Evaluation of 'Reduced' Intrusive-Related Gold Mineralization in the Area West of Cranbrook, Southeastern British Columbia (NTS 082F/08, 16)

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INTRODUCTION

Gold mineralization is widespread in the vicinity of Cranbrook in southeastern British Columbia but especially abundant some 5–30 km west of the town, where many significant Au prospects have been known since the 19th and early 20th centuries (Figure 1). Since then, several exploration campaigns have been undertaken in this area, resulting in the discovery of numerous Au occurrences and delineation of local small Au resources. Recent 'peaks' in exploration occurred in 2002–2004, when Chapleau Resources Ltd. conducted massive data compilation, prospecting and rock and soil sampling programs, followed by almost 7000 m of reconnaissance, structural and delineation drilling. In 2007–2008, Ruby Red Resources Inc. also undertook significant diamond-drilling. These studies identified many new mineralized showings and demonstrated styles of Au mineralization characteristic of proximal and distal intrusive-related settings. This contributed to a better understanding of likely intrusive-related Au mineralization in southeastern BC. Gold exploration continues in the area, making it worthwhile to summarize and interpret some of the existing data.

EXPLORATION HISTORY

Placer Au was first discovered in the East Kootenay region at Wildhorse River, Moyie River, Perry Creek and Palmer Bar Creek in the 1860s, resulting in a Au rush and construction of the town of Fort Steele. Although no reliable estimate of Au production exists, the Wildhorse River is believed to have produced more than $20 million in Au from placer mining, suggesting total Au production of approximately 1.7–2.5 million oz. (BC Ministry of Energy, Mines and Petroleum Resources, 1898). Significant placer Au production also occurred within the Perry Creek drainage and in the Moyie River basin. The East Kootenay region also underwent exploration for 'Sullivan-type' sedimentary-exhalative (SEDEX) Pb-Zn mineralization following the discovery of the Sullivan mine in the late 19th century.

The area west of Cranbrook has undergone multiple episodes of Au exploration, beginning in the early 20th century, that led to the discovery of numerous mineral prospects. Many historical workings are present in the area. The largest of them include adits, shafts and open cuts (now caved) at the Columbia vein (MINFILE 082FSE009; BC Geological Survey, 2009), Homestake (082FSE012), Shakespeare (082FSE119), Leader (082FNE060) and other higher grade Au-bearing quartz veins ('lodes'). More recently, lode Au exploration in the area included prospecting, soil sampling, very low frequency electromagnetic (VLF-EM) surveys, geological mapping, bulldozer trenching and sampling for heavy-mineral concentrates (e.g., Troup and Wang, 1981; Holcapek, 1982). Some of the larger quartz veins were drilled, but samples returned only sporadic (although locally high-grade) intercepts of Au (Ridley and Troup, 1984; Hardy, 1986). Drilling was also conducted on the Zeus claims to the east.

In 1985–1987, Partners Oil & Minerals Ltd. established the presence of a large and strong Au-in-soil anomaly near Gold Run Lake (Brewer, 1987). Also in the mid-1980s, the old Yellow Metal prospect was explored using soil geochemistry and ground geophysics (Mark, 1986). In 1993, Consolidated Ramrod Gold Corp. expanded the soil anomaly and established its relationship to a north-northeast-striking Au-mineralized vein–shear-zone system (Klewchuk, 1994). In 1999, more detailed surface prospecting and rock geochemistry established the presence of widespread anomalous Au in bedrock, associated with quartz-pyrite stockworks and breccias. This style of Au mineralization is distinctly different from the high-grade lode Au occurrences (Klewchuk, 2000). In 2000, National Gold Corporation expanded the soil anomaly in a northeasterly-trending zone measuring 3.5 km by 2.0 km (Klewchuk, 2000, 2001). Subsequent work established this occurrence as the Zinger prospect (MINFILE 082FSE122).

In 1983–1985 and 1990–1991, significant exploration was conducted on the Bar prospect (MINFILE 082GSW068), initially targeting its base-metal potential (McDonald, 1986) and then its Au (Leask, 1992) potential. A large multi-element geochemical anomaly was identified and follow-up trenching uncovered a series of Au-mineralized zones associated with strongly altered syenite dikes. Highlights of the trenching included 4.52 g/t Au over 26.0 m, including 7.42 g/t Au over 11.0 m, 3.08 g/t Au over 18.0 m, 2.09 g/t Au over 16.0 m and 1.54 g/t Au over 30 m (Leask, 1992). The Au mineralization was traced in trenches for 280 m along strike and remained open ended. In 2002, Chapleau Resources Ltd. generally confirmed the Au grades and intervals encountered in the trenches. In addition, an extension of the mineralized structure farther

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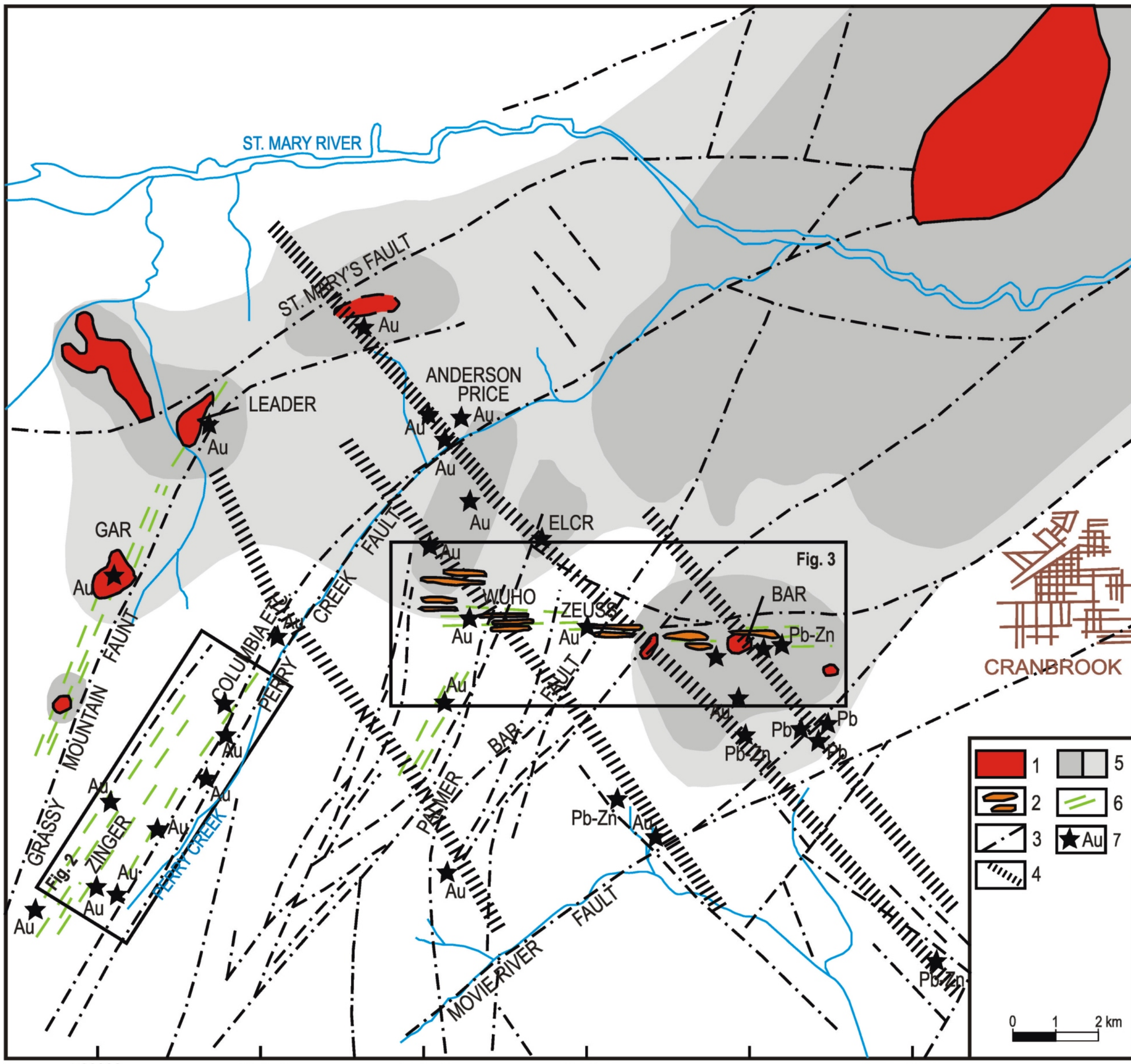

Figure 1. Geological setting of the Cranbrook area (compiled after Brown, 1998; BC Geological Survey, 2009), southeastern British Columbia, showing regional magnetic survey data (MapPlace, 2009). Legend: 1, Mesozoic (mid-Cretaceous ?) quartz monzonite to granodiorite and granite intrusive rocks (Bayonne plutonic belt); 2, syenite to quartz syenite dike (not to scale); 3, major fault zone; 4, suggested concealed fault (airphoto lineament); 5, strong and moderately strong positive magnetic anomaly (total magnetic intensity); 6, large zone of quartz veining; 7, mineral occurrence.

west and east was confirmed by surface rock sampling, establishing a total strike length for the mineralized structure in excess of 1 km (Soloviev, 2003).

In 2002–2004, Chapleau Resources Ltd. conducted significant exploration work on the majority of the prospects found in the area. Reconnaissance-style and detailed follow-up prospecting and rock geochemical sampling were conducted on the Bar, Zeus, ELCR (MINFILE 082FSE117), Wuho, Zinger, Gar (082FSE065), Leader, Lov and other prospects, covering a total area in excess of 650 km^2. Detailed prospecting was carried out on the Bar, Zeus, ELCR, Wuho, Zinger and Gar prospects. Grid soil-geochemical sampling was conducted on three prospects (Bar, Zinger and Zeus); on Zinger, the soil sampling covered an area measuring 18 km by 3 km. The Bar and Zinger prospects were drilled (7000 m in total). In 2007–2009, Ruby Red Resources Ltd. conducted another round of exploration, which included diamond-drilling, on the Gar and Zeus prospects (e.g., Ransom, 2006; Klewchuk et al., 2007). The drilling encountered Au and Cu mineralization in zones of intense hydrothermal alteration associated with the intrusive bodies.

