Geology and Mineral Deposits of the Skeena Arch, West-Central British Columbia: A Geoscience BC Digital Data Compilation Project[1]

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INTRODUCTION

The Skeena arch is a northeast-trending belt of uplifted Jurassic and older rocks that transects central British Columbia. This uplift is believed to have formed in the Middle Jurassic and resulted in separation of the Bowser and Nechako basins (Yorath, 1991). Rocks exposed along the Skeena arch represent a long-lived magmatic arc that has produced a diverse range of mineral deposits in a wide variety of geological settings. This area represents some of the most richly endowed terrain in BC and has been the site of mineral exploration for the past 125 years. Since 1985, the BC Geological Survey and the Geological Survey of Canada have been involved in regional mapping projects along the Skeena arch, first as part of the Whitesail and Smithers projects (*e.g.*, MacIntyre *et al.*, 1989) and more recently as part of the Interior Plateau (Diakow *et al.*, 1997) and Nechako NATMAP (MacIntyre *et al.*, 1996a, 1996b, 1997, 1998; MacIntyre 1998, 2001a, b; MacIntyre and Villeneuve, 2001) projects. This work has resulted in a much better understanding of the geological evolution of the arch, particularly during the metallogenically important Jurassic through Cretaceous time periods. Although there are gaps in the map coverage, a large part of the project area (80%) has now been mapped in detail. These data were originally compiled at 1:100 000 scale as part of the Mineral Potential Project (MacIntyre *et al.*, 1994) and revised and updated as part of the Digital Geology of BC Project (Massey *et al.*, 2003, 2003a). The Skeena arch Project will provide a means of bringing this and other digital datasets together as a series of standardized, digital geological maps with linked databases for structure, mineral occurrences, geochemistry, geophysics, geochronology and paleontology. A new series of 1:100 000-scale maps will be produced for the area and made available in digital and hardcopy format.

The aim and scope of this proposed two-year project is to promote new exploration along the Skeena arch by:

- compiling all existing data relevant to mineral exploration along the arch and building a GIS database, using Manifold 6.5 GIS software, for use by explorationists; various data formats will be produced in order to make the data as widely useable as possible; data will be made available on CD and possibly over the Internet in standard GIS format; and
- spatial analysis of the data and definition of exploration targets based on correlation of positive indicators, such as geochemical and geophysical anomalies and stratigraphic setting.

The project will generate the following deliverables over a two year period:

- Updated and standardized 1:100 000-scale geological, geochemical and geophysical compilation maps for the maps sheets covered by the project area (Fig. 1)
- A CD containing reports documenting the results of the project and new exploration targets, plus a complete suite of data files and maps in GIS format for use in Manifold 6.5 GIS and other popular GIS packages (ArcView®, MapInfo®, AutoCAD® Map, etc.); the CD will also contain 1:100 000-scale digital maps in PDF format portraying the geology, mineral occurrences, geochemistry and geophysics of the project area, and assessed exploration potential for key mineral deposit types
- Updated MINFILE (2005) occurrences, as required.

Projected release of final report, maps and database files is October 2006.

LOCATION OF THE PROJECT AREA

The area covered by the Skeena Arch Project is shown in Figure 1. The area includes all of the Hazelton (93M), Smithers (93L) and Whitesail (93E) maps sheets, and the south half of the McConnell Creek (94D), east half of the Terrace (103I) and southeast corner of the Nass River (103P) map sheets.

KEY DATASETS AND PRODUCTS

New geology and exploration-potential maps will be compiled and released as digital products for each of the map tiles shown in Figure 1. The digital files will include bedrock geology and exploration potential for specific mineral-deposit types, such as epithermal veins, Eskay Creek – type VMS, porphyry Cu and Mo, etc. Potential for hydrocarbons may also be included if sufficient data can be

