Geology and Mineral Deposits of the Skeena Arch, West-Central British Columbia (Parts of NTS 093E, L, M; 094D; 103I, P): Update on a Geoscience BC Digital Data Compilation Project[1]

by D. MacIntyre[2]

KEYWORDS: Skeena Arch, mineral deposits, geology, metallogeny, MapPlace, digital data, GIS

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 British Columbia 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, 1998, 2001a, b; MacIntyre and Villeneuve, 2001; MacIntyre *et al.*, 1996a, b, 1997, 1998) 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.*, 2005).

The Skeena Arch project will provide a means of accessing new and existing geoscience data through an interactive map on MapPlace, a website hosted by the BC Ministry of Energy, Mines and Petroleum Resources. This report describes how the site can be used in the exploration for new mineral resources along the trend of the Skeena Arch. The site will provide four significant components, to be published as GeoFiles: an interactive MapPlace map with layer groups designed to highlight specific metallogenic targets, such as porphyry Cu-Mo deposits; downloadable data in shape-file format for use in most GIS systems, such as ArcView® and ArcExplorer®; Manifold® map files for use in Manifold® GIS; and KML files for use in viewers such as the free Google™ Earth application.

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 (093M), Smithers (093L) and Whitesail (093E) NTS map sheets, and the south half of McConnell Creek (094D), east half of Terrace (103I) and southeast corner of Nass River (103P).

GEOLOGY AND MINERAL DEPOSITS OF THE SKEENA ARCH

The geology and mineral deposits of the Skeena Arch have been described in a previous report (MacIntyre, 2006). This information is repeated here in abbreviated form for completeness of this report.

The Skeena Arch project area lies within the Intermontane Belt, which at this latitude includes the Stikine (Stikinia) volcanic arc 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; Monger and Nokleberg, 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 the 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

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[1] *Geoscience BC contribution GBC042*

[2] *Consulting Geologist, D.G. MacIntyre & Associates Ltd., Victoria, BC*

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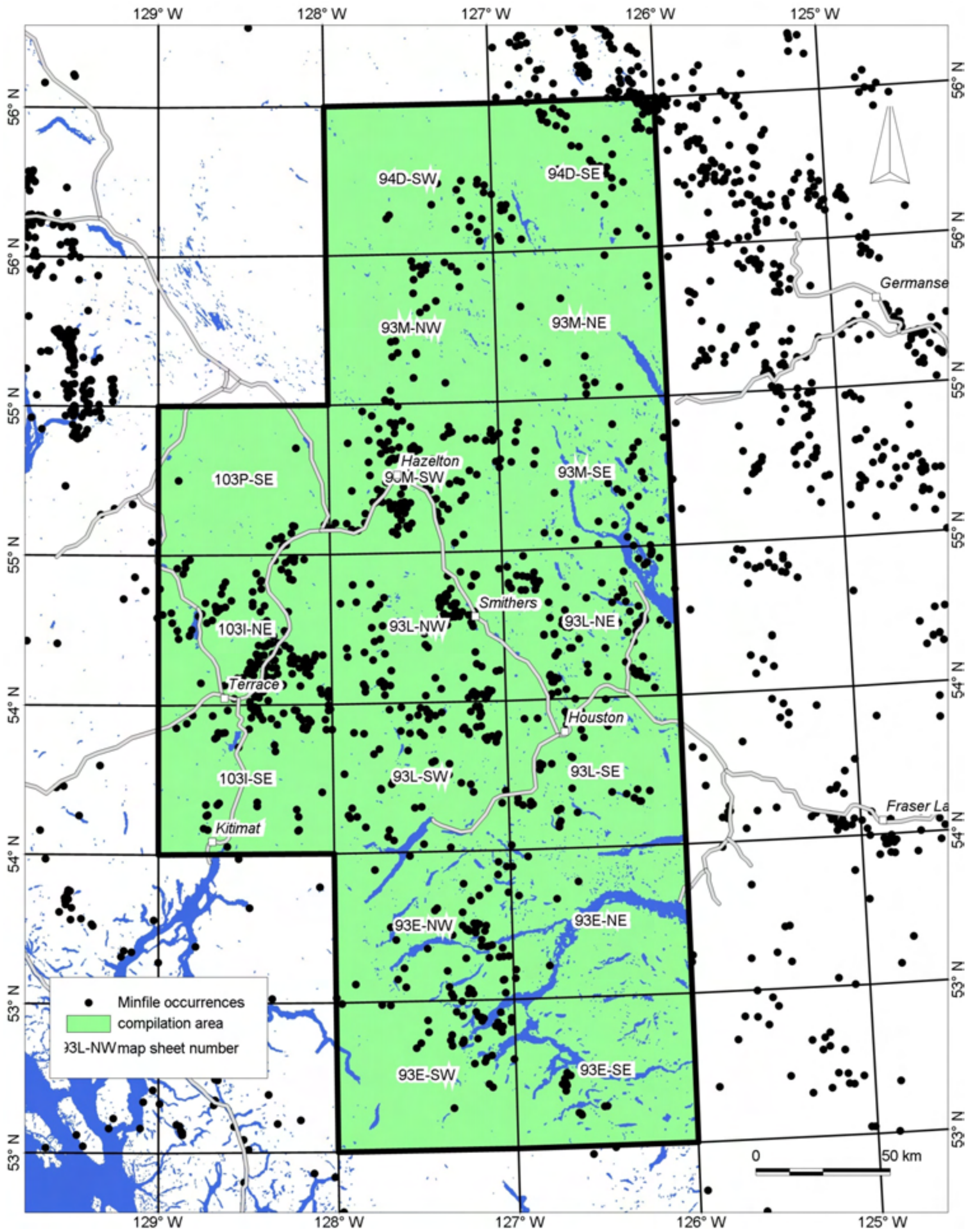