DISTRICT GEOLOGY AND METALLOGENY

The Cranbrook area of southeastern BC lies west of the Rocky Mountain Trench within the Purcell Anticlinorium of the Omineca orogenic belt, a Proterozoic pericratonic terrane subjected to tectonic and magmatic activation (of distal subduction-related and/or anorogenic type) that occurred mainly in the Mesozoic (e.g., Hoy and Van der Heyden, 1988; Hoy, 1993). The area comprises an older (Precambrian) metasedimentary package and younger (Mesozoic) igneous suites.

Precambrian Metasedimentary and Igneous Rocks

The Cranbrook area is underlain by Mesoproterozoic terrigenous clastic, carbonate and minor volcanic rocks of the Purcell Supergroup that are believed to have been deposited in an intracontinental rift system (e.g., Hoy, 1993; Hoy et al., 1995; Lydon, 2007). They include the basal Aldridge Formation, composed of siliciclastic turbidites 4000 m thick and informally divided into the lower, middle and upper units. The lower Aldridge, the base of which is not exposed, comprises about 1500 m of thin- to medium-bedded argillite, wacke and quartzitic wacke, generally interpreted as distal turbidites. The Sullivan SEDEX orebody occurs at the top of this division (Lydon, 2007). The middle Aldridge contains about 2500 m of grey to rusty, dominantly medium-thick–bedded, quartzitic wacke turbidites with minor thin-bedded argillite, some of which forms finely laminated marker beds (time stratigraphic units correlated over great distances within the Purcell Basin). The upper Aldridge includes about 300 m of dark argillite and grey siltite. The Aldridge Formation is tectonically (?) overlain by the Creston Formation, consisting of quartzite and grey, green and maroon wacke up to 1800 m thick (Hoy, 1993). In turn, the Creston Formation is overlain by the Kitchener Formation, which includes oolitic limestone and dolomitic siltstone (Hoy, 1993). The Purcell Supergroup has been intruded by sills and somewhat discordant sheets and dikes of the 1443 ±10 Ma Moyie Sill suite, which are most prominent in the lower portions of the Aldridge Formation.

Mesozoic Plutonic Suite(s)

In the Cranbrook area, the Purcell Supergroup is intruded by a number of dikes, stocks and larger plutons of mostly granodiorite, monzonite and possibly syenite composition, which are assigned to the Mesozoic. However, their age relationships are not well constrained.

The larger intrusions, composed essentially of granodiorite, likely correspond to the mid- Cretaceous Bayonne plutonic suite. As defined by Logan (2002), this suite comprises monzogranite, granodiorite, biotite granite and biotite-muscovite granite. The Bayonne suite intrusions occupy north-northeast-trending corridors in the larger north-trending magmatic belt that roughly parallels the orientation of major Cordilleran structures in the region. These plutons include the Reade Lake stock (94 Ma, U-Pb method) in the northeastern part of the area (Figure 1) and possibly the Kiakho stock (122 Ma, K-Ar method) in the southeastern part of the Bar prospect (Hoy and Van der Heyden, 1988). These stocks are alkalic, with a relative enrichment of alkali elements within the Kiakho stock. Other likely Bayonne suite intrusions in the area include the large (at least 2 km by 1 km) granodiorite to granite stock outcropping on the Gar prospect (Grassy Mountain) and the large granodiorite stock in the Palmer Bar Creek area.

The airborne magnetic survey data (MapPlace, 2009) show the presence of a large positive magnetic anomaly surrounding the Reade Lake pluton and extending roughly northeastward. This suggests that the pluton has much greater dimensions at depth and that its emplacement or modification was controlled by the northeast- to north-northeast-trending lineaments (Figure 1). The smaller stocks are also accompanied by positive magnetic anomalies that trend northeastward. In general, most of the Au and other metal occurrences in the area are located proximal to the larger positive magnetic anomalies (Figure 1), thus emphasizing the intrusive-related nature of these occurrences.

A distinct set of intrusive units occupies east-trending zones within the area. These include swarms of parallel dikes or narrow intrusive apophyses adjoining larger intrusions at depth (Figure 1). The best exposed and most studied dike swarm is traceable for 10–12 km between the Bar, Zeus and Wuho prospects. The dikes are medium- to coarse-grained porphyritic syenite or quartz syenite characterized by large phenocrysts of potassium feldspar. Drilling on the Bar prospect has demonstrated a gradual transition of these dikes into medium-grained, weakly porphyritic quartz monzonite at depth (Soloviev, 2003). Apart from this, there is no direct evidence to constrain the relationships of these ‘dikes’ to other plutons in the area. It appears, however, that the north-northeast-trending structures hosting Au mineralization and controlling the Bayonne suite intrusions are younger than the east-trending structures hosting the dikes and associated mineralization.

Tectonic and Metallogenic Setting

The oldest and best known metallogenic feature in the area is the SEDEX Pb-Zn mineralization preserved in the Mesoproterozoic sedimentary rocks. This mineralization includes the world-class Sullivan SEDEX Pb-Zn deposit, located north of the area, and a number of much smaller Pb-Zn occurrences that are hypothesized to correspond with this age and style of mineralization (Hoy et al., 1995).

Southeastern BC is underlain by continental-margin rocks of ancestral North America and various magmatic suites, suggesting it is a southern continuation of the metallogenically significant Tintina Au belt of Yukon-Alaska. This was originally pointed out by Lefebure and Cathro (1999) and Logan (2000, 2002), who emphasized that the Mesozoic (mid-Cretaceous) age and composition (mostly granodiorite) of the intrusions found in southeastern BC are similar to those of the Tombstone and other plutonic suites in the Yukon that are accompanied by intrusive-related Au mineralization. Extending the Au-W-Sn metallogenic province, or belt, 1600 km from the Yukon south to Salmo (Lefebure and Cathro, 1999; Logan, 2000, 2002) highlights the potential for similar mineralization in the Cranbrook area. This belt contains significant Au mineralization from the Cariboo and Cassiar camps along its entire length. In the south, the mid-Cretaceous Bayonne plutonic suite forms an arcuate metallogenic zone extending along the eastern edge of the Kootenay Arc from northwest of Salmon Arm through the Revelstoke, Golden and Cranbrook areas to beyond the Canada–United States border (Logan, 2002).

There are at least three structural trends in the Cranbrook area that control possible Mesozoic intrusive-related Au mineralization. First, the major north-northeast- to northeast-trending fault system that roughly parallels the orientation of the major Cordilleran orogenic belts extends through the entire area. This system includes a number of well-exposed faults (Palmer Bar, Old Baldy, Perry Creek, Dublin and Grassy Mountain) that cut and displace Mesoproterozoic rock sequences and Mesozoic intrusions. These faults appear to follow older faults, which control the emplacement of the Mesozoic stocks arranged as north-northeast- to northeast-trending chains and mostly corresponding to magnetic features, suggesting the presence of hidden intrusions at depth. In total, this suggests long-lasting activity on these faults. Fault and deformation zones with this orientation commonly host significant occurrences of Au-bearing quartz and quartz-sulphide veins and stockworks. Typically, native Au occurs in isolation in quartz or is associated with elevated abundances of pyrite, galena and chalcopyrite (e.g., Soloviev, 2004b).

Second, east-striking faults and airphoto lineaments are also common in the area, although these faults are typically less well expressed than the north-northeast- to northeast-trending varieties or have experienced less reactivation. One of the most pronounced east-trending features occurs in the central part of the area and is marked by swarms of porphyry dikes (quartz syenite to quartz monzonite to granite). Gold mineralization is associated with this structural trend. The Au-bearing zones are characterized by intense silicification, phyllic and argillic alteration, and quartz and quartz-sulphide veins and stockworks. Gold is commonly associated with elevated contents of As, Cu and locally Bi. Some larger quartz veins (up to 3–5 m thick) contain native Au with or without pyrite. Other smaller (?), east-trending zones are present elsewhere in the area (Figure 1).

The third structural trend is oriented to the northwest. It is expressed to a lesser degree, although it can be found to control some smaller granodiorite to granite stocks, relatively small deformation zones and swarms of quartz veins. This orientation is coincident with that reported for the Vine vein (MINFILE 082GSW050), which is interpreted to be Middle Proterozoic ‘Sullivan-style feeder’ mineralization (e.g., Hoy and Pighin, 1995), although its upper age limit is not constrained. It contains abundant arsenopyrite and lesser pyrrhotite, sphalerite and galena in a gangue assemblage of quartz, sericite, calcite, chlorite and minor albite. The fault zone hosting this vein can be traced to the Bar prospect, where similar Pb-Zn-As mineralization also occurs in northwest-striking zones that apparently overprint the east-striking Au mineralization. Other northwest-striking Pb-Zn-As (+Au+Ag) veins are common in the area, suggesting that they may be part of a district-scale vein system. Although hosted by Precambrian metasedimentary rocks, these base-metal veins may have formed in response to Mesozoic magmatism. Zonation of Au and base-metal mineralization in relation to the causative intrusion is well documented for intrusive-related mineralization (Hart, 2007).

In summary, these three fault systems have likely experienced reactivation to form an interconnected structural network that acted as permeable ‘conduits’ to localize the deposition of Au and associated minerals in the area.

