Age, geochemistry, paleotectonic setting and metallogeny of Late Triassic-Early Jurassic intrusions in the Yukon and eastern Alaska: A preliminary report

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ABSTRACT

Late Triassic to Early Jurassic age (~220-185 Ma) intrusions comprise one of the most widespread and volumetrically significant plutonic suites in central and western Yukon, and eastern Alaska, but have received very limited study thus far. A new research project has been initiated that will examine the temporal, geochemical and petrotectonic evolution of this magmatic event, and the nature and origin of associated Cu, Au and PGE mineralization. The intrusions are mainly hornblende- and biotite-bearing granodiorites and quartz monzonites, although granitic phases and rare ultramafic phases (as at Pyroxene Mountain) are also present. Several bodies of coarse-grained muscovite granite that are included within the suite have been recognized in southwestern Dawson, and central and western Stewart River map areas. Most intrusions give preliminary U-Pb zircon and titanite ages of ~195 Ma to ~185 Ma, although scattered bodies give ages up to 218 Ma. Geochemical studies completed thus far indicate that most intrusions are metaluminous and formed in a volcanic arc environment, although some of the muscovite-granite phases in western Yukon are peraluminous and trend into the anorogenic (within-plate) granite field on various tectonic discriminant plots. Dating studies at Minto and Williams Creek indicate that copper-gold mineralization in both areas is hosted in part by deformed intrusions dated at ~194 Ma and is crosscut by massive, post-mineralization Granite Mountain batholith dated at ~190 Ma. The mineralization is therefore intimately associated with the Triassic-Jurassic magmatism, and we tentatively interpret the deposits as deformed copper-gold porphyries.

RÉSUMÉ

Les intrusions du Trias supérieur au Jurassique inférieur (~220 à 185 Ma) sont une des suites plutoniques les plus répandues et les plus volumineuses du centre et de l'ouest du Yukon et de l'est de l'Alaska, mais elles n'ont pas encore fait l'objet d'une étude détaillée. On a entrepris un nouveau projet de recherche dans le cadre duquel on examinera l'évolution temporelle, géochimique et pétrotectonique de cet événement magmatique ainsi que la nature et l'origine de la minéralisation en Cu, Au et EGP qui lui est associée. Les intrusions sont surtout constituées de granodiorites et de monzonites quartzifères à hornblende et à biotite, bien qu'on retrouve également des phases granitiques et de rares phases ultramafiques (comme le mont Pyroxène). Plusieurs masses de granite à muscovite à grain grossier sont incluses dans la suite et on été identifiées dans le sud-ouest et le centre de la région de Dawson ainsi que les parties centrales et occidentales de la région de Stewart River. La datation au U-Pb du zircon et de la titanite de la plupart des plutons fournit des âges préliminaires entre ~ 195 Ma et ~185 Ma, bien que pour quelques plutons épars on obtient des âges allant jusqu'à 218 Ma. Les études géochimiques complétées jusqu'à maintenant indiquent que la plupart des plutons sont méta-alumineux et ont été formés dans un environnement d'arc volcanique insulaire, quoi que certaines des phases de granite à muscovite de l'ouest du Yukon soient hyperalumineuses et aient une affinité qui tend vers le champ anorogénique (intraplaque) sur divers graphiques de discrimination tectonique. Les études de datation à Minto et à Williams Creek indiquent que la minéralisation en cuivre-or dans ces deux régions est en partie encaissée dans des intrusions déformées qui ont été datées à ~ 194 Ma et qu'elle est recoupée par le batholite massif post minéralisation de Granite Mountain qui a été daté à ~ 190 Ma. La minéralisation est donc intimement associée avec le magmatisme du Trias-Jurassique et l'interprétation proposée est que les gisements représentent des gisements de porphyres à cuivre-or déformés.

