Finlayson Lake Targeted Geoscience Initiative (southeastern Yukon), Part 1: Bedrock geology

Donald C. Murphy[1] and Maurice Colpron[2]
Yukon Geology Program

Charlie F. Roots[3]
Geological Survey of Canada and Yukon Geology Program

S.P. Gordey[4]
Geological Survey of Canada[4]

J. Grant Abbott[5]
Yukon Geology Program

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ABSTRACT

The Finlayson Lake Targeted Geoscience Initiative, conducted jointly by the Geological Survey of Canada and Yukon Geology Program, comprised new geological mapping and till geochemistry in the northern two-thirds of Finlayson Lake map area, in and around the Finlayson Lake massive sulphide district. The goals of the initiative were to document the nature of Yukon-Tanana Terrane in this area, and, as bedrock exposures are sparse, to use till geochemistry to remotely sense new exploration targets.

The new mapping illustrates that much of the area south of the Robert Campbell Highway is underlain by the rock units that host the Fyre Lake, Kudz Ze Kayah and GP4F deposits. These rocks are thrust northwardly over a succession of carbonaceous clastic rocks, chert and felsic meta-volcanic rocks, with potential for syngenetic deposits. The Permian Campbell Range basalt, host of the Ice deposit, unconformably overlies both sequences, and all of these rocks are thrust onto rocks of the North American miogeocline.

RÉSUMÉ

Dans le cadre de l'Initiative géoscientifique ciblée du lac Finlayson, la Commission géologique du Canada, en collaboration avec le programme de géologie du Yukon, a dressé une nouvelle carte géologique et effectué une nouvelle analyse géochimique du till des deux tiers de la partie nord de la carte représentant la région du lac Finlayson, dans le district de sulfures massifs du lac Finlayson et aux alentours. L'Initiative avait comme objectifs de documenter la nature du terrane de Yukon-Tanana dans cette région, et d'utiliser des analyses géochimiques du till, étant donné que le substratum n'affleure que par endroits, pour « télédétecter » de nouvelles cibles d'exploration. La nouvelle carte indique que le substratum d'une grande partie de la région au sud de la route Robert Campbell est constitué d'unités rocheuses renfermant les gisements Fyre Lake, Kudz Ze Kayah et GP4F. Ces roches chevauchent vers le nord une succession de roches clastiques carbonées, de chert et de roches métavolcaniques felsiques pouvant renfermer des gisements syngénétiques. Le basalte permien de la chaîne Campbell, qui renferme le gisement Ice, repose en discordance sur les deux séquences; toutes ces roches chevauchent des roches du miogéoclinal nord-américain.

[1]*don.murphy@gov.yk.ca*

[2]*maurice.colpron@gov.yk.ca*

[3]*charlie.roots@gov.yk.ca*

[4]*Geological Survey of Canada, 101-605 Robson Street, Vancouver, British Columbia, Canada V6B 5J3, sgordey@gsc.nrcan.gc.ca*

[5]*abbottg@inac.gc.ca*

INTRODUCTION

In 2001, Yukon Geology Program joined with the Geological Survey of Canada to fund and implement the Finlayson Lake Targeted Geoscience Initiative (TGI), a program of bedrock geological mapping and till geochemistry in and around the Finlayson Lake massive sulphide district (Fig. 1). The intent of the TGI was to produce new geoscience data that would enhance understanding of the district's host rocks and facilitate mineral exploration in the poorly exposed areas. Under the auspices of the TGI, personnel from both organizations worked for five weeks with a contract helicopter out of a base camp at the Finlayson airstrip. A new bedrock geological map of the northern two-thirds of Finlayson Lake area (Murphy et al., 2001; Fig. 2) and the results of the till geochemical survey are now available (Bond and Plouffe, this volume). In this report, the authors present an overview of the bedrock geology of the northern part of the Finlayson Lake map area (105G) and discuss the implications for mineral exploration.

PREVIOUS WORK

Dawson traversed the area in 1887 (Dawson, 1888), followed by Keele's reconnaissance in 1907-08 (Keele, 1910). Wheeler, Green and Roddick (1960) outlined the distribution of many of the major rock types in the area without subdividing the metamorphic rock units. Tempelman-Kluit (1977) further refined the earlier maps and subsequently interpreted the metamorphic rocks as a subduction complex formed between an offshore arc and the North American continent (Tempelman-Kluit, 1979). Mortensen (1983), Mortensen and Jilson (1985), and Mortensen (1992a), showed that the area was underlain by a coherent regional stratigraphic sequence. The aforementioned authors used U-Pb geochronology to constrain the ages of the meta-igneous rocks, and concluded that Yukon-Tanana Terrane in the Finlayson Lake area represented a mid- and Late Paleozoic continental magmatic arc. Plint (1995), and Plint and Gordon (1995; 1996a,b; 1997) mapped part of northern Finlayson Lake map area in their study of the rocks of the Campbell Range belt, its relationship to Yukon-Tanana Terrane, and the implications of this relationship for the evolution of the Finlayson Lake fault zone.

Systematic geological mapping of parts of Finlayson Lake and Frances Lake areas by Murphy and others at 1:50 000 scale has been ongoing since 1996 (Murphy, 1997; Murphy and Piercey, 1999a; Murphy, 2000a,b,c, along with related reports: Murphy and Timmerman, 1997; Murphy, 1998; Hunt and Murphy, 1998; Murphy and Piercey, 1999b, 2000; Piercey and Murphy, 2000; Piercey et al., 1999, 2000, 2001a,b,c; Sebert and Hunt, 1999). Murphy and Piercey (1999c) published a 1:100 000-scale compilation that included the southeastern part of the area and neighbouring parts of 105H (105G/7 and 8; and parts of 105G/1, 2, and 9, as well as 105H/5 and 12).

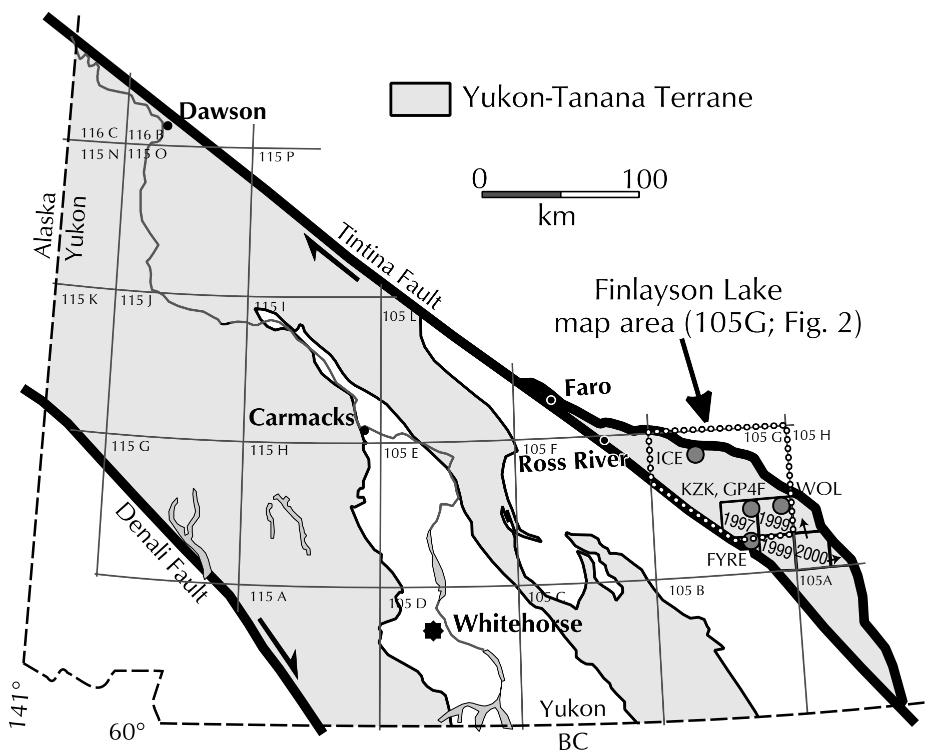

Figure 1. *Map of southern Yukon displaying location of Figure 2 with respect to the distribution of Yukon-Tanana Terrane, the main deposits of the Finlayson Lake massive sulphide district and areas that were mapped in previous years.*

EXPOSURE AND ACCESS

With local exception, bedrock in northern Finlayson Lake area is sparsely exposed due to relatively low-relief topography and an extensive blanket of surficial sediment. Foot traversing was done where outcrops were relatively continuous, however, much of the area was covered by spot landings on isolated outcrops. Over the entire northern half of the Finlayson Lake map area, very few, if any, helicopter-accessible outcrops were not visited during the Targeted Geoscience Initiative and previous programs.

