Detrital zircon analysis of Mesoproterozoic and Neoproterozoic high-grade metasedimentary rocks of north-central Idaho: reduction of the mapped extent of the Belt basin

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ABSTRACT

We analyzed detrital zircons in 10 amphibolite facies metasedimentary rock samples from north-central Idaho to test the previous assignment of these rocks to the Mesoproterozoic Belt-Purcell Supergroup and to determine whether some may be pre-Belt basement rocks. In addition, zircons from 2 samples of the Prichard Formation (lower Belt), and one sample of Cambrian quartzite were also analyzed. Correlating the amphibolite facies rocks with known sedimentary units through field observations is difficult if not impossible due to the high metamorphic grade and intensity of deformation. Zircon analysis by laser-ablation inductively coupled plasma mass spectrometry (LA-ICPMS) reveals that six of the 10 samples contain multiple zircon populations between 1900 and 1400 Ma and a scatter of older ages, similar to results reported from the Belt Supergroup to the north and east. These results indicate that the likely protoliths of many high-grade metamorphic rocks in northern Idaho were strata of the Belt Supergroup. In contrast, three samples of quartzite from the Syringa metamorphic sequence northwest of the Idaho batholith contain zircons younger than the Belt Supergroup and indicate a Neoproterozoic age. A sample from the Dicks Creek north of Orofino yielded a large number of 1380 Ma zircons, most of which had high Th/U ratios that suggest a 1380 intrusive event (and contamination of the sample with igneous zircons) or the transport and deposition of zircons from 1380 Ma plutonic or volcanic rocks. None of the metasedimentary rocks dated can be older than the Belt-Purcell Supergroup.

INTRODUCTION

The Mesoproterozoic Belt-Purcell Supergroup is exposed throughout much of northern Idaho, western Montana, and northeastern Washington (Fig. 1). The age is known to be about 1470-1400 Ma based on U-Pb dating of sills and rare volcanic rocks (Anderson and Davis, 1995; Sears et al., 1998; Evans et al., 2000) although the uppermost strata (Libby and McNamara formations) have not been dated. Ross et al. (1992) and Ross and Villeneuve (2003) established that zircon populations in eastern Belt-Purcell rocks are characterized by prominent age groupings at 2700 Ma and 1800 Ma and lack grains with ages 1610 to 1490 Ma, corresponding to the "North American magmatic gap". Many western Belt units have zircons with ages in this gap, presumably derived from non-North American (non-Laurentian) sources. They also contain detrital zircons younger than the “gap” that overlap the age of deposition. These zircons are presumably volcanic in origin and derived from synsedimentary volcanic activity.

Amphibolite facies metamorphism northwest of the Idaho batholith and within the Priest River complex southwest of Sandpoint has made correlation with lower grade Belt rocks and pre-Belt basement rocks difficult. The recent advent of detrital zircon geochronology has allowed more rigorous evaluation of previous correlations (e.g. Hietanen, 1962, 1963b; Reid et al., 1973) that were based on field characteristics. Our first reconnaissance effort using detrital zircons from seven samples in northern Idaho yielded four amphibolite facies samples with zircons ages similar to those in low-grade Belt-Purcell Supergroup rocks to the north, indicating that upper units of the Belt-Purcell basin probably extend at least as far southwest as Pierce (Lewis and others, in press). Results from two additional amphibolite facies rocks indicted that rocks we previously thought might be either Belt Supergroup or pre-Belt basement were instead most likely younger than the Belt, and probably Neoproterozoic in age. Most metasedimentary rocks in northern Idaho appear to have Mesoproterozoic protoliths. Exceptions include the rocks near Boehls Butte (Fig. 1), which several workers have speculated are basement rocks that predate the Belt (Reid et al., 1973; Armstrong, 1975; Hietanen, 1984, Doughty and Chamberlain, in press), Archean rocks in the core of the Priest River metamorphic complex (Doughty et al., 1998), and a 1576 Ma orthogneiss in the Priest River metamorphic complex (Evans and Fischer, 1986; Doughty and others, 1998). Metasedimentary rocks that postdate the Belt are also present. Low metamorphic grade rocks of the Neoproterozoic Windermere Supergroup are exposed in northeastern Washington and northwestern Idaho (Fig. 1; Miller, 1994). Higher grade rocks in central Idaho have been dated and correlated with these (Lund et al., 2003), and recent detrital zircon dating shows that Neoproterozoic rocks exist in the Lowell area as well (Fig. 1; Lund et al., 2005).

To obtain age spectra for comparison with our previous work, as well as that of Ross and Villeneuve (2003) and Lund et al. (2005), we broadened our sampling area to include low-grade Belt and Cambrian rocks in the Idaho Panhandle and amphibolite facies rocks to the west in the Priest River metamorphic complex and south near Orofino and Lowell (Fig. 1). U-Pb ages for zircons were obtained by laser-ablation inductively coupled plasma mass spectrometry (LA-ICPMS).

REGIONAL GEOLOGY

Low-grade Belt Rocks

Lower greenschist facies metasedimentary rocks of the Belt Supergroup are exposed over much of northern Idaho and western Montana (Fig. 1). Correlative rocks in Canada are assigned to the Purcell Supergroup. The stratigraphically lowest exposed rocks in western Montana and the Idaho panhandle are deep-water turbidites of the Prichard Formation (Cressman, 1989) that were intruded by penecontemporaneous mafic sills dated at about 1470 Ma (Anderson and Davis, 1995; Sears et al., 1998). On the northeast side of the basin in Canada and central Montana, the lowermost rocks are near-shore, shallow-water strata that include carbonate and fluvial-deltaic deposits (Höy et al., 2000). The Prichard Formation is overlain by shallow-water clastic rocks of the Ravalli Group, which are characterized by fine-grained feldspathic quartzite (Winston, 1986). The Ravalli Group, in turn, is overlain by carbonate rocks of the Wallace and Helena formations. These consist of dolomitic and calcitic siltite and quartzite, and, toward the southwest, carbonate-poor black argillite (Winston, in press). A bentonite near the top of the Helena Formation in Glacier National Park is dated at about 1454 Ma (Evans et al., 2000). Overlying these carbonate rocks are shallow-water clastic rocks of the Missoula Group. The youngest age determined for the Belt Supergroup (1401 Ma) is from a felsic tuff in the upper part of the Missoula Group in Montana (uppermost Bonner Formation; Evans et al., 2000).

High-grade Belt Rocks

Formations within the Belt Supergroup can be traced 5-10 km south of the garnet isograd, in the area east-northeast of Moscow, despite increasing metamorphic grade (Fig. 1). Farther south of the garnet isograd, individual formations become increasingly difficult to identify. Calc-silicate gneiss, granofels, and mica schist east of Pierce are thought to be derived from the Wallace (or Helena) formations. Quartzite, most of which is feldspathic, appears to occur stratigraphically beneath the calc-silicate rocks and may correlate with the Ravalli Group. Calc-silicate gneiss and quartzitic rocks along the western edge of the Bitterroot lobe of the Idaho batholith southeast of Pierce (Fig.1) are probably metamorphic equivalents of the Belt Supergroup, but correlation is highly uncertain.