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INTRODUCTION

Intrusions of Late Triassic to Early Jurassic age (~220-185 Ma) are widespread throughout central and western Yukon, and eastern Alaska; however, the age, lithogeochemistry, paleotectonic evolution and metallogenic significance of this magmatism have received very limited study thus far. In view of the current high level of industry interest in intrusion-related mineralization in this region, and the recognition that several important mineral deposits and occurrences are spatially and genetically associated with the Triassic-Jurassic intrusions, more detailed study of this magmatic event is clearly required. A new research project has been initiated that will include geological mapping, U-Pb and Ar-Ar dating, and petrochemical studies of the intrusions, as well as several of the mineral deposits and occurrences that are thought to be temporally and genetically related to them. In this paper we present a synthesis of our present understanding of the Triassic-Jurassic magmatism, and report new geochemical results for some of the main intrusions in the suite.

REGIONAL FRAMEWORK FOR THE MAGMATISM

Late Triassic and Early Jurassic plutonic rocks in the Yukon (Fig. 1) have been assigned to various plutonic suites, including the Klotassin, Long Lake and Aishihik suites (e.g., Woodsworth et al., 1991; Johnston et al., 1996). Many of the isotopic ages on which these subdivisions were based, however, have proven to be incorrect (e.g., Mortensen, 1999). A revised map showing the distribution of Late Triassic and Early Jurassic plutonic rocks presents a considerably different pattern of magmatism than appears on currently available compilations (e.g., Wheeler and McFeely, 1991). Several plutons that were previously thought to be Cretaceous or Paleozoic in age have now given Triassic or Jurassic U-Pb ages. At the same time, some large bodies (such as the large expanse of granitoids in the western Dawson Range) that were previously considered to be Triassic or Jurassic have given Early Cretaceous U-Pb ages. The available mapping and age database for these intrusions does not appear to be adequate to support a subdivision of the intrusions into individual suites as yet.

The revised map distribution of plutons of Late Triassic-Early Jurassic age in the Yukon and easternmost Alaska (Fig. 1) shows that the intrusions form two distinct, sub-parallel belts. Most plutons fall within a sinuous western belt that stretches from west of Whitehorse through the eastern Dawson Range in the Williams Creek and Minto areas, and across the Stewart River map area, before terminating in the south-central Eagle quadrangle in eastern Alaska. An eastern belt of smaller and more widely scattered intrusions extends from the Seagull area (Abbott, 1981) through the Thirtymile Range (Gordey et al., 1998), the Sawtooth Range (Stevens et al., 1993), to the Lokken batholith. It then crosses the future trace of the Tintina Fault, which, if reconstructed before dextral strike-slip displacement, would extend into the Simpson Lake and Finlayson Lake areas (now in southeast Yukon). It is uncertain whether this belt re-crosses the trace of the Tintina Fault back into the eastern Eagle quadrangle in Alaska. Intrusions in both belts appear to be mainly emplaced into metamorphic rocks of the Yukon-Tanana Terrane. Preliminary field observations indicate that these intrusions are broadly late syn- to post-tectonic with respect to the main ductile deformation that affected this region. This deformation is thought to be associated with final terrane amalgamation in the northern Cordillera, and an improved understanding of the Triassic-Jurassic magmatism may shed new light on processes of terrane accretion as they operated in this area.

LITHOLOGY

The Late Triassic-Early Jurassic intrusions are compositionally highly variable. Most bodies are broadly intermediate in composition, but mafic to ultramafic phases, including mafic syenite, hornblendite, dunite, troctolite and clinopyroxenite are also locally present. Granitic phases are well developed in the western plutonic belt in the Stewart River map area and Eagle quadrangle. There, they occur both as relatively large, discrete plutons such as at Jim Creek and Crag Mountain (Fig. 1), and as swarms of felsic dykes and sills, such as those along the Yukon River between the mouths of the Stewart and Sixtymile rivers. Intermediate composition bodies commonly display a weakly to moderately developed foliation, although this fabric generally appears to be a result of magmatic flow, rather than tectonic deformation. Intermediate composition phases typically also contain abundant coarse pink K-feldspar phenocrysts, with strong igneous zoning defined by bands of biotite inclusions.

