Detrital zircon geochronology of

Proterozoic to Devonian rocks in interior Alaska

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Background. Detrital zircon geochronology is a rapidly growing field that can yield several types of information bearing on problems of stratigraphy, regional geology, tectonic evolution, and geodynamics. Detrital zircons—especially in active tectonics settings—often provide new age constraints on the depositional age of the host sandstone, which can be no older than the youngest zircons. This is especially important in strata that are devoid of fossils. Detrital zircon age distributions ("barcodes") can be used to evaluate possible correlations between sandstone-bearing stratigraphic units. This information has applications in geologic mapping at the quadrangle scale (making decisions about problematic rocks), and on a regional scale (matching displaced parts of an originally continuous sedimentary or metasedimentary succession). Detrital zircons can be linked to possible bedrock source regions by their age. Information of the latter type, in turn, can bear on the timing of tectonic events such as juxtaposition of terranes. Finally, detrital zircons may be the only surviving record of rocks that have since been obliterated or are now on the other side of the world.

Most sandstones and metasandstones contain detrital zircons. Very coarse to medium-grained, compositionally mature sandstones are preferred; a 5 kg sample will generally yield hundreds to thousands of zircons. Like igneous ones, detrital zircons are extracted by crushing the rock and then using a combination of density and magnetic separation techniques (detrital zircons are quite sturdy and generally survive the process unbroken.) Zircons are dated by the U-Pb method. Two analytical procedures are in common use today, each with its pros and cons. The ion microprobe (e.g., SHRIMP) features a narrow ion beam that analyzes the U and Pb from a very shallow depression that the beam excavates in the polished surface of the zircon crystal, allowing analyses of the most favorable zones within crystals. The other common technique is laser-ablation inductively coupled mass spectrometry (LAICPMS), which employs a much wider beam that burns a deep hole into or even through each zircon crystal, including any bad parts. Analytical costs being comparable, the tradeoffs are between spatial resolution (better on the SHRIMP), sample destruction (no on SHRIMP, yes on LAICPMS), and speed (faster on the LAICPMS). Generally, 60 zircons per sandstone are analyzed by SHRIMP, compared to 100 grains by LAICPMS. Commercial rates for LAICPMS range from $1100 to $1500 per 100-grain sample.

Results. Detrital zircon populations have now been analyzed for all major terranes in interior Alaska that are thought to include Precambrian rocks (Fig. 1).

Laurentia. The only Neoproterozoic to early Paleozoic rocks in Alaska that are of clear Laurentian (North American) origin crop out north of the Yukon River in easternmost Alaska. Detrital zircon data have been reported from the Cambrian and Devonian by Gehrels et al.

(1999); detrital zircons from the Neoproterozoic part of the section have not yet been dated. The Cambrian Adams Argillite has distinctive triple zircon peaks at 1085, 1805, and 2609 Ma (Fig. 1a), all traceable to Laurentian sources. The Devonian Nation River Formation has similar peaks 1838, 1922 and 2740 Ma, as well as a peak at 431 Ma that must have been derived from an outboard source that has now gone elsewhere.

Wickersham terrane. The Wickersham terrane, which consists of low-grade coarse sandstones, red and green mudstone, and minor limestone of inferred late Neoproterozoic to Cambrian age, is mapped in Livengood and Tanana quadrangles (Weber et al., 1992; Chapman et al., 1982). A composite Wickersham barcode, based on 3 samples, has peaks at 1060, 1091, 1840, 1947, 2551, and 2689 Ma (Fig. 1b). This is quite similar to the barcode of the roughly coeval Adams Argillite; a Laurentian provenance is inferred.

Yukon-Tanana terrane. The Wickersham is bounded to the southeast by higher-grade metasedimentary rocks of comparable protolith that are assigned to the vast Yukon-Tanana terrane. The Yukon-Tanana underlies much of east-central Alaska and has been traced as far southeast as the Alaskan panhandle, and as far southwest as the Talkeetna quadrangle. In addition to protoliths that seem to correlate with the Wickersham grit (Weber et al., 1985), the Yukon-Tanana terrane also includes a metamorphosed Devonian-Mississippian continental-margin magmatic belt (Dusel-Bacon et al., 2004). Similar detrital zircon data support correlation between these two terranes; a composite Yukon-Tanana barcode, based on 3 samples, shows peaks at 1807 and 2598 Ma and mainly differs from the Wickersham in the absence of the so-called "Grenville" peak at about 1 Ga (Fig. 1c). The zircons are traceable to the Laurentian craton. A tuffaceous metasandstone in the Yukon-Tanana schist belt at Denali Village (Unit Pzp€s of Csejtey et al., 1994) yielded a few zircons that define a young peak at about 670 Ma, suggesting a Neoproterozoic depositional age for these previously undated rocks.