Elk City and Golden Metamorphic Sequences

The Elk City metamorphic sequence consists of biotite gneiss and biotite schist exposed in west and northwest of Elk City (Fig. 1). The sequence is distinguished by the abundance of gneiss and the scattered presence of cm-scale lenses of sillimanite and muscovite within the schist. These rocks appear to have Belt protoliths (Lewis et al., 1998), and detrital zircons from a sample at Dutch Oven Creek support correlation with the younger parts of the Belt Supergroup (Lund et al., 2005). The Golden metamorphic sequence consists of quartzite, biotite gneiss, biotite schist, and calc-silicate rocks exposed west of Elk City. The sequence is distinguished by the abundance of quartzite in association with gneissic rocks. Previously mapped as part of the Syringa metamorphic sequence (Lewis and others, 1992) but later reassigned (Lewis and others, unpublished 2002 mapping). Quartzite in the Golden metamorphic sequence is finer grained and more feldspathic than typical Syringa quartzite. Biotite gneiss predominates over schist whereas the opposite is true in the Syringa sequence. The sequence is named for the hamlet of Golden, where one of the quartzite intervals is well exposed (Lewis and others, 1998).

Priest River Metamorphic Complex

The Priest River metamorphic complex is exposed in a north-south belt west and northwest of Coeur d'Alene (Fig. 1). The structurally lowest part of the complex contains Archean gneiss overlain by the Gold Cup quartzite of uncertain age (Clark, 1973; Doughty and others, 1998). The most extensive unit is the Hauser Lake gneiss, a paragneiss that locally contain sillimanite or kyanite. Amphibolite sills and subordinate calc-silicate rocks and feldspathic quartzite are also present. Cretaceous plutonic rocks, typically mylonitic, make up a significant part of the complex. The Hauser Lake gneiss has been correlated either with the Prichard Formation of the Belt-Purcell Supergroup (Weissenborn and Weis, 1976; Doughty and others, 1998; Miller and others, 1999) or pre-Belt basement rocks (Armstrong et al., 1987). Recent detrital zircon results from the Hauser Lake gneiss indicate a protolith age no older than the Belt Supergroup (P. Ted Doughty, personal comm., 2005).

Mesoproterozoic Intrusive Rocks

Granitic augen gneiss extends in a Belt from Elk City north to Dent Bridge (DB on Fig. 1) and west toward Moscow as sill-like bodies (small circles on Fig. 1). Most bodies are too small to show on Figure 1, or even at 1:100,000 map scale. This gneiss is granite to granodiorite in composition but now exists as coarse-grained garnet-muscovite-biotite augen gneiss with potassium feldspar augen typically 4-6 cm (locally as much as 12 cm) in length. The augen gneiss near Elk City is dated at about 1370 Ma (U-Pb zircon; Evans and Fisher, 1986) and SHRIMP dating of zircon from one of these bodies west of Dent Bridge has yielded a 1379 ± 12 Ma age (Lewis et al., in press). Chemically, these Proterozoic augen gneisses are characterized by high K_2O/Na_2O ratios (1.3-2.0) and high Y concentrations (25-122 ppm) relative to the Idaho batholith. These characteristics, along with low Al_2O_3 concentrations, are typical of A-type "anorogenic" Proterozoic granites and granitic gneisses of similar age elsewhere in the western United States (Anderson, 1983).

Syringa Metamorphic Sequence

Occurring with the metasedimentary units described above, which are interpreted to be high-grade Belt, is a quartzite-rich assemblage termed the Syringa metamorphic sequence (Lewis et al., 1992; 1998). This sequence, previously correlated with Belt-Purcell strata (Prichard Formation and Ravalli Group) west of Lowell and north of Orofino (Heitanen, 1962, Reid et al., 1973), differs from Belt-Purcell strata in that the quartzite is clean (typically 2 percent or less feldspar) and is associated with calc-silicate rocks. These features are not common within the Ravalli Group or elsewhere in the Belt Supergroup, where quartzite generally contains 20 percent or more feldspar and is interlayered with argillite and siltite rather than carbonate rocks. Recent mapping by Lewis et al. (2005) has expanded the area of rocks assigned to the Syringa sequence from the region west of Lowell to areas north of Orofino and west to Smoot Hill northwest of Moscow (SH, Fig. 1). Similar rocks in the Gospel Hump Wilderness southeast of Grangeville are assigned to the Umbrella Butte Formation (Lund et al., 2003). Typical lithologies are coarsely crystalline quartzite, sillimanite-muscovite-biotite schist, and calc-silicate gneiss. Less common compositions include garnet- and sillimanite-bearing quartzite and garnet-kyanite-biotite schist. Rocks at Smoot Hill are mostly highly recrystallized quartzite with sparse feldspar stringers. The boundary between the Syringa sequence and the meta-Belt Supergroup is poorly defined, but is placed between quartzite-dominated Syringa rocks and calc-silicate and schist-dominated meta-Belt sequences. Detrital zircon dating by Lund et al. (2005) has shown that the Syringa quartzite near Lowell (quartzite of Wild Goose Camp) is Neoproterozoic and thus younger than the Belt Supergroup. Detrital zircons from a quartzite at Smoot Hill are mostly 1875 to 1725 Ma, with smaller populations between 2840 and 2460 Ma (Mueller et al., 2003). Absent are zircons with syn-Belt ages and ages in the North American magmatic gap. The Smoot Hill quartzite sample contains a single 1290 Ma concordant zircon (Mueller et al., 2003), which suggests that it is younger than 1290 Ma. Because of this age, and the lithologic similarity to quartzite near Syringa, we have tentatively assigned the Smoot Hill quartzite to the Neoproterozoic Syringa metamorphic sequence that is exposed along strike to the east in Idaho (Fig. 1).

Paleozoic sedimentary rocks

Limited in extent (Fig. 1), the Paleozoic sedimentary rocks in north central Idaho consist of a basal quartzite (Gold Creek Quartzite), a thin shale unit (Rennie Shale), and an overlying carbonate unit (Lakeview Limestone; Bush, 1989). All are Cambrian age. The Gold Creek quartzite is medium grained and thick bedded clean quartzite with little or no feldspar that is easily distinguished from the fine-grained feldspathic quartzite in the Belt Supergroup.

METHODS

LA-ICPMS

The detrital zircons in this study were analyzed by laser ablation-inductively coupled plasma mass spectrometry (LA-ICPMS) at Washington State University. The full description of this method is reported in Chang et al. (2006), so only a brief summary will be presented here. Zircons were separated from 5-10 kg rock samples by standard gravimetric and magnetic techniques at the University of Idaho. Approximately 200 grains were randomly selected from each sample, mounted in epoxy along with zircon standards and two to three other unknown samples, and polished to expose the interiors of the grains. The U-Pb analyses were performed using a New Wave™ UP 213 Nd-YAG (213 nm) laser ablation system coupled with a ThermoFinnigan Element2™ single collector, high-resolution magnetic sector ICP-MS. The laser was operated using a 10 Hz repetition rate and fluence of 10^{-11} J/cm^2. Laser beam size was typically 30 µm in diameter, although on some zircons 40 µm spots were used. The typical pit depth was approximately 25 microns. Blanks were measured before each analysis with the laser off to determine background signals on the peaks of interest. The laser was then fired and, after a delay to allow for sample uptake, the signals were collected for ~35 seconds in 300 sweeps through the mass range. Signals of ^{202}Hg, ^{204}(Pb+Hg), ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{232}Th, ^{235}U, and ^{238}U were measured. We calculated ^{206}Pb/^{238}U and ^{207}Pb/^{206}Pb ratios from the measured intensities and calculated ^{207}Pb/^{235}U ratios from the ^{206}Pb/^{238}U and ^{207}Pb/^{206}Pb ratios and using the natural abundance of U. Data were reduced off line using an Excel-based program (Chang et al., 2006) that plots time series of the analytical results (ratios and intensities for all measurements as a function of time) with programmed 2σ filters to remove outliers. Cumulative probability, histogram, and concordia plots were generated using Isoplot/Ex v. 3.32 (Ludwig, 2005).