AGE CONSTRAINTS ON THE MAGMATISM

Preliminary U-Pb and Ar-Ar dating studies of the intrusions indicate crystallization ages that are mainly in the range of 195 Ma to 185 Ma (Early Jurassic) in both the western and eastern plutonic belts (Fig. 1). Scattered intrusions in the western belt yield ages up to 220 Ma (Late Triassic; Johnston et al., 1996; Hart, 1995; Mortensen, this study). Available data are too scattered at present to indicate any spatial or temporal trends in the magmatism. U-Pb zircon systematics of the intrusions are typically very complex, and indicate the presence of abundant inherited zircon components with a wide variety of ages. U-Pb dating of titanite has proven to be very useful for determining crystallization ages. Most K-Ar ages for the intrusions reflect at least minor disturbance, and should be considered suspect unless confirmed by an independent dating method.

GEOCHEMISTRY OF LATE TRIASSIC-EARLY JURASSIC PLUTONIC ROCKS

Major, trace and rare-earth element (REE) analyses have been obtained for a number of plutons of known Late Triassic-Early Jurassic age. This includes several phases of the Jim Creek pluton, as well as the Granite Mountain pluton, and syndeformational biotite-granodiorite orthogneiss and K-feldspar-megacrystic granite at the Minto copper deposit, all in the western plutonic belt. It also includes several small porphyritic hornblende-biotite granodiorite bodies from the Simpson Lake area in the eastern plutonic belt (Fig. 1). Preliminary interpretations of these data are presented here, together with data from the Aishihik batholith and Long Lake suite in the western plutonic belt (Johnston, unpublished data).