GEOLOGY OF NORTHERN FINLAYSON LAKE AREA

Northern Finlayson Lake map area is underlain primarily by rocks belonging to Yukon-Tanana Terrane and the North American miogeocline (Fig. 2). Most of the southern part of the area consists of polydeformed and thrust-imbricated meta-igneous and meta-sedimentary rocks of Yukon-Tanana Terrane. The northernmost part of the area is underlain by weakly deformed and slightly metamorphosed Silurian to Triassic sedimentary rock units of the North American miogeocline. The boundary between the two geological assemblages is the newly defined 'Inconnu thrust'. Minor Permian and locally voluminous Jurassic granitic rocks intrude Yukon-Tanana Terrane, while variably foliated Cretaceous granite, possibly of different ages, intrude both Yukon-Tanana Terrane and North American rocks. Undeformed Eocene basalt, rhyolite and gabbro also occur throughout the area.

YUKON-TANANA TERRANE

Yukon-Tanana Terrane north of the Tintina Fault comprises several fault- and unconformity-bound meta-sedimentary and meta-volcanic successions and affiliated meta-plutonic suites (Figs. 2 and 3; Murphy, 2001). The structurally deepest rocks are those in the footwall of the Money Creek thrust. These include the Grass Lakes succession, mid-Paleozoic granitic meta-plutonic rocks, and the unconformably overlying Wolverine succession. The hanging wall of the thrust comprises the herein defined 'Tuchitua succession', which is composed of Carboniferous limestone and quartzite, as well as meta-volcanic rocks coeval to those in both the Grass Lakes and Wolverine successions, but primarily of an intermediate composition. The footwall and hanging wall of the Money Creek thrust are both overlain by dark clastic rocks and chert of probable Late Pennsylvanian age. All of these rocks are emplaced along the Jules Creek thrust over dark clastic rocks, chert, limestone and meta-volcanic rocks of the herein defined Finlayson succession. Permian basalt and chert of the Campbell Range succession overlie all the thrust sheets. Mafic and ultramafic meta-plutonic rocks, thought to be the sub-volcanic feeders to the Campbell Range basalt, occur within most older rock units. Permian granitic dykes occur locally. Relatively weakly deformed mid-Permian to possibly Triassic conglomerate overlies all rocks of Yukon-Tanana Terrane. Three bodies of Jurassic granitic rocks intrude rocks of Yukon-Tanana Terrane in the west-central part of the map area.

FOOTWALL OF THE MONEY CREEK THRUST

Grass Lakes succession

Murphy (1997), and Murphy and Piercey (1999b), described the rocks of the Grass Lakes succession in detail, therefore only a short summary is provided here. The lowest exposed unit of the Grass Lakes succession (Fig. 3), is composed of grit, psammite, meta-pelite, locally important muscovite-quartz phyllite, as well as augen phyllite of probable felsic meta-volcanic protolith, minor chloritic phyllite of mafic meta-igneous protolith, and marble and calcareous schist. It is overlain by the Fire Lake unit (Fig. 3), a mafic meta-volcanic unit composed mainly of chloritic phyllite, but also including carbonaceous phyllite and rare muscovite-quartz phyllite of probable felsic meta-volcanic protolith. The Fyre Lake massive sulphide deposit (Yukon MINFILE, 2001, 105G 034) is hosted in chloritic phyllite of the Fire Lake unit. Mafic and ultramafic meta-plutonic rocks are spatially associated with the Fire Lake unit and are inferred to be comagmatic sills and dykes (Murphy and Piercey, 2000). The Fire Lake unit is overlain by carbonaceous phyllite, lesser quartz-feldspar grit and pebble meta-conglomerate, and feldspar-muscovite-quartz phyllite and augen phyllite (felsic meta-volcanic rocks) of the Kudz Ze Kayah unit. These latter rocks host the Kudz Ze Kayah and GP4F massive sulphide deposits (Yukon MINFILE, 2001, 105G 117 and 143). The upper unit of the Grass Lakes succession is composed of carbonaceous phyllite, chloritic phyllite (mafic meta-volcanic rocks and dykes), quartzite and quartzo-feldspathic meta-conglomerate. The latter conglomerate unit was deposited on all underlying units of the Grass Lakes succession, implying an angular unconformity following a phase of deformation.

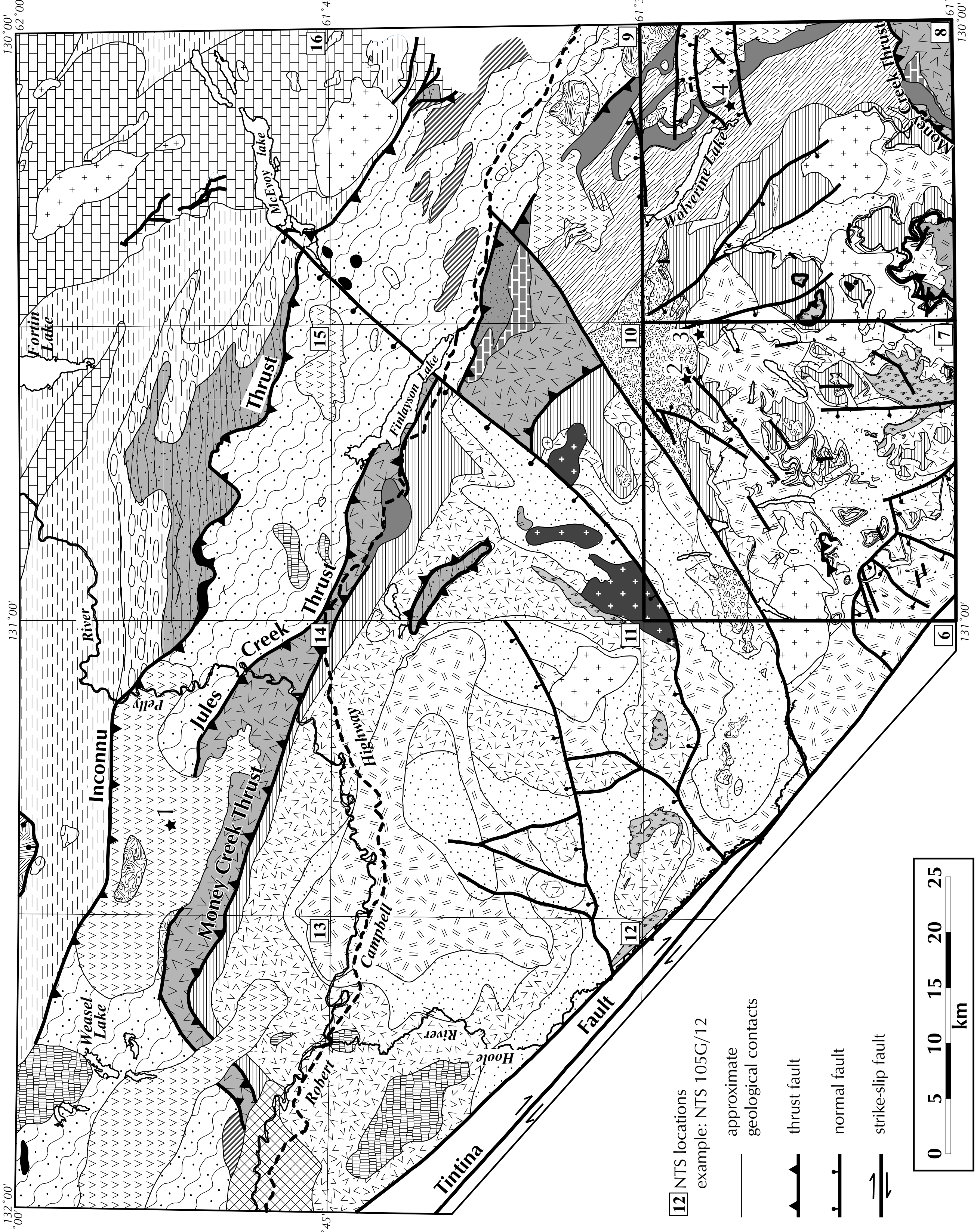

Figure 2. *Simplified bedrock geological map of the northern part of Finlayson Lake area. Map areas highlighted in southeastern corner (105G/7 and 8) are available at 1:50 000 scale (Murphy, 1997; Murphy and Piercey, 1999a).*