Figure 1. Location of the Skeena Arch project area and MINFILE (2006) occurrences.

Late Cretaceous to Eocene or younger block-faulting events (MacIntyre *et al.*, 1997, 1998). In most parts of the project area, Stikine Terrane rocks display broad, open fold patterns. The occurrence of a penetrative cleavage and metamorphic grade higher than lower greenschist facies is rare.

The geology of the Skeena Arch project area is based on a recent compilation completed by the BC Geological Survey (Massey *et al.*, 2005). 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 (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. These rocks were deposited 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. 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 (Carter, 1981; MacIntyre, 1985). In the vicinity of Babine Lake, the Stikine Terrane is unconformably overlain by porphyritic andesite flows of the Early Eocene Newman Formation and 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 form the Nanika plutonic suite. Important porphyry copper deposits are associated with the Bulkley, Babine and Nanika intrusive rocks (Carter, 1976, 1981; MacIntyre and Villeneuve, 2001; Carter *et al.*, 1995).

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 (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.

The Skeena Arch project area is richly endowed with metallic mineral deposits, with over 800 occurrences listed in the BC Geological Survey's MINFILE (2006) database. The different deposit types that have been recognized include polymetallic veins (268), subvolcanic Cu-Ag-Au-(As-Sb) mineralization (153), porphyry Cu±Mo±Au (140), volcanic red-bed copper (86), porphyry Mo (66), intrusion-related Au pyrrhotite veins (38) and copper 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.

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, 2001a, b).

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 (aka Glacier Gulch or Yorke-Hardy) porphyry Mo deposit at Smithers and the Morrison porphyry Cu deposit at Babine Lake.

ACCESSING AND VIEWING DATA FOR THE SKEENA ARCH AREA

As mentioned previously, data for the Skeena Arch project are now available on the BC Ministry of Energy, Mines and Petroleum Resources MapPlace (2006) website. To locate the data and view the map, select the Thematic Maps hyperlink and scroll down to the section entitled 'Detailed Geology Maps', where the Skeena Arch project is listed. Selecting the *more details* hyperlink at the end of the brief project description will open another page that gives an overview of the project and provides links to data downloadable as ESRI® shape files, Manifold® GIS map files and KML files for Google™ Earth. Shape files are provided in both geographic (longitude-latitude) and UTM projections. Unlike the main BC Geological Survey Geology Map, which is in BC Albers projection, the Skeena Arch map is in Zone 9 UTM projection. It was felt that this projection would be more useful for those who wish to print maps from the website and plot their own data using UTM co-ordinates captured from a GPS unit. The map is built using the Autodesk® MapGuide™ application.