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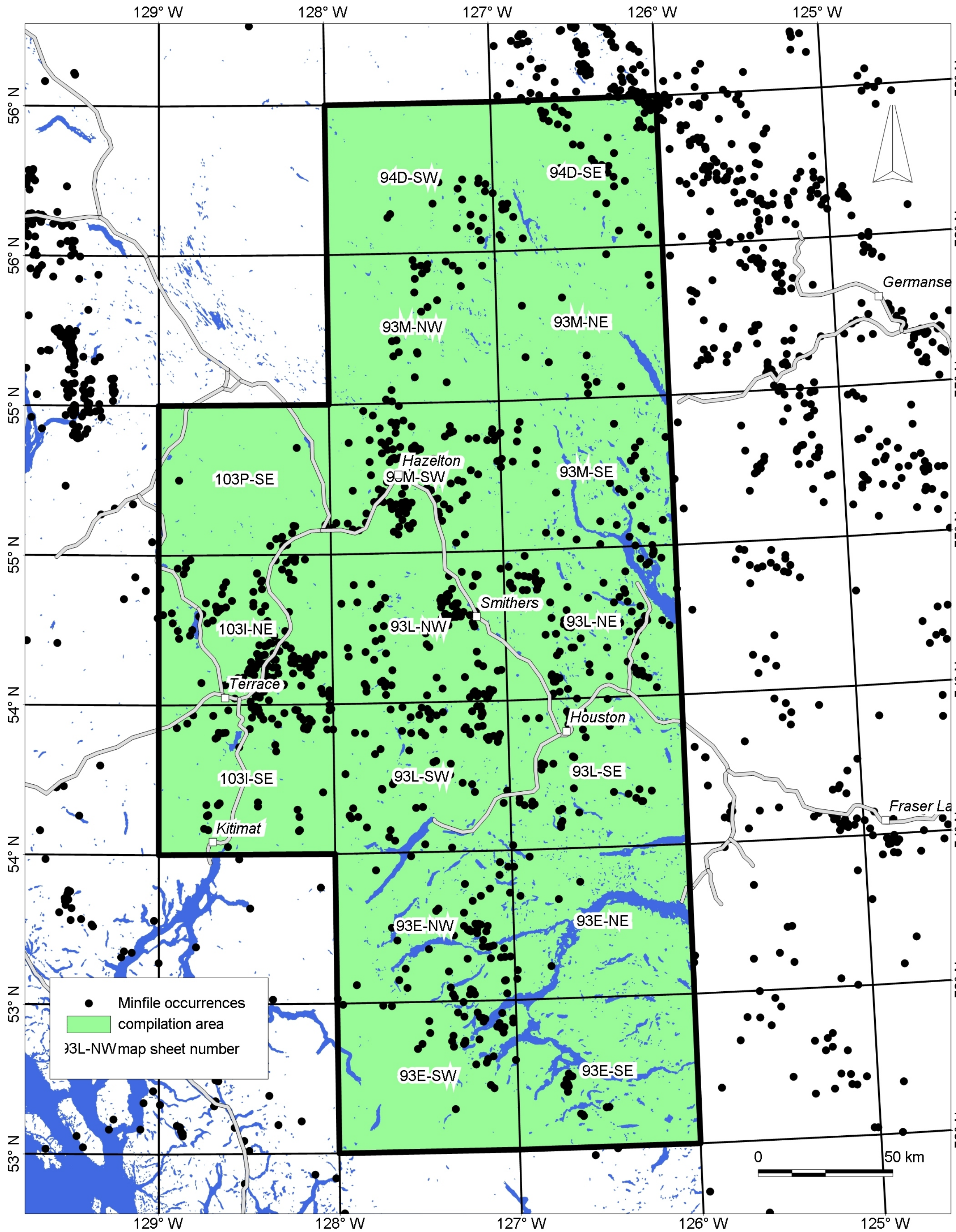

Figure 1. Skeena Arch Project area, showing map tiles to be compiled and location of MINFILE occurrences.

obtained. Digital compilation products will be derived from the datasets shown in Table 1. A key criterion for the project is that all datasets used to produce the derivative geology and exploration-potential maps and databases are available to the public for free. Unfortunately, this means that TRIM topographic data cannot be used in this project because of its high cost and distribution restrictions. However, digital elevation data are available for free from the Government of Canada GEOBASE website, and these will be used to generate contour maps and hillshade surfaces for the project area using the capabilities of the Manifold 6.5 GIS software. Manifold was chosen as the GIS platform for this project because of its exceptional functionality and low cost (currently selling for around $300 Canadian). In addi-

TABLE 1. KEY DATASETS TO BE USED IN THE SKEENA ARCH COMPILATION PROJECT

Name	Description	Source
Geology	Bedrock geology polygons, faults and related databases	BCGS
Quaternary	Quaternary cover polygons	BCGS
Age Dates	Isotopic ages	BCGS
Minfile	Mineral occcurrence locations and related databases	BCGS
ARIS	Assessment report locations and descriptions	BCGS
RGS	Regional silt, water and till geochemistry sample locations and related databases	BCGS
Minpot	Mineral potential tracts, location of known resources and related databases	BCGS
Geophysics	Airborne geophysical surveys	GSC
DEM	Digital elevation model points (used to generate contours and hillshade relief maps)	GEOBASE
Rivers	Major rivers as lines and polygons	GEOGRATIS
Lakes	Major lake polygons	GEOGRATIS
Sea	Ocean polygons	GEOGRATIS
Roads	Road network	GEOGRATIS
FSR	Logging road network	BCMOF
Cities	Cities, towns and communities	GEOGRATIS
Ice Cover	Areas of ice cover	GEOGRATIS
Parks	Location of parks	BCMENV
Grid 250K	NTS map sheet grids for 1:250K and 1:50K maps	GEOGRATIS
Grid 20K	Map sheet grid for BC 1:20K TRIM maps	BCMENV

tion to the Manifold data format, however, all files will also be made available in ESRI shapefile, MapInfo® MIF and AutoDesk® DWG format. All file formats will be available in three projections: geographic, Universal Transverse Mercator and BC Albers. These projections will be based on the North American Datum 1983.