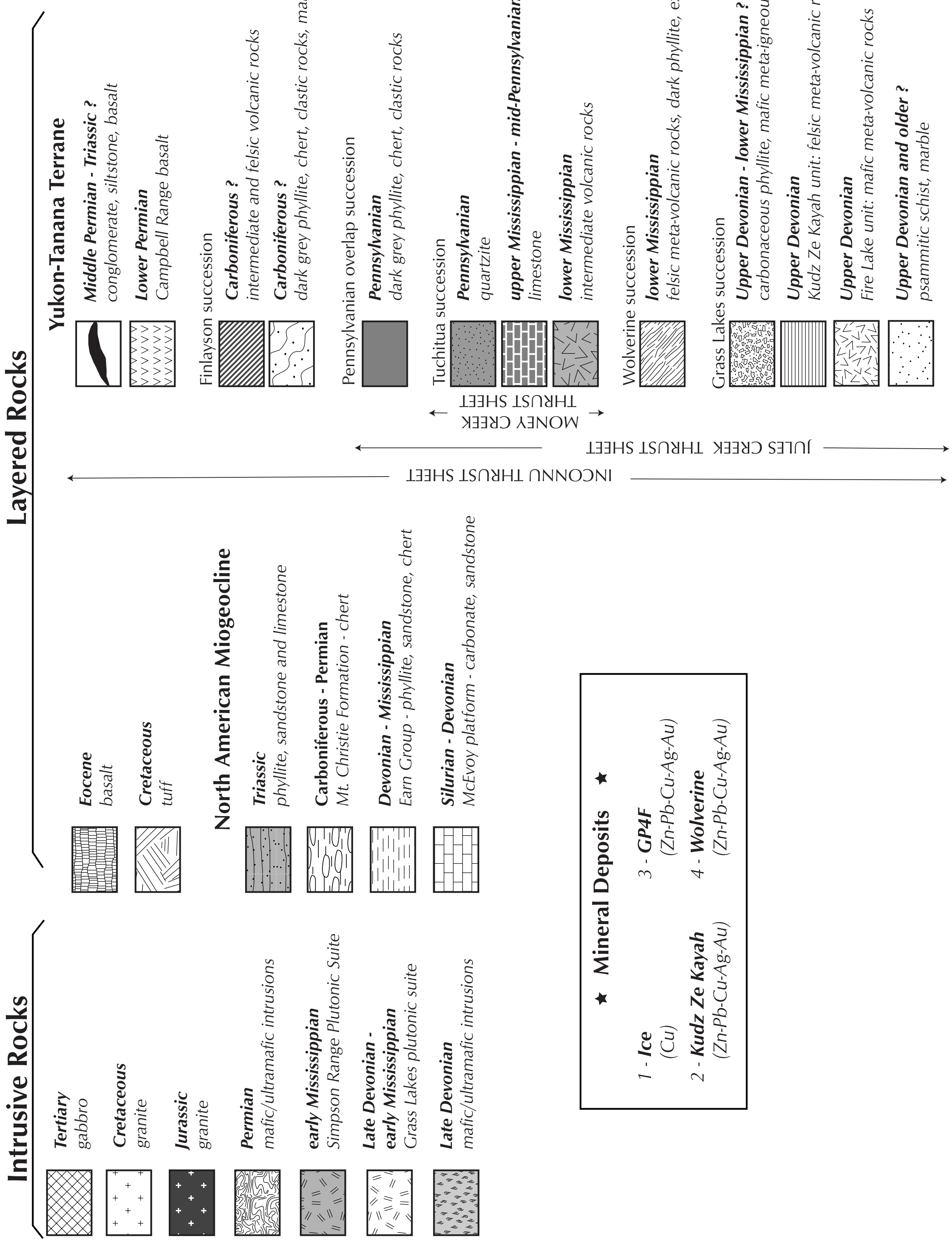

Figure 2. *(continued) Legend.*

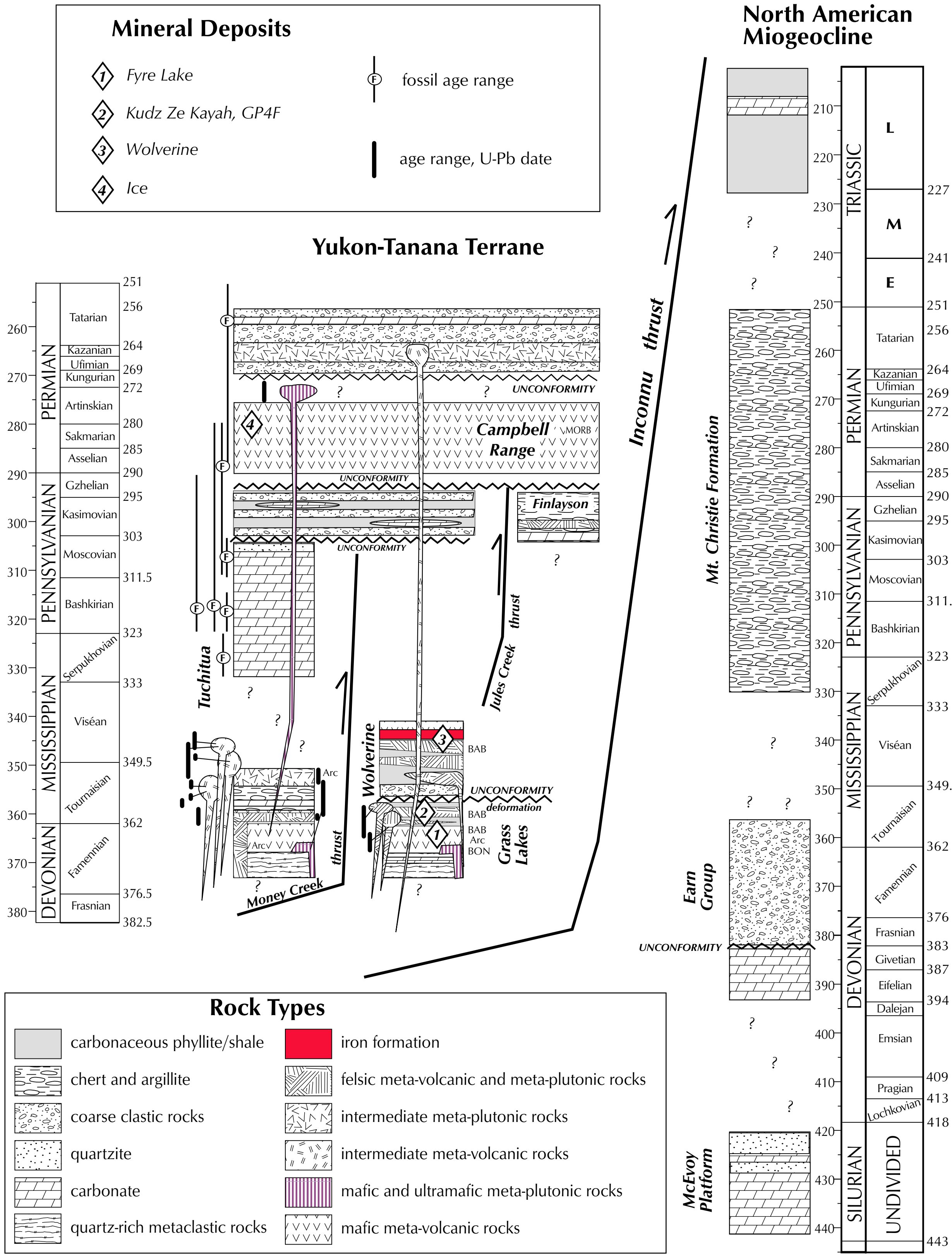

Figure 3. *Summary of stratigraphy and stratigraphic relationships in northern Finlayson Lake area. MORB = mid ocean ridge basalt; BAB = back-arc basin; BON = boninite.*