The Skeena Arch map can be launched either by clicking on the map image or Skeena Arch hyperlink on the Thematic Maps page, or by clicking on the image on the More Details page. Clicking on this map will launch the Mapguide viewer, thus enabling interactive display of the data layers that constitute the Skeena Arch map. The different components of the metallogenic map are arranged in the Skeena Arch Metallogeny layer group, which can be activated or deactivated by checking the box next to the layer group name. By default this layer group is set to 'On', with the MINFILE, Faults, Bedrock Geology and Project Area layers selected for display when the map is launched (Fig 2).

The Skeena Arch map includes most of the layer groups that make up the main MapPlace geology maps, although some layers have been deleted because they are not relevant to the Skeena Arch project area or because they present data that are not of sufficient detail to be useful in displaying metallogenic themes for the project area. Also, some layers have been rearranged for simplicity of use. This is particularly true of the topographic layers, which have been put into layer groups so that features like lakes, rivers, etc. can be turned on or off by simply selecting or deselecting the layer group they are in. As mentioned above, the display of layers within a topographic layer group is scale dependent, so the layers that are displayed will depend on the scale of the map. For example, topographic contours will be displayed at increasing detail as the user zooms into an area, with the most detailed being the 20 m contours from the TRIM contour layer. Key geological layer groups, such as geology, mineral potential, mineral titles, mineral inventory and regional geochemistry, are all included as part of the Skeena Arch map.

A key component of the Skeena Arch Metallogeny map is the ability to display different deposit types by turning their corresponding layers on or off. Layers have been created for the deposit types shown in Table 1, which make up 93% of the metallic mineral occurrences in the project

TABLE 1. MAIN DEPOSIT TYPES IN THE SKEENA ARCH PROJECT AREA.

Deposit type	Profile code	No of occurrences
Volcanic red-bed Cu	D03	86
Intrusion-related Au pyrrhotite veins	I02	38
Polymetallic Ag-Pb-Zn Au veins	I05	268
Cu skarns	K01	20
Subvolcanic Cu-Ag-Au-(As-Sb)	L01	153
Porphyry Cu Mo Au	L04	140
Porphyry Mo (low-F-type)	L05	66

