Geological Investigations of the Basement of the Quesnel Terrane in Southern British Columbia (NTS 082E, F, L, 092H, I): Progress Report

J.K. Mortensen, The University of British Columbia, Vancouver, BC, jmortensen@eos.ubc.ca

K. Lucas, The University of British Columbia, Vancouver, BC

J.W.H. Monger, Natural Resources Canada, Geological Survey of Canada–Pacific, retired

F. Cordey, Sciences de la Terre, Université Lyon, France

Mortensen, J.K., Lucas, K., Monger, J.W.H. and Cordey, F. (2011): Geological investigations of the basement of the Quesnel terrane in southern British Columbia (NTS 082E, F, L, 092H, I): Progress Report; *in* Geoscience BC Summary of Activities 2010, Report 2011-1, p. 133–142.

Introduction

Many aspects of the nature and metallogeny of the southern Quesnel terrane in southern and south-central British Columbia are not well understood. Most research conducted within the Quesnel terrane over the past 40 years has focused on the Late Triassic Nicola Group and Early Jurassic Rossland Group volcanic arcs and their associated intrusions in the southern Quesnel terrane. These younger portions of the southern Quesnel terrane host important Cu±Au porphyry deposits such as Copper Mountain, Mt. Polley and Highland Valley, as well as younger (Cretaceous) Au-Cu porphyry deposits such as Prosperity, and shear-zone–hosted precious-metal deposits and occurrences. Important gold and base-metal deposits have been exploited in the Hedley area and in the Boundary District near Greenwood, where the pre–Late Triassic basement of the Nicola Group is more widely exposed. The Hedley gold skarn deposit is hosted in volcanic and sedimentary strata of the Nicola Group that lie close to the contact with the older rocks investigated in this study, and is genetically associated with Late Triassic intrusions. Some of these deposits, however, including copper and gold skarn and porphyry (?) deposits in the Boundary District (Figure 1) are hosted in part by older rock units that form the basement to the Late Triassic and Early Jurassic arc-related strata that define the Quesnel terrane. Although most known base- and precious-metal occurrences within the older portions of the southern Quesnel terrane are spatially and probably genetically related to early Mesozoic and younger intrusions, the potential for pre-Triassic mineralization in the area, and the possible role of the older basement rocks in controlling the distribution and character of younger mineralization, are largely unknown.

Geoscience BC is currently undertaking a major investigation of the geology and mineral potential of the southern Quesnel terrane as part of the QUEST-South Project, which includes regional soil and silt geochemical surveys of the entire southern part of the Quesnel terrane, as well as airborne geophysical surveys of the western portion of the terrane. The geology of most pre-Mesozoic basement assemblages of the southern Quesnel terrane, however, is not well understood at present, and without such information it is not possible to fully interpret the geochemical or geophysical results of the QUEST-South Project.

Paleozoic Components of the Southern Quesnel Terrane

Basement assemblages that are reported to unconformably underlie the early Mesozoic arc-related strata of the southern Quesnel terrane (Read and Okulitch, 1977) have generally been subdivided into two main lithotectonic assemblages, both considered to be of middle to late Paleozoic age (e.g., Monger, 1977; Peatfield, 1978; Wheeler and McFeely, 1991). These are the Harper Ranch subterrane, which in southern BC comprises mainly clastic sedimentary rocks, volcaniclastic rocks and limestone, which are interpreted to have been deposited in the vicinity of a juvenile island arc, and the Okanagan subterrane, which consists of mafic volcanic rocks, chert, argillite and minor ultramafic rocks, which are thought to have been deposited in, or near, an ocean basin. With the exception of recent studies in the Boundary District near Greenwood by the BC Geological Survey (BCGS; Massey, 2006; Massey and Duffy, 2008), the Paleozoic assemblages that form the basement to the early Mesozoic Quesnel terrane arcs have received very limited geological, geochemical or geochronological study. Contacts within and between the Harper Ranch and Okanagan subterranes are commonly obscured by younger volcanic or sedimentary units, younger intrusions and/or

Keywords: *Quesnel terrane, southern Okanagan, Paleozoic, basement, volcanic, chert, detrital zircon, lithogeochemistry, radiolarian, conodont*

This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the Geoscience BC website: http://www.geosciencebc.com/s/DataReleases.asp.

later deformation; therefore, the original tectonic relationship between the two subterranes remains speculative. Some workers (e.g., Thompson et al., 2006) suggest that parts of the Quesnel terrane depositionally overlie rocks that are interpreted to be high-standing, westernmost parts of the early Paleozoic continental margin of North America. However, the relationship, if any, between any possible old continental margin rocks and the Harper Ranch and Okanagan subterranes is unknown.

The type locality for the Harper Ranch subterrane is the Harper Ranch Group in the Kamloops area (Figure 1). There, the Harper Ranch Group consists of a lower sequence of chert-pebble conglomerate and sandstone of Late Devonian (Famennian) age, grading stratigraphically upwards into arc-related volcaniclastic and sedimentary strata of the Late Mississippian, which are overlain by a Permian carbonate platformal sequence of Permian age (Beatty et al., 2006). It is these rocks that possibly overlie outboard parts of the old continental margin (Thompson et al., 2006).

