products | www.hitestsand.com |
| Elkhorn (Elkhorn Quarry West Extension) | CertainTeed Gypsum Canada Inc. | Gypsum | 400,000 tonnes anually | N/A | N/A | 7 years mine-life remaining | www.certainteed.com |
| Kootenay West | CertainTeed Gypsum Canada Inc. | Gypsum | North and South Quarries: Total 15 Mt (at average quality of 83-85%) | Estimated 15 Mt gypsum | N/A | Pre-application of EA (2014); 400,000 t/yr; 38-year mine life; environmental baseline work | www.certainteed.com |
| Winner; Friday Quarry | Roxul Inc. | Gabbro/Basalt (for mineral wool) | Quarrying to supply feed stock for mineral wool plant | N/A | N/A | Crushing, screening, stockpiling; environmental; bulk sample | www.roxul.com |

**Table 3.** Continued.

| Mine | Operator | Commodity; deposit type | Production | Reserves (Proven + Probable | Resource (Meas. & Ind.) | Near-mine exploration and project highlights | Website |
|---|---|---|---|---|---|---|---|
| 4-J | Georgia-Pacific Canada Limited | Gypsum | N/A | N/A | N/A | Care and Maintenance | www.gp.com |
| Marten Phosphate | Fertoz Limited | Phosphate; upwelling | N/A | N/A | N/A | Drilling (7 RC: 301 m), mapping; trenching; bulk sample (2,000 t); XRF of stockpiles: 24-27% $P_2O_5$ | www.fertoz.com |
| Zim Frac Sand | 92 Resources Corp. | Silica; industrial use | N/A | N/A | N/A | Sampling; metallurgical testing: 98.3-99.0% $SiO_2$ | www.92resources.com |
| Black Crystal | Eagle Graphite Corporation | Graphite | N/A | Regolith: Measured + Indicated: 0.648 Mt @ 1.83% fixed carbon; Calc-silicate: Indicated: 4.765 Mt @ 1.21% fixed carbon | Surface work; mine design; permitting | Road and drill pad construction for exploration work | www.eaglegraphite.com |
| Mt Heimdal | Lithium Corporation | Graphite | N/A | N/A | Mapping; sampling | Graphitic horizon; up to 3.7% graphite | www.lithiumcorporation.com |
| Jumbo Graphite | Noram Ventures Inc. | 082LSE 076, 77, 78 | Flake graphite | N/A | Analytical drill results reported from Phase I (8 DDH: 1,295 m) | 2013 Drill results released: 86.7 m grading 1.81% C; 40.9 m grading 2.49% C | www.noramventures.com |
| Driftwood Magnesite | MGX Minerals Inc. | 082KNE 068 | Magnesite | N/A | Drilling (8 DDH: 438 m); mapping; metallurgical testwork; re-assay of 2008 core | Recovery rates of 93.4% reverse flotation and removal of up to 70% silica and 30% calcium oxides | www.mgxminerals.com |

deposit is in Cambrian carbonates of the Cathedral Formation (Fig. 15) that were originally deposited on the edge of the Cathedral escarpment, which formed at the shelf edge (Fig. 16). The deposit is a result of magnesium hydrothermal alteration, with characteristics similar to Mississippi Valley Type mineralization. Magnesite ore is transported by truck to the company's processing facilities in Exshaw, Alberta for production of magnesium oxide (magnesia or MgO) and magnesium hydroxide (MgOH). Production in 2014 is expected to remain flat at approximately 180 kt.

**Fig. 15.** Magnesite at the Baymag mine.

#### 4.1.2. Silica

Silica is produced by Heemskirk Canada Limited at the **Moberly Silica** operation. The deposit is in orthoquartzites of the Mount Wilson Formation (middle to upper Ordovician) that continue for 300 km along the trend of the western Rocky Mountain Fold and Thrust Belt. Moberly Mountain is the northern extent of the unit, where it is terminated by a thrust fault. At Moberly, the unit is nearly vertical, about 200 m thick, and extends along strike for an 800 m. The orthoquartzite (Fig. 17) is commonly de-cemented, rendering many exposures friable. The deposit was mined from the early 1980s to 2008 for silica sand, glass-making, and other industrial uses. In 2011, the company completed a feasibility study to produce frac sand for the western Canadian oil and gas industry, conducted detailed engineering studies, and outlined a mine plan for a 400,000 tonnes per year at a 35-year mine life. In 2014, the company updated the feasibility study and the resource estimate specific to producing 20 to 140-mesh frac. Upgrades necessary to convert the current silica operation to produce frac sand include redesigning and upgrading the haul roads and constructing a new processing plant. Plant engineering is progressing, and construction of footings for the plant building began in late 2014.

At the **Horse Creek Silica** mine, HiTest Sand Inc. operates a seasonal quarry in Mount Wilson orthoquartzites for a variety of industrial use and aggregate products. The quarry is in an area where the formation is more consolidated than at Moberly,

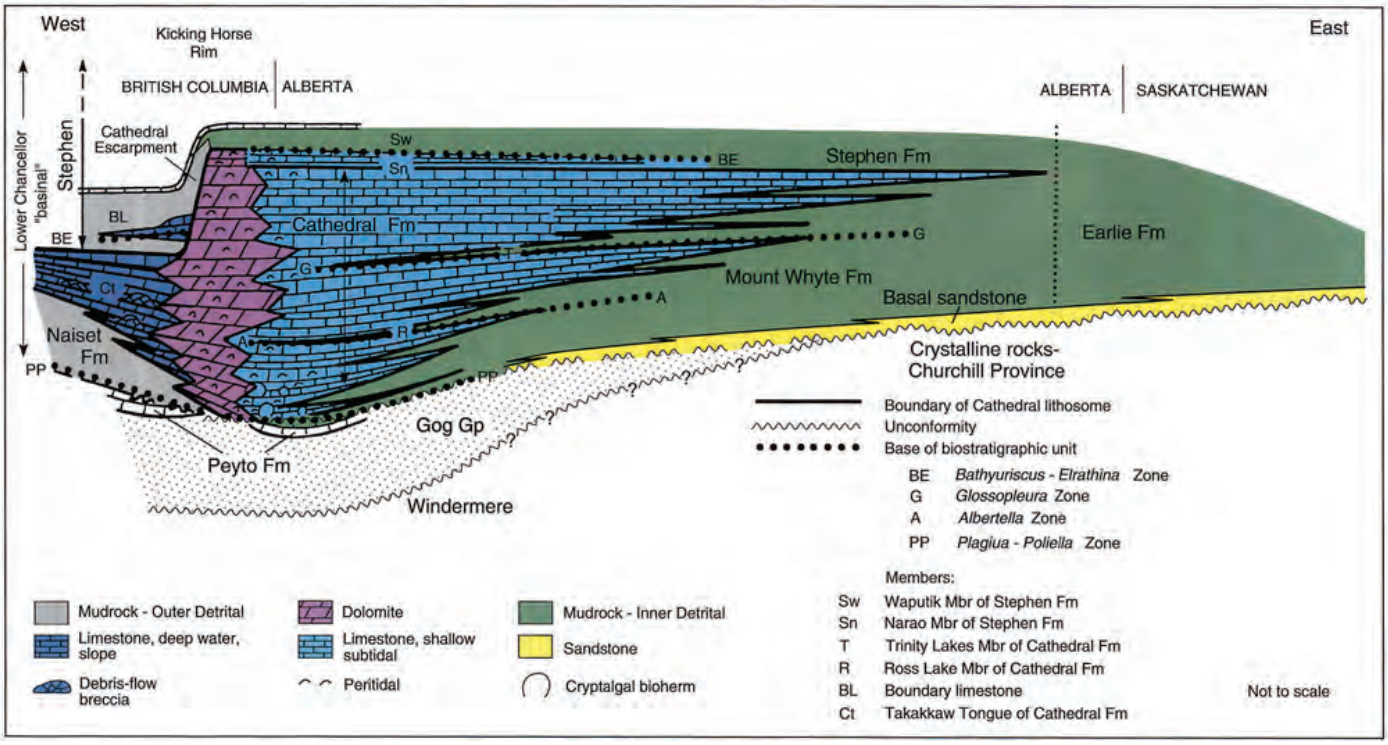


**Fig. 16.** Diagrammatic stratigraphic cross section of the Cathedral carbonate lithosome, a regional body of Middle Cambrian platformal carbonate rock that surrounded by siliciclastic mudrocks. The lithosome, (upper part of the Mount Whyte - Cathedral grand cycle) is abruptly terminated in the west, thins to the east, is diachronous at its base, and has a near-synchronous upper surface. From Slind, et al. (2014).

**Fig. 17.** Wave-rippled bedding surface, Mount Wilson Formation orthoquartzite, Moberly silica.

**Fig. 18.** Laminated evaporitic gypsum, Burnais Formation, Elkhorn mine.

however, the company is also evaluating processes for the production of frac sand.

#### 4.1.3. Gypsum

Gypsum is produced from an evaporite unit in the Burnais Formation (Middle Devonian; Fig. 18) that was deposited in a restricted shallow gulf. Gypsum-bearing strata are structurally disturbed, occurring as sections of steeply dipping, contorted rock gypsum, ranging in thickness from 30 to 80 m (Butrenchuk, 1991). CertainTeed Gypsum Canada Inc. operates the **Elkhorn** mine, which is expected to continue for another 7-12 years. The company also continues to advance the proposed **Kootenay West** mine, which entered the pre-application stages of Environmental Assessment in 2014. The quarry will target gypsum from a deformed hydrated evaporite layer, 5-40 m thick. The mine would have an average production rate of 400,000 tonnes per year, over a 38-year mine life. The total mineral reserve is estimated at 15 Mt and an average quality of 83-85% gypsum.

Georgia-Pacific Canada Limited operates the **4J** gypsum mine, also within Burnais Formation evaporites. The mine remained on care and maintenance in 2014.

