British Columbia Gold Composition Atlas Update 2020: Developing a New Tool for the Exploration Community

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Introduction

This ongoing project seeks to develop a new tool for use by exploration companies in projects of all sizes, which focus on either orogenic gold, epithermal gold or Cu-Au porphyry deposits, across British Columbia (BC). The background to the project was provided in full in Murphy et al. (2020) and is summarized below.

The use of indicator minerals as a vector to in situ mineralization is well established (McClenaghan and Layton-Matthews, 2017). However, detrital gold particles have not found widespread use in this regard thus far because: 1) they are formed in a variety of ore deposits; and 2) they are chemically indestructible and physically durable, thereby permitting recycling into successive surficial facies. Thus, discovery of particulate gold in heavy concentrates collected during routine stream-sediment sampling is not in itself evidence for a specific source-style of mineralization. However, there is significant alloy and mineralogical variations within gold particles. This project utilizes such variations to identify key markers within gold particles, by which their deposit-specific origins may be deduced. The approach is based both on alloy composition according to Au and Ag+Cu, Hg and Pd (where detectable) by electron probe microanalysis (EPMA), and characterization of the suite of ore and gangue minerals present as inclusions within the gold particles using the energy dispersive spectrometry (EDS) facility of the scanning electron microscope (SEM). In addition, trace-element composition of gold particles may be established using laser-ablation inductively coupled plasma–mass spectrometry (LA-ICP-MS; Banks et al., 2018). Combination of these datasets on a particle-by-particle basis permits 'microchemical characterization' of populations of gold particles from a single locality and reconstruction of the nature of the source mineralization, more specifically, whether the gold originates from an orogenic system (Chapman and Mortensen, 2016) or from a Cu-Au porphyry deposit (Chapman et al., 2017). The first stage of the current project has established a database containing microchemical EPMA/EDS characterization of gold particles, with subsets analyzed by LA-ICP-MS. The second stage of the project will involve identifying gold signatures from specific styles of mineralization using exploratory data analysis. The output will be a publicly available template in the form of a data-driven workflow accessible to other researchers, who may then interpret the results of their own sampling projects.

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Methodology

Data Acquisition

The geographic distribution of the study samples is presented in Figure 1. Breakdowns of the sample suite according to historical BC mineral districts and deposit type are presented in Figure 2. The microchemical characterizations of 13 999 gold particles from 327 localities populate the database for the project. A description of the sample preparation and microchemical characterization procedures was provided in Murphy et al. (2020).

In addition to the routine gold characterization via EPMA and SEM, 537 gold particles have been analyzed by LA-ICP-MS. The study can draw on some previous data flowing from a Geoscience BC funded project on LA-ICP-MS characterization of gold in BC (Banks et al., 2018) but additional analyses have also been undertaken. These datasets await processing and further interrogation.