The Okanagan subterrane is best preserved near Keremeos (Figure 1). The rocks in this area were mapped between 1927 and 1930 by H.S. Bostock, who divided them into the 'Triassic or older' Old Tom, Independence, Shoemaker, Bradshaw and Barslow formations, and the 'Permian' Blind Creek formation (Bostock, 1939, 1940). The first four of these formations were included in what has been called the Apex Mountain Complex by Milford (1984). Rock types present are chert; massive and pillowed basalt and minor gabbro; argillite, sandstone and conglomerate; and local lenses of carbonate. The paleontological ages of these rocks are mainly late Paleozoic, although older fossils have been found in one location (see later discussion).

Several other pre-Triassic rock assemblages in the southern Quesnel terrane contain a range of rock types similar to those observed in the Keremeos area, and are also known or inferred to be mid- to late Paleozoic in age. The Knob Hill Complex and Attwood Formation in the Boundary District (Massey, 2006, 2009; Massey and Duffy, 2008) are the only assemblages that have been examined in detail prior to the current study. These comprise basalt, gabbro and amphibolite, chert, argillite, minor sandstone and conglomerate, carbonate, and ultramafic rocks, and have yielded Late Devonian and Carboniferous fossils and Late Devonian U-Pb zircon ages. The Anarchist Group (or Anarchist schist of Massey and Duffy, 2008), which lies between the Green-

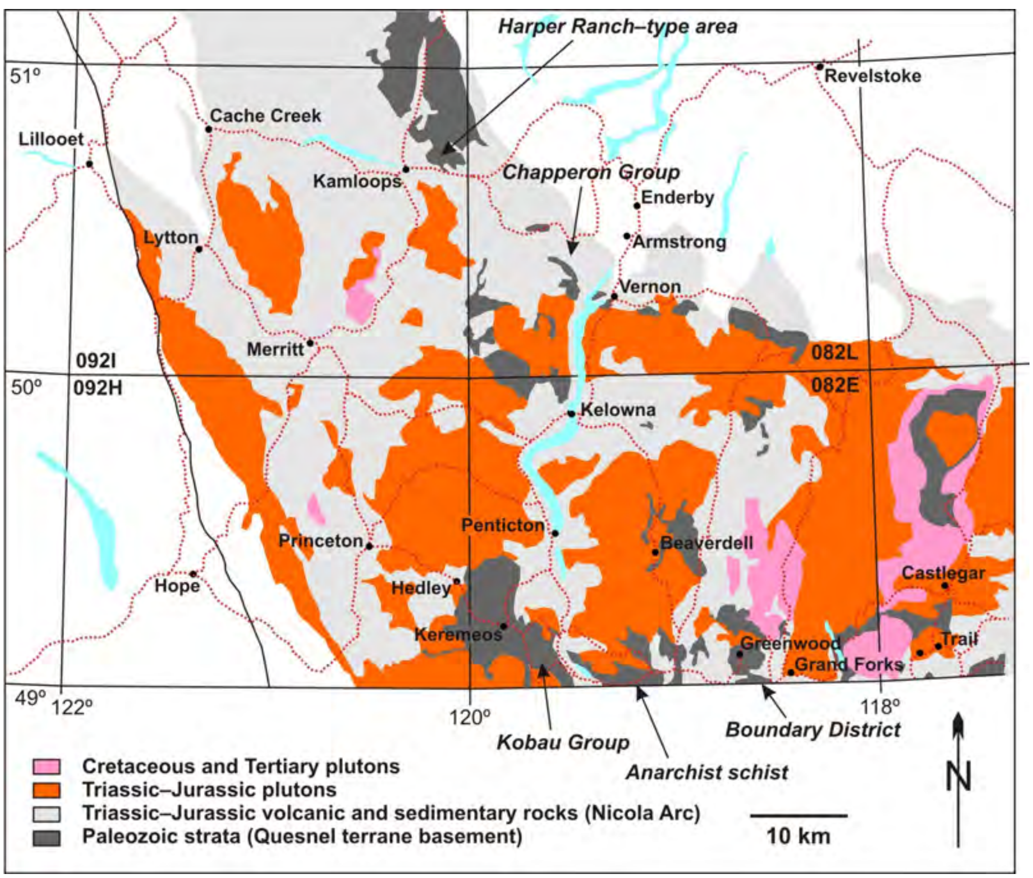

Figure 1. Map showing the distribution of Paleozoic basement units and early and late Mesozoic intrusions in the Quesnel terrane in southern and south-central BC.

wood area and the southern Okanagan Valley to the west (Figure 1), was described by Daly (1912) as follows: "The name is literally not inappropriate, for these rocks cannot as yet be reduced to stratigraphic order or a structural system. The dominant species are quartzite and phyllite, apparently in about equal proportion. Greenstone is next in importance, while limestone is represented by a few local pod-like masses generally from 200 to 100 feet or less in thickness". Carboniferous fossils have been recovered from probable Anarchist schist in the Greenwood area (N. Massey, pers. comm., 2010).

The range of protoliths for the more schistose, metamorphosed and also undated Kobau Group (Bostock, 1939; Okulitch, 1969, 1973), which lies west of the Okanagan Valley between the Anarchist Group and the rocks near Keremeos (Figure 1), is similar to those of the rocks near Keremeos, Greenwood and the Anarchist Group. Finally, north and west of Vernon, the pre–Late Triassic but as yet undated Chapperon Group southeast of Kamloops (Figure 1; Jones, 1959; Read and Okulitch, 1977) has a similar range of rock types.