#### 4.1.4. Gabbro

Roxul Inc. seasonally operates two small quarries near Grand Forks. Gabbro is quarried from the **Winner** quarry, and basalt is quarried from the **Friday Quarry** (North Fork). The material is trucked to the Roxul Inc. manufacturing plant in Grand Forks, where it is blended with other mineral material to make mineral wool insulation, boards, blankets, and pipe covering.

### 4.2. Exploration projects

#### 4.2.1. Phosphate

Fertoz Limited was active at their **Marten Phosphate** project (MINFILE 082GNE027), where thin phosphoritic beds are at the base of the Fernie Formation (Jurassic), immediately above the Spray River Group (Triassic; Fig. 10). Phosphoritic beds in the Fernie are thin oolitic sandstones. In 2014, the company conducted a drilling and trenching program, and extracted a bulk sample to test for agricultural use.

#### 4.2.2. Silica

92 Resources Corp. sampled at the **Zim Frac** sand property. The property is along strike of the nearby Moberley silica project, in Mount Wilson orthoquartzites. Samples were tested for frac sand potential and metallurgical-grade silicon dioxide.

#### 4.2.3. Graphite

Eagle Graphite Corp. operates the **Black Crystal** flake graphite (MINFILE 082FNW260) operation where graphite ore is produced from an open-pit quarry on Hodder Creek and processed at a pilot plant 10 km west of Passmore (Fig. 1). The property is in the central part of the Valhalla complex an upper amphibolite-grade gneiss dome in the Omineca physiographic belt (Fig. 4) that was exhumed during Tertiary extension. Disseminated fine- to coarse-flake graphite is distributed along foliation in organic-rich calc-silicates and marbles (Fig. 19), across an area of about 500 $m^2$. The graphitic horizon is 80 to 100 m thick. Carbon grades up to 6.95% in two zones: a 'hard rock' zone, and an overlying regolith zone. Most of the deposit, especially the regolith zone, is friable and blasting is not required. Sand and aggregate are produced as byproducts during the mining and refining process. In 2014, the company focused on redeveloping the mine plan and expanding exploration and construction on the property.

In 2014, Lithium Corporation explored at the **Mt Heimdal** flake graphite property, which is approximately 10 km south of the Black Crystal quarry, and underlain by the same package of gneisses, graphite mineralized marbles, and calc-silicate rocks. The mapping and sampling program focused on flake graphite mineralization discovered in 2013, which assayed up to 3.7% flake graphite, and prospecting in other areas.

**Fig. 19.** Graphite at the Black Crystal property, formed from metamorphism of organic-rich calc-silicates.

In 2014, Noram Ventures Inc. release results from a 2013 drill program at their **Jumbo** flake graphite property. The property is underlain by Proterozoic to Paleozoic Monashee complex paragneiss and quartz-rich metasedimentary rocks that have undergone upper amphibolite-grade polyphase deformation. Three primary targets were identified by SkyTEM airborne surveys at the **Black Fly**, **South Limb**, and **Big Flake** areas,. Analytical results from rock sampling indicated grades ranging from 0.5-7.3% graphite in tightly folded strata.

#### 4.2.4. Magnesite

At the **Driftwood Magnesite** property (MGX Minerals Inc.) cliff-forming, upturned beds of sparry magnesite, 40-70 m thick, are interlayered with dolostones and dolomitic limestones of the Mount Nelson Formation (Purcell Supergroup, Fig. 20). The coarse-grained textures in the magnesite zone suggest that hydrothermal alteration and recrystallization of magnesite occurred during regional metamorphism (Kikauka, 2000). In 2014, the company drilled the **East** zone, and resampled 8 drill cores from drilling by Tusk Exploration Ltd. in 2008 at the **West** zone. The company is currently working on completing a NI 43-101 compliant resource, has filed for a mine lease application, and is moving towards development of a magnesite quarry.

## 5. Metals

Although metals were not mined in the Kootenay-Boundary Region in 2014, exploration continued in the Purcell Anticlinorium, the Kootenay Arc, Quesnellia, and the Okanagan sub-terrane (Figs. 1, 4; Table 4), with several projects evaluating the potential for rehabilitating historic underground workings.

### 5.1. Purcell Anticlinorium

The Purcell Anticlinorium is a broad, north-plunging structure in the Omineca Belt, between the Rocky Mountains and the Kootenay Arc (Fig. 4). It is underlain by Proterozoic rift successions of ancestral North America (Fig. 7). Mineralization types include: sedimentary exhalative (SEDEX) deposits (bedded sulphide, feeder pipe, and vein); massive sulphide replacement deposits (Irish, Mississippi Valley, and manto); Mesoproterozoic intrusion and fault-related Ag-Pb-Zn and Cu-Ag veins; Mesozoic shear and vein gold, and associated placer deposits (Höy, 1993; McMechan, 2012).

The Purcell Anticlinorium formed during Mesozoic contraction, when imbricated thrusts faults carried up to 15 km of Belt-Purcell and Paleozoic margin sedimentary rocks eastward over a basement ramp (Cook and Van der Veolden,1995). The Anticlinorium is transected by steep north-northwest longitudinal faults and northeast-trending transverse faults. The transverse faults may be related to the Vulcan low basement structure (Figs. 4, 5) and were likely reactivated repeatedly, including during Proterozoic Belt-Purcell Supergroup and Windermere Supergroup sedimentation (Höy, 1982a). The Vulcan low may also have influenced Mesozoic shear and vein gold along the Kimberley Gold Trend, which runs east-west through the historic gold rush town of Fort Steele.

The Belt-Purcell Supergroup (1.5-1.3 Ga) consists of up to 12 km of sedimentary rocks and tholeiitic sills that were deposited in an intracratonic rift (Figs. 6, 20). Sedimentary facies include rusty-weathering deep-water turbidites, shallow-water platform and fan-delta deposits at the margins of the rift and surrounding shelf, and shallow-water carbonates, mud flat, lagoonal, and alluvial deposits of the rift-cover succession (Fig. 21). Synsedimentary faulting during graben extension and sporadic tholeiitic to alkaline magmatism characterize lower units. Apparently, metal rich brines migrated along synsedimentary faults and interacted with sea floor boron and aluminous sediments to form stratabound massive sulphides. Exhalative-style indicators and alteration include tourmalinite (boron) horizons, sections of fragmental sediments, anomalous Pb-Zn-Ag-Sn-Cu, and indicator element geochemistry. Most exploration has focused on SEDEX Pb-Zn-Ag mineralization in the Aldridge Formation similar to that of the historic Sullivan mine at Kimberley (MINFILE 082FNE052). The mine operated from 1909 to 2001 and produced over 17.5 Mt of zinc, 18.5 Mt of lead, and 297 million ounces of silver. The contact between the lower and middle Aldridge members hosts the Sullivan Pb-Zn-Ag ore body (Fig. 21). Indicators of Sullivan-style mineralization are distributed throughout the Aldridge Formation, including disseminated sphalerite and galena. In addition to stratabound base metals, extensional tectonics also led to the development of vent and feeder pipe complexes and base metal vein deposits. Pb-Zn-Ag mineralization with characteristic tourmaline alteration is commonly localized at the intersections of north-northwest trending and northeast-trending faults, including the St Mary, Kimberley, and Moyie-Dibble Creek faults (Price, 1981; Höy et al., 2000; McMechan, 2012). These fault intersections have been the focus of exploration. The upper part of the Purcell Supergroup contains carbonate-hosted, stratiform replacement-

**Table 4.** Metals exploration, Kootenay-Boundary Region, 2014.

| Property | Operator | MINFILE | Commodity; deposit type | Resource | Work program | Significant results | Website |
|---|---|---|---|---|---|---|---|
| Bul River (underground) | Purcell Basin Minerals Inc. | 082GNW 002 | Cu-Ag-Au+/-Pb-Zn; Cu-Ag veins | N/A | Permitting; environmental baseline; mine plan and mine design; ARD/ML | Proposed restart of Bul River Mine; draft project proposal | - |
| Findlay | MMG Limited | 082KSE 041, 53, 60, 75 | Pb-Zn-Ag+/-Cu; SEDEX, polymetallic vein | N/A | Drilling (2 DDH); mapping; geophysics; modelling | Failed to reach drill target due to poor ground conditions | www.mmg.com |
| Sully | Santa Fe Metals Corp. | - | Gravity anomaly | N/A | Drilling (4 DDH); mapping; magnetics; geophysical and geological modeling | Drill hole correlations and geophysical modeling suggest two gravity targets in thrust repeat; sulphides and alteration halo intersected | www.santafemetals.com |
| Vine | PJX Resources Inc. | 082GSW 050 | Pb-Zn-Ag+/-Au; polymetallic vein, SEDEX | 1.3 Mt grading 2.2 g/t Au, 3.12% Pb, 36.3 g/t Ag, 3.12% Zn (2011; non-compliant) | Drilling (1 DDH: 400 m); gravity survey; geophysical and geological modelling | Infilled gravity survey grid; detailed geophysical and geological model | www.pjxresources.com |
| Iron Range | Santa Fe Metals Corp. | 082FSE 014 to 28 | Pb-Zn-Ag+/-Au-Cu; polymetallic veins and breccia; SEDEC; IOCG | N/A | Geological modeling; sampling | Prioritized targets | www.santafemetals.com |
| Zinger | PJX Resources Inc. | - | Au+/-Pb-Zn-Ag; veins | N/A | Mapping; soil sampling | Two soil grids; West grid: values up to 7 x baseline; East grid: soil values up to 4.9 g/t | www.pjxresources.com |
| Ptarmigan | Silver Mountain Mines Inc. | 082KSE 030, 36 | Ag-Pb-Zn+/-Au-Cu; manto, polymetallic veins | N/A | Drilling (28 DDH: 3,690 m); | Extension of mineralized zones; 4.60 m grading 1.949 g/t Ag, 0.803 g/t Au, 0.72% Cu; 3.96 m grading 1.05 g/t Au, 260 g/t Ag, 0.14% Cu | www.silvermountainmines.com |