LOCAL GEOLOGY OF SOME AU PROSPECTS

The most studied Au occurrences include the Zinger, Gar (Grassy Mountain) and Leader prospects from the north-northeasterly mineralized trends, and the Bar, Zeus and Wuho prospects from the easterly mineralized trends. Some of these mineralized trends correspond to distinct corridors of small intrusive stocks and dikes, probably marking the fault zones that controlled magmatism and mineralization. A north-northeast-trending corridor of small granodiorite to monzonite intrusions and the Grassy Mountain fault can be traced between the Gar and Leader prospects in the western portion of the area. Farther northeast, this corridor trends toward the large northeast-elongated Reade Lake intrusion. The smaller intrusions to the southwest of the Reade Lake body might be correlative satellite bodies. At least, most of these smaller stocks lie within the large positive magnetic anomaly surrounding the Reade Lake intrusion to the southwest. The Bar, Zeus and Wuho prospects follow a swarm of easterly-trending quartz syenite (?) dikes (Figure 1).

Gar (Grassy Mountain; MINFILE 082FSE065) and Leader (MINFILE 082FNE060) Prospects

These prospects cover a broad north-northeast-trending strip of highly deformed, altered and mineralized rocks that extends for 7–8 km along the western edge of the area. This mineralized corridor is coincident with a chain of granodiorite stocks and displays a variety of auriferous mineralization styles from quartz stockworks within the intrusions and in their proximity to shear-controlled quartz-sulphide veins in more distal settings.

In particular, the Gar prospect occupies the southern part of this corridor and is represented by intense auriferous quartz to quartz–Fe-carbonate–sericite–pyrite (locally with traces of galena) stockwork veins and larger quartz veins overprinting a 2 km by 1 km stock of granodiorite to granite and adjacent metasedimentary rocks with a coincident positive magnetic anomaly. The stockwork comprises several north-northeast-striking mineralized zones that are 100–150 m in width and traceable for more than 2–3 km along strike. About 250 rock samples, collected in 2001–2004 over a large part of the stockwork, returned values of generally less than 0.5–1 g/t Au, with several values in the range of 8–12 g/t Au. The zone of structural complexity and quartz veining corresponding to the mineralized zone encountered on the Gar prospect was traced farther southwest for a distance of 3–4 km (Soloviev, 2004b). In 2007, the Gar prospect was drilled by Ruby Red Resources Inc.; drilling encountered quartz veinlets in a stockwork overprinting quartz monzonite and containing up to 0.11 g/t Au over 1 m, and quartz-sulphide veinlets containing up to 3.0 g/t Au, 394 g/t Ag and 2.4% Pb, with minor Zn and Cu (Klewchuk et al., 2007). Ransom (2006) reported a strong Mo-in-soil anomaly coincident with the stock; rock sampling also revealed locally elevated Mo values in Au-bearing and Au-free quartz veinlets (Table 1).

To the north-northeast, the zone of quartz veining was traced for 2–3 km to the Leader prospect. This prospect is represented by a narrow (averaging 0.5 m) but extended (traced for 650 m), subvertical quartz-sulphide vein in the vicinity of a porphyry granite intrusive outcropping west of the vein. The vein contains abundant galena and chalcopyrite, along with pyrite and scheelite; it returned high Au values for its entire length, with numbers varying from 0.7 to 164 g/t Au, together with 10–1971 g/t Ag, 1.5–69.5% Pb and 6.8–10% Cu (Sookochoff, 1985). Another round of sampling in 2003 returned similarly high values: 12 of the 28 samples returned values exceeding 1 g/t Au, and six of them contained more than 10 g/t Au, the highest being 37.7 g/t Au. Many samples also returned high values of Pb (up to 19.4%), Ag (up to 675 g/t), Cu, Zn, Sb and elevated W (Soloviev, 2004b).

Zinger Prospect (MINFILE 082FSE122)

The Zinger prospect covers a broad mineralized corridor parallel to and 2–3 km east of the Gar and Leader prospects. It is apparently the largest Au prospect in the area; it incorporates numerous Au occurrences represented by auriferous quartz and quartz-sulphide veins and stockworks that are traceable for at least 8 km along strike as a continuous mineralized package some 2 km wide (Figure 2). This prospect occurs along the Perry Creek–Hellroaring Creek divide. Perry Creek is known for its large Au placers, whereas none occur on the western side of the divide. The prospect is underlain mainly by rocks of the Creston Formation and, along its extreme western edge, by the Kitchener Formation (Klewchuk, 2001; Kennedy and Klewchuk, 2002). The Kitchener Formation crops out west of the prospect along the Hellroaring Creek road, and the lowermost bedrock exposures in the western part of the prospect appear to be near the Creston-Kitchener contact. The Creston Formation consists mainly of laminated and thin-bedded argillite, medium-thick–bedded siltstone, and quartzite. A number of north-northeast-striking (i.e., bedding parallel) mafic dikes occur in the Creston Formation on the eastern flank of the prospect; however, some dikes extend into transverse east- and west-northwest-trending structures.

The major structural pattern of the prospect is defined by a series of parallel, north-northeast-trending (020) deformation zones that are roughly parallel to bedding and together form a thick and continuous package of sheared, faulted and mineralized sedimentary rocks. The deformation zones alternate with relatively less deformed and undeformed rocks, and often occur ‘en échelon’. Degree and expression of deformation also vary in different rock types: according to Klewchuk (2001), argillaceous units have responded to deformation in a more ductile manner, providing an abundance of thin continuous quartz veins, whereas quartzite and siltstone are often brecciated and form ‘crackle breccia’ units, with branching and merging, irregularly shaped quartz veins (Figure 3). Klewchuk (2001) described common small drag folds along the faults with west-side-up sense of the movement, suggesting thrust faulting. In addition to the linear stockwork zones, the deformation package also incorporates larger single shears striking north-northeast and typically dipping steeply to the east-southeast; they host large (up to 10–15 m thick) quartz and quartz-sulphide veins that are traceable for up to 1–2 km along strike.

The Zinger prospect incorporates at least three relatively more intensely mineralized sectors, referred to as the ‘Central Zinger’, ‘South Zinger’ and ‘North Zinger’ sectors, each exceeding approximately 1.5 km by 2.5 km in surface area. The structural settings and styles of mineralization are somewhat different among these sectors. In particular, the Central Zinger sector is characterized by development of an auriferous linear quartz stockwork (in the western part) and massive quartz-sulphide veins (in the eastern part), both trending northeast. Numerous (several hundred) outcrop grab and chip (including channel chip) samples returned highly anomalous Au values ranging from a few hundred parts per billion to several grams/tonne and locally up to 15–25 g/t. The South Zinger (‘Gold Run Lake’) sector is centred about 2 km south of the Central Zinger sector and is characterized by a strong Au-in-soil anomaly more than 2 km across. The Au-in-soil values locally exceed 1 g/t, with a peak at 50–300 ppb. Although most of the area is covered by overburden and intense vegetation, limited outcrops suggest the presence of a large auriferous quartz stockwork with minor development of massive quartz veins. Some of these veins returned values up to 5–15 g/t Au, with historical data reaching 3.9 oz./ton Au in grab samples. A notable feature of the sector is the presence of east-striking mafic (lamprophyre?) dikes and numerous east-striking quartz veins. Limited drilling on the Central and Southern Zinger sectors conducted in 2003 (Soloviev, 2004a) failed to intersect the ‘roots’ of the intense and often high-grade Au mineralization outcropping on the surface, but did encounter alternating sequences of low-grade auriferous and barren intervals. The North Zinger sector (‘Columbia-Homestake veins’) is centred about 3 km north of the Central Zinger sector and is characterized by predominance of massive quartz and quartz-sulphide veins, with only minor quartz stockworks. Four or five large, northeast-striking quartz-veined deformation zones have been identified to date; some of them were traced for 2–3 km, continuing the trend on the Central Zinger sector.

The Au-bearing and barren systems of quartz (quartz-sulphide) veining found on the prospect represent four or five different structural settings (Soloviev, 2004a). First, northeast-striking (about 020), vertical or steeply (70–85) northwest-dipping Au-bearing quartz-sericite (plus pyrite, Fe-carbonate and occasional galena and chalcopyrite) stringers, veinlets, veins and wider pervasive alteration and stockwork zones represent the most abundant mineralization. Locally, stockworks contain up to 50 stringers per metre and form broad (up to 30–50 m wide) and extensive (up to 300–400 m in strike length) zones. The stockworks contain the most intensive and consistent Au mineralization, grading from a few hundred parts per billion to several grams/tonne Au, although barren zones are also common. Visible Au is locally present. The individual stockworks are 10–30 m in thickness and extend 300–900 m downdip. These stockworks, situated en échelon and separated by barren intervals, can be combined into at least seven to eight larger mineralized ‘corridors’, some of which are 200–300 m thick and traceable for 1–5 km along strike.

Secondly, north-northeast-striking (about 020), vertical or steeply (70–85) west-northwest-dipping, massive quartz veins (with minor sericite, pyrite and Fe-carbonate) vary in thickness from 0.5–1 m to 10–15 m. Some individual veins exhibit significant strike extent (up to 150–200 m); a number of more prominent zones hosting these veins were followed for 3–5 km. The veins are often surrounded by quartz-sericite (plus pyrite and carbonate) stockworks. Locally, these veins contain galena, sphalerite (occasionally in high concentrations—up to 20–30% together with pyrite), tennantite-tetrahedrite and sporadic ar-

Table 1. Selected compositions showing geochemical signatures of various Au-bearing and associated assemblages from the Au prospects of the western Cranbrook area, southeastern British Columbia.

