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Common minerals and common Pb isotopes:
Uncommon applications and new method development for detrital K-feldspar provenance analysis

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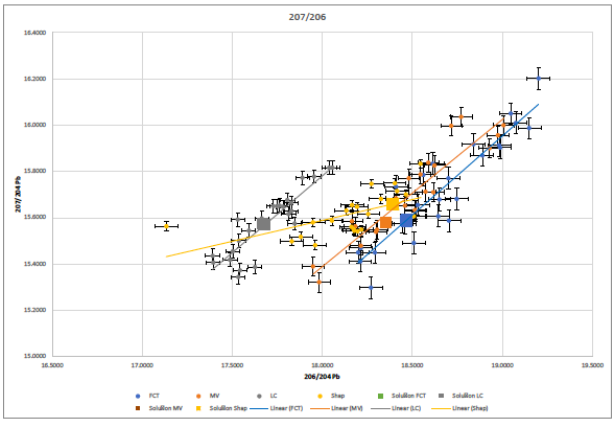
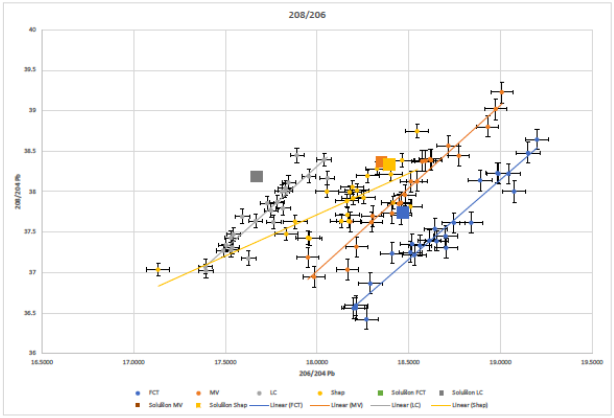
We have been developing new standards for detrital grain Pb-Pb LA-ICP-MS analysis, based on four locations: Mary's Vale (Utah), Little Cottonwood Stock (Utah), Shap Granite (Ireland), and Fish Canyon Tuff (Colorado). These were chosen to demonstrate a range of ages (23-400 Ma), geographic locations, and formation processes. We compared dissolved solution analyses with grain separate analyses and published *in situ* analyses to better understand heterogeneity and error constraints. Unsurprisingly, detrital grain data have a larger spread than data collected from solutions and *in situ* analyses, although each sample set provided clearly identifiable clusters, apart from $^{207}Pb/^{206}Pb$ for the Fish Canyon Tuff and the Mary's Vale samples, which were not statistically distinct from each other. Additionally, our methods demonstrate lower ratios of $^{208}Pb/^{206}Pb$ for the Fish Canyon Tuff than shown in previously published literature, indicating previously unidentified Pb-isotopic heterogeneity within this commonly used standard. We have thus identified the Shap Granite and the Little Cottonwood Stock as preferred standards for LA-ICP-MS analysis.