Metallogeny of Quesnel Terrane Basement Assemblages

The mineral potential of the Paleozoic basement rocks in the southern Quesnel terrane is uncertain at this time. As discussed above, most known mineralization in the southern Quesnel terrane is hosted by, or is closely associated with, igneous rock units of the Nicola Arc or younger assemblages. A number of ultramafic-hosted chrome and nickel occurrences and possible volcanic massive sulphide occurrences have been described in the Boundary District (Peatfield, 1978; Fyles, 1990; Hancock, 1990; Massey, 2006). Exploration within these older units has been greatly hampered by an incomplete understanding of the nature and distribution of the rock units.

Current Study

A study of the basement to the early Mesozoic arc assemblages of the Quesnel terrane in southern BC was started by the authors in October 2009. The goal of this work is to obtain new information concerning the nature, age and paleotectonic setting of the various Paleozoic basement components in the southern Quesnel terrane, so as to provide a basis for better understanding the nature and controls on the superimposed intrusion-related mineralization of the Mesozoic and Tertiary ages. The study focused mainly on rock units in the vicinity of Keremeos, but possibly correlative rock units as far east as Grand Forks (Figure 1) were also examined and sampled. Although exposures of basement rock units in this large area are reasonably widespread, stratigraphic contacts between the different rock units are generally difficult to find. Most of the main exposures of the basement units in the study area had been previously mapped and this provided a geographic framework for locating specific rock units for this study.

All available information has been compiled on the nature, ages and mineral deposits of the pre-Mesozoic rocks that make up the basement of the early Mesozoic strata in the study area. Reconnaissance-scale sampling of easily accessible rock units in the Keremeos and Osoyoos areas was done in October 2009. Samples obtained were examined petrographically and, for some, detrital zircon ages and lithogeochemical signatures were determined. Mortensen, Lucas and Monger subsequently spent a total of three weeks in the field in July 2010, examining key localities between Hedley and Grand Forks, and carrying out detailed sampling for detrital zircon dating and lithogeochemical analysis. Cordey spent two weeks in the study area, re-examining and resampling previously visited chert localities for microfossil dating, and collecting additional chert samples from elsewhere in the area. N. Massey of the BCGS spent three days introducing the authors to Paleozoic rock units in the Boundary District and providing guidance in sampling for dating and lithogeochemical studies of that area.

In addition to petrographic studies of the main Paleozoic basement assemblages in the study area, four other main tools are being used to help characterize each of the assemblages and to provide a basis for reconstructing the tectonostratigraphic relations within and between these rock units, including

- U-Pb zircon dates of intrusive phases associated with the main Paleozoic volcanic rock packages. Additional age information for the various basement assemblages is badly needed to constrain possible relationships between these packages.
- micropaleontological ages for chert and carbonate rocks (using radiolarians and conodonts) within the different basement assemblages to provide additional age constraints on the rock units present.
- lithogeochemical analysis of igneous rock units within each of the basement assemblages, which provides information on the nature and paleotectonic setting in which each assemblage formed (e.g., volcanic arc or backarc versus within-plate or rift setting). This information will help in reconstructing the original tectonic settings of and possible relationships between the various assemblages.
- U-Pb dates of detrital zircon grains in clastic sedimentary units within each of the Paleozoic assemblages. This is a new approach in this area. The ages of detrital zircons reflects the sources from which the host sediments were derived. The age of the Precambrian basement of the northwestern part of the North American continent, former Laurentia, is well known and is reflected by the ages of detrital zircon populations in sedi-

ments derived from it and deposited on the western margin of Laurentia. The latter are substantially different from detrital zircon ages known from westernmost terranes in the northern Cordillera, such as the Alexander terrane or the Wrangell terrane. Detrital zircon ages therefore provide a means of exploring paleogeographic relationships between the various components of the Paleozoic basement in the southern Quesnel terrane, between these units and rocks deposited on northwestern Laurentia, and with other Cordilleran terranes with known detrital zircon populations.

In a separate part of the study, a number of the main Mesozoic intrusive phases in the project area were sampled, especially those that are spatially and possibly genetically associated with significant mineral occurrences and deposits (e.g., in the Nickel Plate mine area and Boundary District), and U-Pb dating of zircon grains will be carried out, along with Pb isotopic analysis of igneous feldspar grains from these bodies. Lead isotopic compositions of sulphide minerals from a wide selection of mineral occurrences in the study area will also be determined. These data will allow for the evaluation of the temporal and genetic relationships between intrusions and sulphide mineral occurrences, and the assessment of the role, if any, that the underlying basement rocks play in controlling the nature and distribution of younger mineralization. It will also be determined whether regional variations in ages and/or styles of mineralization in the southern Quesnel terrane can be correlated with the age and nature of the underlying basement, based on Pb isotopic signatures.

Studies of the Southern Quesnel Terrane Paleozoic Rocks

The field studies focused on the Keremeos and Mt. Kobau areas (Figure 1), where exposure is relatively good. For comparison, portions of the Boundary District were examined, where detailed mapping had been carried out in recent years by the BCGS (Fyles, 1990; Massey, 2006; Massey and Duffy, 2008).