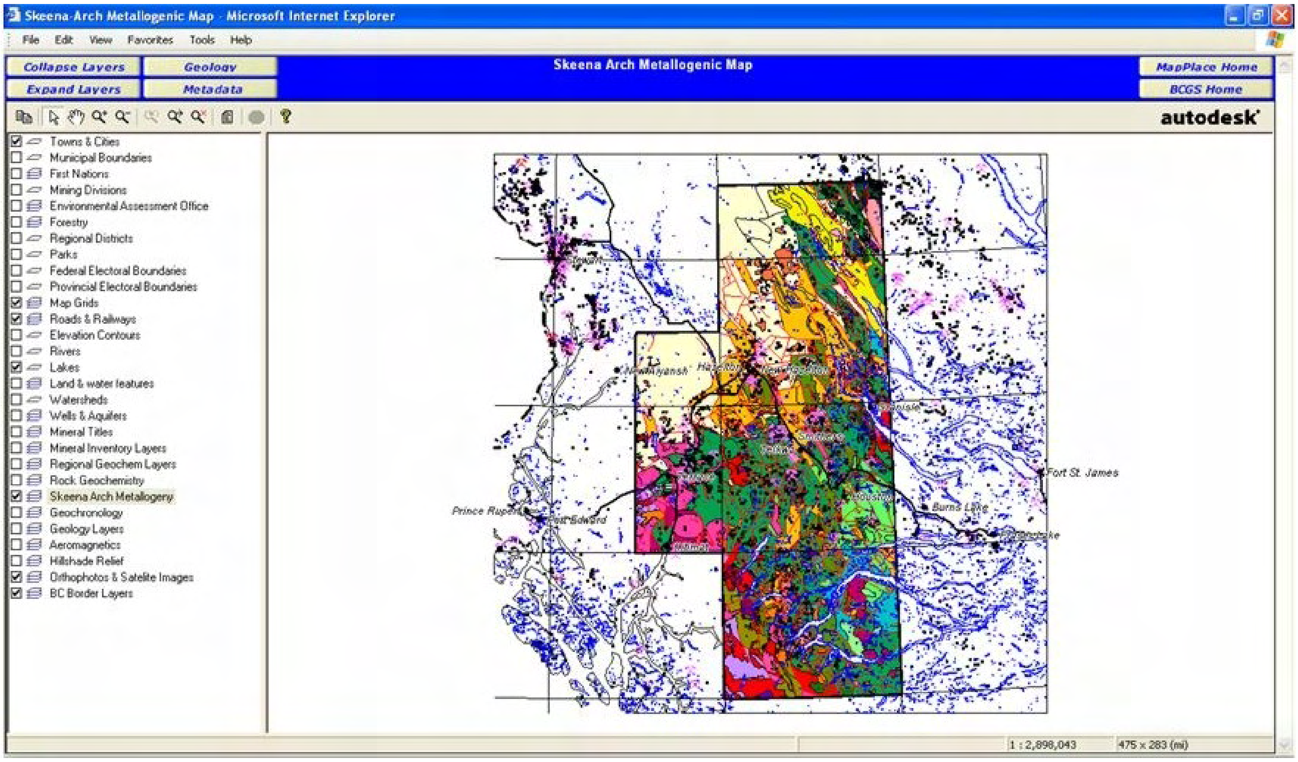

Figure 2. Screen capture of the default map for the Skeena Arch site, showing bedrock geology within the project area.

area. These layers are designed to be used in conjunction with the main MINFILE layer, which provides direct access to information on individual occurrences in the MINFILE database.

In addition to creation of layers for specific MINFILE deposit types, 95th percentile threshold values for Regional Geochemical Survey data within the project area have been calculated. Separate layers showing the locations of anomalous samples for Cu, Mo, Au, Ag, Hg, As, Sb, Pb and Zn have also been created. Recalculated threshold values are shown in Table 2.

Porphyry Molybdenum Example

The following example illustrates how the Skeena Arch map can be used to produce metallogenic maps for a specific deposit type, in this case porphyry molybdenum occurrences. This particular deposit type is currently of interest to exploration companies because of high Mo commodity prices. A number of properties in the area, including the Red Bird, Lucky Ship and Davidson (formerly Yorke-Hardy and Glacier Gulch) deposits, are currently the sites of active exploration programs. As shown in Table 1, there are 66 MINFILE occurrences in the project area that have been classified as porphyry Mo. This particular deposit type is characterized by the presence of molybdenite-bearing quartz vein stockworks and fractures that are spatially and genetically associated with high-level to subvolcanic felsic to intermediate intrusive complexes. In the project area, deposits of this type are associated with intrusions that are Late Cretaceous (*e.g.*, Bulkley plutonic suite) or Eocene (*e.g.*, Nanika and Babine plutonic suites) in age. Intrusive phases that are associated with Mo mineralization are typically medium to fine-grained biotite-quartz-feldspar-phyric intrusions that range from quartz monzonite to granite in composition. Multiple stages of fracture and vein-controlled Mo mineralization are typically found near an intrusive contact, either within the intrusion itself or in surrounding hornfelsed country rocks. Molybdenite is the pri-

TABLE 2. RECALCULATED REGIONAL GEOCHEMICAL SURVEY (RGS) THRESHOLD VALUES AT THE 95TH PERCENTILE FOR THE SKEENA ARCH PROJECT AREA.

Element	Method	95th percentile threshold value	
Ag	AAS	0.40	ppm
As	AASH	37.00	ppm
As	NA	44.00	ppm
Au	FA	6.00	ppb
Au	NA	15.00	ppb
Cu	AAS	80.00	ppm
Hg	AASF	120.00	ppb
Mo	AAS	4.00	ppm
Mo	NA	4.00	ppm
Pb	AAS	19.00	ppm
Sb	AASH	2.00	ppm
Sb	NA	3.40	ppm
W	NA	3.00	ppm
Zn	AAS	175.00	ppm

Abbreviations: AAS, atomic absorption spectrophotometry; AASF, flameless atomic absorption spectrophotometry; AASH, hybride-generation atomic absorption spectrophotometry; FA, fire assay; NA, neutron activation