Sample	UTM		Element (ppm, except where indicated as %)													
	Northing	Easting	Au	Ag	As	Ba	Bi	Co	Cu	Hg	Mo	Ni	Pb	Sb	W	Zn
Gar:																
1	5484211	564012	<0.005	<0.2	<2	30	<2	1	3	<1	213	2	2	<2	<10	<2
2	5484218	560450	0.118	0.2	<2	10	<2	1	2	<1	3	1	100	<2	<10	54
3	5484213	560453	1.035	0.5	<2	40	27	7	32	<1	1	9	56	<2	<10	7
4	5484215	560476	0.549	<0.2	2	90	3	18	16	<1	1	16	12	<2	<10	42
5	5484215	560458	0.368	0.2	3	30	30	20	18	<1	8	9	31	<2	<10	7
6	5484222	560523	9.24	11.8	8	70	32	43	60	<1	52	19	95	<2	<10	18
7	5484214	560575	0.118	0.2	<2	80	5	4	29	<1	1	5	16	<2	<10	4
Leader:																
8	5489521	563522	6.73	675	299	600	2	12	8940	23	14	18	8160	1550	300	709
9	5489525	563523	23.3	185	120	480	10	10	9430	8	6	10	4.80%	650	200	685
Zinger:																
10	5476202	559800	14.4	16.8	2	100	<2	1	337	<1	1	2	57	<2	<10	4
11	5476182	559880	23.7	26.6	<2	20	<2	1	1165	<1	<1	2	76	<2	<10	4
12	5477855	559933	16.75	78.8	<2	170	5	3	3170	1	5	10	2.56%	8	<10	2120
13	5475834	559805	3.03	9.5	<2	190	<2	1	119	<1	<1	1	1850	<2	<10	136
14	5475805	560426	0.785	3	2	40	<2	2	191	<1	<1	3	52	<2	<10	4
15	5475602	560236	3.21	1	2	200	<2	2	8	<1	2	3	111	<2	<10	276
16	5475552	560205	0.289	1.1	2	30	<2	2	26	<1	<1	2	11	<2	<10	3
17	5475005	559223	2.11	0.6	<2	20	<2	<1	8	<1	<1	1	15	<2	<10	<2
18	5475631	561045	0.006	0.6	4	40	5	2	5	<1	1	2	26	<2	540	6
19	5475625	561040	0.007	<0.2	26	40	<2	6	6	<1	1	11	16	<2	150	34
20	5475003	558801	0.66	0.2	9	10	<2	7	9	<1	30	17	10	<2	<10	3
21	5474804	560925	<0.005	<0.2	<2	40	<2	4	4	<1	40	3	3	<2	<10	6
Columbia-Shakespeare-Homestake:																
22	5479555	564205	0.764	0.2	5	210	<2	13	2	<1	1	7	<2	<2	10	4
23	5479522	564253	8.35	0.5	44	60	2	82	9	<1	2	43	7	2	10	51
24	5479116	563533	0.186	<0.2	160	20	4	417	231	<1	11	28	261	32	20	107
25	5479851	563354	3.53	0.7	8	<10	<2	8	979	<1	1	43	527	<2	<10	6
Anderson-Price:																
26	5494508	570041	19.65	34.8	9	30	24	1	53	1	8	7	1.32%	11	<10	525
27	5494492	570045	25.1	23.6	<2	<10	29	1	15	<1	4	3	1.16%	17	<10	138
ELCR:																
28	5484513	574020	11.9	1.5	8	50	94	9	192	<1	2	16	123	108	<10	20
29	5484505	574010	8.21	0.8	4	30	184	5	129	<1	1	15	88	19	<10	7
Bar:																
30	5482312	577910	14.95	12.6	3490	50	12	52	80	2	4	13	1330	16	<10	535
31	5482330	577922	7.34	531	>10000	10	990	291	137	6	12	8	>30%	618	<10	638
32	5482375	577902	2.02	5	3010	50	<2	51	77	<1	5	16	1065	15	<10	626
33	5482406	577897	2.51	8.3	>10000	320	<2	47	113	<1	6	18	1440	41	<10	691
34	5482481	578277	16.85	40	2820	10	35	2	1185	<1	28	4	1.48%	36	<10	139
35	5482350	577781	9.36	2.5	133	20	5	11	64	<1	3	6	528	<2	<10	24
36	5482341	577855	0.847	2.5	26	10	<2	2	25	<1	1	4	311	2	<10	13
37	5482374	577801	98/281	1.7	85	10	3	8	41	<1	2	4	344	<2	<10	15
38	5482435	577415	4.36	5	6	20	<2	4	5	<1	1	7	4	<2	<10	8
39	5482373	577571	0.827	0.3	9	20	<2	11	2	<1	1	4	13	<2	<10	<2
Zeus:																
40	5482505	575215	391	42.8	188	40	21	14	343	<1	3	25	101	<2	10	11
41	5482512	575235	0.088	3.3	197	10	63	66	4650	2	2	15	18	<2	<10	13
42	5482522	575240	0.117	5.2	229	<10	115	101	7050	1	7	20	3	<2	10	10
43	5482515	575223	2.84	0.6	323	10	218	4	1665	<1	2	9	28	<2	<10	11
44	5482513	575213	0.036	1.8	105	<10	318	34	6010	<1	1	16	18	2	<10	9
45	5482506	575211	2.48	16.3	125	20	9	3	149	<1	3	8	5560	9	<10	53
46	5482505	575212	5.09	76.1	1435	10	32	20	3000	1	20	19	2.00%	61	20	426
Wuho:																
47	5482602	571720	158	19	<2	<10	<2	37	6	<1	<1	19	12	1	<10	10
48	5482650	571771	0.191	<0.2	4	60	<2	7	53	<1	2	8	42	4	<10	88
49	5482616	571712	0.097	<0.2	5	140	4	13	153	<1	<1	11	18	8	<10	176
50	5484074	571018	0.071	<0.2	1015	50	<2	34	10	<1	3	192	6	<2	<10	57
51	5484075	571005	0.431	0.4	3640	50	2	39	10	<1	3	132	9	<2	<10	33
52	5484071	571016	0.008	4.9	8	40	19	36	8230	<1	<1	40	5	<2	<10	110

senopyrite and chalcopyrite, although the sulphide content generally is low. Scheelite occurs locally. Visible Au has been identified in a number of veins and stockworks. Locally, the Au-bearing quartz stockworks and veins are superimposed on the gabbroic dikes or border the dikes. These massive quartz veins (‘lodes’) include the Columbia vein (MINFILE 082FSE009), which averages 9–12 m thick and contains Au values as high as 50.2 g/t but typically not exceeding 9–11 g/t. Another showing, called the ‘Homestake mine’ (MINFILE 082FSE012), is located east of the Columbia vein; it locally contains up to 96.5 g/t Au in grab samples and one drill intersection returned 9.5 g/t Au over 1 m. To the south, the Columbia vein can be traced to the Shakespeare vein (MINFILE 082FSE119), where values up to 32 g/t Au have been reported (Brewer, 1997), and then to the Petra vein (MINFILE 082FSE121). However, Au mineralization in these veins is typically erratic.

Other structural settings appear to have less importance in controlling Au mineralization. They include the north-northeast-striking (~020), flat to moderately (10–40) west-northwest-dipping quartz-hematite stringers that are typically very thin (~5 mm) and form a weak stockwork (locally up to 5–10 stringers per metre but usually less) spread throughout the property but relatively more intense in its southern portion. Usually, these stringers are barren but, in a few locations, they returned up to 6 g/t Au. Also, roughly east-striking (060–070), steeply (70–90) south-dipping quartz (plus pyrite) veins, typically narrow (0.5–5 m thick), were traced for up to 300–400 m along strike; they bear low Au values (50–100 ppb), with just sporadic enrichment up to 10 g/t in the intersections with the north-northeast-striking stockwork zones. Finally, the west-northwest-striking (290–320), steeply (70–90) south-southwest-dipping, quartz–chlorite–hematite–Fe-carbonate veins and veined zones, typically narrow (from a few centimetres to 5 m), were traced for more than 1000 m along strike; they are typically barren and appear to represent the latest mineralizing event. Significant displacements of the other (including Au-bearing) mineralized zones often occurs along these veins.

Bar Prospect (MINFILE 082GSW068)

The Bar prospect (Figure 4) is remarkable due to close spatial association of Au mineralization with an intrusion and the distinct structural control of its higher grade portion by a well-expressed low-angle fault (possibly thrust fault) zone. The prospect is underlain by the Middle Aldridge quartzite wacke and the Creston quartzite, intruded by the monzonitic Kiakho stock; the monzonite forms large outcrops on the northern side of the prospect and occurs in large boulders (rubble crops) on the southern side, suggesting that the pluton underlies the entire prospect. In addition, there are several east-striking dikes, up to 60 m thick and traceable for 1 km along strike, that follow a large fault zone. These dikes exhibit porphyry texture (with K-feldspar in phenocrysts) and are believed to be syenite or quartz syenite. As revealed by drilling, these syenite dikes adjoin (or are cut off by?) at depth a much larger pluton of weakly porphyritic to equigranular medium-grained rock visually similar to the Kiakho stock monzonite. Thus, they may be either just porphyry apophyses of the stock or older dikes preserved in the roof pendant.

The mineralization is closely associated with these syenite dikes and traceable on surface within a zone up to 60 m wide and extending for >1 km along strike. It is represented by dense quartz-sulphide stockworks and disseminations in strongly brecciated, gouged, phyllically (quartz–sericite–Fe-carbonate) and argillically altered quartz syenite (?) and adjacent sedimentary rocks. The altered rocks contain 5–10% finely disseminated sulphides (mostly pyrite and arsenopyrite); surface sampling of this material returned typically low to moderate values of 0.1–3.0 g/t Au, including 2.09 g/t Au over 16.0 m and 1.54 g/t Au over 30 m (Leask, 1992). The drilling indicated that the stockwork is present to a depth of at least 350 m; it forms a number of nearly vertical to steeply north-dipping zones up to a few tens of metres thick. The majority of drill intercepts on these stockwork zones returned low Au grades, typically 0.1–0.5 g/t Au over short intervals, which are much shorter than the total width of the zone (i.e., significant portions of the stockworks contain sulphides but no Au). Some of the stockworks exhibit a strong ‘nugget effect’; however, fine disseminated Au is also common.