Keremeos Area

Paleozoic basement units are well exposed in the steep walls of the Similkameen River valley from Hedley to east of Keremeos, in the Keremeos Creek area north of Keremeos, and in the high country in the vicinity of the Apex Mountain Resort. As noted above, Bostock (1939, 1940) divided the highly deformed but generally only slightly metamorphosed Triassic or older rocks in this area into the Old Tom, Shoemaker, Independence, Bradshaw, Barslow and Blind Creek formations. As recognized by Bostock, the first three of these units contain metabasalt (greenstone), chert, argillite and minor lenses of limestone, and the mapped units differ mainly in terms of the relative proportion of each rock type present. Few, if any, defined boundaries are known between formations although many depositional contacts between different rock types within formations were observed. As shown on existing geological maps, the Barslow Formation comprises mainly argillite, the Bradshaw Formation consists mainly of argillite, siltstone, quartzite, tuff, breccia and mafic to intermediate composition volcanic rocks, and the Blind Creek Formation is limestone. The only definitive age given by Bostock was a Permian age from the Blind Creek Formation.

Milford (1984) carried out mapping and structural studies northwest of Keremeos and defined the Apex Mountain Complex, which contains Bostock's Old Tom, Shoemaker, Independence and Bradshaw formations. The Apex Mountain Complex was interpreted by Milford (1984), mainly on structural grounds, to represent a pre–Late Triassic accretionary complex. A major contribution by Milford was the discovery of several fossil localities, including crinoidal limestone in Olalla Creek, identified by W.R. Danner (The University of British Columbia; UBC) as probably Carboniferous (Milford, 1984), Pennsylvanian and/or Permian radiolarians in the same area, identified by D.L. Jones (The United States Geological Survey; USGS; Milford, 1984), and an enigmatic limestone unit in Shoemaker Creek, east of Hedley, within which are limestone blocks containing Silurian to Early Carboniferous micro- and macrofossils (identified by A.E.H. Pedder and B.L. Mamet; *in* Read and Okulitch, 1977) and Triassic conodonts (M.L. Orchard, *in* Milford, 1984).

Ray and Dawson (1994) carried out detailed geological mapping of the Hedley area, although their study focused mainly on the Late Triassic strata that host the Nickel Plate deposit, associated mineral deposits and accompanying intrusions. They also mapped across the still-enigmatic boundary between the Late Triassic rocks and the westernmost parts of the Apex Mountain Complex, from which they reported a few possible early Paleozoic and some definite Late Devonian fossils.

Later studies have contributed more information on the age of these rocks. Pohler et al. (1989) found Ordovician conodonts in a limestone block in a disrupted shale, sandstone and chert matrix near Cedar Creek, on the west side of the valley of Keremeos Creek. This was a notable discovery because these are the oldest known fossils from any terrane in the interior of BC. A re-study of the Blind Creek limestone showed it to be of Early Mississippian age rather than Permian (M.L. Orchard, pers. comm., 2010). Tempelman-Kluit (1989), in the course of regional mapping, made a collection of Mississippian macrofossils from talus in Bostock's Barslow Formation. Radiolarians present in several localities in bedded chert, mainly in Bostock's Shoemaker Formation, were generally too recrystallized to extract and identify; however, latest Devonian and Pennsylvanian–Permian ages have been obtained from chert blocks in talus slopes on the north side of the Similkameen valley northwest of Keremeos (F. Cordey, unpublished data, 2010).

The 2010 fieldwork in the Keremeos area was guided by the distribution of the broad lithological groupings that Bostock (1939, 1940) called 'formations'. Below, rock descriptions are framed in terms of his formations but it is recognized that most are not clearly distinct and may grade one into the other. For this reason, the informal term 'assemblage' has been used.

The Old Tom assemblage consists predominantly of massive to locally pillowed basalt or greenstone, with local interlayers of cream, green, grey and locally red chert and cherty argillite, rare thin sandstone and siltstone beds, and minor gabbro. The greenstone contains mineral assemblages consistent with lower greenschist facies metamorphism; however, recrystallization fabrics are only locally developed in the greenstone and the mineral assemblages may be mainly due to hydrothermal alteration on the seafloor. Pale to dark pink jasper, commonly with manganese oxide staining on fracture surfaces, is locally abundant (especially on the ridges south of Apex Mountain).

The main rock types in the Shoemaker assemblage is massive to bedded chert and cherty argillite, which are identical in appearance and character as those interlayered in the Old Tom assemblage. Bands of massive greenstone, local sandstone beds and lenses of carbonate are also present within the Shoemaker assemblage. Almost all of the fossil ages obtained by Milford (1984), Pohler et al. (1989) and F. Cordey (unpublished data, 2010) have been obtained from the Shoemaker assemblage. One structural characteristic of parts of the Shoemaker assemblage is the highly disrupted fabric of interbedded argillite, sandstone and chert, in which competent layers such as sandstone beds are broken into separate lens-like (phacoidal) bodies. This is readily seen northwest of Keremeos above the garbage disposal site and in Cedar Creek north of Olalla, where it is the matrix of the block of Ordovician limestone. This kind of fabric is common in most accretionary complexes, but is only seen locally in these rocks.

The Independence assemblage contains elements of both the Old Tom and Shoemaker assemblages, along with many small recrystallized limestone lenses, and on Beaconsfield Mountain at the Apex Mountain Resort, a locally thick mass of chert breccia with local argillite rip-up clasts.