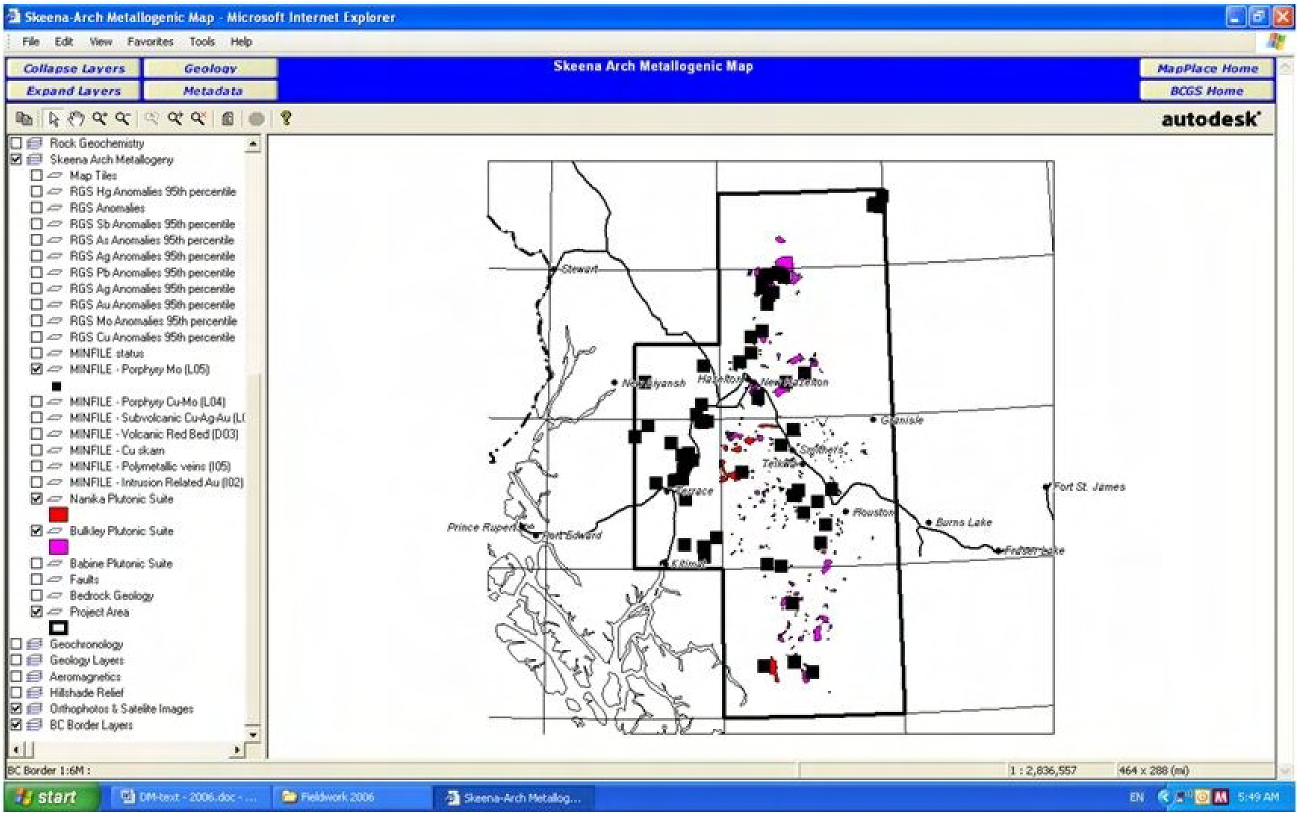

Figure 3. Screen capture of the Skeena Arch metallogenic map, showing the distribution of porphyry Mo occurrences in the project area.