**Table 4.** Continued.

| Property | Operator | MINFILE | Commodity; deposit type | Resource | Work program | Significant results | Website |
|---|---|---|---|---|---|---|---|
| Iron Range | Santa Fe Metals Corp. | 082FSE 014 to 28 | Ag-Pb-Zn+/-Au-Cu; polymetallic vein, SEDEX, IOCG | N/A | Data compilation; mapping | Geological model | www.santafemetals.com |
| J & L (underground) | Huakan International Inc. | 0825M 003 | Ag-Pb-Zn+/-Au; SEDEX, Irish-type carbonate-hosted, polymetallic veins | Main Zone: 3.95 Mt grading 5.68 g/t Au, 56.5 g/t Ag, 1.94% Pb, 3.56% Zn (Measured+Indicated); Yellowjacket Zone: 1.0 Mt at 64.1 g/t Ag, 2.77% Pb, 9.08% Zn, 0.21 g/t Au (Indicated) (2011) | Engineering and baseline studies; metallurgical testwork | Care and maintenance; process optimization | www.huakanmining.com |
| Thor | Taranis Resources Inc. | 082KNW 030, 31, 60, 61 | Ag-Pb-Zn+/-Au; polymetallic veins, stratiform manto | Indicated: 640,000 t grading 0.88 g/t Au, 187 g/t Ag, 0.14% Cu, 2.51% Pb, and 3.51% Zn; Inferred: 424,000 t grading 0.98% Au, 176 g/t Ag, 0.14% Cu, 2.26% Pb, and 3.2% Zn (2013: potential open pit and underground) | Surface drilling (29 EW core, pack drill); trenching; mapping; panel sampling; metallurgical testwork; assessment of stockpiles to NI 43-101 standards | Extended gold-bearing zone at the SIF, including 30.59 g/t Au over 17.55 m; metallurgical testing at SIF shows 75% gravity recoveries for Au; discovery of SIF Carbon zone | www.taranisresources.com |
| Teddy Glacier / Spider Mine | Jazz Resources Inc. | 082KNW 069 | Ag-Pb-Zn+/-Au; polymetallic veins | Inferred: 44,000 t grading 4.457 g/t Au, 7.94% Pb, 6.74% Zn (2007; non-compliant) | Metallurgical testwork (flotation); ARD | Pb flotation concentrate with 62% Pb, 83% Au and 92% Ag; Zn flotation concentrate with 48.7% Zn; Permit for pilot mill and tailings pond at former Spider Mine to process bulk samples(2013) | www.jazzresources.ca |
| Jersey-Emerald | Margaux Resources Inc. | 082FSW 010, 9 | Pb-Zn-Ag+/-W-Au-Mo-Bi; stratiform, skarn | Measured and Indicated: 2.766 Mt grading 0.36% $WO_3$; Indicated: 1.724 Mt 1.96% Pb, 4.1% Zn ; Indicated: 25,000 t grading 0.098% Mo (2010) | Drilling (35 DDH: 6,319 m); mapping; sampling; geological modeling | Initial assay results indicated zones of 10-20 m width, grading 0.10 to 0.15% $WO_3$; and >0.5% over 1-3 m; 10.2 m grading 24.98 g/t Au with elevated bismuth | www.margauxresources.com |

**Table 4.** Continued.

| Property | Operator | MINFILE | Commodity; deposit type | Resource | Work program | Significant results | Website |
|---|---|---|---|---|---|---|---|
| Slocan Silver (Silvana - underground) | Klondike Silver Corp. | 082FNW 050, 13; 082KSW 006 | Ag-Pb-Zn+/-Au; polymetallic vein | N/A | Engineering reports: underground mining structure and tailings storage facilities; mine emergency response plan update; dam safety inspection review; hydrological inspection of Carpenter Creek | Work identified in engineering reports to begin in early 2015 | www.klondikesilver.com |
| Iron Range | Santa Fe Metals Corp. | 082FSE 014 to 28 | Ag-Pb-Zn+/-Au-Cu; polymetallic vein, SEDEX, IOCG | N/A | Data compilation; mapping | Geological model | www.santafemetals.com |
| Willa | Discovery Ventures Inc. | 082FNW 070, 71 | Ag-Pb-Zn +/-Au-Cu-Mo; subvolcanic breccia, polymetallic veins, porphyry Mo, Au-skarn | Measured and Indicated: Using a 3.5 g/t Au cutoff: 758,199 t grading 6.67 g/t Au, 0.85% Cu, 12.54 g/t Ag; Using a 2.5 g/t Au cutoff: 1,337,457 t grading 5.05 g/t Au, 0.74% Cu, 10.72 g/t Ag (2012) | Preliminary Economic Assessment; geological modelling; mine design; Dam safety inspection of MAX tailing facility; MAX mill upgrades; core re-sampling; Lidar survey; permitting | Acquisition of partial interest in MAX Mine and mill for processing; mill upgrades | www.discoveryventuresinc.com |
| LH | Magnum Goldcorp Inc. | 082FNW 212 | Cu-Ag-Au; subvolcanic, Au-veins | N/A | Drilling (4 DDH: 707 m); SP and IP/magnetometer survey | Two conductive anomalies were drilled; results pending | - |
| Daylight | Sultan Minerals Inc. | 082FSW 175, 174 | Ag-Pb-Zn+/-Au-Cu; polymetallic vein; porphyry | N/A | Mapping; sampling | Four new veins/ silicified zones discovered; grab samples 80.4 g/t Au + 117.0 g/t Ag; 23.4 g/t Au + 7.8 g/t Ag | www.sultanminerals.com |
| Kennville | 0995237 B.C. Ltd. (privately owned) | 082FSW086 | Au-Cu-Pb-Zn-Ag-W; Au-veins, Cu-Au alkali porphyry, intrusion-related Au, pyrrhotite veins | N/A | Permitting for surface and underground; surface work; mine planning; public consultation; mapping | Extension of powerline to site; plans for underground development and bulk sampling | - |
| Yankee-Dundee | Armex Mining Corp. | 082FSW 067, 68, 082ESE 189 | Ag-Pb-Zn+/-Au; polymetallic veins | Inferred reserve estimate: 872,000 t grading 10 g/t Au, 170 g/t Ag (1983: Non-compliant) | Permitting; mapping | - | - |

**Table 4.** Continued.

| Property | Operator | MINFILE | Commodity; deposit type | Resource | Work program | Significant results | Website |
|---|---|---|---|---|---|---|---|
| Swift Katie | Riverside Resources Inc. | 082FSW 290 | Cu-Au-Ag+/-Mo; porphyry | 70.7 Mt grading 0.23% Cu, 0.22 g/t Au (2006; Non-compliant) | Drilling (5 DDH: 1,423 m); soil geochem; mapping | Precious metal and polymetallic zones encountered, including: 23.4 g/t Au, 0.62% Cu, and 435 g/t Ag over 1.5 m; 5.69 g/t Au, 0.13% Cu and 26.6 g/t Ag over 2 m; | www.rivres.com |
| Jumping Josephine | Orex Minerals Inc. | 082ESE 275 | Au-Ag; Au-quartz veins | JJ Main - Indicated: 363,000 t grading 2.95 g/t Au, with 34,000 oz contained (2011) | Drillling (25 DDH: 8,115 m); mapping; trenching | Drill results expected early 2015; trenching results included: 7 m grading 80.18 g/t Au, 706 g/t Ag; 8 m grading 6.34 g/t Au, 2.7 g/t Ag (coarse gold signature) | www.orexminerals.com |
| Rossland Gold | West High Yield (W.H.Y) Resources Ltd. | 082FSW 119, 116, 117 | Au-Ag-Pb-Zn, Mg; polymetallic veins, ultramafic-hosted talc-magnesite | N/A | Mapping; sampling | Four samples grading 70.3 g/t Au, 13.4 g/t Au, 17.9 g/t Au, and 52.0 g/t Au | www.whyresources.com |
| Gold Drop | Ximen Mining Corp. | 082ESE 153, 152, 126 | Au-Ag-Pb-Zn+/-Cu; vein, alkalic intrusion-associated Au | N/A | Trenching; mapping; sampling | Chip sample results up to 0.60 m grading 43.6 g/t Au, 141 g/t Ag; and 0.55 m grading 56.2 g/t Au, 259 g/t Ag; upper North Star vein extended along 315 m strike | www.ximenminingcorp.com |
| Lexington (Greenwood) | Huakan International Mining Inc. | 082ESE 041, 32 | Au-Cu-Ag+/-Pb,Zn; porphyry, epithermal, polymetallic veins | 131,500 t grading 9.6 g/t Au, 1.48% Cu (1993; Non-compliant) | Re-acquired property; Care and maintenance; environmental | Permitted 200 t/d flotation mill and tailings facility | www.huakanmining.com |