One of the major sources of uncertainty during U-Pb LA-ICPMS analyses is time dependent, laser induced U/Pb fractionation. Our approach, following the methods of George Gehrels (personal communication) and described by Sylvester and Ghaderi (1997) and Kosler et al. (2002), is to use the regression line method. The assumption is that the Pb/U fractionation trend over the signal acquisition time (~35 seconds) is linear, which is demonstrated by the linear distribution of data points on a Pb/U vs. time plot (Chang et al., 2006). The intercept at time 0 is assumed to be free of laser-induced time-dependent fractionation (Sylvester and Ghaderi, 1997). The ^{206}Pb/^{238}U intercept is determined for each standard analysis and compared to the accepted ^{206}Pb/^{238}U value (determined by TIMS) for that standard in order to calculate a ^{206}Pb/^{238}U fractionation factor. A similar approach is used for the ^{207}Pb/^{206}Pb value except that an average (rather than intercept) value is used to determine the fractionation factor because the ^{207}Pb/^{206}Pb value is not measurably time-dependent over the duration of the analysis. The fractionation factors determined from the standards are then applied to the unknowns to calculate the corrected ratios. These factors are typically in the range of 0.75 to 0.90 for ^{206}Pb/^{238}U and 0.98-0.99 for ^{207}Pb/^{206}Pb. The reported ^{207}Pb/^{235}U values are derivative from the calculated ^{206}Pb/^{238}U and ^{207}Pb/^{206}Pb ratios. We also calculate ^{207}Pb/^{235}U ratios and ages directly from the measured ^{207}Pb and ^{235}U intensities as a check on the calculated ^{207}Pb/^{235}U values. These are useful when there is a problem with the measurement of the ^{206}Pb/^{238}U or ^{207}Pb/^{206}Pb ratios. Hg is present in our argon gases and produces a significant isobaric interference (^{204}Hg) with ^{204}Pb that cannot be resolved during zircon analysis. Owing to the persistent ^{204}Hg peak, we were unable to determine excess ^{204}Pb in the zircon analyses and, therefore, did not apply a correction for common lead in any of the reported zircon analyses. Because the ^{207}Pb/^{206}Pb ages are not corrected for common Pb, these ages should be regarded as maximum ages.

We used two primary standards during the course of this study: an in-house standard, Peixe (provided by George Gehrels, University of Arizona; Klepeis et al., 2004) with a TIMS age of 564 ± 4 Ma (George Gehrels, personal communication); and TEMORA 1 with a TIMS age of 416.8 ± 1.1 (Black et al., 2003). Our reported uncertainty is a combination of two sources combined quadratically: (1) uncertainty (2σ) in the ^{206}Pb/^{238}U intercept and in the average ^{207}Pb/^{206}Pb ratio determined during each analysis and (2) variance in the ^{206}Pb/^{238}U and ^{207}Pb/^{206}Pb determinations of the standards that bracket the unknowns (reported as 2 standard deviations of the population). These in-run errors for individual determinations average 3 percent for the ^{206}Pb/^{238}U ages and 2 percent for the ^{207}Pb/^{206}Pb ages (2σ). These errors do not take into account uncertainty in the TIMS values of the standards or any bias that might exist between the analysis of the standard and unknown zircon due to matrix or cumulative instrumental effects. In practice, we determined our fractionation factors using Peixe and checked the validity of these values by treating the TEMORA 1 standard as an unknown. Typically, we analyze both Peixe and Temora 2-3 times every 5-10 unknowns. This approach over the course of this work yielded a ^{206}Pb/^{238}U age of 414.6 ± 1.2, a ^{207}Pb/^{235}U age of 414.8 ± 1.5, and a ^{207}Pb/^{235}U age of 414.5 ± 4.5 (2 standard error weighted average, n = 93) for TEMORA 1, all of which are within error of its published TIMS age of 416.8 ± 1.1 (Black et al., 2003). Our determinations represent laser analyses performed on several different days and using different normalization factors and, therefore, provide an estimate (albeit probably "best case") of the reproducibility, precision, and accuracy of Pb/U and Pb/Pb analyses of a homogenous zircon population.

In the cumulative probability plots, we included only those analyses that are less than 10 percent discordant based on the calculated ^{206}Pb/^{238}U and ^{207}Pb/^{206}Pb ages. Cumulative probability plots use ^{207}Pb/^{206}Pb ages only. Not shown are analyses that produced ^{207}Pb/^{206}Pb ages, but unreliable ^{206}Pb/^{238}U ages. This occurs when there are irregular Pb/U spectra during the analyses.

RESULTS

Location and lithologic information are summarized in Table 1.

LOW-GRADE METASEDIMENTARY ROCKS

Lunch Peak (LP)

The northernmost sample (04RL175) was collected from Belt strata where formational assignment is well constrained. This sample is a medium-grained, feldspathic quartzite from the member e of the Prichard Formation at Lunch Peak northeast of Sandpoint along the Idaho-Montana border (LP, Fig. 1). Most analyzed grains are concordant, or nearly so. The ^{207}Pb/^{206}Pb ages of the zircons from Lunch Peak are mostly 1440-1820 Ma (Fig. 2) with single grains at 1977 ± 16 Ma, 2011 ± 16 Ma, 2298 ± 17 Ma, 2383 ± 17 Ma and 3066 ± 16 Ma (2σ). Eight grains that are more than 10 percent discordant and three grains that yielded only ^{207}Pb/^{206}Pb ages are not used in the probability plot. Of the 114 grains that were 10 percent or less discordant, 9 have ages within the North American magmatic gap (1610-1490 Ma). However, all 9 are between 1600 and 1610 Ma, and have errors that could place them outside the magmatic gap. These results are similar to those reported by Ross and Villeneuve (2003) for a sample of the Prichard Formation from east of Bonners Ferry, Idaho, but the number of grains within the North American gap are fewer in our Prichard sample.