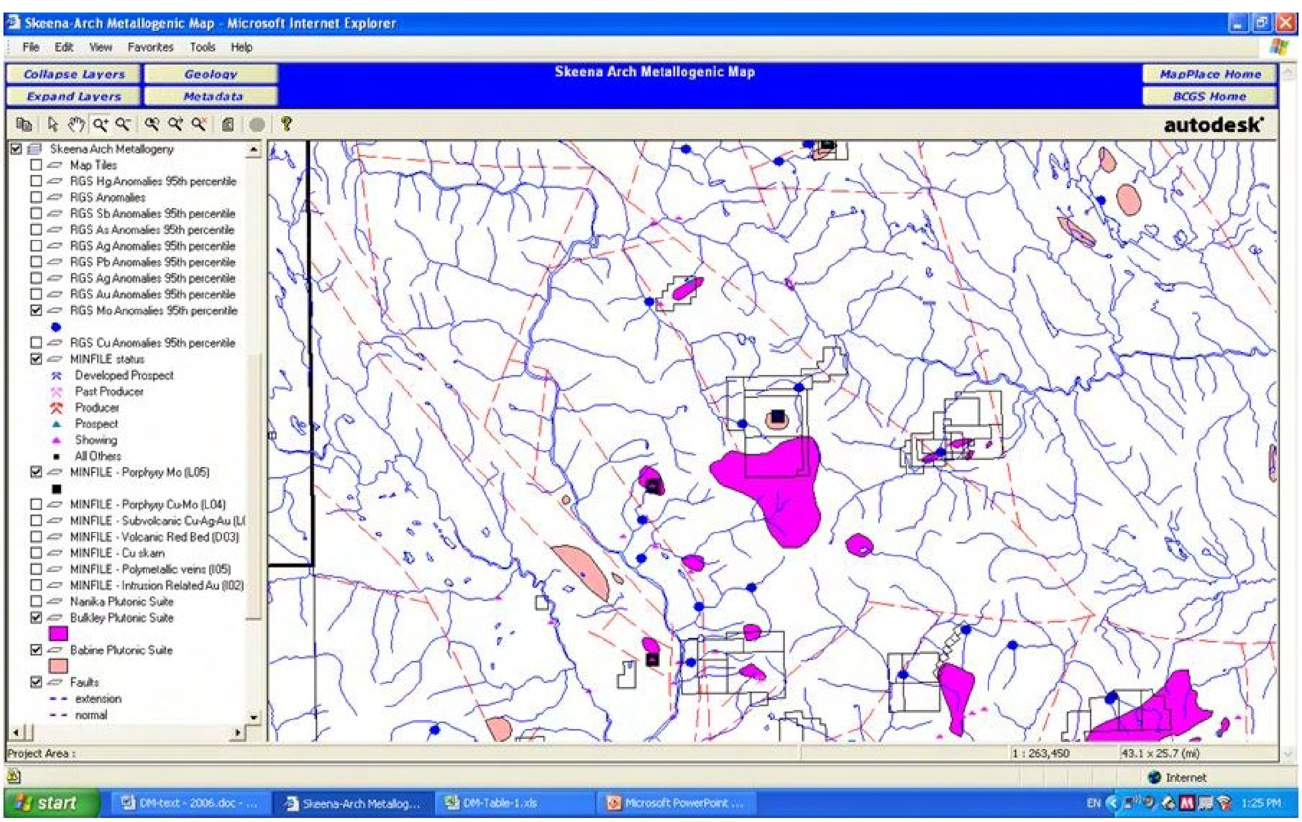

Figure 4. Screen capture of the Skeena Arch metallogenic map, showing porphyry Mo occurrences and related intrusions in the Mount Thomlinson area.