TECTONIC SETTING

The project area is within the Intermontane Belt, which at this latitude includes the volcanic-arc Stikine (Stikinia) Terrane and a small part of the oceanic Cache Creek Terrane. The Stikine Terrane comprises Carboniferous to Middle Jurassic island-arc volcanic and sedimentary rocks and related plutonic suites (Schiarizza and MacIntyre, 1999). The Stikine Terrane is believed to have evolved in the eastern Pacific of the northern hemisphere and moved northward to dock with ancestral North America sometime during the Middle Jurassic (Monger *et al.*, 1972, 1996). The Stikine Terrane is well exposed along the Skeena arch. North of the Skeena arch, the Stikine Terrane is overlain by postaccretion Late Jurassic to Early Cretaceous marine and nonmarine sedimentary rocks of the Bowser Basin. The southern part of the Skeena arch is overlapped by Late Cretaceous and Eocene continental volcanic arc and related sedimentary rocks of the Ootsa Lake and Endako groups.

The project area spans the zone of westward-directed thrust faulting that marks the boundary between the Stikine and Cache Creek terranes (Struik *et al.*, 2001). This structural imbrication occurred prior to 165 Ma (Schiarizza and MacIntyre 1999), as indicated by isotopic ages for postkinematic plutons that cut both terranes. Folds and thrust faults related to this imbrication are offset by a complex pattern of high-angle faults. This pattern of faulting is not unique to the boundary between Stikine and Cache Creek terranes, as it is observed throughout the Smithers and Hazelton map sheets (Tipper and Richards 1976a, b; Richards 1980, 1990). Most of these faults formed during Late Cretaceous to Eocene or younger block-faulting events (MacIntyre *et al.*, 1997, 1998). In most parts of the project area, rocks of the Stikine Terrane display broad open fold patterns. The occurrence of a penetrative cleavage and metamorphic grade higher than lower greenschist facies is rare.

GEOLOGY

The geology of the Skeena Arch Project area is based on a recent compilation completed by the BC Geological Survey (Massey *et al.*, 2003a, b). This information has been used to generate Figures 2–5. Figure 6 is a schematic cross-section, extending from the Skeena arch to the Bowser basin, that shows the relationships of major lithostratigraphic map units. Also shown are the stratigraphic positions of geochronological and paleontological age controls.

Most of the project area is underlain by the Stikine Terrane, which here includes the Carboniferous to Permian Asitka Group island-arc metavolcanic rocks and limestone; Middle to Late Triassic augite-phyric basalt, andesite and related island-arc marine sedimentary rocks of the Takla Group; and Early to Middle Jurassic andesitic volcanic, volcaniclastic and related marine sedimentary rocks of the Hazelton Group island-arc to continental-arc assemblage (Fig. 2; Thorkelson *et al.*, 1995; Richards 1980, 1990). The stratified rocks are cut by the granodiorite and quartz diorite of the Late Triassic to Early Jurassic Topley intrusive suite and the newly recognized Early to Middle Jurassic Spike Peak intrusive suite (MacIntyre *et al.*, 2001), which are probably comagmatic with the Takla and Hazelton volcanic-arc successions.

In the northwest corner of the project area, the Stikine Terrane is overlain by marine to nonmarine clastic sedimentary strata of the Late Jurassic Bowser Lake and Early Cretaceous Skeena groups (Fig. 3). These rocks were de-