Pine Creek (PC)

Sample 04RL213 is medium grained quartzite from member e of the Prichard Formation along Pine Creek southwest of Kellogg, Idaho (PC, Fig. 1). Of 123 grains with 10 percent or less discordance, most are 1820 to 1460 Ma and 51 are in the range of the North American magmatic gap (Fig. 3). The youngest is 1456 ± 15 Ma, within error of the dates on sills in the Prichard (1468-1470 Ma; Anderson and Davis, 1995, Sears and others, 1998). Not included in the probability plot are 5 that produced only ^{207}Pb/^{206}Pb ages; none were >10 percent discordant. The age distribution is similar overall to that found in the Lunch Peak sample, although a higher proportion of ages are in the North American magmatic gap and in that respect the results are more similar to the previously analyzed Prichard sample reported by Ross and Villeneuve (2003).

Lakeview (LV)

Sample 04MDM069 is Cambrian quartzite (Gold Creek Quartzite) from near the town of Lakeview southeast of Sandpoint (LV, Fig. 1). Of the 109 grains that are less than 10 percent discordant, the youngest is 1756 ± 18 Ma, and the sample has a single large peak at about 1780 Ma (Fig. 4). It also contains 15 grains older than 2500 Ma, the oldest being 3370 ± 14 Ma. This sample differs from all the other samples analyzed in this study by the absence of young (<1750 Ma) ages. Not used in the probability plot are 11 grains that were >10 percent discordant and 16 that produced only ^{207}Pb/^{206}Pb ages. The Cambrian Lakeview sample has a zircon population similar to the Laurentian sourced sediments described by Ross and Villeneuve (2003) and contrasts strongly with the two Prichard Formation samples.

HIGH-GRADE METASEDIMENTARY ROCKS IN THE PRIEST RIVER COMPLEX

Mt. Casey (MC)

Sample 04RL196 is coarsely recrystallized quartzite within a quartzite and granofels unit in the Priest River metamorphic complex northwest of Sandpoint (MC, Fig. 1). Of 111 grains with 10 percent or less discordance, 15 are 1500-1450 Ma, 22 are 1800-1750 Ma, and 14 are 2550-2500 Ma (Fig. 5). The youngest is 1441 ± 22 Ma. Only four are in the range of the North American magmatic gap (Fig. 5) and the errors on two of these are such that they may be younger than the gap (<1490 Ma). Not shown in the probability plot are 5 grains that were >10 percent discordant and 13 that produced only ^{207}Pb/^{206}Pb ages. The sample shares the 1800-1750 population with the Lakeview sample but contains syn-Belt (1500-1450 Ma) grains that are also found in the two Prichard samples. Of the samples we analyzed, the Mt. Casey quartzite contains the largest number of pre-2400 Ma zircons.

Coolin (CO)

Sample 04RL193 is sillimanite-biotite-quartz-feldspar gneiss within a gneissic unit (Hauser Lake gneiss) in the Priest River metamorphic complex northwest of Sandpoint (CO, Fig. 1). Because the zircon grains were unusually small in this sample (probably because of a siltite protolith), we had difficulty obtaining enough spot data before the laser burned through the grains. Only 20 grains were 10 percent or less discordant (Fig. 6); 14 grains were >10 percent discordant and 31 produced only ^{207}Pb/^{206}Pb ages. Ages of those with <10 percent discordance ranged from 1462 ± 22 to 1826 ± 30 Ma. Although few in number, the results are similar to those obtained for the Lunch Peak and Pine Creek Prichard samples.

Hauser Lake (HL)

Sample 04RL212 is recrystallized feldspathic quartzite within a biotite-feldspar-quartz gneiss sequence (Hauser Lake gneiss) southwest of Sandpoint (HL, Fig. 1). Of 109 grains with 10 percent or less discordance, 33 are between 1800 and 1750 Ma and 5 are in the range of 1500-1450 Ma (Fig. 7). Also notable are the 23 grains older than 2000 Ma. Omitted from the probability plot are 14 grains that were >10 percent discordant and 5 that produced only ^{207}Pb/^{206}Pb ages. The major peak at about 1780 Ma, the abundance of >2000 Ma grains, and the scarcity of grains between 1700 and 1500 Ma, sets this sample apart from the Pine Creek and Lunch Peak Prichard samples. The overall age range, however, is similar.

HIGH-GRADE METASEDIMENTARY ROCKS WEST OF THE BITTERROOT LOBE

Hamby Quarry (HQ)

Sample 04RL207 is sillimanite-biotite-quartz-feldspar gneiss from the Elk City sequence southwest of Lowell (HQ, Fig. 1). Of the 59 grains that are less than 10 percent discordant, most are 1750 to 1650 Ma and only two are in the range of the North American magmatic gap (Fig. 8). The youngest is 1387 ± 38 Ma. Not used in the probability plot are 50 grains that were >10 percent discordant and 16 that produced only $^{207}\text{Pb}/^{206}\text{Pb}$ ages. The age distribution is dissimilar overall to that found in the samples listed above in that it contains few ages in the North American magmatic gap and lacks 1750-1800 Ma grains.

Goddard Point (GP)

Sample 04RL206 is quartzite from a gneissic unit southwest of Lowell that is near the contact between the Elk City metamorphic sequence and the Golden metamorphic sequence (GP, Fig. 1). The unit is tentatively placed in the Golden metamorphic sequence. Of the 57 grains that are less than 10 percent discordant, most are 1800 to 1650 Ma and only 3 are in the range of the North American magmatic gap (Fig. 9). The age distribution is similar to that in the Hamby Quarry sample. Rims of five zircon grains yielded discordant results with widely varied $^{207}\text{Pb}/^{206}\text{Pb}$ ages. The $^{206}\text{Pb}/^{238}\text{U}$ ages were 82-72 Ma.

Golden (GQ)

Sample 04RL208 is feldspathic quartzite from the Golden metamorphic sequence southwest of Lowell (HQ, Fig. 1). Of the 113 grains that are less than 10 percent discordant, most are 1750 to 1650 Ma and 18 are in the range of the North American magmatic gap (Fig. 10). Not used in the probability plot are 21 grains that were >10 percent discordant and 4 that produced only $^{207}\text{Pb}/^{206}\text{Pb}$ ages. The age distribution is similar overall to that found in the Hamby Quarry and Goddard Point samples. However, more ages are concordant, and more ages in the North American magmatic gap are present. Rims of three zircon grains yielded discordant results with widely varied $^{207}\text{Pb}/^{206}\text{Pb}$ ages. The $^{206}\text{Pb}/^{238}\text{U}$ ages were 77-73 Ma.

Wall Point (WP)

Sample 04RL210 is coarsely recrystallized quartzite in the Syringa metamorphic sequence from southwest of Lowell (WP, Fig. 1). Of the 95 grains that are less than 10 percent discordant, most are between 1150 and 1050 Ma, with a secondary peak at about 1770 Ma (Fig. 11). Importantly, one grain yielded relatively young ages of 686 ± 34 Ma and 672 ± 34 Ma and a second grain yielded an age of 698 ± 31 Ma. Not used in the probability plot are 40 grains that were >10 percent discordant and 5 that produced only $^{207}\text{Pb}/^{206}\text{Pb}$ ages. Rims of four zircon grains yielded discordant results with widely varied $^{207}\text{Pb}/^{206}\text{Pb}$ ages. The $^{206}\text{Pb}/^{238}\text{U}$ ages were 93-77 Ma. The Wall Point sample shares the 1750-1800 Ma population with several other samples, but has an unusual abundance of 1050-1150 grains and a small population of relatively young (less than 700 Ma) grains.