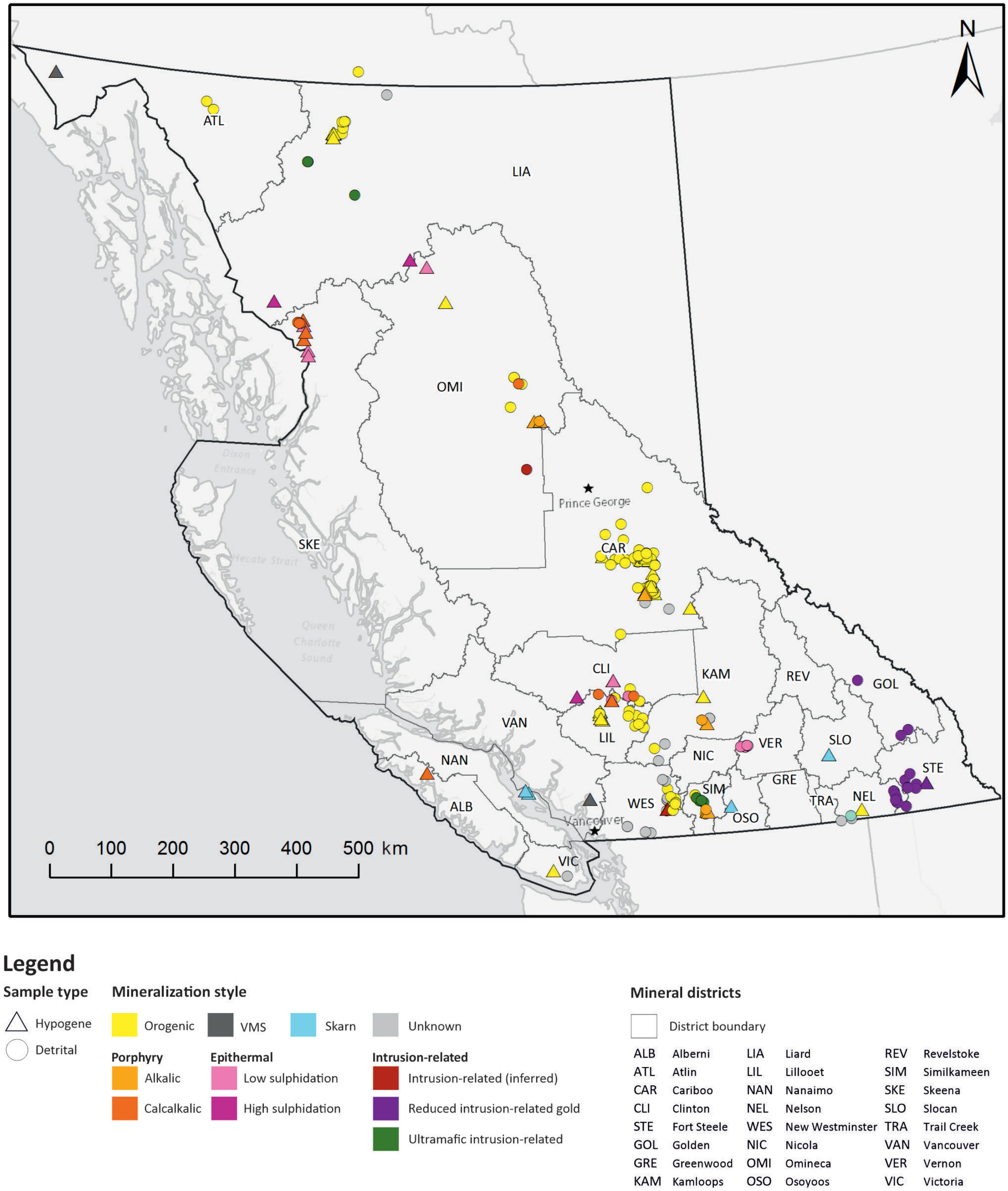


Figure 1. Geographic distribution of study samples according to historical British Columbia mineral districts. Base map created using ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used herein under licence. Copyright© Esri. All rights reserved. Abbreviation: VMS, volcanogenic massive sulphide.