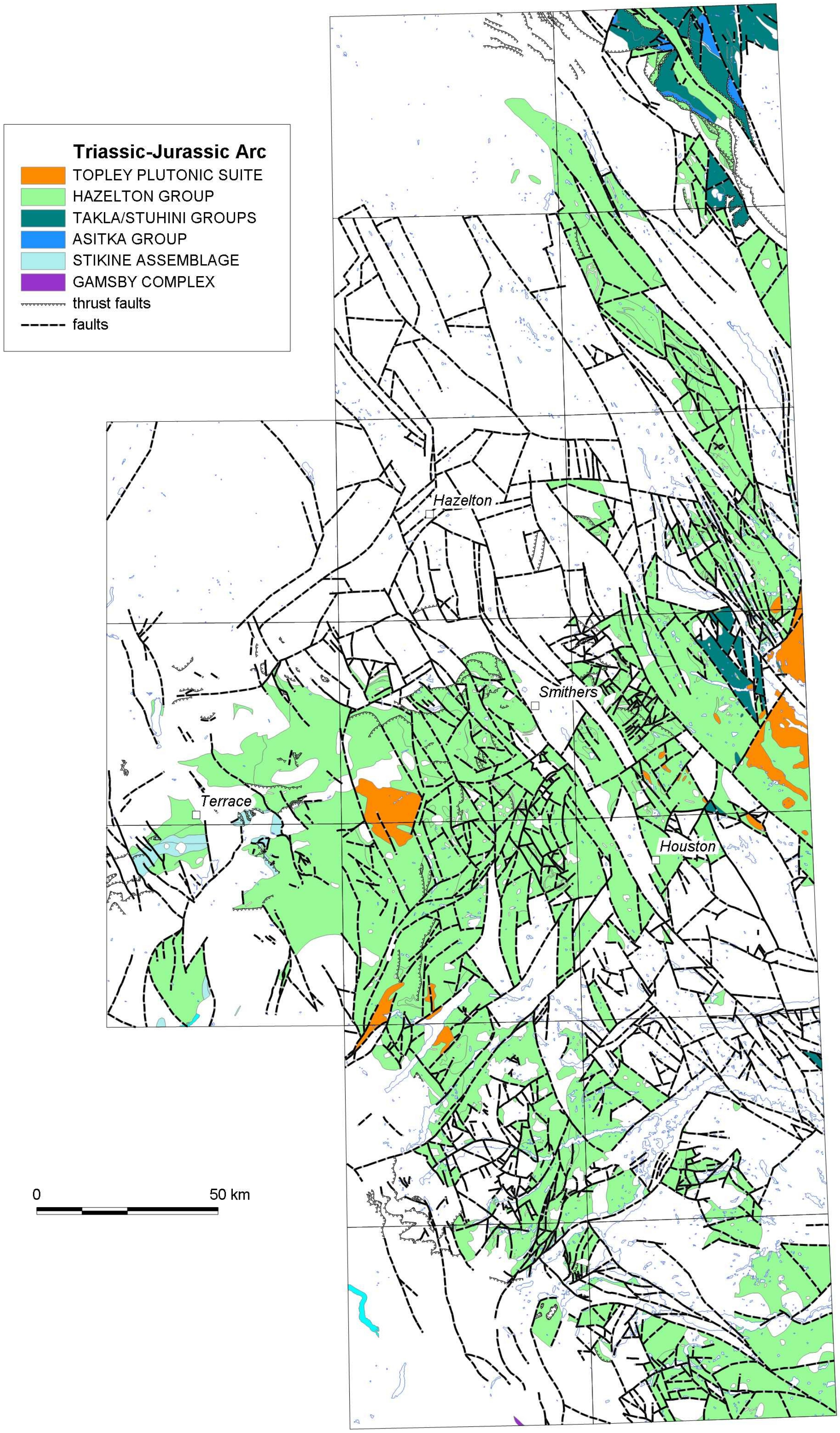

Figure 2. Distribution of Triassic and Jurassic volcanic and plutonic rocks of the Stikine Terrane.