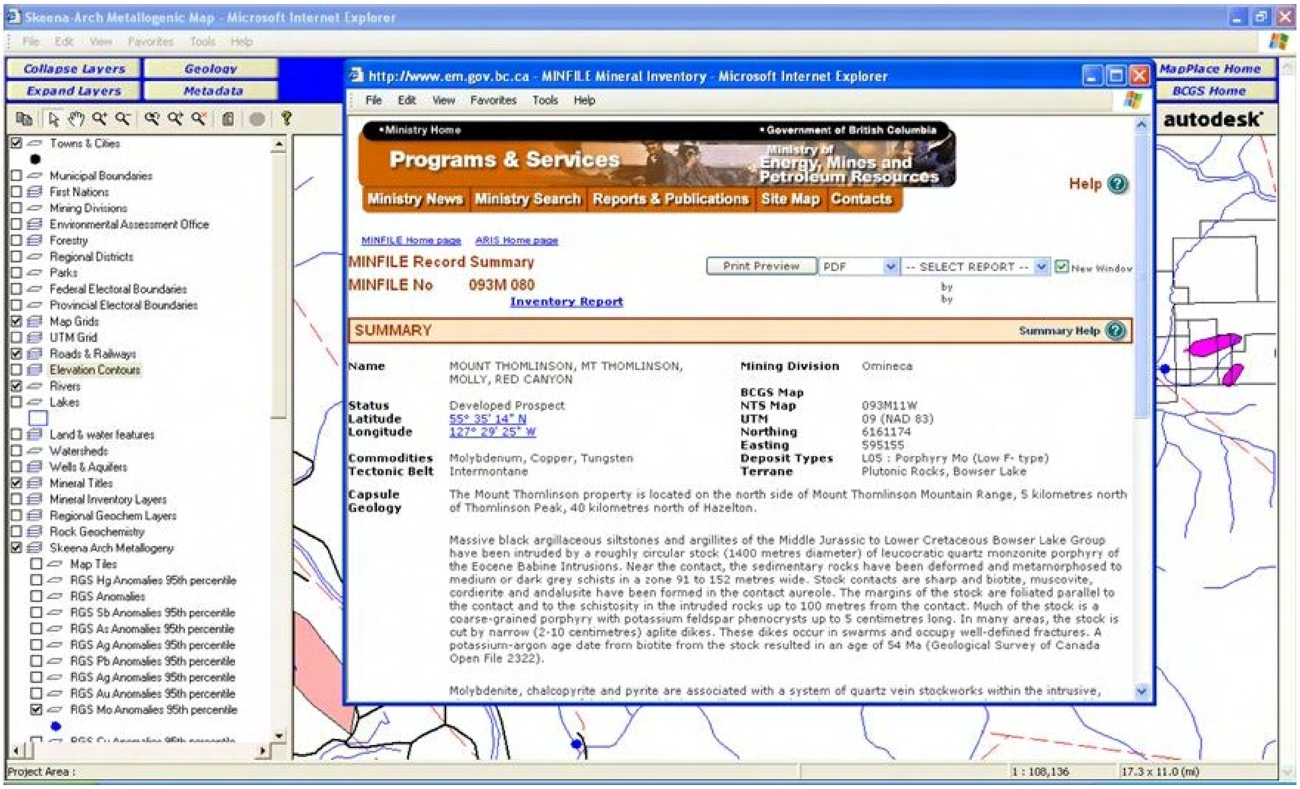

Figure 5. Screen capture showing MINFILE information for the Mount Thomlinson occurrence; MINFILE database is accessed by clicking on the location markers that are displayed when the MINFILE status layer is on.