In contrast, much higher grade Au mineralization is hosted by a low-angle fault, possibly a thrust fault, that dips moderately steeply (40–50) to the north and by a number of steeper ‘splays’ occurring along its hangingwall side (Soloviev, 2003). It is unclear whether this fault corresponds to the east-trending Cranbrook fault (previously believed to be a normal fault) or represents another (but also roughly east-striking) fault zone ‘superimposed’ on and displacing the Cranbrook fault. The low-angle fault cuts and displaces the intrusion, forming one of its contacts. The high-grade Au mineralization occurs in strongly brecciated massive quartz veins, often with intense cataclasis, that contain oxidized and gouged sulphides (mostly pyrite, with some galena, sphalerite and arsenopyrite), Fe-carbonate and sericite, and continues for ~150 m downdip before gradually pinching out; smaller ‘swellings’ are present in other parts of the structure. The best drill intercepts were as high as 10.3 g/t Au over 7.5 m, 15.3 g/t Au over 1.6 m and 38.0 g/t Au over 1.0 m; a strong ‘nugget effect’ is common. Remarkably, the highest grade Au mineralization in the low-angle fault corresponds to its intersection with a transverse, northwest-trending (310–320) fault zone that lies directly along strike from the alteration and mineralization zone on the Vine prospect (MINFILE 082GSW050). This structural intersection is consistently marked by abundant northwest-striking quartz-galena veins and corresponds to

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Notes: 1, Au-free, Mo-rich quartz veinlet; 2–7, auriferous quartz veinlets with trace sulphides (galena, etc.); 8–9, sulphide-rich quartz vein; 10–11, high-grade Au-bearing quartz veins; 12, auriferous quartz-sulphide veins; 13–21, north-northeast-striking Au-bearing quartz and quartz-sulphide stockworks and ‘crackle breccia’; 22–23, Au-bearing quartz veins; 24–25, Au-bearing quartz-sulphide veins; 26–27, high-grade Au-bearing quartz-sulphide veins; 28–29, high-grade Au-bearing quartz veins with minor sulphides; 30–34, Au-bearing quartz-sulphide veins (arsenopyrite, galena, chalcopyrite, etc.); 35–37, sulphide-poor quartz veins with coarse Au; 38–39, sulphide-free quartz veins and veinlets; 40–44, Au-bearing quartz-pyrite-bornite stockworks; 45–46, northwest-striking Au-bearing quartz-galena veinlets; 47–49, quartz and quartz-pyrite veins with coarse Au; 50–51, Au-bearing quartz stockwork with arsenopyrite; 52, Au-bearing quartz-bornite veinlets. Assaying by ALS Chemex, North Vancouver, BC using atomic absorption spectrophotometry for Au and inductively coupled plasma–emission spectroscopy for other elements.

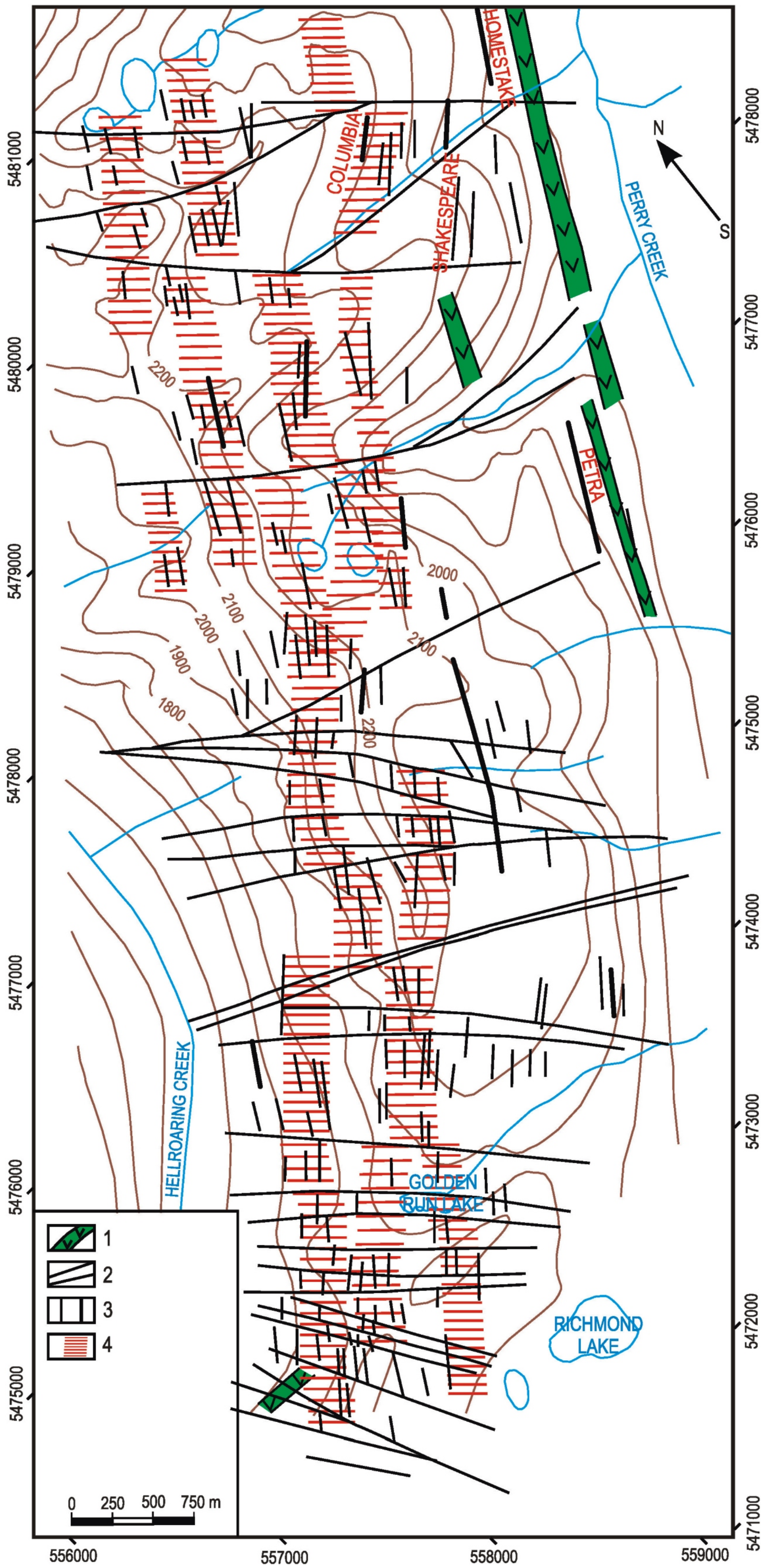

Figure 2. Geology of the Zinger and adjacent prospects (simplified after Klewchuk, 2000, 2003a, b; Soloviev, 2004a, b). Legend: 1, mafic dike; 2, fault zone; 3, zones of small and large quartz veins; 4, zone of auriferous quartz stockwork and silicification.

the widest portion of the east-striking mineralized zone, which is some 300 m in strike length. There are also thick massive quartz veins and zones of total silicification overprinting the brecciated rocks (Figure 3). Surface sampling of the mineralized material returned very high local Au grades (up to 98–281 g/t in rock grab samples and up to 7.4 g/t over 11 m in channel samples; Leask, 1992; Soloviev, 2003, 2004b). To the east and west, the mineralized zone splits into two or more parallel but narrower (<5 m thick) branches that are traceable for several hundred metres along strike; grab samples returned up to 15 g/t Au.

Zeus Prospect (Centred at UTM ~5482500N, ~575500E)

The Zeus prospect (Figure 4), located 2–4 km west of the Bar prospect, traces the immediate extension of the east-trending quartz syenite (?) dike and corresponding mineralized zone. The prospect incorporates a number of east-trending quartz syenite (?) dikes dipping 45 to the north; they are subjected to strong quartz-carbonate-sericite-pyrite and argillic alteration, and locally contain quartz and quartz-sulphide veins and stockworks. The latter are