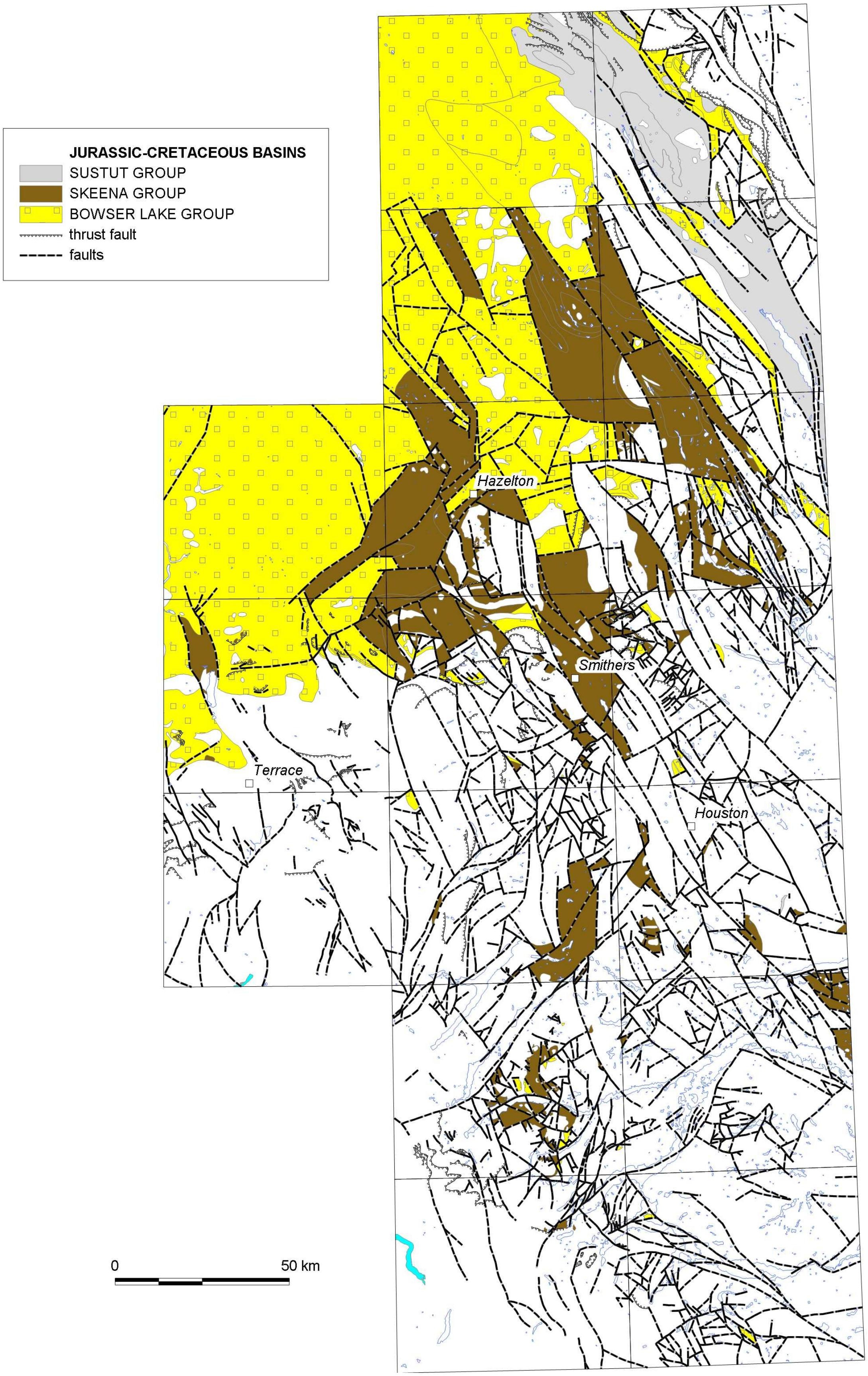

Figure 3. Distribution of Jurassic and Cretaceous sedimentary rocks of the Bowser and Skeena basins.