The Bradshaw assemblage is distinctive in that it dominantly comprises clastic rocks, including argillite, siltstone, minor quartzite and conglomerate, breccia and mafic to intermediate volcanic rocks. Southwest of Apex Mountain, the Bradshaw assemblage lies along strike from the Independence assemblage but is separated from it by a later granitic intrusion.

The Barslow assemblage is exposed only in the vicinity of Cawston, approximately 6 km east of Keremeos (Figure 1). As mapped by Bostock, the Barslow assemblage forms the core of a northeast-trending antiform, and it is flanked structurally or stratigraphically underlies massive greenstone rocks of the Old Tom assemblage. The Barslow assemblage consists mainly of sedimentary rocks, including distinctive chert pebble and granule conglomerate, as well as sandstone, siltstone, radiolarian-bearing cherty argillite and minor crinoidal limestone. At least two greenstone bands are interlayered within the Barslow assemblage; these comprise massive metabasalt and basaltic tuff and tuff-breccia. Macrofossils (brachiopods, clams, ammonoids and wood fragments) are locally abundant within talus originating from some of the sandstone and siltstone units, and are of Early Mississippian (Tournaisian) age (E.W. Bamber, pers. comm., 2010).

The Blind Creek Formation, which is exposed to the east of the Barslow assemblage approximately 8 km east of Keremeos (Figure 1), consists entirely of carbonate. Originally thought to be Permian by Bostock (1939) and Barnes and Ross (1975), it is now known to be Early Mississippian (M.L. Orchard, pers. comm., 2010). Bostock showed the formation to be faulted against Barslow and Old Tom assemblages and the Kobau Group, but Barnes and Ross (1975) suggest that it is may be entirely a large slide-block.

Mt. Kobau Area

The 'Kobau Group', named by Bostock (1939; Figure 1), was mapped in detail by Okulitch (1969, 1973). It consists of greenstone, amphibolite and metaclastic rocks, abundant fine-grained quartzite thought to be mainly metachert and several small marble bodies (Okulitch, 1969, 1973; Lewis et al., 1989). The range of rock types is similar to that of the rocks near Keremeos, but the metamorphic grade is somewhat higher (upper greenschist facies) and the rocks are strongly deformed and schistose. Rock units in the Mt. Kobau area are strongly hornfelsed around Mesozoic intrusions including the Osoyoos and Oliver granite. Tempelman-Kluit (1989) shows the Kobau to be separated from the rocks near Keremeos by an inferred north-trending, east-side-up normal fault.

Lithogeochemistry

Major, trace and rare earth element compositions of igneous rocks can be used to constrain the probable paleotectonic setting(s) in which the units were erupted, based on analogy with the geochemistry of volcanic rocks from modern plate tectonic settings (e.g., Piercey et al., 2006). Mafic volcanic units and less abundant hypabyssal and plutonic equivalents are abundant in most of the Paleozoic basement assemblages in the southern Quesnel terrane; however, lithogeochemistry has only been used to investigate the origin of these assemblages in the Boundary District. Massey's lithogeochemical studies of mafic volcanic rocks in the Knob Hill Complex in the Boundary District shows that they are mainly island-arc tholeiitic rocks, with minor amounts of N- and E-MORB (Massey, 2009). In contrast, volcanic rocks in the Anarchist schist have within-plate geochemical signatures (N. Massey, pers. comm., 2010).

Geochemical compositions were determined for three samples of massive greenstone from the Old Tom assemblage between Keremeos and Hedley and three samples of greenstone from within the Kobau assemblage on Mt. Kobau, all collected in 2009. Minor and trace elements considered to be relatively immobile during hydrothermal alteration and regional metamorphism have been plotted on tectonic discriminant plots in Figure 2. The results show a very clear distinction between island arc tholeiite compositions for the Old Tom samples and an alkaline/within-plate composition for the Kobau samples. Although based on a very limited dataset at this point, current indications from lithogeochemistry are that the Knob Hill and Old Tom assemblages may be correlative, and similarly the Anarchist and Kobau rocks may be correlative.

In 2010, a total of 40 samples of mafic volcanic rocks and related dikes and sills from throughout the Old Tom assemblage and from the less abundant greenstone units within Shoemaker, Independence, Barslow and Kobau rocks were systematically sampled for lithogeochemical analysis. In addition, samples were collected from a dated Late Devonian gabbro and sheeted diabase dikes from the Boundary District. Together with previously obtained results, this will provide an excellent regional lithogeochemical database to test possible relationships within and between the various basement assemblages, and constrain the paleotectonic setting(s) in which they formed.

Detrital Zircon Dating

Two samples of sandstone were collected for detrital zircon dating by J. Wright (University of Georgia) and Monger in 2007. One of these was from Late Devonian strata in the type section of the Harper Ranch assemblage east of Kamloops, and yielded single-grain ages ranging from 340 to 400 Ma (n = 25) with a prominent peak in the 360–380 Ma range (J. Wright, pers. comm., 2008). A second sample was sandstone from the Barslow Formation near Cawston (Figure 1). This sample yielded a very different detrital zircon age distribution, with the majority of grains giving ages between 1700 and 2900 Ma (dominantly 1800–2100 Ma) with a single grain at ca. 520 Ma (J. Wright, pers. comm., 2008).