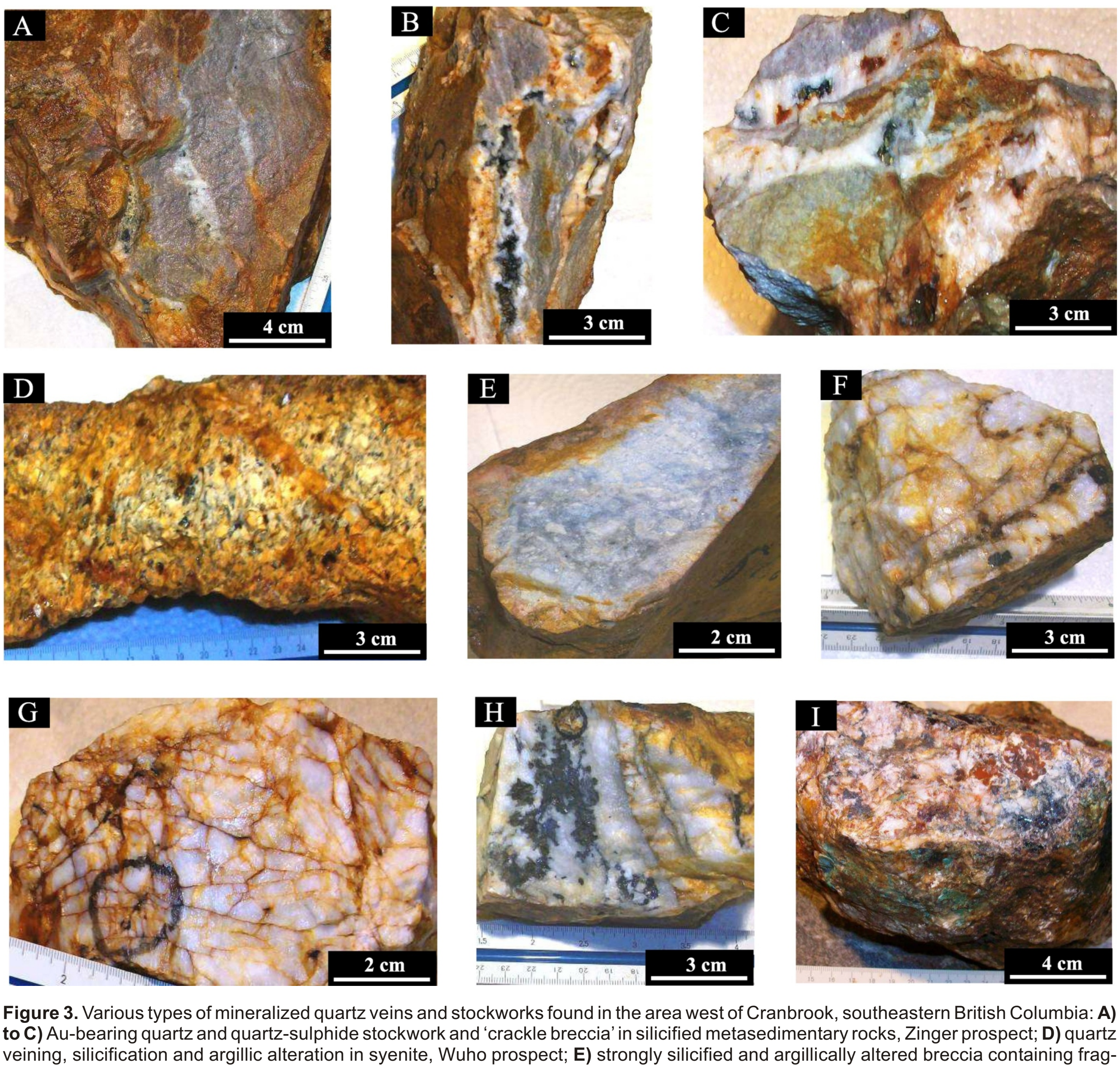

Figure 3. Various types of mineralized quartz veins and stockworks found in the area west of Cranbrook, southeastern British Columbia: **A) to C)** Au-bearing quartz and quartz-sulphide stockwork and 'crackle breccia' in silicified metasedimentary rocks, Zinger prospect; **D)** quartz veining, silicification and argillic alteration in syenite, Wuho prospect; **E)** strongly silicified and argillically altered breccia containing fragments of metasedimentary (?) rocks, Bar prospect; **F)** massive Au-bearing quartz vein with minor sulphides, ELCR prospect; **G)** massive quartz vein containing native Au with no association with sulphides, Anderson-Price prospect; **H)** massive Au-bearing quartz vein with elevated amount of sulphides, Anderson-Price prospect; **I)** massive Au-Ag-bearing quartz-sulphide vein, Leader prospect.

especially intense in those areas where the major east-trending zone is intersected by the northeast-trending district-scale Palmer Bar fault, associated with a 100 m wide mineralized zone, and by a northwest-trending fault similar to those observed on the Bar prospect and corresponding to the 'Vine vein' structural trend. These structural intersections control a number of more localized mineral showings, including the 'Quartz Pit' trench, yielding anomalous Cu, Ag and Au values (up to 10.8 g/t Au); the 'Horseshoe Pit', with massive galena samples returning 16.4 oz./ton Ag; the 'Pink Mountain' trench, yielding values up to 0.2% Cu; and the 'Quartz Float Train', with samples returning 0.01–0.258 oz./ton Au (Allen, 1984; Banting, 1988).

The drilling in 1988 identified a "large structurally controlled quartz-sulphide flooded zone along the Cranbrook Fault" (Banting, 1988), with some holes returning sporadic Au values up to 0.3 oz./ton over widths of 0.1–0.3 m and consistently anomalous Au values within the syenite dikes. The quartz-flooded zone also hosts elevated Cu values, with drill intersections of 1.4% Cu over 4.1 m and 0.57% Cu over 50.5 m. Rock sampling of quartz-pyrite-bornite mineralization with minor quartz-pyrite-galena stockwork, found in the 'Limonite pit', returned values up to 1.93 g/t Au over 2.3 m. Resampling of a 0.8 m portion returned a value of 381 g/t Au (410 g/t Au in check assay). Grid soil sampling revealed a number of other narrow, northwest-trending zones of anomalous Au values corresponding to the 'Vine vein trend' (Soloviev, 2003, 2004b). These northwest-trending zones are traceable to the ELCR prospect, located 3 km northwest of the Zeus prospect.

In 2007–2008, another drilling program returned 0.63% Cu over 57 m, together with elevated Bi (up to 130 ppm over 10 m) and Co (up to 304 ppm over 46 m). The elevated Co content corresponds to abundant pyrite in a zone of intense silicification, quartz-albite breccia, and quartz–Fe-carbonate–sericite and subsequent argillic alteration. The follow-up drilling in 2007 returned wide intercepts of elevated Cu values, with locally elevated Au (up to 3.7 g/t over 0.8 m), and the zone was interpreted to represent the uppermost parts of a buried porphyry system.

Eastern and Western Wuho Creek Areas (Centred at UTM ~5483000N and ~571500E)

The Eastern and Western Wuho Creek areas (unrecorded prospects) are located 2.0 and 4.0 km, respectively, west of the Zeus prospect (Figure 4). Both prospects cover the intersections of west-northwest- and north-northeast-trending faults, including the larger Old Baldy fault, with the east-trending structure controlling quartz syenite (?) dikes and mineralization of the Zeus and Bar prospects. A strong positive magnetic anomaly, measuring 2.0 km by 1.0 km, occurs between the Eastern and Western Wuho Creek prospects, suggesting a buried intrusion.

The Eastern Wuho Creek prospect contains abundant quartz syenite (?), quartz and quartz-sulphide float. Rock grab samples of quartz-pyrite float returned Au values of up to 2.99 g/t, 15.3 g/t and 158 g/t (Soloviev, 2004b). Interestingly, the third high-grade Au value was obtained from a series of ten samples taken from the same large quartz boulder, nine of which returned Au values below detection

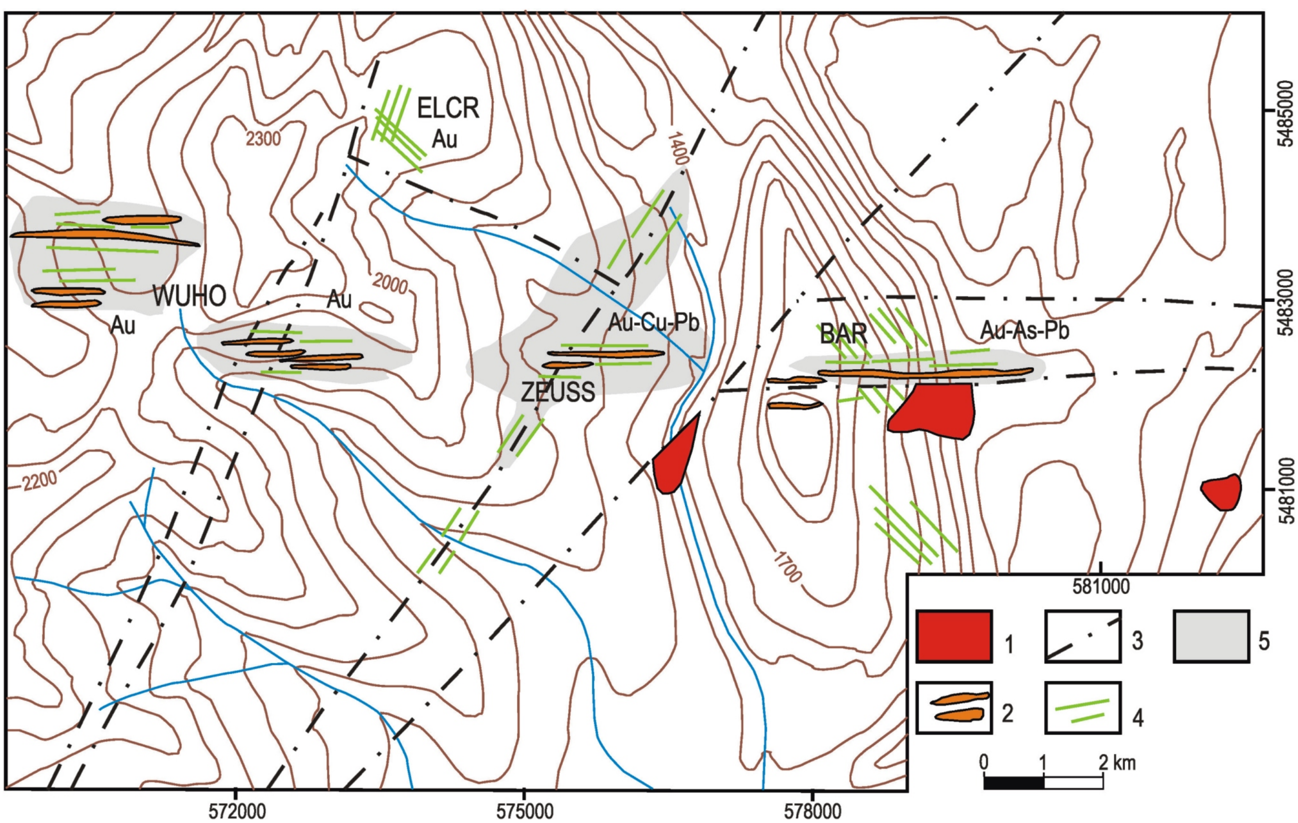

Figure 4. Geology of the Bar-Zeus-Wuho prospects: 1, Mesozoic quartz monzonite to granodiorite intrusions; 2, syenite to quartz syenite (?) dikes; 3, fault zones; 4, zones of quartz veining; 5, areas of hydrothermal alteration (silicic, phyllic and/or argillic alteration).