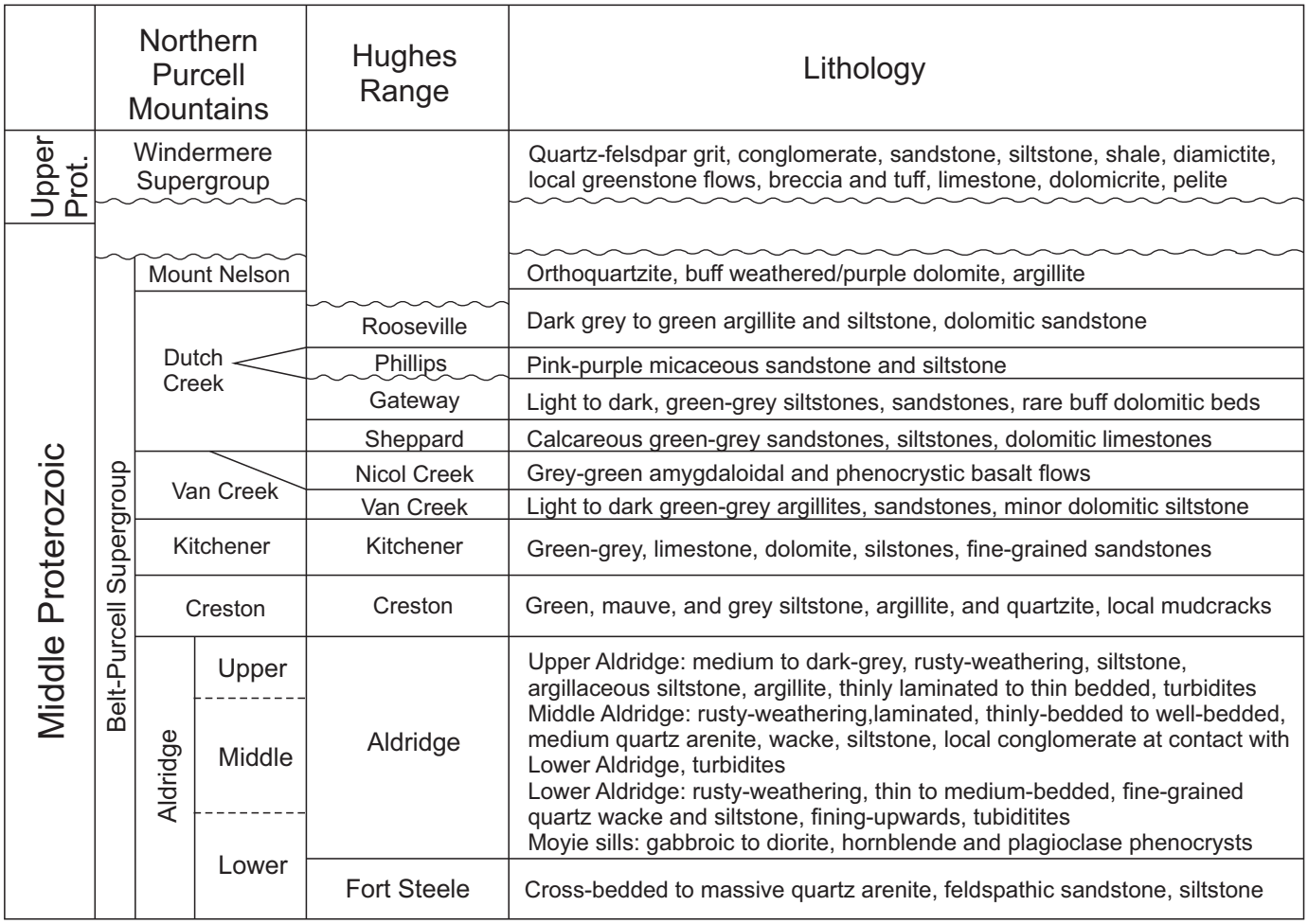


**Fig. 20.** Stratigraphy of the Belt-Purcell Supergroup. Modified from Hein, et al (2012).

style sulphide mineralization in dolomites of the Mount Nelson Formation (Fig. 20), and structurally related polymetallic Ag-Pb-Zn veins.

The Purcell Supergroup is unconformably overlain by the Neoproterozoic Windermere Supergroup (Fig. 22), which outcrops at the northern end of the Purcell Anticlinorium. Deposition of the Horsethief Creek Group and the overlying Hamill-Gog Group appears to be related to two main phases of rifting, with 2-3 km of strata eroded from parts of the succession by the sub-Lower Cambrian unconformity (Aitken, 1969; Simony and Aitken, 1990). Deposition may have been locally affected by small- and large-scale structures, including the 'Windermere High', which was a northwest-trending offshore high that developed south of 53°N (Hein and McMechan, 2012). The Windermere Supergroup hosts limited syngenetic manto-style replacement, MVT, and polymetallic vein mineralization, mainly along north-trending faults.

The Geological Survey of Canada (GSC) is conducting a multi-year project in the area as part of the Targeted Geoscience Initiative (**TGI-4**). The main focus is to develop geoscience knowledge and techniques to better understand and model SEDEX mineral systems, and mineral potential in the Purcell anticlinorium. Geological, geophysical, and geochemical data throughout the Purcell Basin are being compiled into a database, in order to generate a regional 3D digital model and maps over a large area of the Purcell anticlinorium, and give new perspectives and understanding on ore controls. The project is still underway, but preliminary releases include results of magnetic susceptibility studies and geophysical perspectives of the Purcell anticlinorium (Thomas, 2012; Thomas, 2013), a magnetic susceptibility study of the Moyie anticline (Thomas, in press), and magnetic contribution to 3D crustal modelling in the Purcell anticlinorium, (Thomas, et al., 2013). The geology and geochemistry of Ag-Pb-Zn veins (Paiement, et al., 2012), and carbonate-hosted nonsulphide Zn-Pb mineralization (Paradis, et al., 2011), evaluations of SEDEX concepts in the Cordillera (Paradis and Goodfellow, 2012), and zircon ages from units on the western margin of the Purcell Basin (Lydon and van Breeman, in press) are also parts of this project. Preliminary interactive digital maps and data (Joseph, et al., 2011) have been released, along with concepts on 3D modelling and interpolation of geological surfaces (Hillier, et al., 2013) and strike and dip observations (Hillier, et al., 2013), which will contribute to concepts applied to the digital

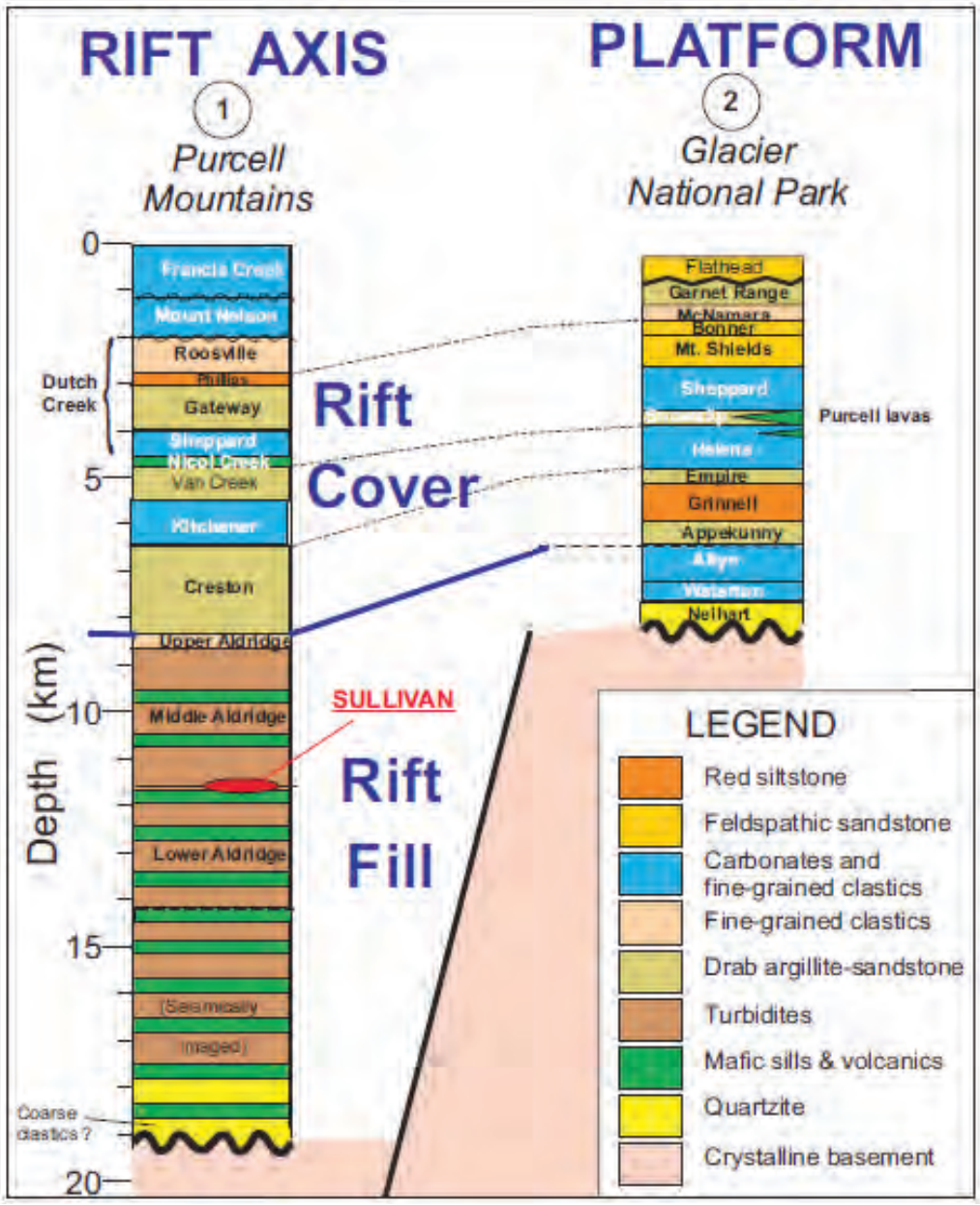


**Fig. 21.** Stratigraphic correlation and comparison of average thicknesses between units of the rift-fill, rift-cover, and platform successions in the Belt-Purcell Supergroup. From Lydon (2007).

modelling.