Detrital zircons from three samples collected during reconnaissance sampling in 2009 have been separated and dated. Results are shown in Figure 3 and are discussed briefly below.

Sample 09KL-01 is from a boudinaged, pale grey greywacke band within dark grey argillite and chert argillite along the north bank of the Ashnola River, approximately 13.5 km west of Keremeos (Figure 1). A total of 30 zircon grains were dated and yielded ages ranging from 350 to 404 Ma, with a strong unimodal peak at approximately 363 Ma (Figure 3a).

Sample 09KL-02 is siltstone to fine sandstone within sheared and hornfelsed, medium to dark grey argillite in a roadcut on the Apex Mountain Resort Road, approximately

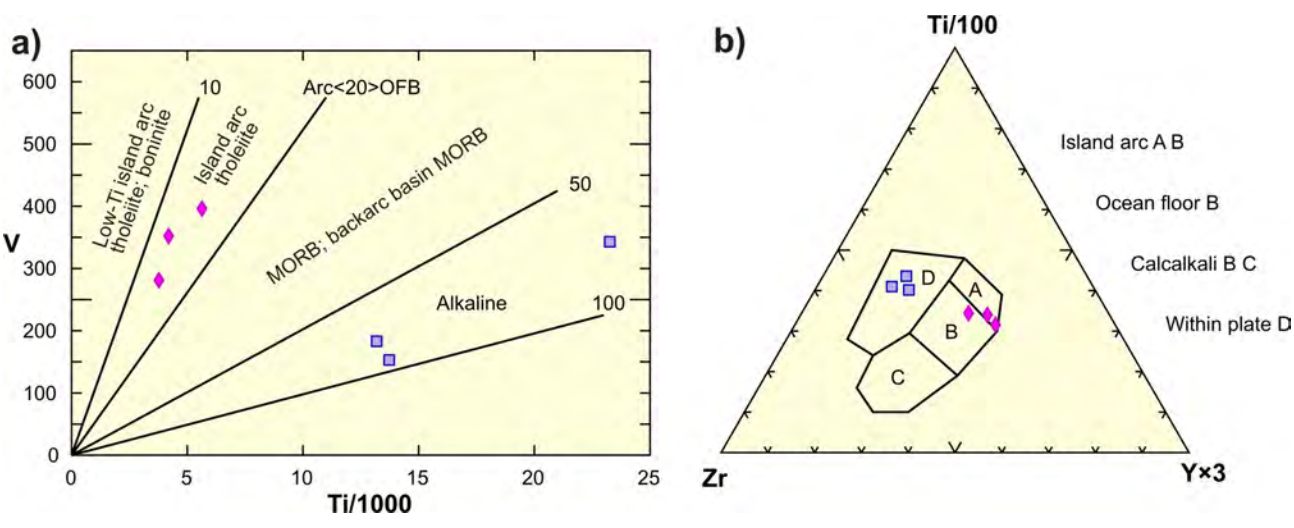

Figure 2. Trace-element discriminant plots showing the distinction between greenstone samples of the Old Tom assemblage (pink diamonds) and the Kobau assemblage (blue squares), southern British Columbia: **a)** Ti/100 versus V discriminant plot; field boundaries from Shervais (1982); **b)** Ti/100–Zr–Y×3 discriminant plot; field boundaries from Pearce and Cann (1973). Abbreviations: MORB, mid-ocean ridge basalt; OFB; ocean floor basalt.