limit, thus indicating a very strong 'nugget effect'. Silt sampling of a 1 km long, south-flowing tributary of Wuho Creek, which flows through the prospect, returned extremely high values of 256 and 401 g/t Au, with associated high Pb values. Panning of larger silt samples revealed numerous fine- to medium-sized (up to 3 mm by 3 mm) free Au particles associated with abundant magnetite. Prospecting identified abundant quartz-galena float upslope. The Western Wuho Creek prospect covers a large (greater than 2 km by 1 km) area of abundant quartz syenite (?) float and rubble crop. Quartz syenite (?) boulders, some more than 2 m across, are strongly silicified and argillically altered, with strong limonitic staining, locally intense quartz stockwork and minor quartz-magnetite veins. The rocks contain 0.4–0.6 g/t Au; a sample of quartz-magnetite vein returned 2.6 g/t Au. The intersecting north-northeast-trending structure was traced by Au-bearing quartz float for a distance of 2–3 km. Sampling has also revealed substantial Cu mineralization (Table 1). In total, the Bar, Zeus and Wuho prospects, although possibly being divided by faults and less mineralized intervals, may be the expression of a single large (traceable for >10 km along strike) mineralized zone.

ELCR (MINFILE 082FSE117) and Anderson-Price (MINFILE 082FNE056) Prospects

These prospects comprise well-expressed 'structurally controlled' quartz and quartz-sulphide veins in the Proterozoic metasedimentary rocks. There are typically two structural settings for the veins on each prospect: both northeast- and northwest-striking veins are present, although the northeast-striking veins predominate. The veins usually occur en échelon, forming parallel swarms of two to three larger (up to 2–4 m thick) 'pivot' veins that locally pinch and swell (to the point of splitting into separate lenses) and are surrounded by a parallel series of much smaller veins and veinlets. At the Anderson-Price prospect, the quartz-vein zone occurs adjacent to a series of small northeast-trending granite dikes, whereas the ELCR prospect is coincident with a local strong positive magnetic anomaly measuring 1 km by 1 km (Figure 1). The Au mineralization is represented by native Au and is either associated with minor sulphides scattered through the quartz veins or occurs separately, strongly enriching selected parts of the veins (where Au grades range from many tens to a few hundred grams per tonne; Table 1).

GEOCHEMICAL SIGNATURES

As noted above, the Au mineralization found in the Cranbrook area is characterized by the presence of various mineral assemblages. The data presented in Table 1 illustrate some important geochemical features of these mineral assemblages.

These data show that at least four to five distinct Au-bearing mineral assemblages, and therefore compositional (mineralogical and geochemical) types of quartz and quartz-sulphide veins and stockworks, can be distinguished. They include

- a sulphide-free Au-quartz assemblage, containing coarse native Au with variable and often high Au:Ag ratios (1:1 to 10:1, up to 100:1) but only minute amounts of sulphides. This mineralization is present on the majority of the prospects studied. As a subtype of this assemblage, a pyrite-rich (5–20 vol. % pyrite) Au-bearing assemblage can be distinguished: it is characterized by elevated Co and Ni values associated with pyrite.
- an auriferous sulphide-rich (20–50 vol. % sulphides) assemblage containing abundant sulphides (especially galena) and occasional scheelite. It is enriched in Ag, with low Au:Ag ratios varying typically from 1:1 to 1:5, and often bears elevated Bi, Sb and Zn values. The geochemical data show that galena is common not only in large quartz-sulphide veins, but also (in minor concentrations) in Au-bearing quartz stockworks (i.e., on the Zinger, Gar and other prospects).
- a series of transitional assemblages containing moderate amounts (from 3–5 to 15–20 vol. %) of sulphides (and sulphosalts) and occasional scheelite. They are distinguishable by characteristic Pb-Zn-Ag (Anderson-Price prospect) or Cu-Pb-Sb (ELCR prospect) geochemical signatures, suggesting the presence of either galena or Cu-Pb sulphosalts (tennantite-tetrahedrite, etc.).
- another distinct sulphide-rich (20–50 vol. % sulphides) Au-bearing assemblage containing elevated Pb and Zn values and accompanied by high Ag and As contents. This assemblage, whose Au:Ag ratio is the lowest (up to 1:100), is present on the Bar, ELCR and Zeus prospects. It closely resembles that encountered on the Vine prospect and some other Pb-Zn prospects elsewhere in the district.
- a Cu-enriched (bornite-pyrite or bornite-chalcopyrite-pyrite) Au-bearing assemblage associated with altered quartz syenite (?) dikes or intrusive apophyses on the Zeus and Wuho prospects. The high Cu values are locally accompanied by elevated As and Bi values.
- Au-bearing mineralization that also has elevated Mo and/or W values (Gar, Leader, Zinger prospects); in addition, Au-free quartz-molybdenite veinlets are locally present in the vicinity of Au-bearing stockworks (e.g., Gar). The presence of these metals provides additional evidence for the intrusive-related character of the Au mineralization, even its distal varieties.

Of special importance is the presence of more than one Au-bearing assemblage on larger prospects. In particular, both sulphide-free and sulphide-rich assemblages are present on the Bar, Zeus and Zinger prospects. Locally, these assemblages may be accompanied by Cu-rich Au-bearing mineralization. This may suggest a long-lasting mineralization event, with the formation of several successive mineral assemblages.

STYLES AND STRUCTURAL SETTINGS OF GOLD MINERALIZATION

The best evidence for a relationship between intrusive-related mineralization in the Cranbrook area and the mid-Cretaceous monzonite and granodiorite of the ilmenite-type (or 'I-type') Bayonne intrusive suite occurs where the mineralization is spatially associated with an intrusion. The mineralization comprises Au-bearing quartz and quartz-sulphide (plus sericite, Fe-carbonate and locally barite) veins and stockworks containing pyrite and locally pyrrhotite, as well as other sulphides and sulphosalts, including arsenopyrite, galena, sphalerite, chalcopyrite and tetrahedrite-tennantite. Magnetite and hematite are typically absent, further suggesting the 'reduced' character of this mineralization. As previously noted, this style of Au mineralization was originally recognized in the region by Lefebure and Cathro (1999) and Logan (2000, 2002). A specific feature of this mineralization in the Cranbrook area is the association of Au with elevated Mo and W (rather than Sn and W) values.

The data obtained on apparent intrusive-related Au mineralization in the area west of Cranbrook make it possible to illustrate the variations in mineralogy and geochemistry that occur on prospects that formed in different structural settings. These structural and compositional varieties may include:

most proximal (?) Au-Cu-Bi-As (+Co+Ni) mineralization in close spatial association with dike swarms or small intrusive apophyses and stocks. This mineralization includes zones of intense silicification, phyllic and argillic alteration, quartz and quartz-sulphide (mostly pyrite) stockworks and possibly hydrothermal breccias.

more distal Au-Cu-Pb (+W) to Au-Pb mineralization, including quartz and quartz-sulphide stockworks (locally possibly evolving into hydrothermal 'crackle' breccias) and larger veins with minor to abundant sulphides and locally scheelite. No direct relationship to significant magmatic bodies is apparent, although rare felsic to mafic dikes may be in the area.

also distal 'structurally controlled', Au-bearing quartz veins and 'sediment-hosted' Au-bearing quartz stockworks, typically with minor sulphides and local scheelite. Veins and stockworks are localized in larger fault zones. The Au-bearing quartz and quartz-sulphide veins also display a strong structural control by larger fault zones and locally attain maximum thicknesses of 10–20 m and strike lengths on the order of a few hundred metres. Steeply dipping veins predominate, although flat-lying veins in low-angle faults (possibly thrust faults) and their splays have also been mapped. The veins are commonly found in close spatial association with gabbroic dikes (Moyie sills?) and/or with apparently younger mafic (possibly lamprophyre?) dikes, locally altered to listwaenite. The veins are characterized by massive quartz, lesser Fe-carbonate and traces of sericite. Gold is found in both finely disseminated and coarse (visible) form, and is often characterized by extremely erratic distribution.

most distal (?) Au-bearing Ag-Pb-Zn mineralization, typically represented by quartz-sulphide veins in fault zones and lacking any spatial association with magmatic bodies. These veins typically contain very little Au, but their occurrence in the same structures that host other types of Au mineralization indicates reactivation (opening) of these structures and possible further enrichment of Au.

The presence and possible significance of low-grade (typically around 1 g/t Au) quartz to quartz-sulphide (quartz–Fe-carbonate–sericite–sulphide) stockworks in the area was recognized recently (e.g., Klewchuk, 2001, 2003a, b; Soloviev, 2004a, b), and the potential of some possibly low-grade, bulk-tonnage Au occurrences remains unevaluated. The stockworks occur both within the intrusions (e.g., Gar prospect) and in sediments (Zinger prospect). In both cases, however, the stockworks trace some district-scale faults, controlling chains of intrusions, that were reactivated as post-intrusive faults. The overprinting of the intrusions and metasedimentary packages by these linear stockworks is especially visible at a larger scale. They consist of subparallel and intersecting quartz stringers forming stockwork zones that are lens-shaped, typically subvertical and situated en échelon, locally attaining maximum widths ranging from a few to several tens of metres and strike lengths of up to several hundred metres. Individual stockwork zones can be amalgamated into much wider (up to 100–200 m) and longer (up to several kilometres) quartz stockwork and alteration units that trace the fault zones. Locally, higher grade Au-bearing veins occur within the low-grade stockworks. The stockworks contain variable amounts of sulphides, mainly pyrite but locally with traces of galena and chalcopyrite; again, there is no correlation between the amount or type of sulphide mineral and the Au grade. Alternatively, some of the Au (Cu) occurrences in the area may be 'oxidized' porphyry Cu-Au deposits. The presence of Cu-Au porphyry mineralization has been suggested by Ransom (2006) for the Zeus prospect. In addition to its Cu-Au-As geochemical signature, Zeus mineralization has a close spatial relationship with probable alkalic (syenitic?) dikes, although the exact composition of these dikes requires further study. Another notable feature is the local abundance of magnetite (Wuho) and bornite (Zeus). The minerals are uncommon in both 'reduced' intrusive-related Au mineralization (e.g., Hart, 2007) and 'reduced porphyry Cu-Au' (RPCG) deposits (Rowins, 2000a), such as may occur in the historical Rossland Au camp (e.g., Rowins, 2000b). Rather, the relatively 'oxidized' character of the magmatic-hydrothermal ore fluids is typical of the Jura-Triassic suite of large alkalic porphyry Cu-Au deposits that occurs throughout central BC (e.g., Chamberlain et al., 2007).