The Grass Lakes succession is intruded by voluminous granitic meta-plutonic rocks of the 'Grass Lakes suite'. In the Grass Lakes area, in the heart of the Finlayson Lake massive sulphide district, the Grass Lakes suite comprises variably foliated, medium- to coarse-grained, equigranular granite to quartz monzonite. An unfoliated phase of the suite that crosscuts structures attests to a phase of deformation during intrusion of the suite, possibly the phase of deformation indicated by the unconformity beneath the upper conglomerate unit of the Grass Lakes succession. To the west and northwest, in the Mink Creek and Hoole River watersheds, the suite comprises foliated potassium feldspar megacrystic granite. Coarse-grained igneous muscovite and biotite occur in both phases indicating a peraluminous composition.

The Grass Lakes succession is constrained to the pre-Late Devonian to Earliest Mississippian. The North Lakes meta-diorite, inferred to be comagmatic with the Fire Lake unit, is 365 Ma (U-Pb, zircon, Mortensen, 1992a; Mortensen and Murphy, unpublished data, 1997). The lowest unit of the Grass Lakes succession is therefore pre-365 Ma. A number of imprecise Late Devonian to Early Mississippian U-Pb ages have been obtained from felsic meta-volcanic rocks of the Kudz Ze Kayah unit (Mortensen, 1992a; Mortensen, Murphy and Piercey, unpublished data, 1997-2001). Late Devonian to Early Mississippian U-Pb ages have been obtained from the Grass Lakes suite, one of which intrudes the youngest unit (op. cit.). The Grass Lakes succession is therefore Devonian to earliest Mississippian in age.

Wolverine succession

The Wolverine succession, occurring mainly in the Wolverine Lake map area (105G/8; Fig. 2), consists of several northwesterly striking map units that cut across the mainly easterly stratigraphic trend of the underlying Grass Lakes succession (Murphy and Piercey, 1999a,b,c; Murphy et al., 2001). The Wolverine succession is truncated to the northwest by a northeast-striking normal fault, and to the southwest by the Money Creek thrust. The oldest unit in the Wolverine succession is composed of a basal, quartz-feldspar-pebble meta-conglomerate and overlying carbonaceous phyllite. This unit passes transitionally upward into carbonaceous phyllite with laterally discontinuous amounts of muscovite-quartz phyllite and quartz-feldspar meta-porphyry of volcanic, volcaniclastic and sub-volcanic protolith (Murphy and Piercey, 1999b; Piercey, 2001; Piercey et al., 2001c; Bradshaw et al., 2001). The Wolverine massive sulphide deposit (Yukon MINFILE, 2001, 105G 072; Bradshaw et al., 2001) occurs at the top of this unit. Medium- to thick-bedded siliceous phyllite (aphyric meta-rhyolite), with barite-magnetite-silica iron formation and carbonate-pyrite exhalite, overlie the deposit stratigraphy. The top of the Wolverine succession comprises chloritic phyllite of mafic meta-volcanic protolith.

HANGING WALL OF THE MONEY CREEK THRUST

Tuchitua succession

Rocks of the hanging wall of the Money Creek thrust occur in a narrow discontinuous belt that trends north-westly across the map area (Fig. 2). The thrust sheet in this area is composed mainly of Mississippian meta-volcanic rocks (primarily intermediate), and Pennsylvanian carbonate and quartzite of the Tuchitua succession. Tuchitua succession is named after the area where it is extensively and well exposed in southwestern Frances Lake map area (Murphy, 2000a,b,c; 2001). Older and structurally deeper parts of the thrust sheet also occur in the southeastern part of the Finlayson Lake map area, where the thrust sheet was originally recognized (Murphy and Piercey, 1999a,c, 2000; Tempelman-Kluit, 1977, 1979; Mortensen and Jilson, 1985). These rocks were thrust northeastwardly over the Grass Lakes and Wolverine successions in the Late Pennsylvanian (Murphy, 2001). In the northern part of the map area, the thrust sheet is discontinuously present beneath unconformably overlying Late Pennsylvanian clastic rocks and Permian Campbell Range basalt. With discontinuous preservation and the general poor exposure in the map area, it was necessary to define an undifferentiated unit to represent the Money Creek thrust sheet where individual units could not be traced.

In the northern part of the Finlayson map area, the Tuchitua succession is best exposed south of the southeast end of Finlayson Lake. In this location, massive bioclastic limestone occurs on hilltops south of the Robert Campbell Highway, underlain by mainly chlorite-muscovite-quartz phyllite of intermediate volcanic and possibly volcaniclastic protolith. Mafic rocks occur locally, consisting of calcareous chloritic phyllite with millimetre-scale calcite pods (amygdules?). Pyritic and altered felsic rocks occur 8 km south of the Robert Campbell Highway at the southeastern end of Finlayson Lake. The bioclastic limestone is inferred to be overlain by massive orthoquartzite. This unit underlies the hills south of the Robert Campbell Highway and the Finlayson River. All units are truncated to the southeast by a northeast-striking normal fault.

With the exception of orthoquartzite, a similar sequence occurs elsewhere in the northern part of the map area. Massive limestone and felsic meta-volcanic rocks, intercalated with thin limestone and dark phyllite, occurring north of the Robert Campbell Highway, west of Finlayson Lake, are also included in the Money Creek thrust sheet. Limestone and intermediate to felsic meta-volcanic rocks included in the Money Creek thrust sheet are also exposed west of the north-trending stretch of the Pelly River, southeast of the Ice deposit. In this locality, the meta-volcanic rocks include quartz- and feldspar-phyric meta-porphyritic varieties.

The Money Creek thrust sheet in the southern part of map area 105G/8 includes older and structurally deeper parts of the sheet than in the north, likely reflecting the presence of a hanging wall ramp. The older rocks include klippe of ultramafic rocks ('North Klippe' of Tempelman-Kluit, 1979) and variably deformed mafic and felsic meta-volcanic rocks, as well as overlying crinoidal limestone in the area of the original 'Money Klippe' of Tempelman-Kluit (1979). These latter rocks have been correlated with the Fire Lake unit of the Grass Lakes succession in the footwall of the thrust. The meta-volcanic rocks in the thrust sheet in the southeastern corner of the map area are intruded by variably foliated metaluminous meta-plutonic rocks of the Simpson Range suite (Hunt and Murphy, 1998; Murphy and Piercey, 2000; Piercey and Murphy, 2000).

The rocks in the Money Creek thrust sheet have been dated in various places in Finlayson Lake and Frances Lake map areas. Limestone along the Robert Campbell Highway, 7 km west of Finlayson Lake, contains Late Mississippian (Serpukhovian) conodonts (J. Hunt and M. Orchard, pers. comm., 1998). Pennsylvanian conodonts were obtained from limestone 8 km south-southeast of Finlayson Lake (Tempelman-Kluit, 1977, 1979). Correlative limestone in the headwaters of the Tuchitua River in Frances Lake map area has conodonts as young as Moscovian, as well as Serpukhovian (M. Orchard and D. Murphy, unpublished data, 2000). Felsic meta-volcanic rocks underlying the Carboniferous limestone have not been dated in Finlayson Lake map area, however, in Frances Lake map area, correlative units have Early Mississippian U-Pb zircon ages (Mortensen, 1983, 1992a; J. Mortensen and D. Murphy, unpublished data). The quartzite unit above the Carboniferous limestone has not been directly dated, but is likely to be Late Pennsylvanian. The basal contact of the limestone is likely a disconformity because all of the U-Pb dates for meta-volcanic rocks beneath the Carboniferous limestone are substantially older than Serpukhovian, the oldest age of the limestone. Quartz-porphyritic granite, inferred to be comagmatic with rhyolite in the older part of the thrust sheet, is ca. 361 Ma (Mortensen, 1992b), and intrusions of the Simpson Range Suite in the Money Creek thrust sheet range from ca. 346 Ma to 358 Ma (Mortensen, 1992a; Grant, 1997).