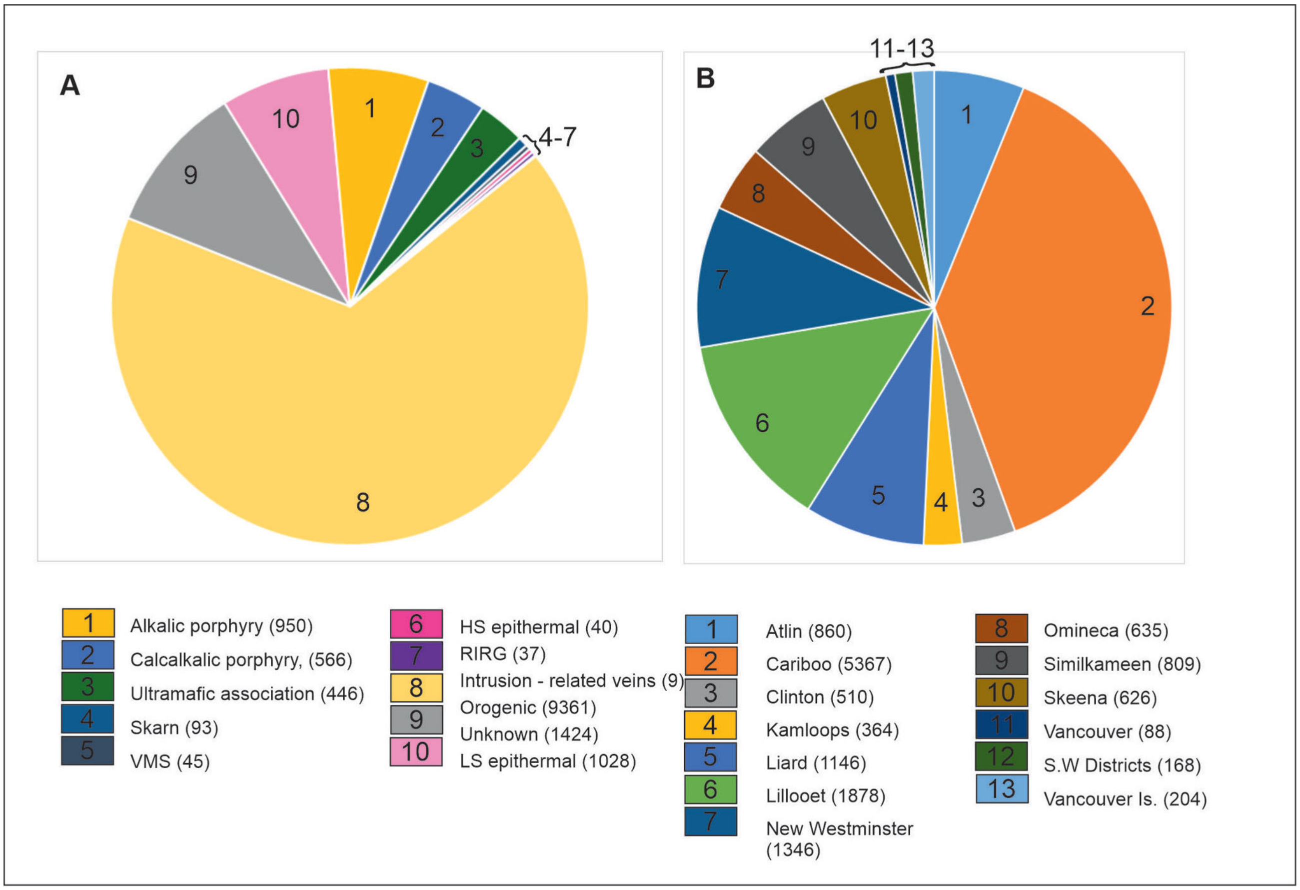


Figure 2. Breakdown of study samples characterized by electron probe microanalysis and scanning electron microscopy, according to **a)** source style and **b)** location in British Columbia mineral districts. Abbreviations: HS, high sulphidation; Is., Island; LS, low sulphidation; RIRG, reduced intrusion-related gold; S.W., southwest; VMS, volcanogenic massive sulphide.