TECHNICAL ASPECTS OF EXPLORATION

The data obtained on the Au mineralization in the Cranbrook area reveal several features that should be considered during exploration.

First, the system of faults, fractures and airphoto lineaments gives considerable structural complexity to the Au occurrences. Gold mineralization is commonly localized at 'double' or even 'triple' fault intersections that lack continuity and consistency along strike and down dip. This setting does, however, create a favourable environment for structural superimposition of multistage, and possibly much more variably aged, mineralization events. Consequently, the application of dense exploration drilling grids to reveal structural patterns that define the most favourable trends is required for future drilling.

Second, the structural controls on Au mineralization are complicated to an even greater degree by multiple syn- and post-mineralization faulting episodes. As a result, common brecciation, gouging and late surficial weathering of mineralized material cause numerous drilling issues related to core-recovery rates and down-hole deviation. Remarkably, many holes drilled in the past exhibit very low drillcore-recovery rates in mineralized zones, which means that reported Au assays, both high and low, are essentially meaningless. This is because an unknown, but potentially significant, fraction of Au (especially free native Au) was possibly removed (likely preferentially) from the mineralized rock, together with soft clay gouge and/or sandy rock fragments. The application of modern drilling techniques that provide core-recovery rates in excess of 95% are required for effective exploration.

Third, as revealed by exploration, many Au occurrences in the Cranbrook area consist mainly of native (free) Au. It is distributed in the mineralized rock very irregularly and commonly forms larger multigrain aggregates. This irregular distribution produces a strong 'nugget effect' (or 'coarse Au effect'; e.g., Stanley, 2008) in Au assays from many of the occurrences. In practical terms, this means that Au assay results are unreliable and unrepresentative where obtained on small amounts of mineralized material. Consistently, the industry-standard 30 g fire assay can be considered inadequate to represent the true Au values of these samples. The use of metallic-screen assays ('dry' metallic screen in sandy and solid rock material, and 'wet' metallic screen in clayey material), in combination with pulverization of the entire sample, is necessary in many cases. Table 2 illustrates the predominance of coarse native Au in many mineralized intervals encountered on the Bar and Zinger prospects. It is apparent that application of the metallic-screen assay method typically 'reduces' grades in high-grade samples and 'increases' grades in otherwise low-grade samples. This makes the overall Au-bearing intervals somewhat lower in grade but more consistent between samples. Regardless, the existence of a very strong 'nugget effect' in the samples requires the use of large-volume bulk-sampling methods to determine the true Au grades of the prospects.

DISCUSSION AND CONCLUSIONS

The data obtained from recent exploration programs highlight some important features of likely intrusion-related Au mineralization in the Cranbrook area. Possible styles of Au mineralization encountered include a) proximal intrusion-hosted and more distal auriferous quartz and quartz-sulphide stockworks; b) distal mineralized faults and deformation zones, including significant breccia; and c) most distal mineralization controlled by faults, including low-angle and possibly thrust faults, with abundant sulphide. To summarize, this proximal to distal zonation of Au mineralization styles from a causative intrusion corresponds to the reduced intrusion-related Au model proposed by Lang and Baker (2001). A difference, however, is the importance of district- and local-scale fault/deformation zones on localizing Au mineralization in the majority of Au prospects in the Cranbrook area. The variably oriented faults form a structural network over the entire area and predetermine the location of Au and other metal occurrences. Further analysis would likely reveal more distinct compositional and structural features associated with this district-scale metal zonation model.

The variety of structural styles of possible intrusion-related Au mineralization corresponds to distinct mineralogical and geochemical diversity in occurrences. These include Au:Ag ratios varying from 100:1 to 1:100, and auriferous mineral assemblages that are both sulphide-free and sulphide-rich. Mineral assemblages also contain different sulphides, with arsenopyrite and/or galena being especially abundant in many of them. Scheelite and/or molybdenite

Table 2. Selected assay results for Au mineralization from the Zinger and Bar prospects, west of Cranbrook, southeastern British Columbia, obtained by standard fire assay versus metallic-screen fire assay.

Prospect	Hole interval or sample number	Au (g/t) by standard fire assay		Au (g/t) by metallic-screen fire assay					
			Check	Total Au	Total weight of Au (mg)	Au in +100 ♦m fraction	Fraction weight (g)	Au in -100 ♦m fraction	Fraction weight (g)
Zinger	GD 1463 (grab)	8.93	9.58	19.1	8.096	182.5	4.44	9.26	812.2
Zinger	GD 1432 (grab)	2.16	2.41	2.74	0.329	144.5	2.28	2.29	686
Zinger	OB 1673 (grab)	3.42	3.47	4.78	0.913	82.8	11.02	3.32	588.7
Zinger	Homestake vein (grab)	8.35	7.49	7.56	0.166	11.55	10.02	7.5	1629
Zinger	Columbia vein (grab)	3.53	2.93	5.69	1.557	269	5.79	3.36	655.5
Bar	Hole B-02-01, 10.25–11.87 m (core)	11.05	14.4	2.43	1.017	88.6	11.48	0.59	536.2
Bar	Hole B-02-01, 45.80–46.10 m (core)	3.48		9.23	1.107	95.1	11.64	6.19	328.7
Bar	Hole B-02-02, 9.28–10.26 m (core)	38	37.4	7.23	1.334	176.5	7.55	2.28	258.4
Bar	Hole B-02-02, 50.05–50.50 m (core)	0.339		7.92	2.428	187.5	12.96	1.38	355.4
Bar	Hole B-02-03, 23.60–24.09 m (core)	1.675		15.8	3.976	287	13.85	2.26	277.3
Bar	Hole B-02-03, 52.88–53.64 m (core)	0.048		8.84	2.078	104.5	19.87	3.62	364.8
Bar	Hole B-02-03, 54.65–55.47 m (core)	>10.0	0.25	1.35	0.142	7.23	19.63	1.1	468.9
Bar	Hole B-02-04A, 18.29–18.54 m (core)	16.35		7.5	2.43	829	2.93	1.73	417.6
Bar	Hole B-02-04A, 18.54–19.80 m (core)	19		5.2	5.867	345	17	2.91	2525

Note: Samples from the Homestake and Columbia veins are the same ones listed in Table 1 as numbers 23 and 25, respectively. Gold assays by ALS Chemex, North Vancouver, BC using metallic-screen methods and atomic absorption spectrophotometry.

are locally present. The presence of various sulphides makes it possible to determine pathfinder elements for different styles of Au mineralization.

Despite the significant exploration work conducted in the area, many aspects pertaining to the recognition and classification of intrusion-related Au occurrences remain controversial. Firstly, it is unclear whether Au mineralization in the Cranbrook area is related to a single plutonic suite or to multiple suites accompanied by different types (e.g., reduced intrusion-related Au; 'oxidized' and 'reduced' porphyry Au [Cu]; polymetallic skarn) and styles (e.g., veins, vein stockworks, disseminations, replacement zones) of Au mineralization. It is notable that the Tintina Au belt in the Yukon and Alaska—the type area for reduced intrusion-related Au deposits (i.e., Ft. Knox and Dublin Gulch)—incorporates at least three productive plutonic suites. These include subalkalic, alkalic and peraluminous plutonic suites (Hart, 2007). If this situation applies to southeastern BC, then it may partially explain the variability of the Au mineralization styles in the Cranbrook area.

Many other aspects and possible genetic relationships between Au mineralization and intrusions in the Cranbrook area require further study. In particular, the possible similarity of some mineral occurrences (e.g., Zeus) to Cu-Au porphyry mineralization should be investigated; if proved, this may demonstrate the presence and potential of this mineralization style in the district. Also, some structurally controlled base-metal (with minor Au) prospects traditionally regarded as Proterozoic and 'Sullivan-feeder' style must be re-examined within the context of a Mesozoic intrusion-related Au model; they may significantly increase the number of intrusion-related Au occurrences found in the area. Interestingly, these Sullivan-style occurrences may have no economic importance in terms of Sullivan-style Pb-Zn targets but may be indicative of the presence of intrusion-related Au mineralization at depth or nearby (e.g., the Vine vein; see Hoy and Pighin, 1995). In addition, it is worthwhile determining if some mafic dikes traditionally considered within the Moyie suite are, in fact, much younger (Mesozoic?) and lamprophyric in composition. Specifically, some mafic dikes on the Zinger prospect appear to be lamprophyric, which raises the question of whether lamprophyre-related Au mineralization (cf., Muller and Groves, 1997) is present in the area. For example, Au mineralization at the Taurus deposit in northwestern BC is closely associated with lamprophyre dikes (Panteleyev et al., 1997; Logan, 2000). Combined with other geological data, a better understanding of these features will help in the evaluation of reduced intrusion-related Au potential in southeastern BC.

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