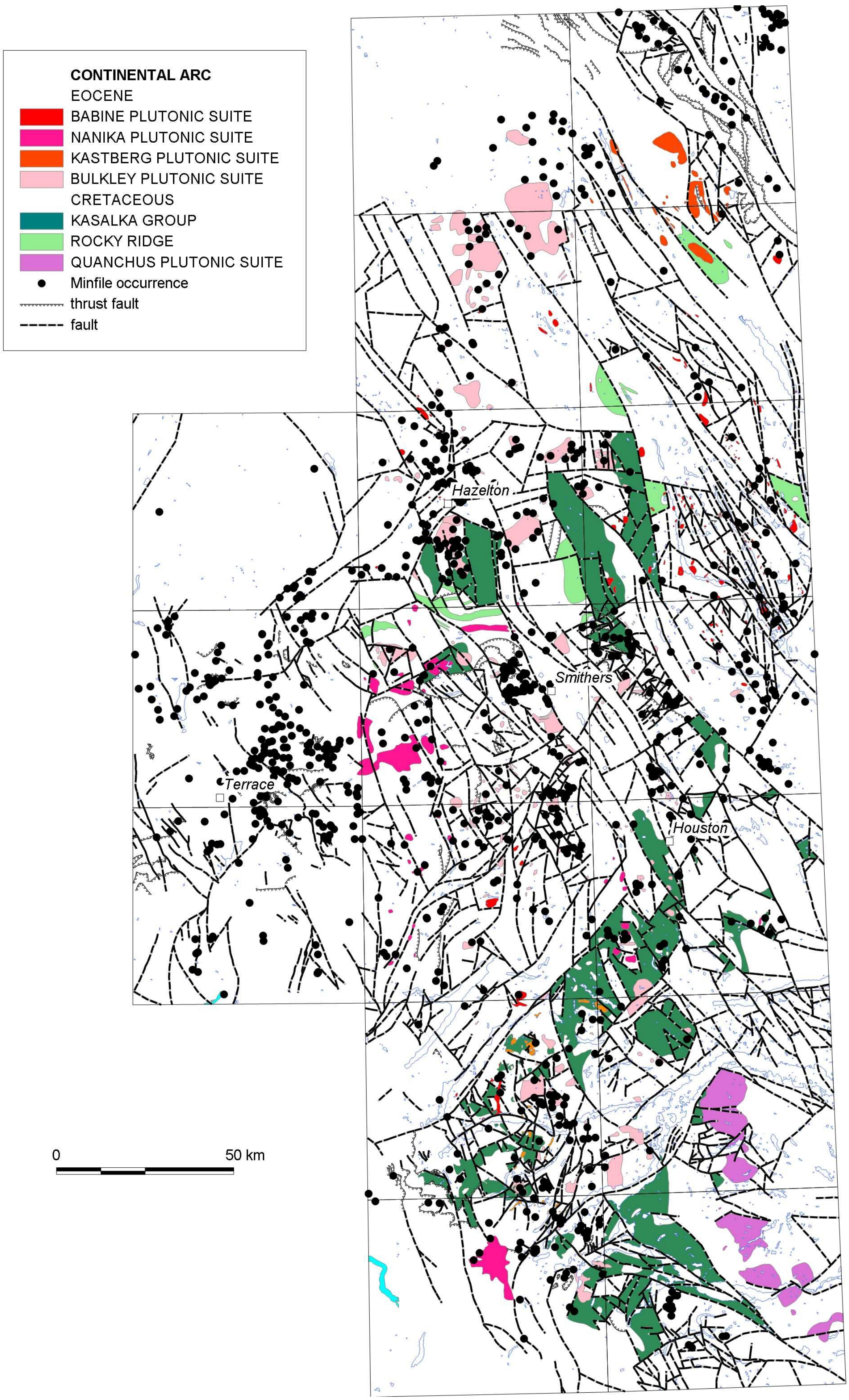

Figure 4. Distribution of Cretaceous and Tertiary volcanic-arc rocks and location of MINFILE occurrences.