Smith Creek Road (SCR)

Sample 04RL199 is coarsely recrystallized mylonitic quartzite in the Syringa metamorphic sequence from west of Lowell (SCR, Fig. 1). In contrast to most of the other samples, a large percentage of grains were either > 10 percent discordant (100) or produced only $^{207}\text{Pb}/^{206}\text{Pb}$ ages (14). Of the 13 grains that are less than 10 percent discordant, 8 are between 1750 and 1900 Ma (Fig. 12). One grain had an age of 755 ± 35 Ma. Rims of four zircon grains yielded discordant results with widely varied $^{207}\text{Pb}/^{206}\text{Pb}$ ages. The $^{206}\text{Pb}/^{238}\text{U}$

ages were 97-88 Ma. The sparse data set from this sample shares the 1750-1800 Ma population with several other samples. The single 755 ± 35 Ma grain is not an age we found in other samples.

Mason Meadows (MM)

Sample 04RL197 is coarsely recrystallized quartzite in the Syringa metamorphic sequence from north of Orofino (MM, Fig. 1). Like the Smith Creek road sample a large percentage of grains were either > 10 percent discordant (50) or produced only $^{207}Pb/^{206}Pb$ ages (30). An additional 30 grains were less than 10 percent discordant and most of these yielded ages between 1700 and 1800 Ma (Fig. 13). Notably, one grain was dated at 680-681 Ma (3 spots). The Mason Meadows sample shares the 1700-1800 Ma population with several other samples, but the small population of relatively young (less than 700 Ma) grains is similar to that of the Wall Point sample. Unlike the Wall Point sample, it lacks the 1050-1150 Ma grains.

Dicks Creek (DC)

Sample 04RL198 is biotite-feldspar-quartz gneiss from north of Orofino (DC, Fig. 1). The sample is from near the mapped boundary between the Syringa metamorphic sequence and rocks most similar to the Elk City metamorphic sequence. The outcrop contained an abundance of granitic material that was thought to be Cretaceous. Like the Smith Creek Road and Mason Meadows samples, a large percentage of grains were either > 10 percent discordant (76) or produced only $^{207}Pb/^{206}Pb$ ages (12). Of the 38 grains that are less than 10 percent discordant, most are between 1400 and 1350 Ma (Fig. 14). Rims of two zircon grains yielded discordant results with widely varied $^{207}Pb/^{206}Pb$ ages. The $^{206}Pb/^{238}U$ ages were 79-78 Ma. The abundance of 1400-1350 Ma zircons sets this sample apart from the others we analyzed.

DISCUSSION

The Prichard member e Pine Creek sample and, to a lesser extent the member e Lunch Peak sample, contain zircon populations with ages within the North American magmatic gap (1610-1490 Ma) and overall are similar to zircon populations reported by Ross and Villeneuve (2003) for the western facies of the Belt-Purcell Supergroup. The youngest ages overlap with the suspected depositional age of the Prichard (about 1470 Ma; Anderson and Davis, 1995; Sears et al., 1998) suggesting a volcanic component of about that age. The non-Laurentian zircons found in these samples are attributed to derivation from a western source area that was rifted from Laurentia in the Neoproterozoic (initial rifting at about 780 Ma; Stewart, 1972, Lund et al., 2003).

In contrast to the Prichard samples, the Cambrian Gold Creek Quartzite from near Lakeview has no grains younger than 1756 ± 18 Ma, despite the fact that this rock is considerably younger than the Belt-Purcell Supergroup. Similar findings are reported for the Cambrian elsewhere in the western U.S. and Canada (Smith and Gehrels, 1991). Clearly the western part of the Belt Supergroup was not a source for these rocks.

Amphibolite facies rocks in the Priest River complex appear to be equivalent in age to the Belt-Purcell Supergroup. Although the Mt. Casey, Coolin, and Hauser Lake gneiss samples have different age distributions, the presence of 1450-1500 Ma grains indicates that these rocks are not basement to the Belt. Similar conclusions were reached by Doughty and others (1998). The Mt. Casey sample, and to a lesser extent Hauser Lake sample, also had a source of old zircons (3600-2500 Ma) that are better represented than in the other samples we analyzed. Some or all may have been derived locally from the Archean basement southwest of Sandpoint.

The three amphibolite facies samples from west of Elk City (Hamby Quarry, Goddard Point, and Golden) have enough 1380-1500 Ma grains to indicate that they do not predate the Belt. Rather, they seem to have relatively young grains when compared to the Prichard samples (Lunch Peak and Pine Creek) and are probably a relatively young, southwestern part of the Belt Supergroup. These results are similar to those reported from the paragneiss of Dutch Oven Creek just west of Elk City (Lund et al., 2005; Lund, personal communication, 2005). Thus far, no Prichard equivalent rocks have been recognized southwest of the Kelly

Forks-Benton Creek fault zone. This area of relatively young Belt-equivalent rocks also contains the 1380 Ma A-type granites (now augen gneiss) which are absent to the north and east.

The quartzite samples from the Syringa metamorphic sequence (Wall Point, Smith Creek road, and Mason Meadows) all share the 1800-1750 Ma population and contain zircons that are younger than the Belt Supergroup (<1380 Ma). Wall Point contains a large number of 1150-1050 Ma grains that are rare or lacking in the other two samples. Both Wall Point and Mason Meadows contain a few zircons that are less than are 700-650 Ma, similar to U-Pb SHRIMP ages on zircon in Windermere Supergroup volcanic rocks in central Idaho (Lund and others, 2003). These results confirm the work of Lund et al. (2005) who recognized Neoproterozoic quartzite (quartzite of Wild Goose camp) just west of Lowell that we mapped as part of the Syringa metamorphic sequence. The Syringa metamorphic series appears to equivalent to the upper part of the Windermere Supergroup (Umbrella Butte unit of Lund et al., 2003) found to the south of the area in the Gospel Hump Wilderness. In the area of Idaho from Wall Point north, the lithostratigraphic packages of Neoproterozoic rocks lack coarse, feldspathic clastics, diamictites, and igneous components as found in the Windermere to the northwest and in the middle and lower parts of the Windermere in the Gospel Hump and Big Creek areas to the south (Lund et al., 2003).

The Dicks Creek sample is problematic in that it contains a large number of grains of about the same age as the augen gneiss (1380 Ma). Because of the abundance of granitic material at the outcrop (at the time suspected to be Cretaceous) we are not certain that all of the zircons are detrital. One possibility is that the granitic material is 1380 Ma and that the sample was contaminated with minute stringers containing 1380 Ma igneous grains. Alternatively, this sample could post-date the Belt and contain 1380 Ma detrital grains. In that case it most likely would be part of the Syringa metamorphic sequence.

Results of this study build on our previous success in obtaining useful ages from detrital zircons in amphibolite-grade metasedimentary rocks in northern Idaho using the LA-ICPMS method (Lewis and others, in press). The amphibolite facies metasedimentary rocks in the Priest River metamorphic complex appear to be metamorphosed lower Belt equivalent. Some of the high-grade metasedimentary rocks west of the Bitterroot lobe of the Idaho batholith contain zircons with ages similar to those in low-grade Belt-Purcell Supergroup rocks to the north, indicating that upper units of the Belt-Purcell basin probably extend at least as far south as Elk City. However, extensive areas once thought to be metamorphosed Belt-Purcell Supergroup or even basement to the Belt, can now be assigned to the much younger (Neoproterozoic) Windermere Supergroup.