GeoscienceBC's **SEEK** project (Stimulating Exploration in the East Kootenays) is a partnership program with the East Kootenay Chamber of Mines focused on mineral potential in the Belt-Purcell Basin. Ground geophysical data have been compiled for the region into a single database (Sanders, 2012; Hartlaub, 2013), and in 2013 new data were added in the St. Mary Valley area, near Kimberley and the historic Sullivan mine (Sanders, 2013). In 2014, SEEK projects included a paleomagnetic study on structures in the Northern Hughes Range (Clifford, 2014; Ransom, in press), geological mapping and compilation along the Kimberley Gold Trend (Seabrook, in press), and mapping of vent systems and sub-basins in the middle Aldridge Formation near Cranbrook (Kennedy, in press). Funding also supports the Fort Steele Drill Core Library Project, which is managed by the East Kootenay Chamber of Mines. The project aims to develop a secure repository to preserve some of the East Kootenay drill core, including core from the Sullivan mine.

### 5.1.1. Exploration projects in the Purcell Anticlinorium

Purcell Basin minerals Inc. is working to restart the **Gallowai Bul River** mine, which has been on care and maintenance since 2009.The property is hosted in fault-bounded blocks of

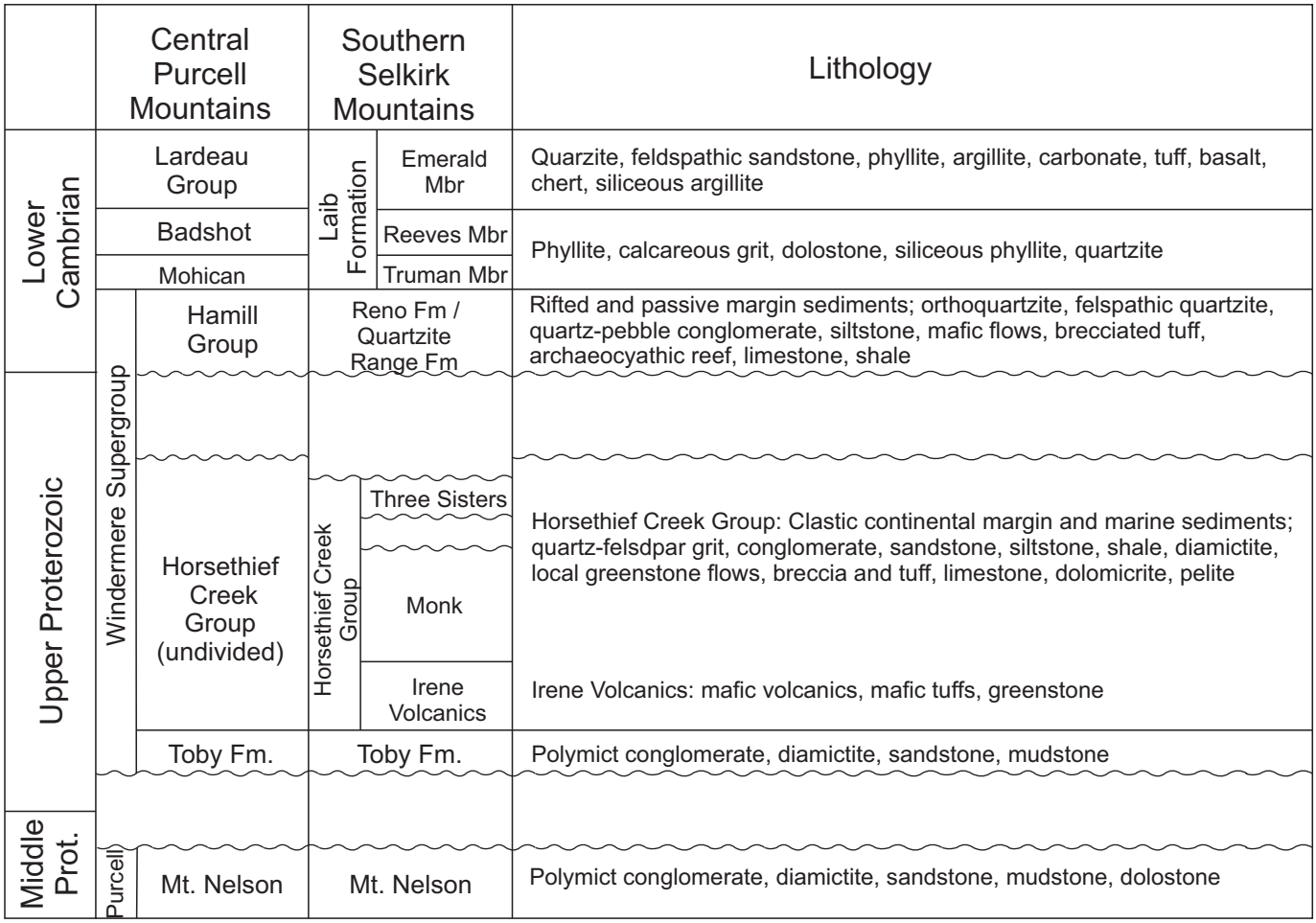


**Fig. 22.** Stratigraphy of the Windermere Supergroup. Modified from Hein, et al. (2012).

the Aldridge Formation. Cu-Ag mineralization is in a network of east-west trending, near-vertical, sulphide-bearing quartz-carbonate veins, in sheared and brecciated host rocks. The main vein structure and stringer zones range from a few cm to >30 m wide. Mineralization occurs as pyrite, pyrrhotite, and chalcopyrite, with minor galena, sphalerite, arsenopyrite, cobalite, and traces of tetrahedrite and native gold. The historic **Dalton** mine operated between 1971 and 1974, and produced 7,260 t of Cu, 6,354 kg of Ag, and 126 kg of Au from 471,900 t milled (BC MINFILE) from open pits. The property has existing infrastructure, including a 750 ton per day conventional mill, assay and metallurgical laboratories, tailings impoundment, waste dumps, and two open pits. The company has been completing environmental baseline work and updating mine plans.

MMG Ltd. continued geological and geophysical work on the **Findlay** property, which is underlain by Purcell Supergroup rocks and Cretaceous intrusions. Targets include the contact between the lower and middle parts of the Aldridge Formation (Fig. 21) and other exhalative-style, stratabound mineralization and alteration, including tourmalinite (boron) horizons, sedimentary breccias, and anomalous Pb-Zn-Ag-Sn-Cu. This part of the Purcell Basin is at the northern extent of the Sullivan-North Star structural corridor, a north oriented graben that hosts the Sullivan ore body (Price, 1981). The property also exhibits polymetallic veining, and hosts the historic Silver Key mine (MINFILE 082KSE053) which produced from structurally controlled polymetallic (Ag-Pb-Zn±Au) quartz veins in lower parts of the Aldridge Formation. In 2013, mapping, sampling and ground geophysics (AMT survey) was completed on the far west **Middle Fork Creek** and the northeastern **Phoenix** areas. The middle Fork Creek area hosts a thick fragmental package with disseminated syngenetic pyrrhotite, banded tourmaline, massive pyrrhotite, and sphalerite mineralization. Tourmaline-rich quartz veins crosscut Moyie sills and middle Aldridge Formation rocks. In 2014, two holes drilled at the **Phoenix** failed to reach the target due to poor ground conditions.

In 2014, Santa Fe metals Corp. drilled three holes on the **Sully** property (Fig. 23), and expanded their gravity and magnetic surveys. They targeted two subsurface gravity anomalies in the Purcell Supergroup that were identified using surface surveys and a 2012 downhole TDEM survey. Mass modeling of the anomalies is consistent with contrasting specific gravities of sulphide mineralization, relative to the country rocks. Recent


**Fig. 23.** Drilling at the Sully property.

mapping and drill-hole correlations suggest that the anomalies may represent fault repetition of an upturned stratabound horizon in the Aldridge Formation. Drilling has intersected traces of Pb-Zn-Cu sulphide mineralization and sericite alteration. The company intends to continue exploration in 2015 with further drilling and gravity and magnetic surveys.

PJX Resources Inc. continued work in 2014 at the **Vine** property, drilling one diamond drill hole, infilling their gravity grid, and updating their geological-geophysical model. The gravity modelling has identified two target areas that are interpreted to be massive sulphide mineralization (Pb-Zn-Ag±Au) in the Aldridge Formation. Close to the gravity targets is the shear-related **Vine Vein** (Pb-Zn-Ag-Au) occurrence, which was discovered in the late 1970s in middle Aldridge Formation argillites and quartzites. Historic trenching and drilling revealed vein-related and disseminated sulphides (pyrite, sphalerite, and galena) along a strike length of over 1000 m and at depths of over 700 m. Bedded massive sulphides were intersected 700 m deep in two historic drill holes at the Vine vein, and a more recent gravity survey identified a 2 x 4 km anomaly east of the two historic holes. This gravity anomaly has been the focus of work by PJX, who plan further drilling early in 2015.

Santa Fe Metals Corp. has begun work on the **Iron Range** property, where the Aldridge Formation hosts Ag-Pb-Zn±Au,Cu mineralization along the Iron Range fault zone, which consists of a number of north-trending faults along a 90 km strike length. Intense hydrothermal alteration, brecciation, tourmalinization, albitization, and fragmental rocks along the fault zone suggest periodic reactivation. The property is also underlain by felsic intrusive rocks, and some showings display hematization of magnetite, albite and chlorite and possible affinities with iron oxide-copper-gold (IOCG) mineralization. In 2014, Santa Fe Metals Corp. began data compilation and geological modeling and sampled for heavy mineral concentrates under an option agreement with Eagle Plains Resources Ltd.

In 2014, PJX Resources Inc. continued mapping and geochemical sampling at the **Zinger** property. Purcell Supergroup quartzites, argillites, and siltstones (Creston Formation; Fig. 20), argillites of the Kitchener Formation, and gabbro sills and dikes host gold in northeast-trending veins and shear zones adjacent to the Perry Creek fault. Veins occur as quartz stockworks and stringers with iron carbonate, sericite, and minor sulphides, including pyrite, galena and chalcopyrite. Soil sampling on two separate grids in the Gold Run Lake area encountered highly anomalous soil results for gold.