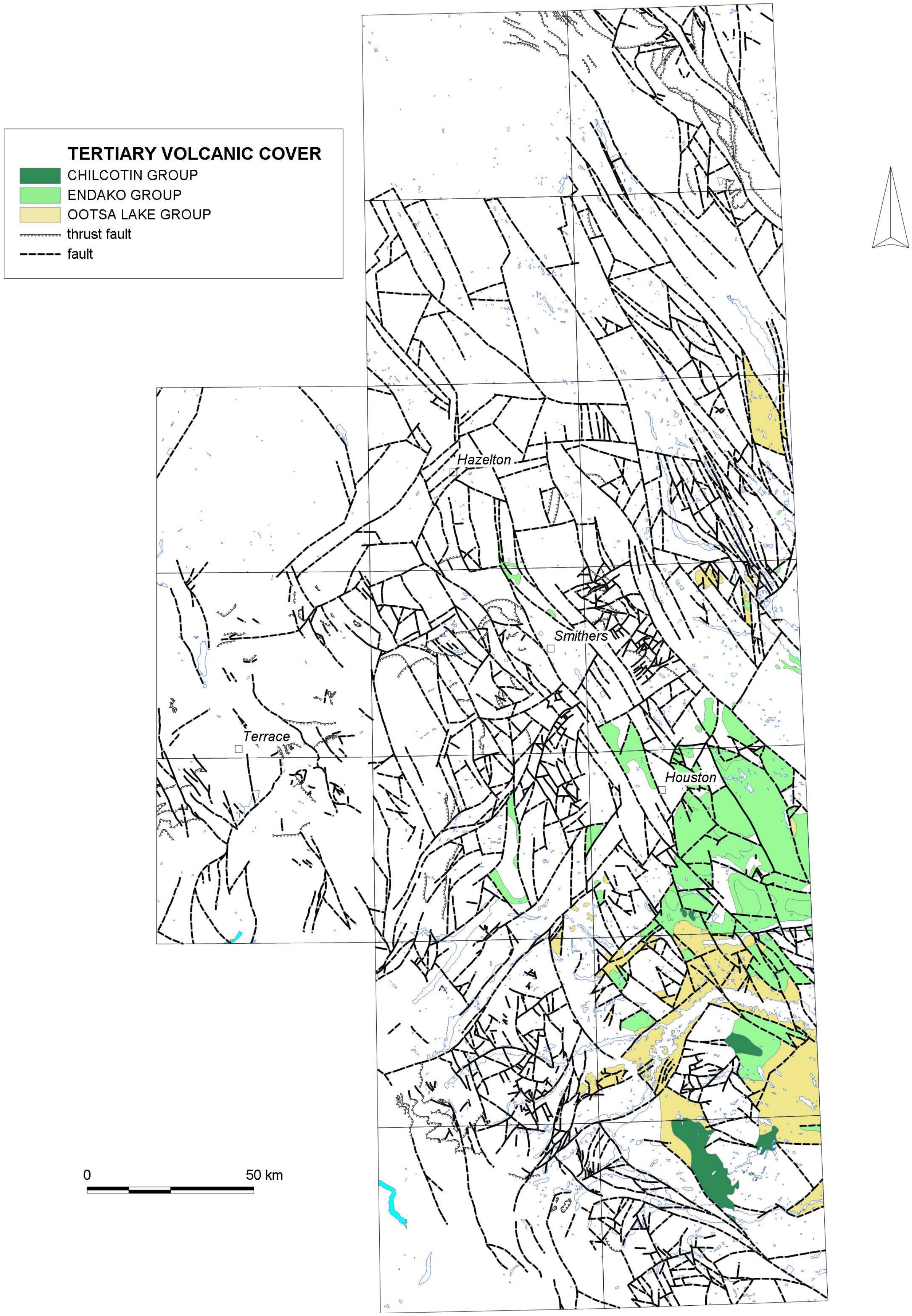

Figure 5. Distribution of Tertiary volcanic cover.

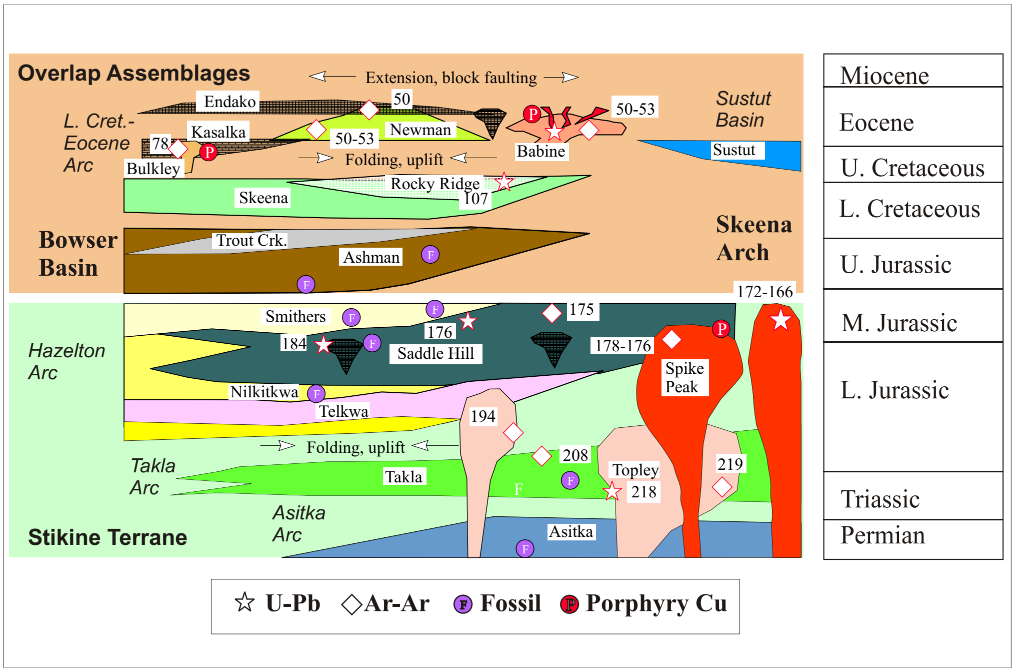

Figure 6. Schematic stratigraphic relationships, northern Skeena arch.

posited in a fluvial-deltaic to nearshore shelf environment along the southeastern margin of the Bowser Basin (Bassett, 1991; Bassett and Kleinspehn, 1996; Evenchick, 1999). A detailed discussion of these overlap assemblages is presented in MacIntyre (1998).

In the western half of the project area, Late Cretaceous to Early Eocene porphyritic andesite, basalt, rhyolite and related pyroclastic and volcaniclastic continental-arc rocks unconformably overlie both folded and uplifted rocks of the Stikine Terrane and Late Jurassic to Early Cretaceous sedimentary rocks of the Bowser Basin (Fig. 4). The younger volcanic rocks are preserved in grabens or as erosional remnants on ridge tops. The Late Cretaceous rocks include porphyritic andesite flows and lahars of the Kasalka Group and coeval granodiorite and quartz diorite plutons of the Bulkley plutonic suite (MacIntyre, 1985; Carter, 1981). In the vicinity of Babine Lake, the Stikine Terrane is unconformably overlain by porphyritic andesite flows of the Early Eocene Newman Formation and is cut by porphyritic granodiorite to quartz monzonite plutons of the Babine plutonic suite. In the southern part of the project area, small porphyritic quartz monzonite and related felsic intrusions constitute the Nanika plutonic suite. Important porphyry copper deposits are associated with the Bulkley, Babine and Nanika intrusive rocks (Carter, 1976, 1981; Carter *et al.*, 1995; MacIntyre and Villeneuve, 2001).