ACKNOWLEDGMENTS

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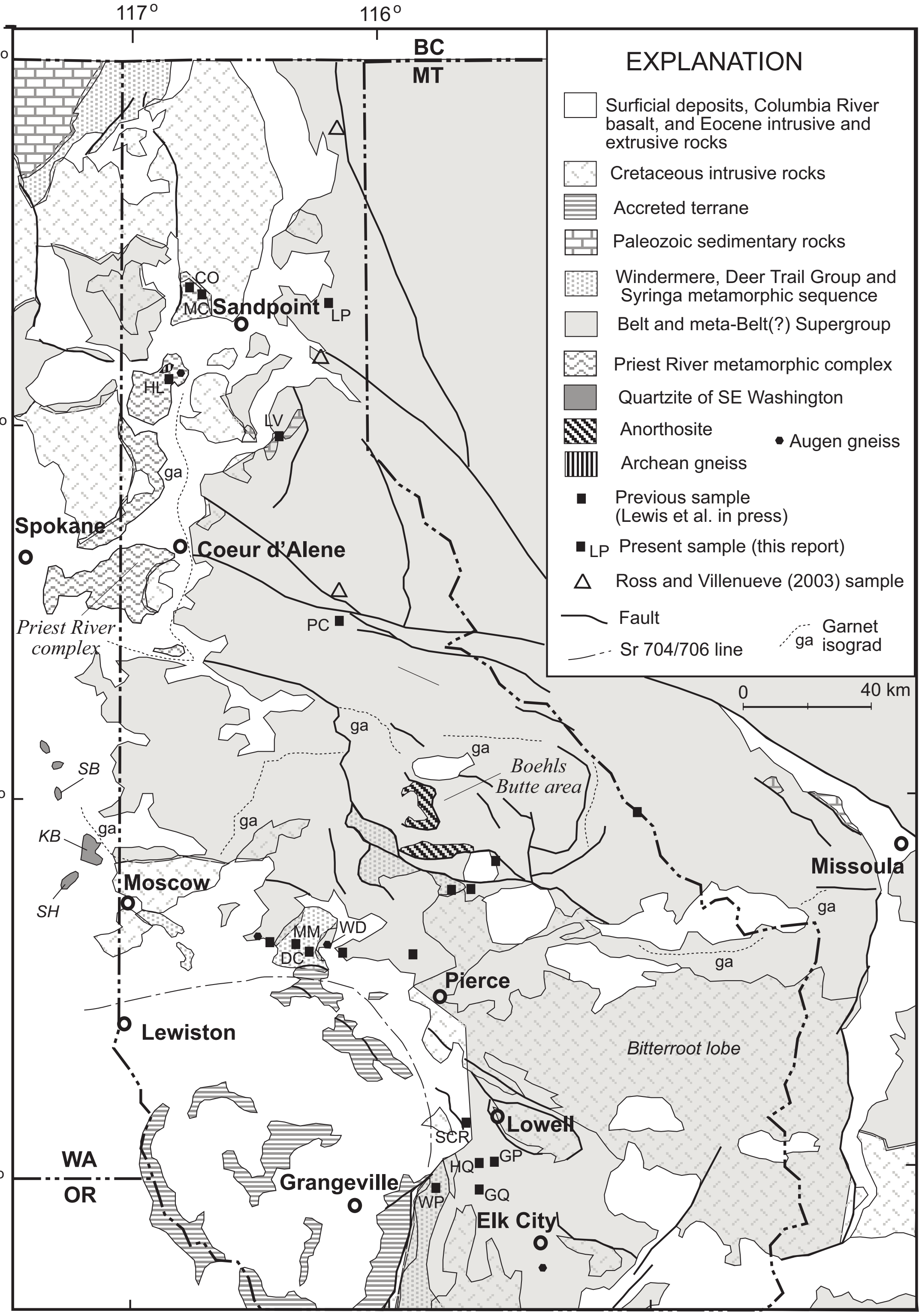
LIST OF FIGURES

LIST OF TABLES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EXPLANATION
Surficial deposits, Columbia River basalt, and Eocene intrusive and extrusive rocks
Cretaceous intrusive rocks
Accreted terrane
Paleozoic sedimentary rocks
Windermere, Deer Trail Group and Syringa metamorphic sequence
Belt and meta-Belt(?) Supergroup
Priest River metamorphic complex
Quartzite of SE Washington
Anorthosite
Augen gneiss
Archean gneiss
Previous sample (Lewis et al. in press)
LP Present sample (this report)
Ross and Villenueve (2003) sample
Fault
Sr 704/706 line
ga Garnet isograd
0
40 km
CO
MC
Sandpoint
LP
HL
LV
ga
Spokane
Coeur d'Alene
Priest River complex
PC
ga
ga
Boehls Butte area
SB
KB
SH
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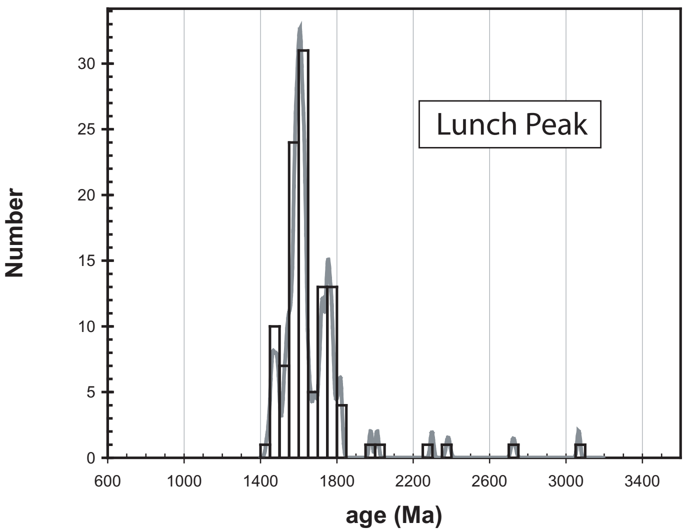
Elk City

Figure 1



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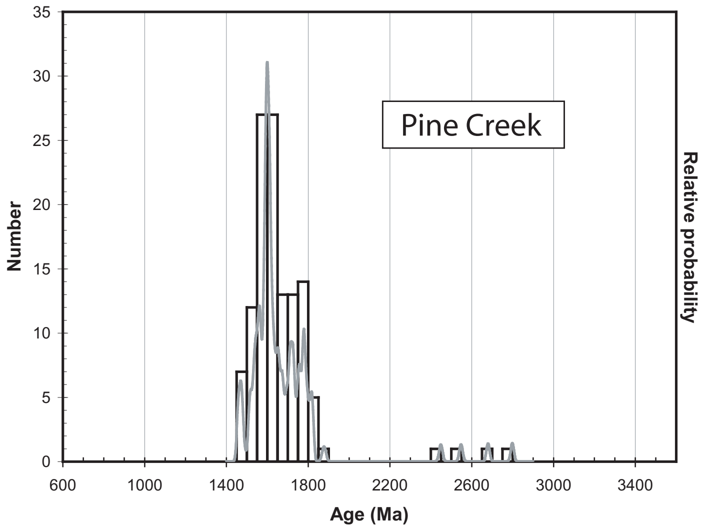