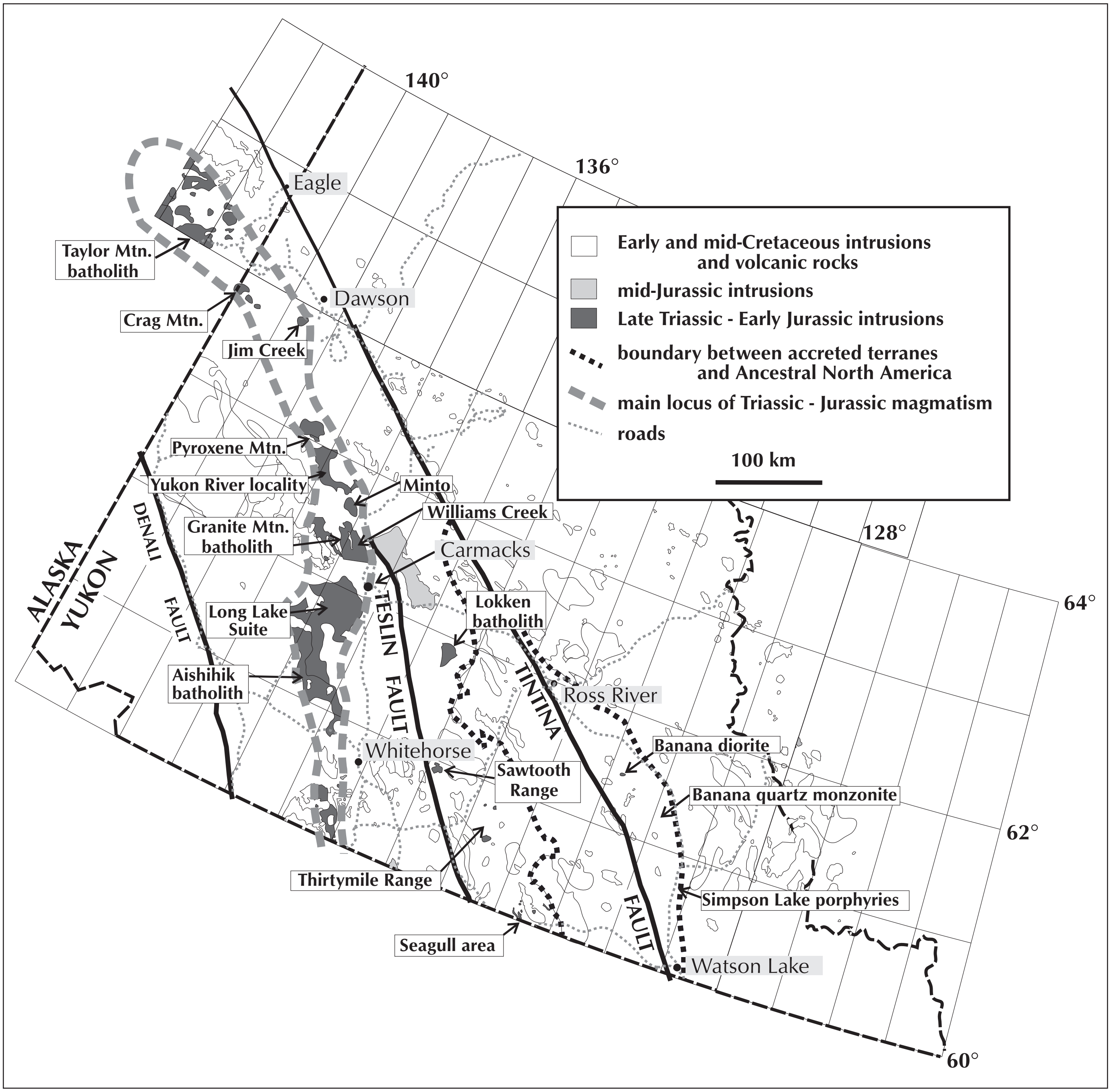

***Figure 1.** Distribution of Late Triassic and Early Jurassic plutons in the Yukon and eastern Alaska (modified from Wheeler and McFeely, 1991).*

A Shand's index plot for the samples (Fig. 2a) shows that the Jim Creek granite and the Minto orthogneiss and megacrystic granite are peraluminous in composition, whereas the Simpson Lake porphyry bodies, the Granite Mountain batholith, and all phases of the Aishihik batholith and Long Lake suite are metaluminous. The Rb vs. Nb+Y discrimination diagram of Pearce et al. (1984) shows all samples plotting in the volcanic-arc-granite field (Fig. 2b). This interpretation is consistent with data from the primitive-mantle-normalized multi-element plots for the samples (Sun and McDonough, 1989). All samples show significant negative Nb and Ti anomalies (Fig. 2c), consistent with production in a dominantly arc setting. High field strength element (such as Ti and Nb) depletion is a common feature in igneous rocks from such an environment. The Jim Creek pluton also shows a higher total content of REE and more strongly developed Nb and Ti anomalies than the other samples. A discrimination plot of Ga/Al-Zr (Fig. 2d; Whalen et al., 1987) shows the majority of the samples plotting within the field for I- and S-type granitoids, with the Jim Creek samples plotting on the boundary with the within-plate, A-type granitoids.