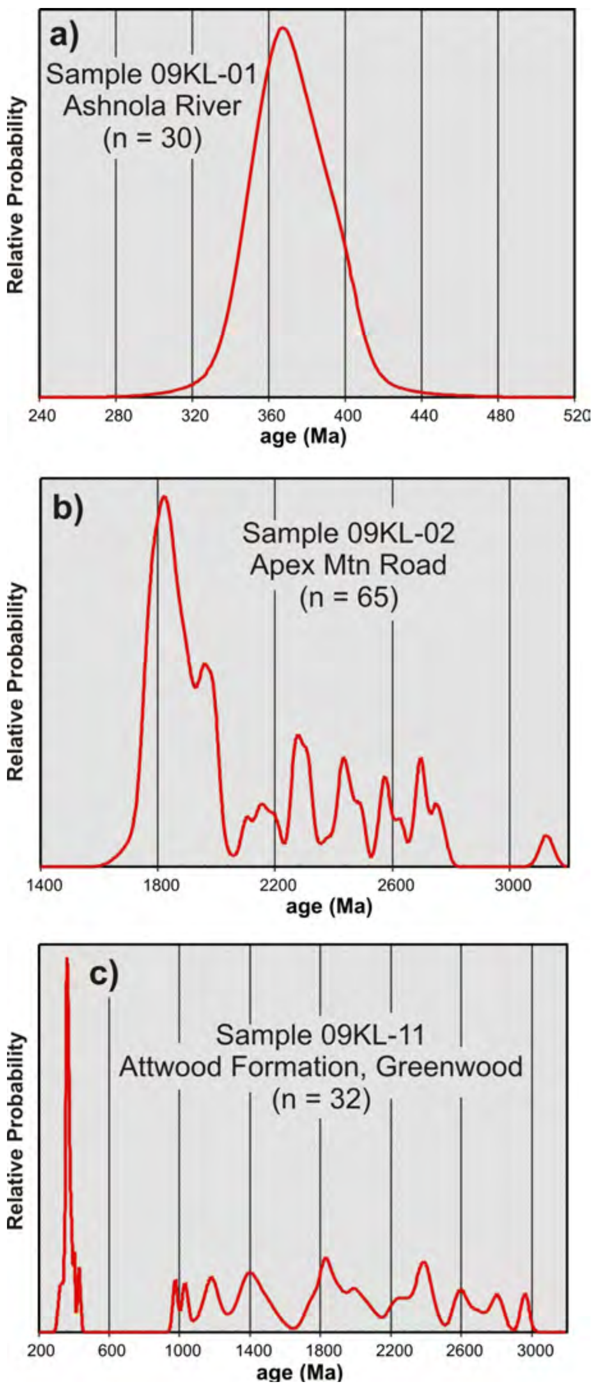

Figure 3. Detrital zircon age plots from clastic metasedimentary samples from the Keremeos and Greenwood areas, southern British Columbia: **a)** sample 09K-01, **b)** sample 09KL-02 and **c)** sample 09KL-11.

3.5 km east of the resort. A total of 65 single zircon grains were analyzed from the sample. Most gave ages in the range of 1720–2766 Ma, with the majority falling between 1700 and 2100 Ma (Figure 3b). A single grain gave a much older age of 3126 Ma. This detrital zircon age distribution is very similar to samples from northwestern Laurentia and suggests that the argillite unit, whatever its age is, has an affiliation with North America.

The third detrital zircon sample (09KL-11) is from a chert pebble conglomerate lens from the Attwood assemblage on Highway 3, approximately 2 km south of Greenwood. Ages for a total of 32 single zircon grains give a scatter of ages from 975 to 2961 Ma and a cluster of ages between 327 and 429 Ma with a prominent peak at 362 Ma (Figure 3c). These age data indicate that the depositional age of the Attwood Formation can be no older than Mississippian and that the Attwood Formation may share provenance with the clastic unit sampled on the Ashnola River near Keremeos (sample 09KL-01 above), and possibly with Late Devonian rocks of the Harper Ranch assemblage near Kamloops.

A total of 41 additional samples were collected during 2010 fieldwork for detrital zircon dating, including samples from all of the Paleozoic lithological assemblages in the area. These samples are now being examined petrographically and detrital zircons will be separated from a subset of the samples. It is anticipated that the results will provide valuable information regarding the terrane affinity of the various assemblages and possible correlations between them.

Biochronology and Isotopic Dating

The fossil age database for the Paleozoic basement assemblages in the southern Quesnel terrane is still very limited, and is currently inadequate to permit confident correlations within or between the various assemblages. Basement units in the Keremeos area contain fossils ranging in age from Late Devonian to Permian; however, limestone units that may represent blocks in Late Triassic olistostromes (Milford, 1984; Pohler et al., 1989) have yielded micro- and macrofossil ages as old as Ordovician. The Blind Creek limestone is known to be Mississippian in age, as is at least part of the Barslow assemblage. In the Boundary District, sedimentary units in the Knob Hill Complex have given Late Devonian to Pennsylvanian fossil ages. The Attwood formation in the Boundary District has yielded Mississippian fossil ages. Thus, although the various assemblages are broadly age equivalent based on existing fossil age constraints, the data are still far too scarce to be able to define a stratigraphy within any one of the assemblages, and some of the assemblages (e.g., Kobau) have no age constraints at all. Approximately 15 chert samples from the Old Tom, Shoemaker and Barslow assemblages in the Keremeos area are currently being processed for radiolarian dating by Cordey, and several samples of limestone that were collected for conodont dating are also being processed. It is hoped that new ages resulting from this work will permit better-constrained stratigraphic and structural interpretations for the area.

With the exception of three Late Devonian U-Pb zircon ages from gabbro of the Knob Hill Complex in the Boundary District by Massey (2009; pers. comm., 2010), there are no isotopic ages currently available for any of the Paleozoic assemblages in the study area. Most of the rock types represented are mafic, and minerals datable using U-Pb methods are typically rare in such rocks. One granophyric segregation was sampled in a thick gabbro sill within the Old Tom assemblage on the south side of the Similkameen River east of Keremeos that might yield zircons or baddeleyite that can be dated by U-Pb methods; if successful, this will provide the only direct age constraint for this assemblage.

Ongoing Research and Timeline

Lithogeochemical and detrital zircon dating studies of the basement of the southern Quesnel terrane are now underway; these are being done by Lucas as part of her M.Sc. thesis at UBC. The processing of all of the microfossil samples collected in 2010 is now underway, with final results expected early in 2011. Uranium-lead dating and Pb isotopic studies of Mesozoic intrusions and related sulphide mineralization will begin shortly and is expected to be complete by early 2011.

Acknowledgments

This project is being funded by Geoscience BC. N. Massey is thanked for his excellent introduction to the geology of the Boundary District, and M. Orchard for sharing his extensive knowledge of the biostratigraphy of the southern Quesnel terrane. R. Friedman is also thanked for a review of an early version of the manuscript.

References

Barnes, W.C. and Ross, J.V. (1975): The Blind Creek limestone, Keremeos, British Columbia: structure and regional tectonic significance; Canadian Journal of Earth Sciences, v. 12, p. 1929–1933.

