U-Pb discordance in Archean detrital quartzites, central Wyoming: Implications for Pb loss mechanisms

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Precise, concordant U-Pb dates on zircon are maximized by a number of strategies, including careful selection of undamaged, clear grains; removal of a thin high-U surface layer by abrasion; and spot analysis to avoid fractures or altered domains. However, when analyzing detrital zircon populations one cannot select only the least damaged zircon grains without biasing the resulting age spectra. In this study, we examine U-Pb data from detrital zircon in Archean quartzites obtained by LA-ICP-MS. Although the samples come from a single metasedimentary package they exhibit dramatically different Pb loss behavior. We investigate the causes of Pb loss in these samples and the implications for Pb loss mechanisms in detrital zircon generally.

Some detrital zircon populations from Mesoarchean quartz-rich paragneisses of the Sacawee block, central Wyoming Province, are dominated by concordant zircon that define a prominent age peak at 3.3 Ga. Others, despite comparable mean U contents and similar age, yielded almost exclusively discordant grains. Discordia define strongly linear chords with Cenozoic lower intercepts. Degree of discordance in these zircon grains correlates with U content.

Discordant U-Pb ages of zircon in Archean metasedimentary rocks may be the result of Pb loss by volume diffusion if they are held at near-surface T for times of ~1 Ga. Thus those samples with concordant zircon may have remained buried whereas the others were nearer the surface and experienced diffusive Pb loss. However, the spatial distribution of the samples and the lack of identifiable structures that could have brought samples to the surface from different depths makes this explanation questionable.

Alternatively, the Pb loss may be related to Eocene fluid-rock interaction that removed ~75% of the U from the Archean rocks to form roll-front uranium deposits in the adjacent basins. We note that the quartz-rich paragneisses with concordant zircon also contain cordierite, which would have altered in the presence of fluids. We conclude that hydrothermal alteration was partitioned: some rocks were unaffected, but fluid interaction in others caused significant Pb loss. The presence of readily altered phases can usefully guide detrital zircon sample selection.

Si and O in the Earth's core and their effects on the metal-silicate partitioning of other siderophile elements

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Oxygen and silicon are both potential light elements in the Earth's outer core. At the liquidus temperature of the mantle at 1 bar, O and Si are mutually exclusive in Fe metal, as the Si content of the metal only starts to increase at low oxygen fugacities where the O concentration has already dropped to low levels. Experiments show, however, that at lower-mantle pressures, the combined concentrations of O and Si in Fe metal can increase to percent levels at silicate liquidus temperatures. O and Si interact strongly in liquid Fe and our results show that the presence of O in liquid Fe causes Si to become more siderophile. Consequently, the Si metal-silicate partition coefficient becomes less dependent on oxygen fugacity at high pressures, which would enhance the partitioning of both O and Si into core-forming Fe. We use a thermodynamic model to explore the partitioning of O and Si between the mantle and core at the present core-mantle boundary. The partitioning of O into liquid Fe is also found to influence the metal-silicate partitioning of other elements. In particular we have examined metal-silicate partitioning of alkali metals at conditions where significant O also enters liquid Fe. Experiments were performed with both 0 wt% and 5% S in the liquid Fe. The Rb/Cs ratio of the silicate Earth is higher than that of carbonaceous chondrites and one explanation is that this results from partitioning of Cs into Earth's core. Our results indicate that metal-silicate partition coefficients for alkali metals increase down the group and with increasing pressure, temperature and metal S-content. Given the trends observed in these experiments it is plausible that the fractionation of Rb and Cs observed in the bulk silicate Earth results from core-mantle equilibration at pressures exceeding 25 GPa. Many previous studies have examined K partitioning between Fe-metal and silicate as there are important implications for the core's heat budget if it contains significant concentrations of the radioactive isotope ^{40}K. We use our partitioning data along with the Rb/Cs ratio of the Earth to place constrains on the maximum K content of the core.