Applying zircon compositional data to detrital zircon studies

J.L. WOODEN* AND F.K. MAZDAB

U.S. Geological Survey, Menlo Park, CA 94025
(*correspondence: jwooden@usgs.gov)

Most detrital zircon studies focus on the age distribution of a zircon population. Recently the availability of ICP-MS laser Hf isotopic analyses for zircons has added this powerful discriminant to detrital zircon studies. However, the intense interest in the detrital Hadean zircons has demonstrated that a wide variety of analytical techniques (age, Hf and O isotopes, composition, temperature, inclusion types, morphology, metamorphic (mm) rims) can be applied to detrital zircons and provide a wealth of information. A careful sequence of analysis must be used, encouraging the mixed use of ion beam and laser techniques. Ideally as many techniques as time and resources allow should be applied to take advantage of the valuable geologic records that may only be preserved in zircons, given the tremendous mass of crust removed by weathering. Compositional data for zircons can be acquired with laser or ion beam techniques combined or not with U-Pb age analysis. While it is still difficult to use zircon composition to predict rock type, it is now possible to obtain magmatic and metamorphic process information and general information about magma and magmatic source characteristics. The ability to obtain information about the temperature of crystallization of zircons from their Ti concentration provided the stimulus for the SUMAC SHRIMP-RG facility to initiate routine trace element of zircons, both as a dedicated technique for 37 elements and as a shorter (REE + Hf,Th,U) technique combined with U-Pb age analysis. Zircon compositional data from numerous igneous and metamorphic rocks form the basis for the interpretation of igneous and mm processes and general parental and source characteristics. While it is admittedly more difficult to apply these interpretative principles to detrital zircons because of the lack of a parent rock context, zircon compositional characteristics can still provide valuable additional information especially in evaluating the heterogeneity of zircons in one age group. Examples of other information that can be distinguished are magmatic arc versus A-type crustal melting sources and magmatic vs. metamorphic origin beyond the ambiguous Th/U ratio. While it is ideal to have a more complete zircon analysis including P, Sc, Ti, Y and Nb, the shorter REE + Hf, U, Th dataset alone provides much useful information including Eu and Ce anomalies, slope of HREE (Yb/Gd), and discriminant ratios such as U/Yb and U/Ce.

Geochemical and isotopic evidence for the origin of the Boulder batholith, Montana

J.L. WOODEN[1], F.K. MAZDAB[1], P.A. MUELLER[2], J.N. ALEINIKOFF[3], K. LUND[3], B. WIEGAND[4], N. KITA[5] AND J.W. VALLEY[5]

[1]U.S. Geological Survey, Menlo Park, CA 94025
(*correspondence: jwooden@usgs.gov)
[2]Geol. Sciences, Univ. of Florida, Gainesville, FL 32611
[3]U.S.G.S., Denver, CO 80225
[4]Geol. Envir. Sciences, Stanford Univ., Stanford, CA 94305
[5]Geol. & Geophy., Univ. of Wisconsin, Madison, WI 53706

New SHRIMP U-Pb ages indicate that the Boulder batholith, Montana, was emplaced over ~7 m.y. Rader Creek (RC), Unionville (U), and Burton Park (BP) plutons are 80.7, 78.2, 77.7 Ma, respectively, and have the lowest SiO_2 (56-65%). Butte Granite (BG), Pulpit Rock (PR), Climax Gulch (CG), and Homestake (H) plutons are 76.5–74.7 Ma with SiO_2 of 64-71%. Moose Creek (MC) and Hell Canyon (HC) are 74.2 and 73.7 Ma, and have 69-74% SiO_2. Whole rock (WR) Sr initial ratios for RC, U, BP, BG, PR, CG, and H range from 0.7069-0.7074, whereas MC and HC have significantly higher ratios of 0.7082 and 0.7089. WR initial εNd ranges from -14.1 to -18.5 (RC, U, BP), -11.9 to -18.9 (BG, PR, CG, H), and -14.8 (MC) and -16.4 (HC), indicating involvement of pC basement in the magmatism. Hf isotopic data for zircon also indicate involvement of the basement and distinguishes between Prot. and Archean sources. Zircons from RC, MC and HC have Archean signatures (εHf(t) -25 to -40), whereas zircons from other plutons are relatively homogeneous with εHf(t) ~-15. O isotopes in zircons also suggest variable degrees of crustal derivation. RC, MC and HC zircons have $\delta^{18}O$ of about 5.5-6.2 whereas zircons from other plutons with higher values (6.2-7.0) suggest greater amounts of crustal components. Zircons from RC, U, and BP have high $T_{Ti\text{-}zircon}$, 930-790°C (est. a_{Ti} = 0.7) and relatively low [Hf]. Zircons from BG, PR, CG and H have $T_{Ti\text{-}zircon}$ 870-700°C and relatively high [Hf], consistent with the differences in WR compositions. Zircons from MC and HC formed at fairly low temperatures (mostly ~800-690°C) but MC has very low [Hf] whereas HC has relatively high [Hf]. Zircon Eu/Eu* distinguishes MC and HC (0.85-0.45) from all older plutons (0.4-0.2), an unexpected contrast given the evolved WR composition of the youngest units. All the isotopic and geochemical data indicate a magmatic progression from the older, less evolved units to the more evolved main phase (BG), followed by sharp changes in the youngest phases that are unlike any unit that preceded them.