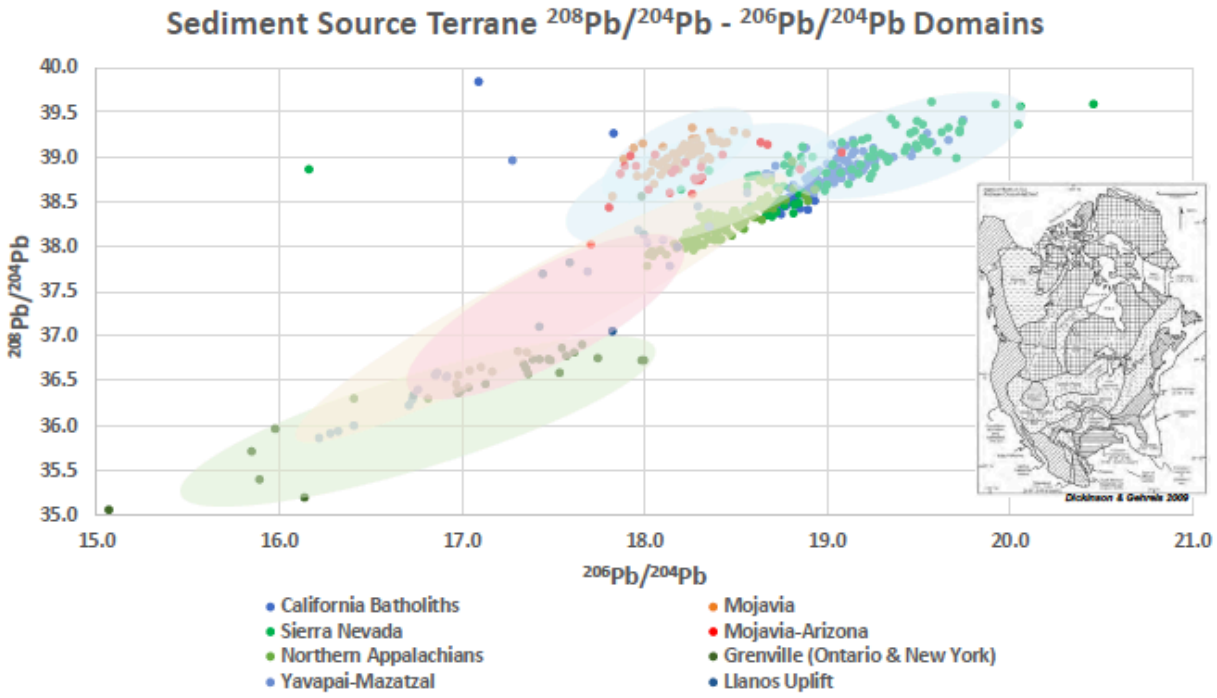
Nine new zircon and nine new k-feldspar samples, from the Kaiparowits Plateau of southern Utah (Cretaceous Straight Cliffs Formation), were mounted and are in the process of being analyzed. Due to new standards for large-n grain analyses, we are analyzing 600 zircon grains per sample and aim for 200-400 k-feldspar grains per sample. This increased sample size will allow us to better characterize the detrital populations represented in these intervals as well as tighten analytical error. These mounts are being imaged by SEM at Utah Valley University under the direction of Dr. Mike Stearns and the dimensions of each grain are measured and compared with isotopic data in order to aid population identification. Through our method development, our University of Utah lab is now well equipped to provide detrital feldspar LA-ICP-MS analysis for Pb-Pb isotopes and comparison analysis of U-Pb in detrital zircon to other workers who wish to begin using this technique.

We are continuing to develop a sediment source K-feldspar Pb-Pb database for western North America from published literature, which allows us to constrain isotopic ranges for most of the tectonic provinces recorded in the Cretaceous foreland basin and others. This database can be applied used to forward model predicted detrital grain distributions, applied to new basins in the future, and will increase efficiency in comparing detrital populations to possible sediment sources. A manuscript detailing the standards and methodology development is in progress with target submission by end of 2019, as well as a second manuscript in progress detailing the specific Cretaceous provenance applications with target submission by summer 2020.

The following figures were presented at the American Association of Petroleum Geologists (AAPG) Annual Convention in San Antonio, TX, in May 2019. Below, preliminary results and interpretations from standards:
Potential standard grain laser ablation Pb isotopic data have linear distributions, and are generally in agreement with solution data. There seems to be variation in 208Pb for the Fish Canyon and Little Cottonwood grains between solution samples and laser ablation samples, indicating heterogeneity within "standard" grains. Grain separate analyses have larger spread than in situ analyses for the Shap Granite grains. Unrelated potential standards, Marysvale, Shap Granite, and Fish Canyon overlap in the 207Pb and 208Pb domains and are potential indistinguishable. Similar data spread for single and multi-collector analyses compared here.







Above: Lead isotopic compositions for western US sediment source terranes, from Shulaker et al. (2019).

Below: Detrital grain samples from the Smoky Hollow Member of Straight Cliffs Formation show a Grenville/Sevier Pb signal, a Yavapai-Mazatzal signal, but very little from Cordilleran arc. This is very different from detrital zircon provenance analyses (e.g., Szwarc et al., 2015), which generally show strong magmatic arc and Yavapai-Mazatzal signals. Pending further analyses, we hypothesize that these methods highlight distinct transport mechanisms as well as source-area-fertility with respect to K-feldspar and zircon. We are developing new mixing models to investigate this issue further.