The **Ptarmigan** property (Fig. 24; Silver Mountain Mines Inc.) includes the past-producing **Ptarmigan** and **Iron Cap** occurrences. Mineralization occurs along north-trending steeply dipping normal faults and in massive sulphide replacements in carbonates (mantos), and generally consists of pyrite, galena, sphalerite, and tetrahedrite. The Ptarmigan mine consists of a series of adits driven along the fault contact between the Mount Nelson Formation (Belt-Purcell Supergroup) to the west, and the Toby Formation (Windermere Supergroup) to the east. Late Cretaceous intrusions may have provided a heat source for hydrothermal fluid enrichment and contributed to metal zonation, with faults acting as the conduits for metal-bearing fluids. Gravity data acquired on the **Ptarmigan/Iron Cap**, **Horsethief and Gopher Creek**, and **Nip and Tuck** grids, surface geochemical sampling, and subsurface drill results

**Fig. 24.** Ptarmigan Basin, looking northwest, near the historic Ptarmigan underground mine.

have been used to update geological modelling and identify targets. In 2013, the newly discovered **Dunwalk** anomaly was targeted by 3-hole drill program and the company released a NI 43-101 report. In 2014, drilling focused on the Ptarmigan mine area, and extended zones of known mineralization.

### 5.2. Kootenay Arc

The Kootenay Arc is a 400 kilometre-long curved belt of sedimentary, volcanic, and metamorphic rocks that lies between the Purcell Anticlinorium to the east, and the Shushwap-Monashee complex and the Quesnel terrane (Fig. 4; Reesor and Moore, 1971; Reesor, 1973) to the west. Deflection of the arc to a southwest trend near its southern end may reflect reactivation of basement structures along the Vulcan low (Fig. 4; Price, 1981). The Kootenay Arc includes Paleozoic to Mesozoic rocks of the Kootenay terrane and parts of the North American platform. In the north, metamorphosed oceanic assemblages of the Slide Mountain terrane (Milford and Kaslo groups) overlie Neoproterozoic to Lower Paleozoic pericratonic successions of the Kootenay terrane (Fig. 25; Fyles, 1967). Deposits include stratiform, laminated to massive sulphides, replacement-style Irish-type, Besshi-type, Cu-Zn-rich VMS, and boron-enriched exhalites (Nelson et al., 2013), and Mesozoic precious-metal and skarn mineralization. Some Pb-Zn deposits are Ordovician to Devonian, which is consistent with an epigenetic MVT rather than syngenetic origin (Simandl and Paradis, 2009). The Badshot Formation, a thick Cambrian carbonate unit, and its southern equivalent, the Reeves member (Laib Formation), host stratiform, laminated to massive sulphides, and replacement-style mineralization. The Laib Formation also hosts skarn mineralization in the Truman member. Overlying the Badshot Formation, the Lardeau Group (Middle Cambrian to Permian) comprises >3.5 km of graphitic phyllites, immature siliciclastic rocks, and mafic volcanic rocks, that are coeval with the shallow-water shelf deposits to the east (Logan and Colpron, 2006; Nelson, et al., 2013). Within the Lardeau Group, rift-basin, MORB, and OIB rocks host Besshi-type, Cu-Zn-rich VMS deposits, and boron-enriched exhalative horizons in the Index and Jowett formations (Nelson et al., 2013), and structurally hosted polymetallic breccias and veins.

#### 5.2.1. Exploration projects in the Kootenay Arc

The **J&L** gold-silver-zinc-lead property remained on care and maintenance in 2014, but Huakan International Mining

| | Northern and Central Kootenay Arc | | Northern and Central Kootenay Arc Lithology | Southern Kootenay Arc | | Southern Kootenay Arc Lithology |
|---|---|---|---|---|---|---|
| Mississippian to Permian | Marten Congl. | | Rusty-weathering greenstone conglomerate | | | |
| | Kaslo Group | | Ultramafic serpentinite, talc-schist, tholeiitic lava, flows, tuffaceous greenstone, cherty tuff | | | |
| | Milford Group | | Chert, shale, argillite, limestone, conglomerate | | | |
| Ordovician to Mississippian | Lardeau Group | Broadview Fm | Green-grey micaceous quartzite, fine-grained mica schist, conglomerate, pyroclastic rocks | | | |
| | | Jowett Fm | Mafic lavas, pyroclastics, argillite, limestone, chlorite and actinolite schist, dolomitic marble | | | |
| | | Sharon Creek Fm | Dark grey to black siliceous argillite, slate, phyllite, minor grit | Active Fm | | Black argillite, shale, argillaceous limestone |
| Mid to Upper Cambrian | | Ajax Fm | Massive grey quartzite | NelwayFm | | Grey dolomite and limestone, argillaceous beds |
| | | Triune / Alkoklex Fm | Grey-black quartzite, argillite, siliceous | Laib Formation | Upper Laib | Grey dolomite and limestone, phyllite, quartzite |
| | | Index Fm | Feldspar chlorite schist, mica schist, phyllite, quartzite, quartzo-feldspathic sandstone, argillite, limestone, volcanics | | Emerald Mbr | Black calcareous argillite, phylllite |
| Lower Cambrian | Badshot | | Grey and white crystalline limestone, dolomite, chert, siliceous dolomite | | Reeves Mbr | Grey / white limestone |
| | Mohican | | Limestone, dolomite, phyllite, mica schist | | Truman Mbr | Phyllite, argillite, limestone |
| | Windermere | Hamill-Gog Group | Orthoquartzite, felspathic quartzite, quartz-pebble conglomerate, siltstone, mafic flows, brecciated tuff, archaeocyathic reef, limestone, shale, phyllite | Reno Fm | | Blocky quartzite, micaeous quartzite, grey / black phyllite |
| | | | | Quartzite Range Fm | | White / grey quartzite, green phyllite, limestone |

**Fig. 25.** Stratigraphy of the Kootenay Arc. Modified from D.Grieve (pers. comm.).

Inc. continued pre-feasibility metallurgical test work (flotation, bio-oxidation, and pressure oxidation tests), baseline work, and mine design. The property is underlain by metasedimentary and metavolcanic rocks of the Hamill and Lardeau groups. Mineralization is hosted by the Hamill Group (Badshot and Mohican formations), which consists of sheared and intensely folded impure quartzites, quartz-sericite, sericite, and chlorite schists and phyllites, and banded carbonaceous limestones. The main Zone is a shear hosted, sheeted Au-Ag-Pb-Zn vein deposit that averages 2.5 m in thickness. Underground drilling and drifting has defined the zone over a 1.4 km strike length and 850 m down dip; on surface the zone has been traced for 1.6 km. The Yellowjacket Zone sub-parallels, and is in the immediate hanging wall of, the main Zone. Stratabound Ag-Pb-Zn is interpreted as a structurally controlled contact-related replacement deposit. An NI 43-101 resource estimate released in 2011 reported 722,000 ounces of gold in the Measured and Indicated categories.

The **Thor** property (Fig. 26; Taranis Resources Inc.) is underlain by a thick succession of folded and faulted rocks of the Badshot Formation and Lardeau Group, with potential for stratiform base metal sulphides (Ag-Pb-Zn-Au-Cu). Primary stratiform mineralization predates folding and faulting, and parallel horizons of galena, chalcopyrite, pyrite, and sphalerite extend along a 2 km strike length. High-grade gold is also found in late quartz veins that flank sulphide deposits. A number of targets have been identified on the property, including the **Scab**, **SIF**, **Gold Pit**, **Mega Gossan**, **West Limb**, and the **Ridge Target**, which appear as VLF conductors and gossans. In 2014, Taranis followed up on 2013 work with EW-sized core drilling at the **SIF** zone, where visible gold occurs in quartz-ankerite veins, and discovered mineralization at the **SIF Carbon** zone. An initial shaker table test from the **SIF Carbon** zone yielded a sulphide concentrate that graded 512.4 g/t Au and 540 g/t Ag. The company plans to conduct bulk sampling in 2015 at the **SIF** and **SIF Carbon** zones, and the **Broadview**, **Great Northern**, and **True Fissure** stockpiles. The NI 43-101 resource estimate (2013), based on drilling of 152 holes between 2007 and 2008, highlights both open-pittable (62% of the property) and underground mining projects. Historic production on the property was from the Silvercup, Triune, Nettie L. and True Fissure mines.

In 2014, Jazz Resources Inc. conducted metallurgical testwork at the **Teddy Glacier** property, which has been intermittently explored since the 1920s. The property is underlain by tightly folded and sheared limestones, carbonaceous phyllites, and grits of the Index and Jowett formations (Lardeau Group, Fig. 25). Mineralization occurs as a series of irregular Ag-Pb-Zn±Au polymetallic veins at the **Big Showing**, **East Vein**, **Dunbar Vein**, and **West Vein**. The **Vimy Ridge** stratabound zone exists as massive galena-pyrite-chalcopyrite in a silicified limestone at a schist-limestone contact (Shearer, 2007).

In 2014, Margaux Resources Ltd. released an NI 43-101 report and conducted a drill program at the **Jersey-Emerald** property (Fig. 27), targeting tungsten and gold mineralization at the **Emerald**. The property is underlain by interstratified carbonates and pelites of the Laib (Cambrian) and Active (Ordovician) formations (Fig. 25). Coarse-grained marble to garnet-pyroxene skarn occurs in the Truman and Reeves members at contacts with small Cretaceous granitic stocks, and Nelson (Jurassic) intrusions. The property contains: stratiform lead-zinc mineralization; tungsten (with minor

**Fig. 26.** Sampling at a gossan zone on the Thor property.

**Fig. 27.** Skarn mineralization at the Jersey Emerald.

molybdenum) skarn mineralization; quartz veins, silicified limestone, and greisen-type alteration with Au, and Bi; and molybdenum porphyry. Exploration on the property dates back to the late 1800s, when gossanous outcrops were discovered by prospectors. The **Emerald** Tungsten mine is a stratabound Pb-Zn deposit with a tungsten skarn, and operated from 1942 to 1943, then intermittently until 1973. The **Jersey** mine is a stratiform Pb-Zn deposit that operated between 1949 and 1970.