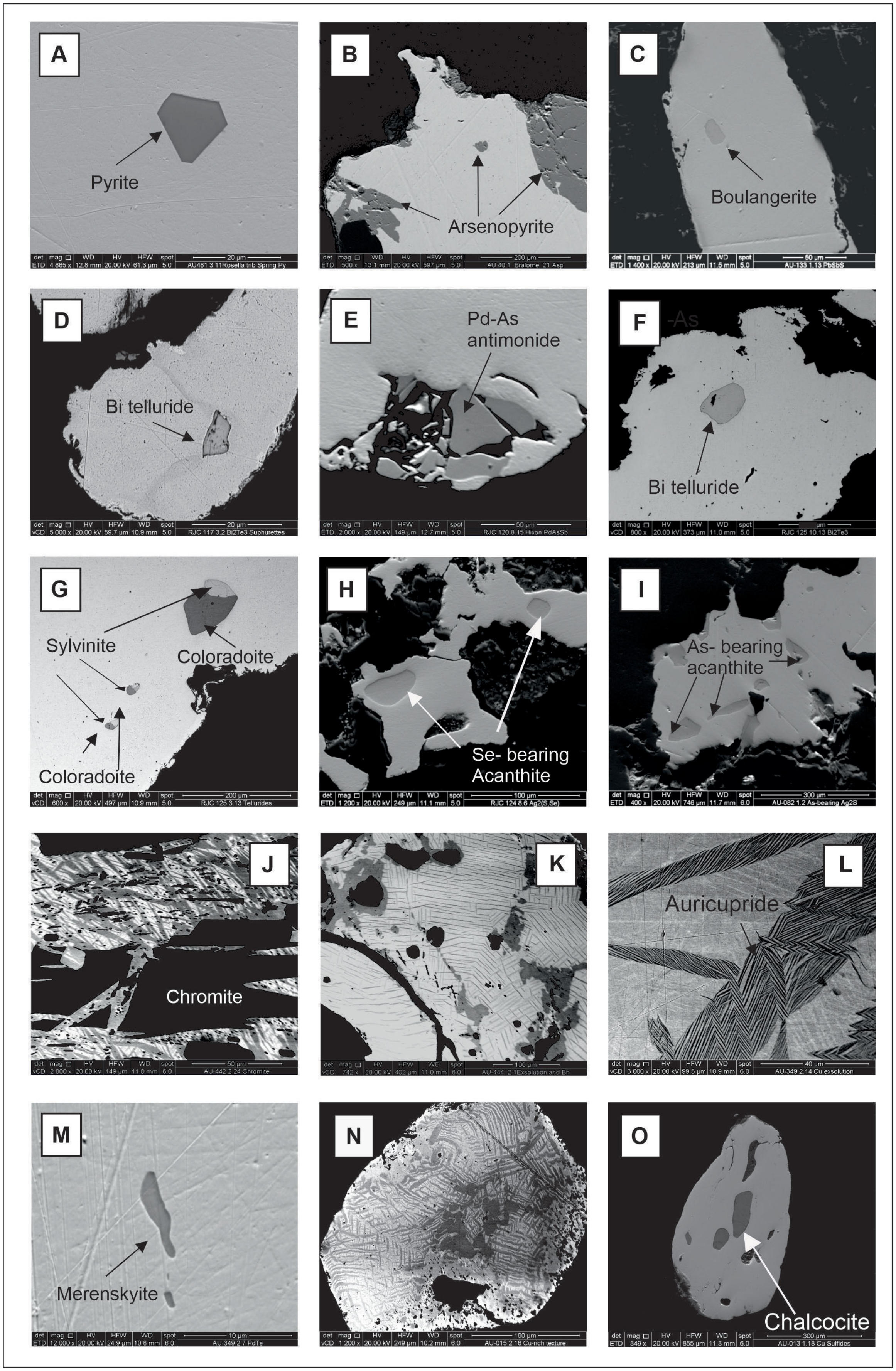
Database Organization

All data have been collated according to a standardized spreadsheet design, which will permit interrogation using various multivariate and geochemical data analysis software packages such as Reflex® ioGAS™, Orange, or the KNIME analytics platform.

Preliminary Results

Previous studies in the Canadian Cordillera have established typical microchemical signatures of gold formed in different styles of mineralization. Gold from orogenic settings is usually a binary Au-Ag alloy, with Cu, Hg and Pd below detection level by EPMA and the inclusion suite is best characterized by the nonmetal components of minerals (i.e., sulphides), including sulphides+sulpharsenides±sulphosalts, sulphides+tellurides or, more rarely, sulphides+sulpharsenides+tellurides (Chapman et al., 2010a, b, 2011; Chapman and Mortensen, 2016). In the Yukon, gold from calcalkalic Cu-Au porphyry deposits has been characterized according to a Pb-Bi-Te-S signature in the inclusion suite (Chapman et al., 2018), whereas alkalic Cu-Au porphyries in BC exhibit an inclusion signature with a small but consistent Pd-Hg component, also evident in alloy compositions (Chapman et al., 2017). In addition, Knight and Leitch (2001) reported high (>3 wt. %) Cu contents in the gold alloy associated with ultramafic-hosted mineralization in both the Coquihalla River valley and Wheaton Creek (Skeena mineral district).