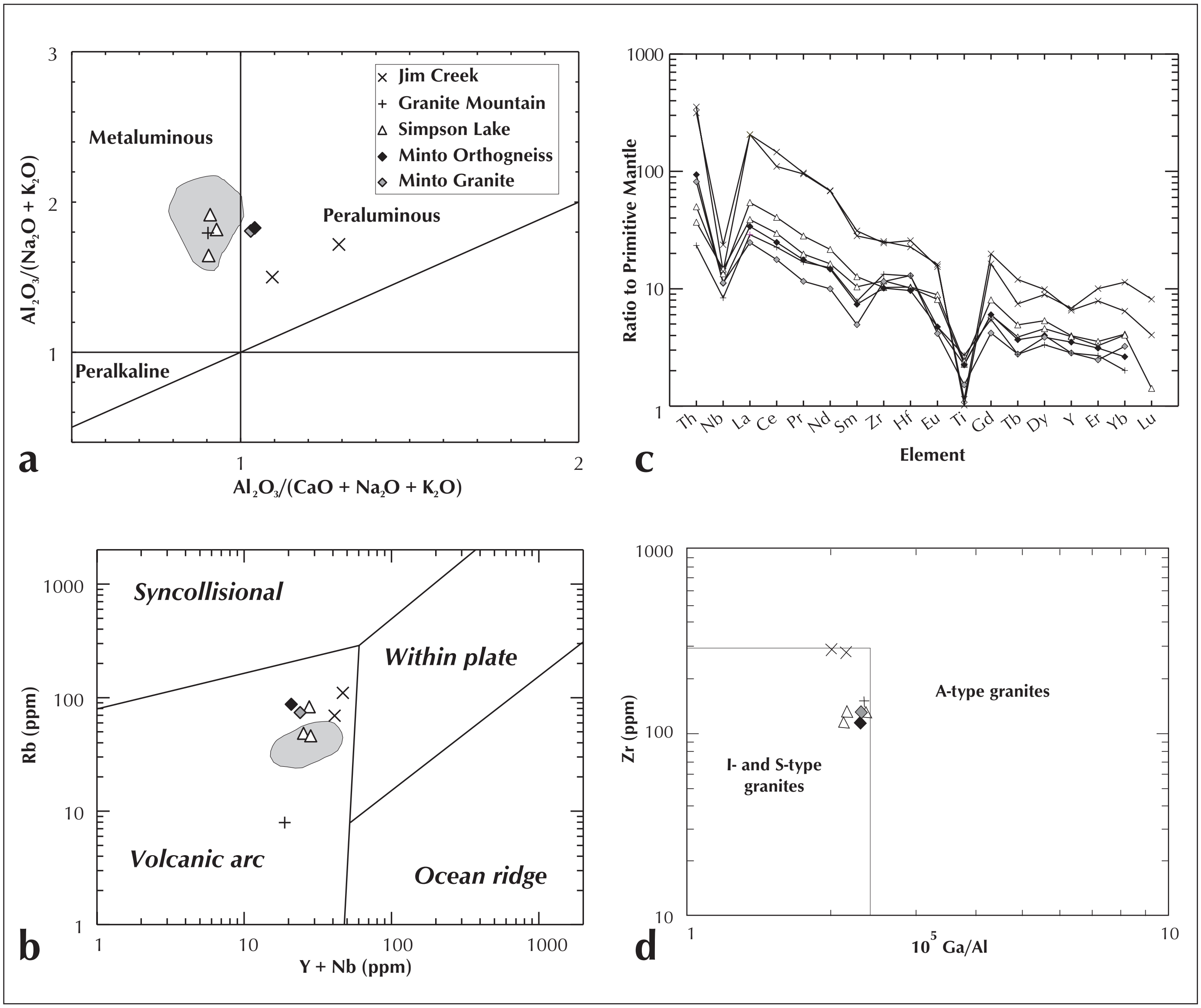

Figure 2. *a) Shand's index plot for Triassic and Jurassic intrusions. Shaded field represents range of analyses from the Aishihik batholith and Long Lake suite (Johnston, unpublished data). b) Nb-Y discrimination diagram for Triassic and Jurassic intrusions from Pearce et al. (1984). Shaded field represents range of analyses from the Aishihik batholith and Long Lake suite (Johnston, unpublished data). c) Primitive-mantle-normalized multi-element plots for Triassic and Jurassic intrusions (from Sun and McDonough, 1989). d) Ga/Al-Zr discrimination plot for I-, S- and A-type granites (from Whalen et al., 1987).*

These preliminary data show that the Late Triassic-Early Jurassic plutons vary from metaluminous to peraluminous, and show trace element distributions consistent with formation in an arc environment. The patterns seen in the Jim Creek samples may indicate evolution toward a more anorogenic environment of formation. At this point, there is no apparent geochemical difference between intrusions in the eastern and western plutonic belts.