### 5.3. Quesnel terrane, Okanagan sub-terrane, and Mesozoic intrusive suites

Exotic terranes that accreted to the western margin of North America are exposed in the southwest part of the Kootenay-Boundary Region. The area has a rich mining history that dates back into the 1800s (Fig. 28). Mineralization occurs as Ag-Pb-Zn±Au,Cu polymetallic vein; shear-hosted, stockwork and breccia deposits; replacement-type base metals; Cu-Au-Ag and base metal skarns; porphyry Cu-Mo; alkalic porphyry Cu-Au-Ag; Au-Ag epithermal vein; Zn-Pb bearing mesothermal quartz veins; and precious and base metal massive sulphides.

In the Kootenay-Boundary region, the Quesnel terrane and Okanagan sub-terrane (Figs. 1, 4, 29) consist of: upper Devonian to Permian cherts, siliciclastic rocks, and basalts (Harper Ranch, Attwood, and Mount Roberts groups) and paragneiss, orthogneiss, cherts, siliciclastic rocks, phyllites, greenstones, ophiolites, and serpentinites (Trail Gneiss, Knob Hill, and Anarchist Group); coeval volcaniclastic rocks, pelites, and carbonates; Upper Triassic to Lower Jurassic volcanic arc rocks (Rossland and Nicola groups); Triassic siliciclastic rocks (Brooklyn and Slocan groups); and Mesozoic to Tertiary intrusions (Kuskanax, and Nelson batholiths; Bayonne magmatic suite; Coryell, Airy, and Ladybird intrusions).

**Fig. 28.** Historic smelter near Greenwood.

In the Slocan, Nelson, and Rossland areas, Ag-Pb-Zn vein, polymetallic Ag-Pb-Zn±Au, breccia, shear-hosted, and replacement deposits are hosted by rocks of the Rossland, Slocan, and Ymir groups, and thought to be genetically related to the Kuskanax and Nelson intrusions (Middle to Late Jurassic). Mineralization commonly occurs at or near deformed contacts. The intrusions are predominantly granite and granodiorite in composition, but have local diorite, monzonite and syenite phases (Armstrong, 1988), commonly with local zones of intense deformation around their margins. The Middle to Late Jurassic intrusive suite comprises syn- to late-tectonic plutons that were emplaced during accretion of Quesnellia (Monger et al., 1982).

Cretaceous intrusions of the Bayonne magmatic belt (Fig. 4) were emplaced inboard of the main magmatic arc in continental margin rocks. They are generally intermediate to felsic alkalic to calc-alkalic, including peraluminous, subalkalic hornblende-biotite granodiorites, highly fractionated two-mica granites, aplites, and pegmatites. Mineralization related to the suite includes Mo-Au±W-quartz veins; W-Cu-Au skarns; Au-Ag-Bi-Cu-Pb fault-veins; and Pb-Zn-Au-As-Sb±W quartz-carbonate veins (Logan, 2002), with a low concentration of base metals and sulphides. At the southern end of the Bayonne magmatic belt, and along northeast-trending faults related to the Vulcan Low, are magmatic-hydrothermal mineral deposits (Fyles and Hewlett, 1959).

Intrusions emplaced during regional Tertiary extension include the Coryell suite of alkalic plutons (with local extrusive equivalents) and stocks of granite and augite-biotite syenite and monzonite. Alkalic intrusives have been the focus of considerable exploration for epithermal mineralization. Tertiary biotite, feldspar, hornblende and augite lamporphyre dikes are commonly along fractures, faults, or prominent foliation planes (L. Caron, pers comm, 2014). Some Tertiary faults expose Proterozoic crystalline basement (Kettle River and Valhalla metamorphic core complexes) in their footwalls.

#### 5.3.1. Projects in the Quesnel terrane, Okanagan sub-terrane, and Mesozoic intrusive suites

Klondike Silver Corp.'s **Slocan Silver** Project (Fig. 1) consists of several past producers in a rich historic Ag-Pb-Zn mining area. The area is underlain by sheared and brecciated argillite and slates of the Slocan Group (Triassic; Fig. 29) that are cut by Nelson granodiorite and quartz monzonite dikes (Middle Jurassic; Fig. 4). Shear-hosted polymetallic veins contain Ag-Pb-Zn mineralization. Klondike's holdings include the Sandon, Hewitt, Silverton Creek, Cody Creek, Payne,

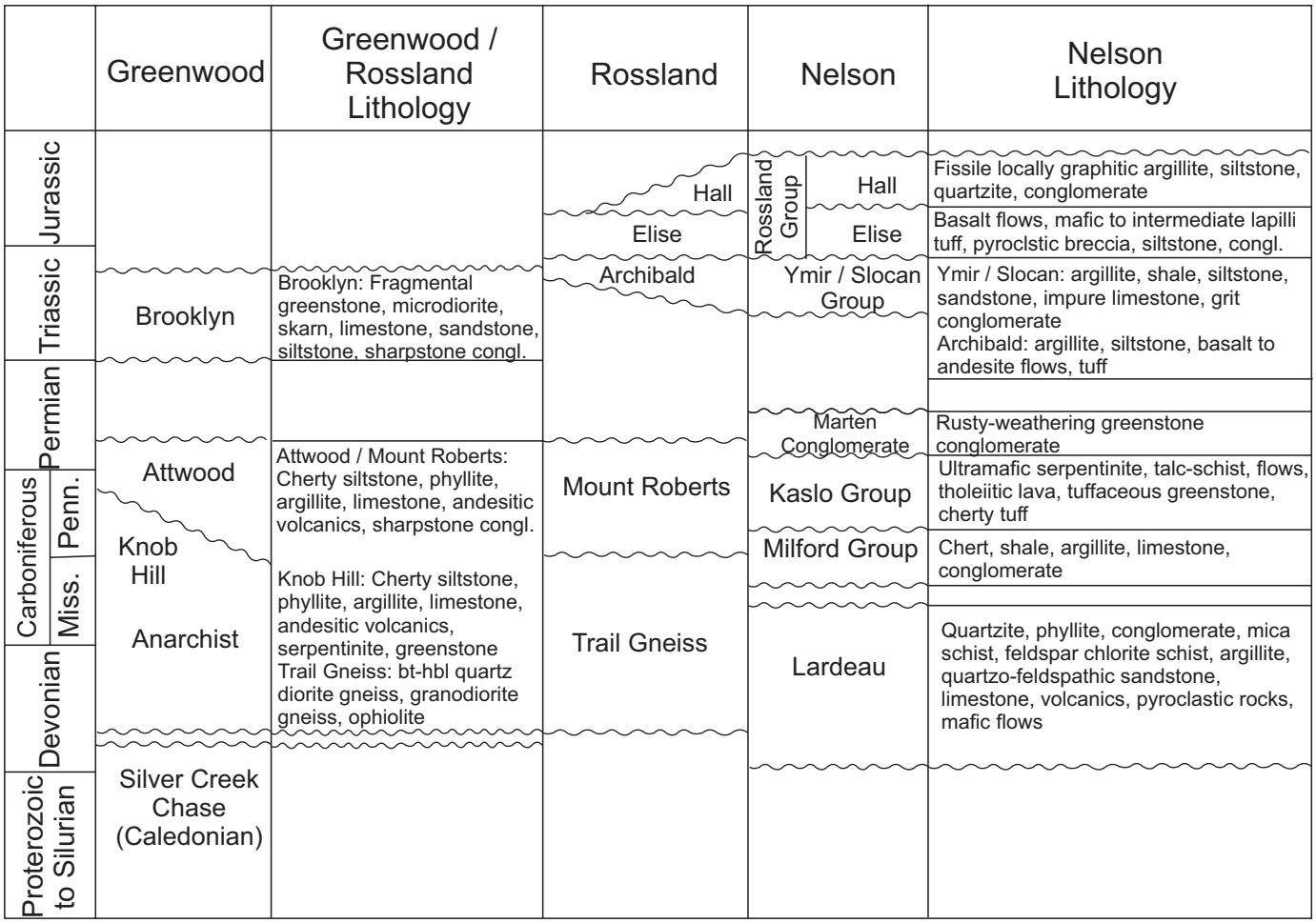


**Fig. 29.** Stratigraphy of Quesnel terrane and the Okanagan sub-terrane. Modified from Colpron et al. (2009).

and Jackson Basin camps, and the **Silvana**, **Wonderful** and **Hinckley** past-producers. The main vein at the **Silvana** is an 8 km long structure that yielded about 242 t Ag, 28,691 t Pb, 26,299 t Zn and 72 t Cd from 510,964 t mined between 1913 and 1993, mainly as argentiferous galena and sphalerite. The company's mill at Sandon is a 100 t/day concentrator that operates at an average rate of 40 t/day. It was shut down in the latter half of 2013 as the company re-evaluated geological modelling and furthered exploration targets. In 2014, the mine and mill remained on care and maintenance, and the company focused on baseline environmental and engineering studies.