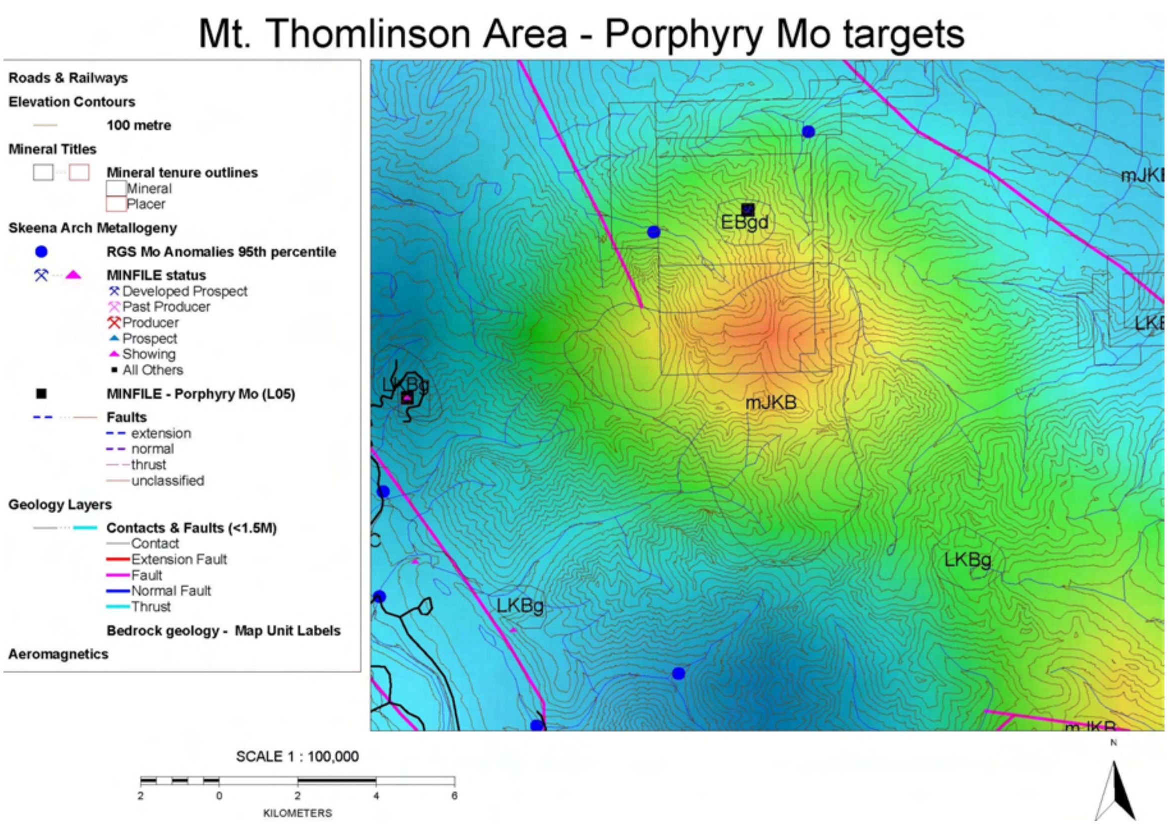

Figure 6. Custom printout generated from the Skeena Arch map, showing MINFILE occurrences, Mo geochemical anomalies, mineral tenure outlines and geological contacts and aeromagnetic anomalies in the Mount Thomlinson area.

mary sulphide mineral, but chalcopyrite may also be present in subordinate amounts. Alteration assemblages associated with Mo mineralization include K-feldspar, biotite, quartz, sericite and pyrite. As would be expected, the primary geochemical signature for porphyry Mo deposits in regional stream sediments is Mo, with F, Cu, W, Pb, Zn and Ag also locally elevated.

As a starting point, a user interested in the distribution of porphyry Mo occurrences in the Skeena Arch project area would turn on the MINFILE porphyry Mo layer. As shown in Figure 3, this will display all MINFILE occurrences whose primary classification is Porphyry Mo (Deposit Profile L05). To get more detailed information for a particular area, the user would then zoom into that area and turn on additional layers, such as Regional Geochemical Survey (RGS) Mo anomalies and the layers for associated plutonic rocks (e.g., the Babine and Bulkley intrusions). They could also show up-to-date mineral tenures in the area by turning on the Mineral Tenure layer group. An example of such a map for the Mount Thomlinson area north of Hazelton is shown in Figure 4. Note that, by left double-clicking on the marker for individual MINFILE occurrences, the user can access the MINFILE database and acquire information about the mineral occurrence selected (Fig 5). Within the MINFILE database are links to assessment reports that are available in PDF format through the Assessment Report Indexing System (ARIS).

In a few minutes, the user has a map of the area of interest that can be printed at any scale and a complete list of information on the mineral occurrences in the area. One of the strengths of the Mapguide system is that it provides the user with the ability to create custom map printouts at any scale. An example of a printout, again using the Mount Thomlinson area example, is shown in Figure 6. This map has 100 m contours, with geological contacts and map unit labels superimposed on an aeromagnetic map of the area. This map shows that intrusions in the area that have associated Mo mineralization are possibly related to a larger intrusive body at depth, corresponding to the extent of a large aeromagnetic anomaly. In addition, there are a number of RGS Mo anomalies that are unexplained by the distribution of known occurrences, suggesting there may be potential for new discoveries in the area.

SUMMARY

Geoscience information for the Skeena Arch project has now been posted to the BC Ministry of Energy, Mines and Petroleum Resources MapPlace (2006) website for download and viewing. The site provides four significant components, published as GeoFile 2007-3: an interactive MapPlace map with layer groups designed to highlight specific metallogenic targets such as porphyry Cu-Mo deposits; downloadable data in shape file format for use in most GIS systems, such as ArcView or ArcExplorer; Manifold map files for use in Manifold GIS; and KML files for use in viewers such as Google Earth. A new set of digital 1:100 000 scale maps will also be made available for the project area early in 2007.

ACKNOWLEDGMENTS

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