UPPER PENNSYLVANIAN OVERLAP SUCCESSION

A succession of carbonaceous phyllite, grey chert, diamictite and quartzofeldspathic sandstone, grit, and local conglomerate, overlies rocks in the footwall of the Money Creek thrust, as well as those in the Money Creek thrust sheet. Bedded chert, inferred to overlie the Kudz Ze Kayah unit of the Grass Lakes succession along Campbell Creek, and carbonaceous phyllite, diamictite, grit and chert overlying the Wolverine succession north of Wolverine Lake, belong to this unit.

The relationship of this sequence to both the hanging wall and footwall of the Money Creek thrust implies that this succession overlaps the thrust itself and its age would therefore place a younger limit on the age of the thrust. There are no direct age constraints in Finlayson Lake area, but the sequence overlies limestone of Moscovian age in Frances Lake area (M. Orchard and D. Murphy, unpublished data, 2000) and is overlain by Campbell Range basalt of probable Early Permian age (Plint and Gordon, 1997; Murphy, 2000a,b,c, 2001). A Late Pennsylvanian age is thus indicated for both the clastic overlap succession and the displacement on the Money Creek thrust.

THE JULES CREEK THRUST AND ITS FOOTWALL

Recent mapping in Frances Lake map area has shown that rocks in the footwall of the Money Creek thrust, the Money Creek thrust sheet, and the Pennsylvanian overlap succession were thrust to the northeast along the Jules Creek thrust (Murphy, 2000a,b,c, 2001). In the Frances Lake area, rocks in the footwall of the Jules Creek thrust comprise mainly carbonaceous phyllite, chert and chert-pebble conglomerate, which have been correlated with the Earn Group of the North American miogeocline (Plint and Gordon, 1997). This fault and its footwall succession, herein termed the Finlayson succession, have been traced into the Finlayson Lake area where they include rock types unlike those in the Earn Group and where a pre-mid-Permian geological history, unlike that of the Earn Group, can be demonstrated.

Finlayson succession

The Finlayson succession, named for the relatively good exposures on the hills north of Finlayson Lake and Finlayson River in the eastern part of the map area (Figs. 2 and 3), is composed mainly of dark grey siliceous carbonaceous phyllite; grey, white, pink and green chert; mottled grey-white chert-pebble conglomerate; and shale chip-bearing, quartzofeldspathic grit and conglomerate. Also included in the succession are significant accumulations of felsic meta-volcanic rocks that occur east of Finlayson Lake and also north of the Pelly River, in the western part of 105G/13. Intermediate meta-volcanic rocks have been found in 105G/16, about 14 km north-northwest of where the Robert Campbell Highway exits Finlayson Lake map area. Mafic meta-volcanic rocks occur locally in 105G/14, southwest of Fortin Lake. Massive limestone occurs north of the Robert Campbell Highway, in the eastern part of 105G/16.

In 105G/15, southwest of Fortin Lake, rocks of the Finlayson succession exhibit a pronounced strain gradient. At the southern end of the north-trending ridges in this area, chert and carbonaceous phyllite are foliated and folded, but bedding is distinct. Northwards along the ridges, foliation is more intense and bedding less distinct. Where observed, bedding is thicker and isoclinally folded at the outcrop scale, suggesting transposition. Although highly strained rocks extend northwards to the post-Late Triassic Inconnu thrust, the presence of clasts of highly strained rocks of the Finlayson succession within mid-Permian (to Triassic?) conglomerate (see next section) demonstrates that the deformation was not related to the Inconnu thrust, but reflects a Paleozoic deformation event.

The age of the Finlayson succession has not been directly determined. The unit is overlain by Campbell Range basalts of late Pennsylvanian to Early Permian age. Similar rocks near Faro have Mississippian conodont ages (L. Pigage, pers. comm., 2000).

UPPER PENNSYLVANIAN TO PERMIAN OVERLAP ASSEMBLAGES

Recent mapping in Frances Lake map area showed that the trace of the Jules Creek thrust is locally overlapped by outliers of basalt of the late Pennsylvanian to Early Permian Campbell Range succession (Murphy, 2000a,b,c, 2001). This relation has also been documented in northern Finlayson Lake area, where the Campbell Range succession lies on all older thrust sheets. In addition, mafic and ultramafic meta-plutonic rocks, inferred to be the sub-volcanic roots to the Campbell Range basalt, occur in rocks belonging to all the thrust sheets. Finally, highly strained rocks of the Finlayson succession and basalt of the Campbell Range succession are overlain by a polymictic conglomerate, sandstone, siltstone and basalt unit thought to correlate with similar rocks of mid-Permian age in Frances Lake and Watson Lake map areas (Murphy, 2000a,b,c, 2001; Mortensen et al., 1997, 1999).

Campbell Range succession

Weakly deformed basalt and chert, occurring intermittently across the map area, have been included in the Campbell Range succession. The succession includes basalt and chert in the Campbell Range where the succession was originally documented (Murphy and Piercey, 1999a,b), as well as occurrences underlying the massifs in the northwestern part of the area, and smaller outliers between the two areas. The current definition, however, excludes carbonaceous meta-clastic rocks and chert of the Upper Pennsylvanian overlap succession, which were included in the original definition of the succession (Murphy and Piercey, 1999a,b). These rocks were placed into a separate unconformity-bound succession when the profound nature of the unconformity at the base of the Campbell Range basalt/chert sequence was recognized in Frances Lake area (Murphy, 2001).

Basalt is the predominant rock type of the Campbell Range succession. It is generally massive, green to brown on weathered surfaces, and dark green to black on fresh surfaces. Pillowed and fragmental varieties are locally important, especially around the Ice massive sulphide deposit in the northern part of the map area (Yukon MINFILE, 2001, 105G 118; Fig. 2). Epidote alteration is a common feature, as is pink to tan jasperoidal silica.

Chert, argillite and rarely limestone are intercalated with basalt. Maroon, pink and green chert, and siliceous argillite are locally important enough to define separate map units. Chert is ribbon-bedded (10- to 30-cm-thick beds with lesser centimetre- to decimetre-scale beds of argillite). Chert/argillite sequences are foliated and internally folded, contrasting with the relatively pristine nature of the intercalated basalt. A metre-scale bed of algal-laminated limestone was observed in one locality.

The age of the Campbell Range succession is constrained to be latest Pennsylvanian to Early Permian. It overlies the post-Moscovian clastic sequence, which overlaps the Money Creek thrust and is intruded by ca. 274 Ma leucogabbro (Mortensen, 1992b; J. Mortensen and D. Murphy, unpublished data, 2000). Plint and Gordon (1997) report Atokan to Wolfcampian (early Pennsylvanian to Early Permian) radiolaria from chert near the base of the succession. Furthermore, the Campbell Range succession is identical to, and likely correlates with, the Anvil Range Group at Rose Mountain near Faro from which Early Permian radiolaria have been obtained (L. Pigage, pers. comm., 2000).

The base of the Campbell Range succession is inferred to be a profound regional unconformity, developed after movement on the Jules Creek thrust. The succession overlies both the Finlayson succession in the footwall of the Jules Creek thrust and rocks in the hanging wall. The succession must therefore overlap the Jules Creek thrust, and thrusting must therefore be late Pennyslvanian in age.