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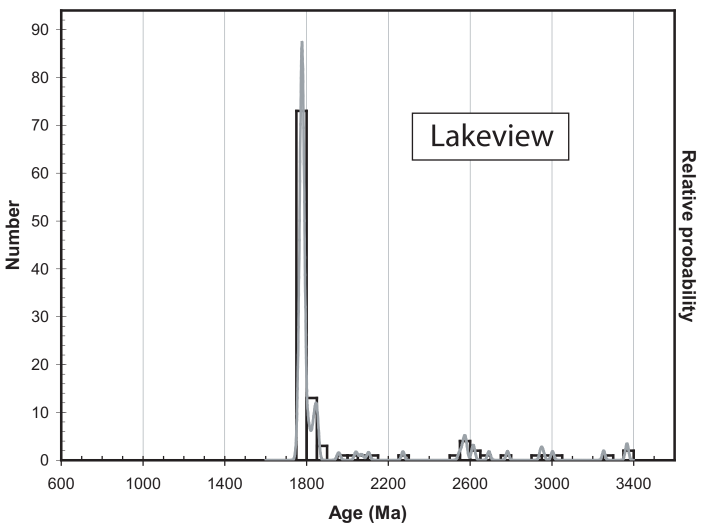

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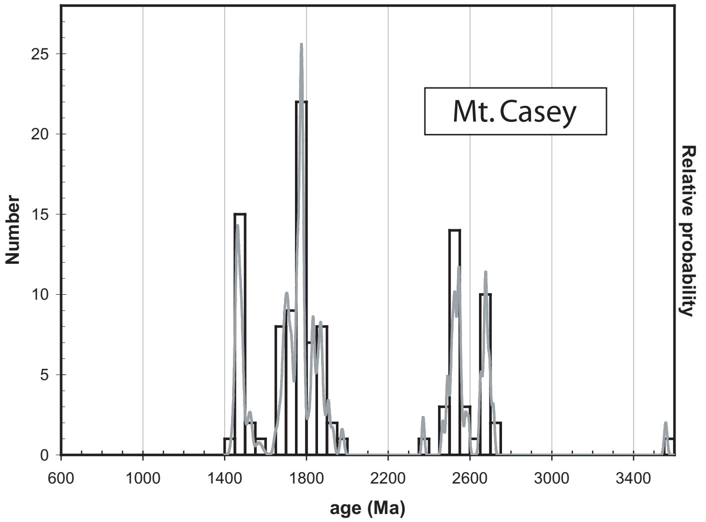

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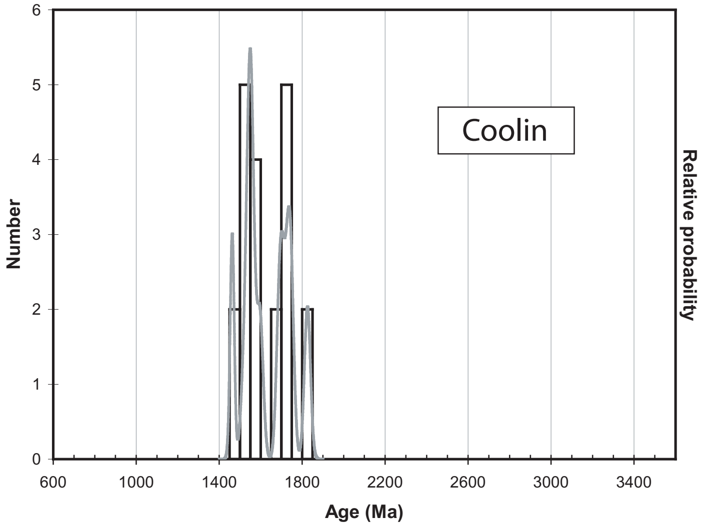

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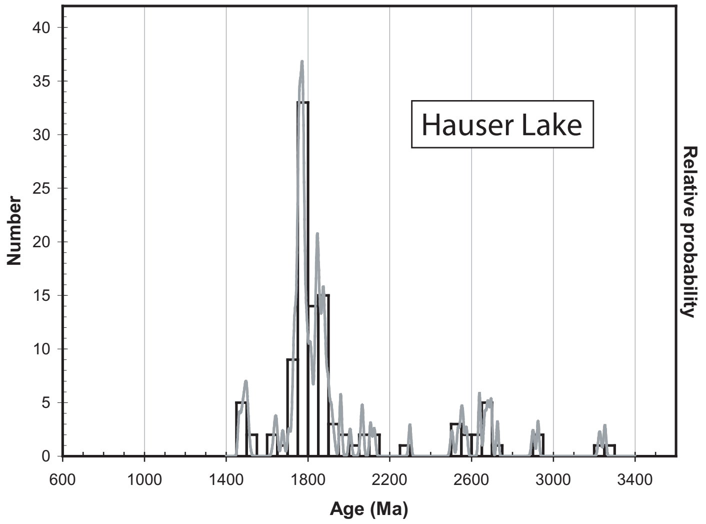

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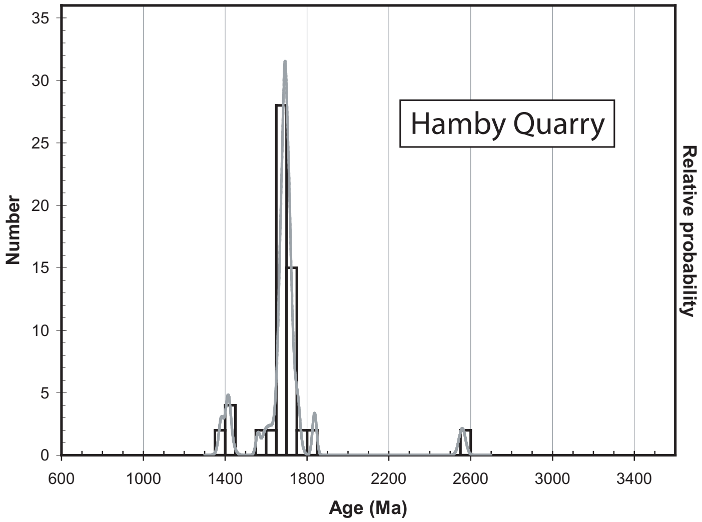