To date, consideration of new data has focused mainly on inclusion suites, as these can provide the most distinctive signatures, and some noteworthy results have been achieved. Suites of minerals typical for gold from orogenic systems have been identified in areas such as Cassiar and Bralorne, and the Quesnel–Cottonwood area (Figure 3a–c). Similar assemblages have been recorded more widely in the catchment area of the Fraser and Coquihalla rivers. The Bi-Pb-Te-S signature of gold from Yukon calcalkalic porphyry systems reported in Chapman et al. (2018) has also been observed in gold from the environs of the KSM deposit (Figure 3d, e) and the Pd-Hg–bearing inclusion mineralogy associated with alkalic Cu-Au porphyries has been confirmed at Friday Creek, near Copper Mountain (Figure 3f). The Bi-Pb-Hg-Te inclusion signature in gold from Stirrup Creek (Figure 3g, h) has yet to be fully interpreted. Low-sulphidation epithermal gold from Black Dome exhibits a dominant Ag-S-Se inclusion suite, and a Ag-S-As


A
Pyrite
B
Arsenopyrite
C
Boulangerite
D
Bi telluride
E
Pd-As
antimonide
F
Bi telluride
G
Sylvinite
Coloradoite
Coloradoite
H
Se- bearing
Acanthite
I
As- bearing
acanthite
J
Chromite
K
L
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M
Merenskyite
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O
Chalcocite

signature is observed in gold from the Brucejack deposit (Figure 3i). In Omineca, gold from the Germansen Landing area showed a typical orogenic inclusion-signature suite but that from Valleau Creek showed a more complex elemental array, including Bi, Te and minor Mo. Knight and Leitch (2001) observed that gold from some sample sites in the Coquihalla River drainage basin and Wheaton Creek contained >3 wt. % Cu and exhibited strong exsolution of auricupride (Au_3Cu) from a Au-Ag-Cu matrix, which suggests the potential of a generic textural signature for gold with an ultrabasic association (Figure 3j–m). This texture has also been identified from sample populations from the Bridge River area, where a genetic link between placer and source has not yet been established. The distinctive exsolution signature is commonly associated with inclusions of chalcocite (Figure 3n). In addition, the presence of Pd-bearing mineral inclusions (Figure 3o) raises the possibility of a further discriminant.

Outputs to Date

The results of the project were presented at a poster session at the 2020 Mineral Exploration Roundup in Vancouver, BC. Some of the inclusion data have been integrated with previous datasets in a scientific journal contribution (R.J. Chapman, J.K. Mortensen, M.M. Allan, R.D. Walshaw, J. Bond and K. MacWilliam, work in progress), which links inclusion assemblages in gold from throughout the Canadian Cordillera with wider metallogenic interpretations.

Conclusions and Future Work

In the second phase of this project, the implications of the datasets in terms of regional and local metallogenic significance will be evaluated. This will involve depiction of both alloy and inclusion assemblages of EPMA/SEM data, and integration with the datasets generated by LA-ICP-MS. These qualitative characterizations will form the training datasets for use in an exploratory data-analysis approach to compositional definition. The aim of this project element is to remove the future need for an experienced researcher to interpret the significance of gold compositions. Therefore, use of the classification workflow will replicate dataset interrogation as if performed by such subject-matter experts. A key deliverable of this project will be the detailed description and workflow template, based on expert-derived linear discriminant analysis, to create a classification algorithm (e.g., naïve Bayes, decision trees, or random forest), which can then be used by any nonspecialist to classify new gold particle data. In this way, the project will generate a new tool immediately available to the exploration community in BC, but one with the potential to expand efficiently to encompass both the Canadian and Alaskan cordilleras.

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Figure 3. Examples of features observed in the gold-particle sample suite (detrital particles observed in backscattered electron scanning electron microscope mode imaging unless otherwise stated), showing inclusion mineralogy typical of orogenic systems (a–c), inclusions in gold from magmatic hydrothermal systems (d–i), exsolution of auricupride (Au_3Cu) from gold alloy matrix in placer particles linked to ultrabasic hosts (j–m) and inclusion species observed in gold from some of the same localities (n, o). Samples were collected at the following locations: **a)** Rosella Creek, Cassiar; **b)** Bralorne (hypogene sample); **c)** Tertiary Creek, near Quesnel; **d, e)** drainage basin in which the KSM property is located; **f)** Friday Creek, near Copper Mountain; **g)** Stirrup Creek, near the Fraser River; **h)** Valleau Creek, Omineca; **i)** the Brucejack property (hypogene sample); **j)** Coquihalla River; **k)** Yalakom River, a tributary of the Bridge River; **l, m)** Wheaton Creek, Stikine; **n)** Bridge River; **o)** Coquihalla River.

Acknowledgments

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