Mafic and ultramafic meta-plutonic rocks

Several aeromagnetically prominent bodies of mafic and ultramafic meta-plutonic rocks occur across the area. These range in area from hundreds of square metres to over 2 km^2. Leucogabbro, meta-pyroxenite and meta-peridotite occur most commonly in this area, the latter being ubiquitously serpentinized with only ghosts of the primary mineralogy preserved. The outcrop distribution of these rocks is coincident with that of the Campbell Range basalt, implying a genetic association. Where contact relations are exposed, the basalt is intruded by the meta-plutonic rocks. Two different bodies of leucogabbro have yielded Early Permian U-Pb ages (ca. 274 Ma, Mortensen, 1992b; J. Mortensen and D. Murphy, unpublished data, 2000).

Mid-Permian (to Triassic?) clastic rocks

Isolated outcrops of weakly deformed polymictic conglomerate, sandstone and siltstone, and rare mafic meta-volcanic rocks, occur sporadically across the central part of the map area, mainly near the northern edge of Yukon-Tanana Terrane. The conglomerate is light green- to tan-weathering and poorly bedded. Sandstone and siltstone are tan, and locally grade to argillite. Clasts in the conglomerate are locally derived, being mainly foliated chert and phyllite where the conglomerate overlies the Finlayson succession, and basalt where the conglomerate overlies the Campbell Range basalt. Other clasts include serpentinized ultramafic rocks, limestone, and quartz- and feldspar-phyric meta-volcanic rock. Randomly oriented foliated clasts, inferred to be derived from the Finlayson succession, imply that the conglomerate post-dates the intense deformation of the succession.

The age of the conglomerate in Finlayson Lake area is poorly constrained, however, lithologic similarity to better dated conglomerate units along strike to the west and southeast imply either a mid-Permian or Triassic age. In one locality in the northern part of the map area, conglomerate clasts are mostly Campbell Range basalt, hence it must be younger than latest Pennsylvanian to Early Permian. If the clasts of serpentinized ultramafic rock were derived from the ultramafic meta-plutonic rocks that intrude the Campbell Range basalt, then the conglomerate is younger than ca. 274 Ma. Southeast of the Finlayson Lake area, throughout Frances Lake map area, and as far south as Watson Lake, lithologically similar polymictic conglomerate occurs at a similar structural position near the leading edge of Yukon-Tanana Terrane. Near Simpson Lake, conglomerate is interbedded with limestone containing Permian conodonts (J. Mortensen, pers. comm., 1999; identification by M.J. Orchard) and with felsic volcanic rocks that have mid-Permian U-Pb dates (J. Mortensen, pers. comm., 2000). Clasts within the conglomerate have mid-Permian to Triassic cooling ages (Mortensen et al., 1999). A mid-Permian age is therefore indicated for the conglomerate unit in Watson Lake area. However, west of the Finlayson Lake area near Faro, lithologically similar polymictic conglomerate is interbedded with limy shales that contain Late Triassic conodonts (Tempelman-Kluit, 1979; Mortensen and Jilson, 1985; Mortensen, et al., 1997, 1999). The Faro conglomerate differs from the Finlayson Lake-Frances Lake-Watson Lake conglomerates in that it does not lie along the leading edge of Yukon-Tanana Terrane. The Faro conglomerate occurs southwest of the belt of basalt of the Anvil Range Group that extends almost to Finlayson Lake map area, and which likely correlates with basalt of the Campbell Range succession. Owing to the overall similarity with the Watson Lake conglomerate, a mid-Permian age for the Finlayson Lake conglomerate succession is preferred.

POST-THRUSTING INTRUSIVE ROCKS OF YUKON-TANANA TERRANE

In addition to the mid-Paleozoic meta-plutonic rocks of the various thrust sheets, rocks of Yukon-Tanana Terrane are intruded by two suites of plutonic rocks that are absent in the North American miogeocline. These include rare, narrow, variably foliated dykes of granite and hornblende granodiorite of probable mid-Permian age

(J. Mortensen and D. Murphy, unpublished data), as well as stocks of weakly foliated Jurassic hornblende granodiorite (Mortensen, 1992a).

NORTH AMERICAN MIOGEOCLINE

Rocks of the North American miogeocline include four units: Silurian to Devonian rocks of McEvoy Platform (S. Gordey, pers. comm., 2001); unconformably overlying dark clastic rocks and chert of the Devonian-Mississippian Earn Group; chert of the Carboniferous to Permian Mt. Christie Formation; and Triassic clastic rocks and limestone. Miogeoclinal rocks are folded and locally weakly foliated, but show no evidence of multiple regional deformations, as do rocks of Yukon-Tanana Terrane.

McEVOY PLATFORM

S. Gordey (pers. comm., 2001) defines McEvoy Platform as the belt of dominantly shallow water siltstone, carbonate and quartzite of Siluro-Devonian age that extends northwestward from Watson Lake map area to southern Sheldon Lake map area, crossing the northeastern corner of Finlayson Lake map area. The platformal rocks in Finlayson Lake area have been subdivided into four map units, which are intermittently exposed beneath the unconformity at the base of the overlying Earn Group. The oldest unit is composed of tan to orange-brown platy siltstone of Silurian age (unit Ss of Tempelman-Kluit, 1977; Poulton et al., 1999). This unit passes upward into a unit of cream-weathering, sandy dolostone and grey quartzite (unit Sdq of Tempelman-Kluit, 1977), which grades upwardly into massive grey orthoquartzite (unit Sq of Tempelman-Kluit, 1977). The top of the McEvoy Platform succession is a unit of dark grey limestone containing two-hole crinoids suggesting a middle Devonian age (unit Sd of Tempelman-Kluit, 1977).

EARN GROUP

Dark clastic rocks of the Earn Group underlie an extensive, east-striking belt across the northern part of the map area. The Earn Group is primarily dark grey, pin-striped slate, but also includes dark chert, chert-pebble conglomerate, bedded barite, and, rarely, sandstone and grit/pebble conglomerate with quartz and feldspar. The basal rocks of the Earn Group overlie different units of McEvoy Platform in the northeastern corner of the map area, suggesting that the regional unconformity that has been documented elsewhere in the Selwyn Basin region (Gordey et al., 1982, 1987) also occurs in Finlayson Lake map area.

The age span of the Earn Group in Finlayson Lake area is not known as no fossils have been reported. Regionally, the Earn Group ranges in age from Middle Devonian to earliest Mississippian (Gordey et al., 1982; Gordey and Anderson, 1993).

MT. CHRISTIE FORMATION

Chert and shale overlying the dark clastic rocks of the Earn Group have been assigned to the Mt. Christie Formation. The unit occurs in an east-striking belt from the Pelly River to McEvoy Creek, south of, and parallel to, the belt of underlying Earn Group. Mt. Christie chert is massive to thick-bedded, pale green to black, and alternates with thinner interbeds of similarly coloured dark shale. Differential erosion of alternating chert and shale lends a corrugated appearance to the terrain underlain by the Mt. Christie Formation.

The age of the Mt. Christie Formation in Finlayson Lake area is not known. Elsewhere, fossils ranging in age from Late Mississippian to Late Permian have been reported (S. Gordey, pers. comm., 2001).

UNNAMED TRIASSIC FORMATION

The Mt. Christie Formation is overlain to the south by a sequence of dark clastic rocks and limestone of Late Triassic age. The sequence consists mostly of tan-brown-weathering, weakly calcareous, grey-green, finely laminated, platy siltstone and fine sandstone. Ripple cross-lamination occurs locally and detrital mica is visible on most parting surfaces. One member of light grey, sandy, bioclastic limestone occurs in the middle of the sequence. This unit has been traced for about 14 km within the Triassic outcrop belt midway between Finlayson and Fortin lakes. Conodonts obtained from this unit are consistently Early Norian in age (Poulton et al., 1999).