Discovery Ventures Inc. is proposing to reopen underground workings on the **Willa** property, and produce ore for processing at the **MAX** mill, 135 km to the west near Trout Lake. The **Willa** has been on care and maintenance since 2005. The deposit is in a roof pendant of the Nelson batholith, containing mafic volcanic rocks of the Rossland Group, intruded by felsic dikes. To the north are Slocan Group metasedimentary rocks that contain silver-lead-zinc mineralization. Lamprophyre dikes and faults post-date and crosscut the metavolanics and intrusions. Mineralization (Pb-Zn-Ag-Au±Mo) is in structurally controlled silica-rich breccias, pipes and stockwork veins, with local massive- to disseminated, replacement zones. The main copper-gold mineralization is hosted in a sub-volcanic breccia pipe at the centre of a hypabyssal complex of quartz and feldspar porphyritic intrusions, and has an alkalic porphyry signature. Chalcopyrite, pyrite, and magnetite mineralization comprise three zones in, and peripheral to, the breccia pipe (Ash, 2014). The resource was updated in 2012, and in 2014, the company continued mapping, sampling, metallurgical testwork, and environmental baseline work. They also acquired an interest in the **MAX** molybdenum mine and mill, which has been on care and maintenance since 2011, and began repairs, maintenance, and modifications. It is estimated that the mine life will be about 4.1 years at mining and milling capacity of 500 t/day.

Magnum Goldcorp Inc. entered into an option agreement with International Bethlehem at the **LH** property. Mineralization follows a zone of fracturing, faulting, and silicification in a roof pendant of Slocan Group sedimentary rocks and Rossland Group metavolcanic rocks, in granodiorites of the Nelson batholith. Gold mineralization is in structurally controlled mesothermal quartz lenses and veins that are 0.6 to 7 m wide and can be traced along strike for over 70 m,, and in silicified

breccias and stockworks in hornfelsed volcanic rocks. Both styles of mineralization are associated with pyrite, pyrrhotite, arsenopyrite, and chalcopyrite. In 2014, the company completed SP and IP magnetometer surveys, and followed up with drill 4 holes. Results from the magnetometer survey suggest that the anomalies may indicate pyrrhotite, which has previously been correlated with elevated gold values in drilling.

In 2014, Sultan Minerals Inc. conducted a small mapping and sampling program on the **Daylight** property and discovered four new quartz veins and silicified zones carrying gold mineralization. The area is underlain by sheared and highly schistose augite basalt flows and subvolcanic intrusions of the Elise Formation (Rossland Group) that are cut by plagioclase-phyric rocks of the Silver King porphyry (Late- to Middle Jurassic). Northwest-trending shears host quartz veins with sulphides. Shear-zone mineralization occurs as vein, stockwork, and porphyry-style Au and Au-Cu. Quartz veins up to 0.9 m wide contain pyrite, chalcopyrite, with tetrahedrite and free gold. The property is 500 m north of the historic Silver King mine, which produced from the polymetallic Silver King Shear zone. Historic production on the Daylight property was from the Starlight, Victoria, and Daylight mines, which operated intermittently from 1937 to 1949 and produced mainly gold, silver, and copper.

In 2014, the **Kenville Gold** property was sold by Anglo Swiss Resources Inc. to a private company (0995237 B.C. Ltd.). Host rocks are the Eagle Creek plutonic complex (Jurassic) which may be co-magmatic with volcanic rocks of the Elise Formation (Rossland Group). Late Jurassic Nelson granodiorites, and Tertiary intrusive rocks are common in the immediate area. The property lies near the Silver King shear zone and hosts Au-Ag-Cu mineralization in a northwest-trending system of quartz veins, and Pb-Zn-Ag sulphide veins. An alkalic porphyry copper-gold signature may be associated with the intrusives. The principal mineralized veins found on the Kenville mine property strike northeasterly, average 0.6 m in thickness, and are traceable for at least 500 m. The past-producing Kenville mine, also known as the **Granite-Poorman** (Au-Ag-Pb-Zn-Cu), was the first underground lode gold mine in British Columbia, and operated intermittently between 1890 and 1954. In 2014, the company received permits for underground exploration work and drilling, began surface work, including a 3-phase power line extension to the site, and completed mapping and sampling. They have plans for bulk sampling and underground work.

Armex Mining Corp. optioned the **Yankee-Dundee** property from Duncastle Gold Corp. and began data compilation and geological mapping; drill permits are in place. The property includes numerous past-producing, high-grade mines including the two largest mines in the Rossland mining camp (Yankee Girl and Ymir). The property is underlain by Elise Formation volcanic rocks, and Ymir Group argillites and slates. Extending northeasterly through the central part of the property is a lobe of Nelson batholith granite with a diorite rind. Medium-grade metamorphism and hornfelsing of the sedimentary rocks occurs at the intrusive contacts. The area is strongly faulted, and the metasedimentary rocks are internally tightly folded, with a prominent north-trending foliation. Mineralization (Ag-Pb-Zn-Au) is hosted in the Ymir Group and Nelson batholith diorites in northeasterly trending veins and can be traced for over a kilometer. Mining from the **Dundee** and **Yankee-Girl** polymetallic veins started in the early 1900s, reached a peak in the 1930s and ceased in the early 1950s (Höy and Dunne, 2001).

In 2014, Riverside Resources Inc. drilled the **Swift Katie** property under an option agreement with Valterra Resource Corp. The property is underlain by volcanic and synvolcanic intrusive rocks of the Elise Formation, Jurassic to Cretaceous (Nelson) intrusions, Eocene intrusive rocks (Coryell), and Tertiary felsic to mafic and lamprophyric dikes. The property contains alkalic porphyry Cu-Au mineralization, with pyrite, chalcopyrite, bornite, pyrrhotite, sphalerite, tetrahedrite and chalcocite, and polymetallic (Pb-Zn-Ag±Au,Cu) shear-hosted quartz-calcite veins. In 2014, Riverside conducted soil geochemistry and drilled on soil and resistivity anomalies identified over a 1 km$^2$ area at the **Swift** target. Drilling tested for porphyry Cu-Au and intersected zones of potassic alteration (biotite and magnetite) and hydrothermal alteration (epidote, chlorite, calcite, pyrite and magnetite). Drilling also identified 20-40 cm wide Au-Ag-Pb bearing veins with pyrite-pyrrhotite-chalcopyrite at the contact between andesite and a diorite intrusion.

In 2014, Orex Minerals Inc. merged with Astral mining Corp. and acquired 100% ownership of the **Jumping Josephine** property. The property is underlain mainly by several phases of the Nelson and Coryell intrusive suites, which cut metavolcanic and metasedimentary rocks of the Mount Roberts Formation (Fig. 29). Vein and shear-related gold mineralization is hosted in northeast-trending brittle shear zones in Middle Jurassic monzonitic plutonic rocks. Exploration has also revealed skarn mineralization. Historic production (pre-1940) includes gold-silver and minor copper, lead, and zinc from several workings. Airborne TEM surveys, soil geochemistry, drilling, and trenching have identified several zones of mineralization. A resource was compiled at the **JJ main** zone in 2011, where mineralization is hosted in sheeted and stockwork quartz veins. In 2014, Orex drilled at the **JJ main** to extend the mineral resource, and reconnaissance holes tested additional prospects and showings at the **JJ main Extension**, **Golden Crown**, **BZT**, **Borrow Pit**, **JJ West**, and **Hillside** zones. Some of the historic trenches at the JJ main were also located and resampled.

In 2014, West High Yield (W.H.Y.) Resources Ltd. sampled at their **Rossland Gold** property. The **IXL**, **Midnight** and **OK** claims straddle the north-dipping contact between a Permian serpentinized ultramafic body to the south, and Rossland Group (Elise Formation) volcanic rocks and Mount Roberts Formation sedimentary rocks to the north (Fig. 29). The volcanic rocks are hornfelsed, with irregular zones of disseminated magnetite, pyrite, pyrrhotite, and local tungsten mineralization. Gold mineralization occurs in quartz veins near

the ultramafic contacts. Veins are typically 0.1-0.6 m wide, extend along strike for up to 70 m, and consist of quartz with minor ankerite, pyrite, chalcopyrite and galena. Mineralization also occurs in local areas of pyrrhotite-pyrite bearing carbonate-talc-quartz alteration and carbonate veining (listwanite-type) in the serpentinites. Dikes and irregular bodies of Rossland monzonite, Coryell syenite and biotite lamprophyres cut both the ultramafic and the volcanic rocks, and some of these are silicified and contain gold. Sampling in 2014 focused on reject rock piles of several historic mines. The property is also being evaluated for potential for magnesium and nickel in the ultramafic rocks. The company released a Preliminary Economic Assessment for their **Record Ridge** magnesium project in 2013.

In 2014, Ximen Mining Corp. conducted an excavator trenching program on the **North Star** and **Gold Drop** veins. The property is underlain by metamorphic rocks of the Knob Hill complex (Paleozoic) that have been intruded by granodiorite and diorite of the Nelson Plutonic suite and by biotite syenite and diorite/andesite dikes of the Coryell suite. Gold-bearing veins in the area post-date the Nelson intrusives and pre-date the Coryell suite. The Gold-Drop-North Star veins range in thickness from 10 cm to 2 m. North-trending, steeply-dipping strike-slip and normal faults, and low-angle detachment faults post-date mineralization (Caron, 2014)

Huakan International Mining Inc. re-acquired their **Greenwood** project (Au-Cu-Ag), which consists of the **Lexington-Grenoble** underground mine, the **Golden Crown** deposit, and the **Lexington** mill. The mill is a fully permitted 200 tonne per day gravity flotation mill and tailings facility for processing gold-copper mineralization from the Lexington underground mine. The project is currently on care and maintenance.

## 6. Outlook for 2015

Exploration and mining increased in 2014, and development is expected to continue on several of the larger and more advanced projects in 2015. Major mine development, expansion plans, and projects in the East Kootenay coalfields with long-term timelines will likely continue to advance, even as companies scale back exploration budgets in response to low coal prices. Base metal targeting in the Purcell Anticlinorium is expected to continue, with several drill projects planned for early in 2015, and base and precious metal mining projects around the Slocan remain active with some projects evaluating underground potential. Industrial minerals will remain a focus for the region.

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