Farewell terrane. The Farewell terrane is a microcontinental fragment that includes both 850-980 Ma basement (McClelland et al., 1999; Bradley et al. 2003) and an overlying passive margin platform sequence (Nixon Fork subterrane) of late Neoproterozoic to Devonian age. Cambrian to Devonian fossils from the Nixon Fork are a mix of Siberian and North American forms (Blodgett et al., 2002; Dumoulin et al., 2002) that rule out the once popular view of the Farewell as a displaced piece of the passive margin of western Canada. A composite detrital zircon barcode of the Farewell terrane, based on 4 samples of late Neoproterozoic? and Cambrian quartzites, shows a dominant peak at 2051 Ma, suggesting derivation either from the Kilbuck terrane (see below), or basement rocks elsewhere of the same age. A Laurentian source is unlikely because of the absence of peaks at ca. 2.6, 1.8, and 1.0, which are so universally seen in sandstones of known Laurentian provenance. A ca. 2050-Ma peak is seen in the detrital zircon barcode of the Paleoproterozoic to Mesoproterozoic (ca. 1650 to 1350 Ma) Uy Group along the eastern margin of the Siberia Craton (Khudoley et al., 2001).

Kilbuck terrane. The Kilbuck terrane and a displaced fragment of it called the Idono Complex contain the oldest known rocks in Alaska—granitic gneisses dated at 2050 to 2084 Ma. The Kilbuck terrane is now known to include at least one younger granite dated at 849 Ma (Bradley et al., 2007), strongly suggesting commonality with parts of the Farewell terrane. Detrital zircon data (Figs. 1d and 1e) also suggest a link. A composite detrital zircon barcode of the Kilbuck terrane, based on 2 samples of Mesoproterozoic? quartzite, shows a dominant peak at 1935 Ma. The main peaks of the Kilbuck and Farewell composites show substantial statistical overlap, and the Kilbuck composite is almost identical to one of the Farewell samples in particular. A ca. 1950-Ma peak is seen in the detrital zircon barcode of the Mesoproterozoic (ca. 1350 to 1000 Ma) Kerpyl Group along the eastern margin of the Siberia Craton (Khudoley et al., 2001), providing further support for a Siberian connection. Detrital zircons and a crosscutting pluton together provide the first age constraint on the depositional age of the Kilbuck terrane's supracrustal sequence, which must be between ca. 1800 and 850 Ma. Correlatives might be sought in the Riphean of eastern Siberia.

Ruby terrane. The Ruby terrane is a belt of Neoproterozoic? and Paleozoic metasedimentary rocks of presumed continental margin affinity, intruded by Devonian orthogneiss and Early Cretaceous granites (Patton et al., 1994). A composite detrital barcode, based on 3 samples (Fig. 1f), shows peaks at 1180 and 1470 Ma superimposed on a broad Mesoproterozoic high. The pattern is similar to that seen in Proterozoic Sequence B of the Canadian Northwest Territories (Rainbird et al., 1997) but also the ca. 1-Ga Uy Group of the eastern margin of the Siberia Craton (Khudoley et al., 2001). The detrital zircon barcode from a fourth sample from a thrust belt in Ruby terrane is completely different from the other three, and not included in the Ruby composite. It is similar to Yukon-Tanana and Wickersham barcodes and hints at complexities that cannot be resolved with available data.

Summary. At this early reconnaissance stage in Alaskan detrital zircon studies, the main goal is to characterize all the major sandstone-bearing rock units. The present subset of samples pertains to the early history of the older terranes and also provides a necessary footing for understanding the post-Devonian assembly of the various terranes. Detrital zircon data support previously debatable correlations between the Wickersham terrane, the Yukon-Tanana terrane, and the essentially autochthonous triangle of Laurentia in easternmost Alaska. The Farewell and Kilbuck terranes appear to be parts of the same microcontinent, and the zircon data are consistent with the paleontological evidence for a Siberian link. The distinctive detrital zircon barcode of the Ruby terrane is perhaps the biggest surprise, as it raises two intriguing possibilities: that the Ruby may well include rocks as old as 1 Ga, and that the terrane could have a Siberian origin. Given the time elapsed and typical rates of plate motion, interpretations of detrital zircon data from Devonian and older rocks require a world view, supported by global databases of both igneous and detrital zircon geochronology.