In the east and southeast parts of the project area, the Stikine and Cache Creek terranes are unconformably overlain by Early Eocene basalt and rhyolite flows and related pyroclastic rocks of the Endako and Ootsa Lake Groups (Fig. 5; Grainger and Anderson, 1999; Grainger *et al.*, 2001) and Miocene basalt flows of the Chilcotin Group. These younger rocks have also been block faulted and tilted during an Eocene or younger extensional tectonic event.

MINERAL DEPOSITS

The Skeena Arch Project area is richly endowed with metallic mineral deposits, with over 800 occurrences listed in the BC Geological Survey's MINFILE database. The different deposit types that have been recognized in the area are listed in Table 2. Of these, the most important types are polymetallic veins (268), subvolcanic Cu-Ag-Au-(As-Sb) (153), porphyry Cu±Mo±Au (140), volcanic redbed Cu (86), porphyry Mo (66), intrusion-related Au pyrrhotite

TABLE 2. MINERAL DEPOSIT TYPES OCCURRING IN THE SKEENA ARCH PROJECT AREA

Profile Code	Name	Count
I05	Polymetallic veins Ag-Pb-Zn Au	268
L01	Subvolcanic Cu-Ag-Au-(As-Sb)	153
L04	Porphyry Cu Mo Au	140
D03	Volcanic redbed Cu	86
L05	Porphyry Mo (low F- type)	66
I02	Intrusion-related Au pyrrhotite veins	38
K01	Cu skarns	20
G06	Noranda-Kuroko massive sulphide Cu-Pb-Zn	7
E04	Sediment-hosted Cu	6
H05	Epithermal Au-Ag (low sulphidation)	6
I01	Au-quartz veins	6
M01	Flood basalt - associated Ni-Cu	4
H04	Epithermal Au-Ag-Cu (high sulphidation)	3
I06	Cu Ag quartz veins	3
I12	W veins	3
K03	Fe skarns	3
K04	Au skarns	3
E14	Sedimentary exhalative Zn-Pb-Ag	2
G04	Besshi massive sulphide Cu-Zn	2
J01	Polymetallic manto Ag-Pb-Zn	2
K02	Pb-Zn skarns	2
L02	Porphyry-related Au	2
L03	Alkalic porphyry Cu-Au	2
		827

veins (38) and Cu skarns (20). Most of these deposits are related to the Late Cretaceous Bulkley and Eocene Babine and Nanika plutonic suites. These intrusions are part of a long-lived magmatic arc that forms the core of the Skeena arch. A schematic diagram showing the evolution of Cretaceous and Tertiary volcanic centres is shown in Fig. 4. Redbed Cu occurrences are mostly associated with basaltic flows of the Takla and Hazelton Groups.

In recent years, potential for the discovery of Eskay Creek – type volcanogenic massive sulphide deposits has been recognized. The most prospective targets are Middle Jurassic submarine volcanic rocks of the Hazelton Group (Massey, 1999; Massey *et al.*, 1999) and mid-Cretaceous bimodal volcanic rocks of the Rocky Ridge Formation (MacIntyre, 2001).

There is currently only one deposit in production in the project area: the Huckleberry porphyry Cu-Mo deposit at Tahtsa Lake, 90 km south of the town of Houston. Two other deposits are in the advanced stages of feasibility studies: the Davidson (a.k.a. Glacier Gulch or Yorke-Hardy) porphyry Mo deposit at Smithers and the Morrison porphyry Cu deposit at Babine Lake.

CONCLUSIONS

This project will help to stimulate mineral exploration by providing mineral explorationists with a comprehensive, up-to-date, all-inclusive GIS-compatible compilation of existing geoscience data in one of the most prospective areas of BC. The current database for this area is a mixture of digital and nondigital data from a wide range of projects that were done at different times and scales by different government agencies and exploration companies. The data from these projects need to be compiled, integrated and standardized into a format that can be used in a GIS. Building such a database will help explorationists identify new exploration targets and re-evaluate areas of known mineral occurrences using new geological and metallogenic models. Particular focus will be directed toward porphyry Mo and Eskay Creek – type deposits. In addition to providing a comprehensive standardized database, this project will also analyze the data and generate a list of potential target areas for consideration, thus assisting the exploration community in their evaluation of the potential for new discoveries.

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