An 11-km-long outlier of Triassic rocks occurs 9 km southwest of the western end of Finlayson Lake. At this locality, folded dark silty shale; fine-grained, laminated and ripple cross-laminated, tan-brown weathering, detrital mica-bearing sandstone; and fetid, dark grey limestone of Late Carnian age (Poulton, et al., 1999) alternate with fragmental basalt and greenstone, and serpentinized ultramafic rock. Although poorly exposed, the repetitions are inferred to be thrust imbricates of an original unconformable depositional contact between the Triassic rocks and the fragmental basalt, greenstone and ultramafic rock. Poly-deformed, pre-Upper Devonian meta-sedimentary and meta-volcanic rocks of the Grass Lakes succession surround the imbricated rocks at higher elevations, as well as structurally overlying them to the south and north (Murphy et al., 2001). This relation suggests that the imbricated rocks are exposed in a structural window through Yukon-Tanana Terrane.

THE INCONNU THRUST

Rocks of Yukon-Tanana Terrane are in contact with rocks of the North American miogeocline along the Inconnu thrust. Although unexposed, the thrust was initially recognized in the 105G/15 mapsheet, southwest of Fortin Lake (Fig. 2). At this locality, polymictic, mid-Permian (to Triassic?) conglomerate and unconformably underlying intensely foliated siliceous phyllite and chert of the Finlayson succession are juxtaposed against dark, south-dipping shale, siltstone and bioclastic limestone of Late Triassic age (see below). Between the Pelly River and the western edge of the map area, progressively older strata are present in the footwall. Similarly, south and southeast of Fortin Lake (Fig. 2), Triassic rocks occur intermittently in the immediate footwall, but locally, the Finlayson succession is juxtaposed against Early Paleozoic quartzite and dolomite of McEvoy Platform.

The structural window through Yukon-Tanana Terrane into Upper Triassic rocks southwest of Finlayson Lake is inferred to be a window through the Inconnu thrust sheet. The Inconnu thrust is the only thrust in the area with Upper Triassic rocks in its footwall; all other faults are Paleozoic in age. Therefore, a geometrically plausible interpretation is that the Upper Triassic rocks under the leading edge of the thrust in 105G/15 are continuous in the subsurface with the Upper Triassic rocks in the window. If so, then the Inconnu thrust must be a gently folded, low angle, large displacement thrust fault.

MESOZOIC AND CENOZOIC IGNEOUS ROCKS

Cretaceous and Tertiary igneous rocks underlie about 5% of northern Finlayson Lake area. The Cretaceous and Eocene episodes are represented by both volcanic and plutonic rocks, suggesting that the present erosion level in some parts of the map area approximates the Cretaceous and Eocene erosion level.

CRETACEOUS IGNEOUS ROCKS

The Cretaceous episode is mainly represented by weakly foliated to unfoliated peraluminous granitic plutons. Weakly foliated intrusions occur mainly in the southeastern part of the area, where the country rock is at a higher metamorphic grade. Crosscutting relationships in this area suggest that the weakly foliated suite is late kinematic with respect to deformation in the host rock (Murphy, 1997; Murphy and Timmerman, 1997; Murphy and Piercey, 1999b). Unfoliated granitic stocks intrude poly-deformed rocks of Yukon-Tanana Terrane in the southern and south-central parts of the map area (Murphy et al., 2001). Two unfoliated granitic stocks with aeromagnetically prominent hornfels zones occur in the northeastern corner of the map area where they intrude rocks of the North American miogeocline.

A small outlier of Cretaceous South Fork volcanics extends into the northern part of the Finlayson Lake map area from Sheldon Lake map area (S. Gordey, pers. comm., 2001; Gordey and Makepeace, 1999). The South Fork volcanics consist of massive, poorly stratified, dacitic crystal-lithic tuff. Lithic clasts can be several cubic metres in size and include blocks of Silurian dolostone suggesting that the volcanic rocks erupted through rocks of McEvoy Platform.

U-Pb crystallization ages suggest that there is more than one episode of Cretaceous magmatism in the area (J.K. Mortensen, 2001). Zircon and monazite ages on weakly foliated to unfoliated intrusions in the southern part of the area are mainly 110 Ma to 112 Ma. No U-Pb dates have been obtained from the intrusions into the miogeocline in the northeastern corner of the map area. The South Fork volcanics, however, have been dated as 97 ± 1 Ma (Mortensen, 1999).

EOCENE IGNEOUS ROCKS

Eocene magmatism was compositionally diverse (Jackson et al., 1986). Basalt is the most extensive product, occurring in a variety of settings ranging from thick pillowed flows and tuff breccia in a massif west of Starr Creek (‘Pillow Mountain’ locality of Jackson et al., 1986), to a columnar-jointed volcanic neck and flow complex near Weasel Lake. Massive flows occur along Starr Creek near the Robert Campbell Highway and along the Hoole River. Aeromagnetically prominent gabbro and pyroxenite in the Pelly River valley in the western part of the map area are inferred to be the sub-volcanic equivalents of the basalt. Quartz-feldspar porphyritic volcanic rocks occur in

Starr Creek in a fault block within the Tintina fault zone, west of the limit of mapping (Jackson et al., 1986). These may be continuous with the Grew Creek volcanic rocks located in the Tintina Trench northwest of the map area (Jackson et al., 1986). Isolated bodies of quartz-feldspar porphyritic intrusions occur north of Finlayson Lake.

K-Ar ages on both basalt and felsic volcanic rocks range from ca. 46 Ma to ca. 58 Ma confirming the Eocene age of these rocks, and attesting to the bimodal nature of Eocene magmatism (Jackson et al., 1986; Mortensen, 1999).

MINERAL OCCURRENCES AND POTENTIAL

The Finlayson Lake map area contains 143 known mineral occurrences (Yukon MINFILE, 2001), and therefore has a correspondingly high potential for new discoveries. The 1994 discovery of the Kudz Ze Kayah volcanic-hosted massive sulphide deposit (op. cit., 105G 117; Schultze, 1996) led to Yukon's largest staking rush. This staking rush lead to the discovery of new volcanic-hosted deposits such as GP4F near Kudz Ze Kayah (Yukon MINFILE, 2001, 105G 143) and Ice (op. cit., 105G 118) in Permian basalt of the Campbell Range succession, as well as the delineation of reserves on previously known occurrences such as Wolverine (Yukon MINFILE, 2001, 105G 072; Tucker et al., 1997) and Fyre Lake (Yukon MINFILE, 2001, 105G 032; Foreman, 1998). In the northern part of Finlayson Lake map area, dark shale of the Earn Group and carbonaceous phyllite in Yukon-Tanana Terrane contain Zn-Pb-Ag-Ba sedimentary-exhalative (SEDEX) deposits (e.g., Dwonk; Yukon MINFILE, 2001, 105G 094) and have seen sporadic interest, especially following discoveries in the Anvil district near Faro. Exploration around mid-Cretaceous granitic intrusions in the area has uncovered skarn, vein and other types of intrusion-related occurrences. Eocene igneous rocks near the Tintina Fault have been the focus of some exploration for epithermal gold deposits similar to the Grew Creek deposit in the Tintina Trench, located about 50 km northwest of the western edge of the map area (Duke and Godwin, 1986; Christie et al., 1992). The area's potential for this type of deposit was recently affirmed by a coincident Hg-As-Sb-Tl-Au-Ag till geochemical anomaly defined in northwestern Weasel Lake map area (105G/13; Bond, 2001; Bond and Plouffe, this volume). A recent addition to this impressive mineral inventory are emeralds, discovered in 1998 in the southern part of the map area. They occur in pockets along quartz-tourmaline-beryl veins in mafic meta-volcanic rocks near where a mid-Cretaceous pluton intrudes ultramafic and mafic meta-plutonic rocks (Crown showing on Goal Net property, Yukon MINFILE, 2001, 105G 123; L.A. Groat, pers. comm., 2001).