METALLOGENY

Several distinct styles of mineralization are spatially and probably genetically associated with the Triassic-Jurassic intrusions. Low-grade, disseminated Au and PGE mineralization occurs within Early Jurassic clinopyroxenite on Pyroxenite Mountain (Fig. 1; occurrence 115NO 116; Yukon Minfile, 1997), and in Early Jurassic mafic and ultramafic intrusions in the Eagle quadrangle in eastern Alaska (Foley et al., 1989; Newberry et al., 1997). In addition, intrusion-hosted, Au-Cu-Te-bearing quartz veins with Early Jurassic Ar-Ar ages in southeastern Eagle quadrangle have also been described by Newberry et al. (1997).

Copper (-gold) deposits at Minto and Williams Creek in west-central Yukon (Fig. 1) represent the most significant mineralization associated with the Triassic-Jurassic magmatism. The nature and origin of mineralization at Minto and Williams Creek has been a topic of debate for many years. The deposits have been variously interpreted as metamorphosed volcanogenic massive sulphide (VMS) deposits, metamorphosed redbed Cu deposits, and deformed Cu (-Au) porphyry deposits (see discussion by Pearson and Clark, 1979). Preliminary work by the authors on the Minto deposit demonstrates that the main host for the ore is a biotite-rich orthogneiss with a U-Pb zircon (crystallization) age of ~194 Ma. Mineralization was probably accompanied by potassic alteration which introduced abundant secondary biotite into the host rock. This occurred prior to deformation and the subsequent intrusion of the undeformed and post-mineral Granite Mountain batholith at ~190 Ma (U-Pb titanite age). These data are quite consistent with a syn-tectonic porphyry model for the deposit, and possible analogies exist with the Gibraltar deposit in south-central B.C.

The Williams Creek deposit is hosted largely within metavolcanic and metasedimentary rocks of the Yukon-Tanana Terrane, and in deformed granitoid bodies that intrude them. These granitoids yield a preliminary zircon U-Pb age of ~193 Ma. As with the Minto deposit, ore bodies at Williams Creek were deformed along with their host rocks prior to the intrusion of the Granite Mountain batholith at ~190 Ma. The Williams Creek deposit is therefore also interpreted by the authors as a deformed, intrusion-related Cu (-Au) deposit resembling better-known Cu-Au deposits such as at Copper Mountain in southern B.C. (Stanley et al., 1995).

Interestingly enough, the age constraints on mineralization at the Minto deposit are very similar to those at the Mt. Milligan Cu-Au porphyry deposit in central B.C. (e.g., Mortensen et al., 1995). Together, the Minto and Williams Creek deposits are thought to represent deformed end members of broadly porphyry-style Cu (-Au) deposits that are intimately associated with Early Jurassic magmatism that is the focus of this study.

DISCUSSION

A better understanding of the Triassic-Jurassic magmatism is important for three main reasons.

- These plutons represent one of the most voluminous plutonic suites in the northern Cordillera, but have received very limited study.
- Emplacement of the intrusions was broadly synchronous with terrane amalgamation in the northern Cordillera; thus, improved constraints on the evolution of the magmatism will help constrain terrane accretion models for this region.
- Two very significant Cu (-Au) deposits (Minto and Williams Creek) are intimately and probably genetically associated with intrusions of this suite. In addition, disseminated magmatic PGE mineralization and gold-bearing quartz-vein occurrences are associated with these intrusions, highlighting the economic importance of the intrusions.

FUTURE WORK

Research to be undertaken over the next three years as part of a Ph.D. dissertation by the second author will include:

- Examination and sampling of Late Triassic and Early Jurassic intrusive rocks throughout southern and western Yukon, and eastern Alaska.
- Geological mapping of intrusions in several specific areas (west-central Stewart River, Minto/Williams Creek deposits) to resolve the exact relationship between intrusion, deformation and mineralization.
- Detailed U-Pb and Ar-Ar dating studies to constrain the emplacement and cooling history of various plutons.
- Additional lithogeochemical and trace isotope (Nd, Sr, Pb) studies to constrain the petrochemical and petrotectonic evolution of the magmatism
- Documentation and Pb isotopic studies of associated mineral occurrences to evaluate the genetic relationships between mineralization and magmatism.

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