Beatty, T.W., Orchard, M.J. and Mustard, P.S. (2006): Geology and tectonic history of the Quesnel terrane in the area of Kamloops, British Columbia; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, M. Colpron and J.L. Nelson (ed.), Geological Association of Canada, Special Paper 45, p. 483–504.

Bostock, H.S. (1939): Geology, Keremeos; Geological Survey of Canada, Map 341A, scale 1:63 360.

Bostock, H.S. (1940): Geology, Olalla; Geological Survey of Canada, Map 628A, scale 1:63 360.

Daly, R.A. (1912): Geology of the North American Cordillera at the forty-ninth parallel; Geological Survey of Canada, Memoir 38, 856 p.

Fyles, J.T. (1990): Geology of the Greenwood-Grand Forks area, British Columbia; BC Ministry of Forests, Mines and Lands, Open File 1990-25, 19 p.

Hancock, K.D. (1990): Ultramafic associated chromite and nickel occurrences in British Columbia; BC Ministry of Forests, Mines and Lands, Open File 1990-27, 62 p.

Jones, A.G. (1959): Vernon map-area, British Columbia; Geological Survey of Canada, Memoir 296, 186 p.

Lewis, P.D., Mäder, U. and Russell, J.K. (1989): Geology and structure of the Kobau Group between Oliver and Cawston, British Columbia (NTS 82E/4E); BC Ministry of Forests, Mines and Lands, Open File 1989-2, scale 1:6667.

Massey, N.W.D. (2006): Boundary project: reassessment of Paleozoic rock units of the Greenwood area (NTS 82E/02), southern British Columbia; *in* Geological Fieldwork 2005, BC Ministry Forests, Mines and Lands, Paper 2006-1, p. 99–107.

Massey, N.W.D. (2009): The Knob Hill Complex: a Paleozoic supra-subduction zone ophiolite in SE BC; Geological Society of America, Abstracts with Program, v. 41, p. 3–4.

Massey, N.W.D. and Duffy, A. (2008): Boundary project: McKinney Creek (NTS 82E/03) and Beaverdell (NTS 82E/06E, 07W, 10W, 11W) areas, south-central British Columbia; *in* Geological Fieldwork 2007, BC Ministry of Forests, Mines and Lands, Paper 2008-1, p. 87–102.

Milford, J.C. (1984): Geology of the Apex Mountain Group, north and east of the Similkameen River, south-central British Columbia; M.Sc. thesis, The University of British Columbia, 108 p.

Monger, J.W.H. (1977): Upper Paleozoic rocks of the western Canadian Cordillera and their bearing on Cordilleran evolution; Canadian Journal of Earth Sciences, v. 14, p. 1832–1859.

Okulitch, A.V. (1969): Geology of Mount Kobau; Ph.D. thesis, The University of British Columbia, 140 p.

Okulitch, A.V. (1973): Age and correlation of the Kobau Group, Mount Kobau, British Columbia; Canadian Journal of Earth Sciences, v. 10, p. 1508–1518.

Pearce, J.A. and Cann, J.R. (1973): Tectonic setting of basic volcanic rocks determined using trace element analyses; Earth and Planetary Science Letters, v. 19, p. 290–300.

Peatfield, G.R. (1978): Geologic history and metallogeny of the 'Boundary District', southern British Columbia and northern Washington; Ph.D. thesis, Queen's University, 462 p.

Piercey, S.J., Nelson, J.L., Colpron, M., Dusel-Bacon, C., Simard, R.-L. and Roots, C.F. (2006): Paleozoic magmatism and crustal recycling along the ancient Pacific margin of North America, northern Cordillera; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, M. Colpron and J.L. Nelson (ed.), Geological Association of Canada, Special Paper 45, p. 281–322.

Pohler, S.M.L., Orchard, M.J. and Tempelman-Kluit, D.J. (1989): Ordovician conodonts identify the oldest sediments in the Intermontane Belt, Olalla, south-central British Columbia; *in* Current Research, Part E, Geological Survey of Canada, Paper 89-1E, p. 61–67.

Ray, G.E. and Dawson, G.L. (1994): The geology and mineral deposits of the Hedley gold skarn district, southern British Columbia; BC Ministry of Forests, Mines and Lands, Bulletin 87, 156 p.

Read, P.B. and Okulitch, A.V. (1977): The Triassic unconformity of south-central British Columbia; Canadian Journal of Earth Sciences, v. 14, p. 606–638.

Shervais, J.W. (1982): Ti-V plots and the petrogenesis of modern and ophiolitic lavas; Earth and Planetary Science Letters, v. 59, p. 101–118.

Tempelman-Kluit, D.J. (1989): Geology, Penticton, British Columbia; Geological Survey of Canada, Map 1736A, scale 1:250 000.

Thompson, R.I., Glombick P., Erdmer, P., Heaman, L.M., Lemieux, Y. and Daughtry, K.L. (2006): Evolution of the ancestral Pacific margin, southern Canadian Cordillera: insights from new geologic maps; *in* Paleozoic Evolution and Metallogeny of Pericratonic Terranes at the Ancient Pacific Margin of North America, Canadian and Alaskan Cordillera, M. Colpron and J.L. Nelson (ed.), Geological Association of Canada, Special Paper 45, p. 505–515.

Wheeler, J.O. and McFeely, P. (1991): Tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States; Geological Survey of Canada, Map 1712A, scale 1:2 000 000.