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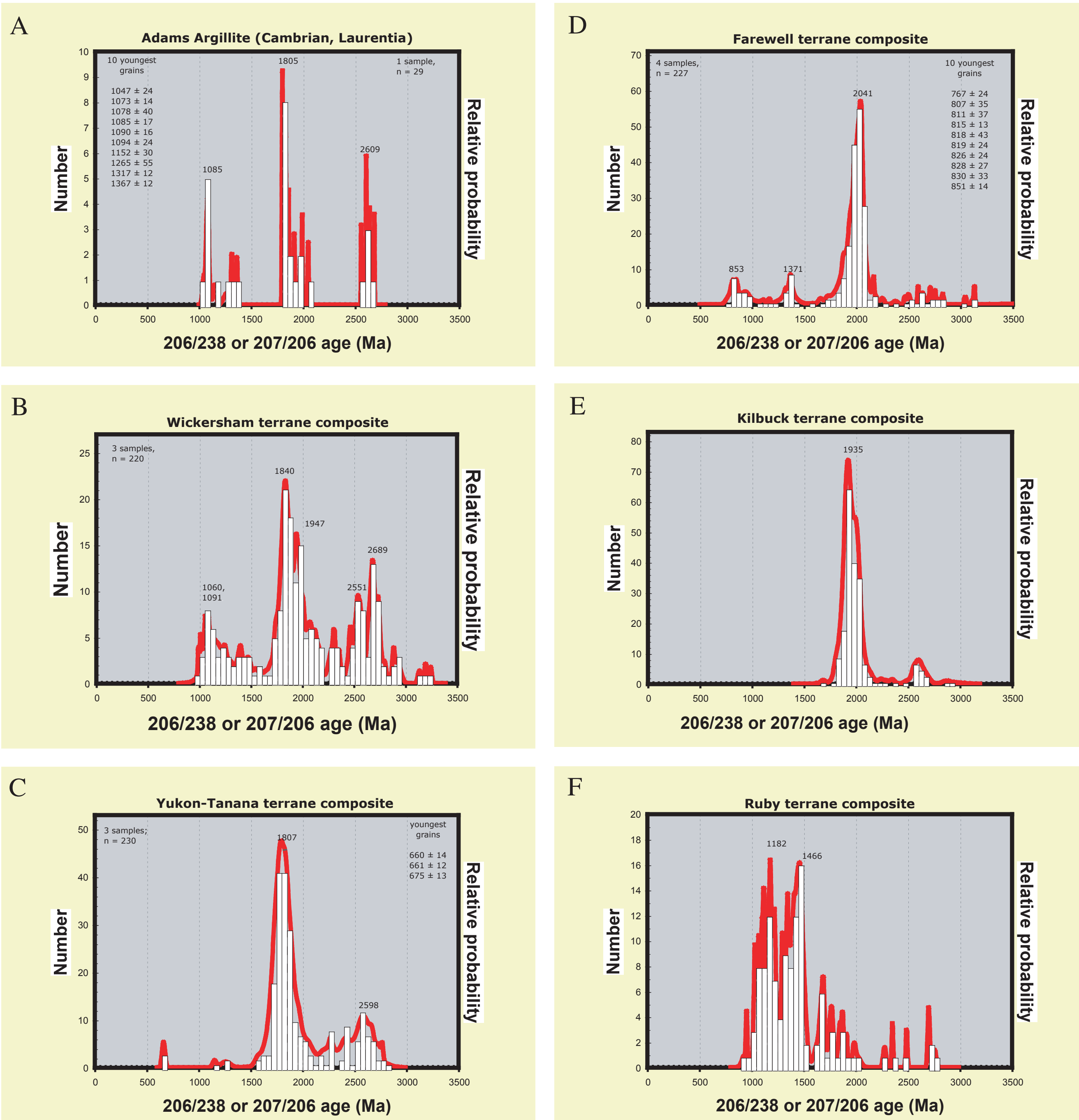

Figure 1. Detrital zircon age distributions for six rock units in interior Alaska. In each plot, the same data are represented by histograms with 50-m.y. bins (open rectangles) and by the probability density curve (dark gray heavy line). (a) Adams Argillite, from Gehrels et al. (1999). This age distribution is based on sparser data than the others; some minor populations probably went undetected. (b) Composite of three samples from the Wickersham terrane, from Bradley et al. (2007) and this study. (c) Composite of three samples from Yukon-Tanana terrane, from Bradley et al. (2007) and this study. (d) Composite of four samples from the Farewell terrane, from Bradley et al. (2007) and this study. (e) Composite of two samples from the Kilbuck terrane, from this study. (f) Composite of three samples from the Ruby terrane, from Bradley et al. (2007).