The new map of the northern part of Finlayson Lake map area (Murphy et al., 2001) extends to the northwest, to areas known to be underlain by the prospective meta-volcanic rock units that host the syngenetic deposits in the core of the Finlayson Lake district. Most of the area west and southwest of Finlayson Lake, between the Robert Campbell Highway and the Tintina Fault, is underlain by the Grass Lakes succession and Mississippian augen orthogneiss. The lowest unit of the Grass Lakes succession contains a greater abundance of felsic meta-volcanic rocks in this area than in the better exposed eastern part of the area (105G/7 and 8) and is locally mineralized (e.g. Yukon MINFILE, 2001, 105G 016). Several occurrences have been found in the area underlain by the Fire Lake unit (Yukon MINFILE, 2001). Higher in the Grass Lakes succession, chloritic phyllite (mafic meta-volcanic rock) of the Fire Lake unit occurs extensively, commonly associated with large and extensive masses of mafic and ultramafic meta-plutonic rocks, an association found near the Fyre Lake deposit. Part of the area shown on previous maps as being underlain by augen orthogneiss (Tempelman-Kluit, 1977; Mortensen and Jilson, 1985) is now known to be underlain by a large roof pendant in the meta-plutonic body consisting of rocks of the Fire Lake unit and the underlying quartz-rich meta-clastic unit (Fig. 2). A new

Table 1. *New mineral showings in northern Finlayson Lake area.*

Name	Type	Easting (83)	Northing (83)
CAM	volcanogenic massive sulphide	408105	6836588
STEVE	volcanogenic massive sulphide	384404	6838698
PAT	volcanogenic massive sulphide	401302	6844329
BEAR	sedimentary exhalative	439637	6837687

showing was discovered in rocks of the Fire Lake unit within the pendant (Steve showing, Table 1; Murphy et al., 2001). The Kudz Ze Kayah unit, host of the deposit of the same name, is less extensive in the western part of the Finlayson Lake area than in the heart of the massive sulphide district, and for the most part, is represented by carbonaceous phyllite. Felsic meta-volcanic rocks of this unit occur in a northeast-trending belt east of the headwaters of Big Campbell Creek, where they host the League occurrence (Yukon MINFILE, 2001, 105G 130), and in the area south of the northwest end of Finlayson Lake, between Campbell Creek and the Robert Campbell Highway. A new showing and kill zone were discovered in rocks of the Kudz Ze Kayah unit along Campbell Creek (Cam showing, Table 1; Murphy et al., 2001).

Intermediate to felsic meta-volcanic rocks of the Money Creek thrust sheet are locally porphyritic, pyritic or altered, suggesting that they may have potential to host massive sulphide deposits. Yukon MINFILE (2001) occurrence 105G 108 is located near outcrops of sericite-altered, pyritic, felsic meta-volcanic rocks, south of the southeastern end of Finlayson Lake. A new showing of pyritic and silicified felsic meta-volcanic rocks was found north of the Robert Campbell Highway, east of the bridge over Campbell Creek (Pat showing, Table 1; Murphy et al., 2001). Pale greenish-white feldspar-quartz meta-porphyry that occurs about 8 km north-northwest of the confluence of Big Campbell Creek and the Pelly River, may be a sub-volcanic intrusion and may possibly indicate a volcanic centre for the meta-volcanic rocks of the thrust sheet.

The Finlayson succession has potential for both volcanic-hosted and sedimentary exhalative massive sulphide deposits. Significant thicknesses of felsic meta-volcanic rocks occur in the succession north of the Finlayson River in the eastern part of the map area, and north of the Pelly River, in the western part of the map area. Porphyritic varieties occur in both localities. A barite occurrence (also noted by Cominco Ltd., B. Mauer, pers. comm., 2001), is hosted by carbonaceous phyllite north of the Finlayson River in the eastern part of the map area (Bear showing, Table 1).

DISCUSSION

The 1996-2001 mapping of Yukon-Tanana Terrane in Finlayson Lake and Frances Lake map areas (Fig. 1) and associated petrochemical (Piercey et al., 1999, 2000, 2001a,b; Piercey, 2001), geochronological and biochronological studies have led to a new understanding of the geological evolution of this complex terrane. The picture that emerges from this work is one of a continental or transitional crustal fragment evolving through rapidly changing convergent margin geodynamic settings during the mid- and Late Paleozoic, and ultimately amalgamating with the North American miogeocline in Jura-Cretaceous time. During Late Devonian and early Mississippian time, a southwest-facing (current geographic coordinates) continental arc and back-arc magmatic system was established on this crustal block. Following the early Mississippian cessation of arc-back-arc magmatism in this area, a mid-Mississippian hiatus and a late Mississippian to mid-Pennsylvanian period of carbonate deposition, the arc rocks and overlying carbonates were thrust to the northeast over the back-arc rocks along the Money Creek thrust. In the late Pennsylvanian, this thrust-shortened terrane became the locus of uplift, erosion, and sedimentation of basinal coarse-grained clastic rocks derived from the hinterland of the thrust belt. The shortened arc-back-arc complex, and the overlapping clastic rocks were subsequently thrust to the northeast over basinal rocks of the Finlayson succession in the latest Pennsylvanian, before the Early Permian deposition of the Campbell Range succession. Originally considered to be part of Slide Mountain Terrane (e.g., Plint and Gordon, 1997 and references therein), the Campbell Range succession is now inferred to be a manifestation of rifting of the thrust-imbricated Yukon-Tanana Terrane, possibly in the back-arc region of an Early Permian arc, which was recently recognized in Wolf Lake map area (Roots et al., in press). Mid-Permian time is represented by a polymictic conglomerate made up of clasts of Yukon-Tanana Terrane lithologies that was likely deposited in a fore-arc setting along the eastern (present geographic coordinates) margin of Yukon-Tanana Terrane (Mortensen et al., 1997, 1999). The switch to subduction along the northern/eastern side of the terrane led to the consumption of the Slide Mountain Terrane ocean rocks that commonly occur between Yukon-Tanana Terrane and North America (Nelson, 1993; Ferri, 1997 and references therein). This subduction is believed to have initiated the process of convergence between Yukon-Tanana Terrane and North America that culminated with the post-Late Triassic thrusting of the terrane onto the North American miogeocline along the Inconnu thrust.

The recognition of the several different and sequentially developed paleogeographic settings within Yukon-Tanana Terrane has implications for the exploration for new mineral deposits. With the exception of the Fyre Lake deposit, all of the known volcanic-hosted massive sulphide deposits occur within rocks inferred to have been deposited in back-arc settings (Piercey and Murphy, 2000; Piercey, 2001b). The Kudz Ze Kayah and GP4F deposits formed in the Late Devonian back-arc region, while Wolverine Lake formed in the early Mississippian back-arc region, all of these in the footwall of the Money Creek thrust. The Ice deposit formed during rifting behind a coeval Early Permian arc recently recognized in southern Yukon (Roots et al., in press). As was noted by Piercey et al. (2000, 2001b), back-arc settings have the structural and thermal characteristics necessary for the generation and maintenance of large-scale hydrothermal circulatory systems that lead to the development of sea floor massive sulphide deposits.

The back-arc regions are clearly prospective for mineral deposits, however, the arc region also holds promise for new discoveries. This region contains one deposit and several occurrences. The Fyre Lake deposit occurs in boninitic rocks that Piercey et al. (2001a) concluded formed in an intra-arc rift. Piercey et al. (2001a) noted that the structural and thermal characteristics of arc-rift settings are similar to those in a back-arc region (high heat-flow and extensional syn-volcanic faults). Numerous gossanous areas occur in felsic intervals within the dominantly intermediate Mississippian meta-volcanic rocks in the hanging wall of the Money Creek thrust of southwestern Frances Lake map area (Murphy, 2001). The new showing in felsic rocks in the hanging wall of the Money Creek thrust, north of the Robert Campbell Highway, was documented in this study (Pat showing, Table 1).

Further insight into the mineral potential of specific areas within northern Finlayson Lake map area can be gained by considering the new bedrock map in conjunction with the results of the concurrently conducted till geochemistry program (Bond and Plouffe, this volume). Several coincident base metal geochemical anomalies occur in the map area, which can be correlated with meta-volcanic units that lie in the ‘up-ice’ direction. Altogether, this bedrock, and surficial mapping and till geochemistry initiative, provide comprehensive coverage and a firm foundation for systematic regional mineral exploration.

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