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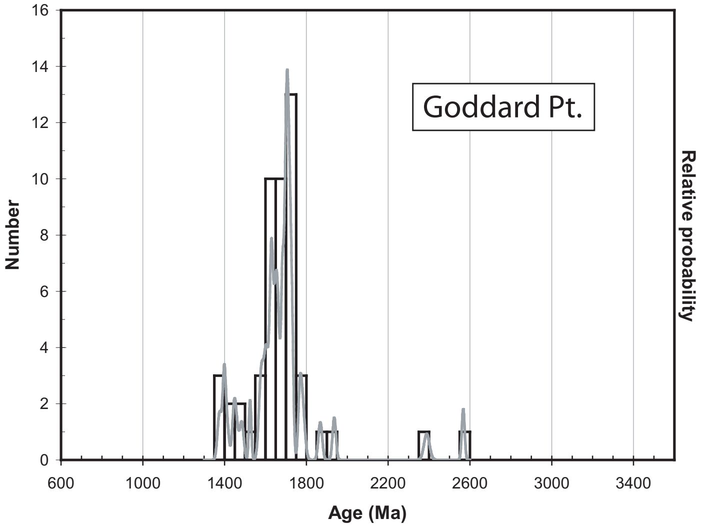

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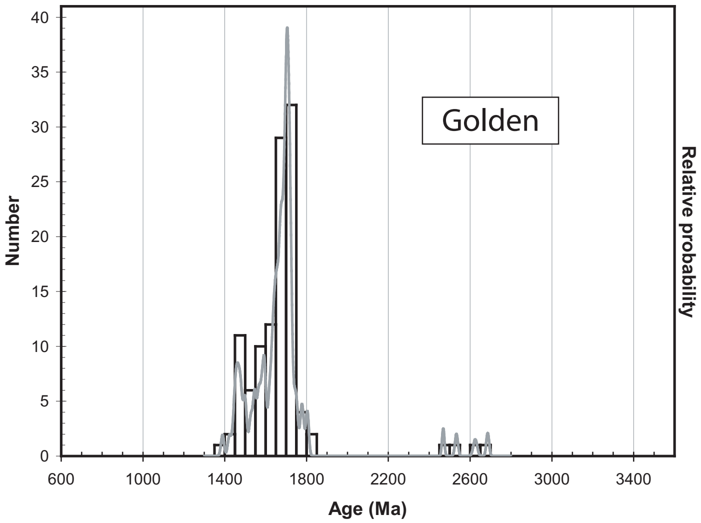

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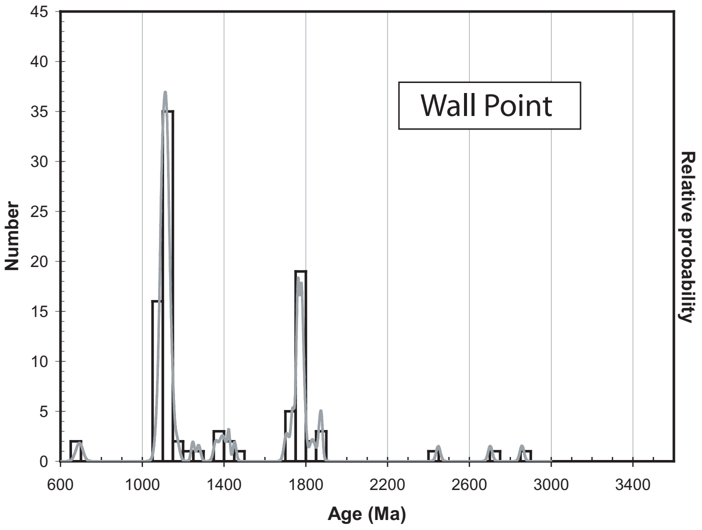

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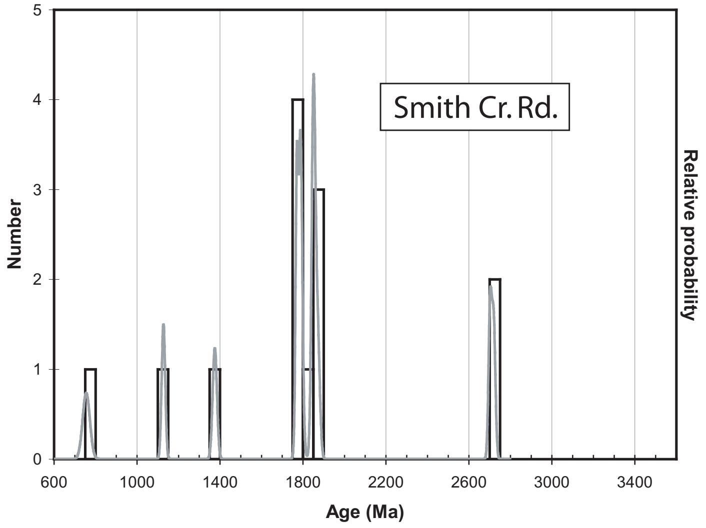

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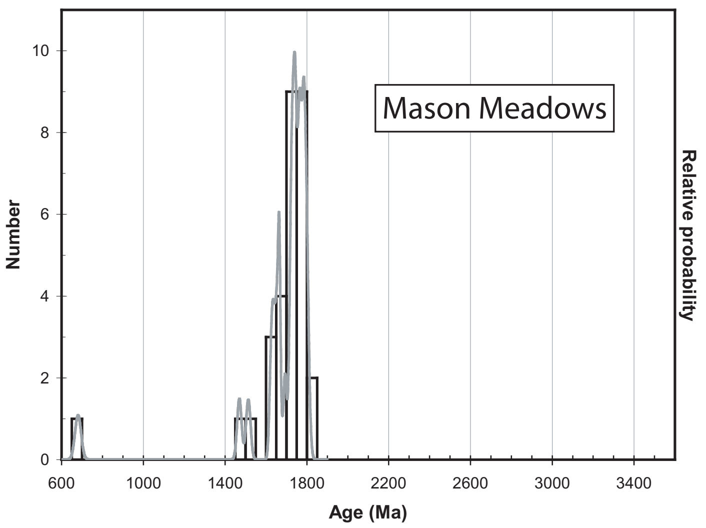

Figure 13

Table 1. Location and lithologic information for detrital zircon samples.

Sample No.	abbr	Location	latitude	longitude	unit name	lithology
04MDM069	LV	Lakeview	47.9765	-116.4211	Gold Creek Quartzite	quartzite
04RL175	LP	Lunch Peak	48.3748	-116.1924	Prichard Formation, member e	quartzite
04RL193	CO	Coolin	48.38065	-116.76723	Priest River metamorphic complex	metasiltstone
04RL196	MC	Mt. Casey	48.38995	-116.69598	Priest River metamorphic complex	quartzite
04RL197	MM	Mason Meadows	46.64533	-116.35958	Syringa metamorphic sequence	quartzite
04RL198	DC	Dicks Creek	46.62705	-116.32188	Elk City metamorphic sequence?	gneiss
04RL199	SCR	Smith Cr. Rd.	46.13871	-115.74359	Syringa metamorphic sequence	quartzite
04RL206	GP	Goddard Point	46.03969	-115.5682	Golden metamorphic sequence?	quartzite
04RL207	HQ	Hamby quarry	46.01217	-115.62818	Elk City sequence	gneiss
04RL208	GQ	Golden qtzite	45.96546	-115.68816	Golden quartzite	quartzite
04RL210	WP	Wall Point	45.97319	-115.84265	Syringa metamorphic sequence	quartzite
04RL212	HL	Hauser Lake	48.1585	-116.7877	Priest River metamorphic complex	quartzite
04RL213	PC	Pine Creek	47.5114	-116.2391	Prichard Formation, member e	quartzite