Characterization of U-bearing phases at a U-tailings facility in Sask. Canada

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Uranium mobility around radioactive waste products such as mine tailings is a growing environmental concern. The characterization of particular U-bearing solid phases in the surface and subsurface around U-mine tailings facilities is essential in understanding and controlling the mobility of uranium [1]. The Key Lake milling facility located in Saskatchewan, Canada, has the world's largest annual U production capacity (25 million pounds U_3O_8) where it processes various grades of U-ore (maximum grade 18%, average grade 4%) from local operations [2]. In general, the ore is crushed; U is dissolved and leached using sulfuric acid and finally extracted and purified using ammonium sulfate and ammonia gas treatments [3]. Mining and milling waste products including tailings (1983-1996) and a portion of the acidic leachates and raffinates are stored in the engineered on-site Above Ground Tailings Management Facility (AGTMF) [4]. The occurrence, paragenesis and chemical composition of U-bearing phases at the AGTMF were examined, in both unconsolidated as well as epoxy impregnated samples to a maximum depth of 10 cm, using Scanning Electron Microscopy, X-ray Diffraction, Raman Spectroscopy, Laser Ablation ICP-MS, X-ray Photoelectron Spectroscopy and synchrotron-based micro-X-ray Fluorescence Spectroscopy. Uranium-bearing phases were observed as micro-sized coatings and included phases belonging to the zippeite group as well as the autunite group. Detailed mineralogical and chemical characterization of the tailings also indicated the presence of β-U_3O_8 (Fig. 1a) and U-bearing gypsum (Fig. 1b).

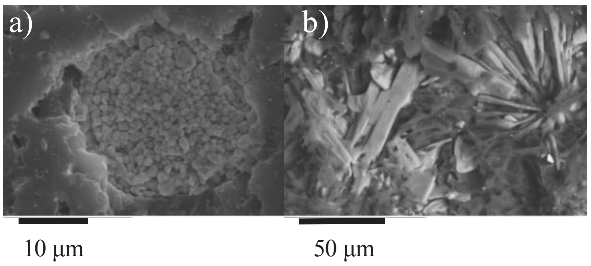

Figure 1: Backskatter electron images of (a) a cluster of β-U_3O_8 and (b) uranium-bearing gypsum.

Pb-isotope measurements and Raman spectra suggest that β-U_3O_8 is an alteration product of uraninite ore rather than a product of the milling process or bacterial reduction. LA-ICP-MS analyses of the gypsum crystals showed surprisingly high U-concentrations which were attributed to nanometre-scale intergrowths and coatings.

[1] Buck *et al.* 1996. *Environmental Science & Technology* **30,** 81. [2] Gandhi 2007. *Geological Survey of Canada,* open file **5005,** *Sask. Industry and Resources,* open file **2007-11.** [3] Cameco 2010. Key Lake Extension Project [4] Jarrell 2004. *IAEA-TECDOC-1419*. 45-74.

The Last Stages of Terrestrial Planet Formation: Dynamical Friction and the Late Veneer

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The final stage of terrestrial planet formation consists of the cleanup of residual planetesimals after the giant impact phase. Dynamically, a residual planetesimal population is needed to damp the high eccentricities and inclinations of the terrestrial planets to circular and coplanar orbits after the giant impacts stage. Geochemically, highly siderophile element (HSE) abundance patterns inferred for the terrestrial planets and the Moon suggest that a total of about $0.01\ M_{\oplus}$ of chondritic material was delivered as 'late veneer' by planetesimals to the terrestrial planets after the end of giant impacts. Here we combine these two independent lines of evidence for a leftover population of planetesimals and show that: 1) A residual population of small planetesimals containing $0.01\ M_{\oplus}$ is able to damp the high eccentricities and inclinations of the terrestrial planets after giant impacts to their observed values. 2) At the same time, this planetesimal population can account for the observed relative amounts of late veneer added to the Earth, Moon and Mars provided that the majority of the accreted late veneer was delivered by small planetesimals with radii ≤10 m. These small planetesimal sizes are required to ensure efficient damping of the planetesimal's velocity dispersion by mutual collisions, which in turn ensures sufficiently low relative velocities between the terrestrial planets and the planetesimals such that the planets' accretion cross sections are significantly enhanced by gravitational focusing above their geometric values. Specifically we find, in the limit that the relative velocity between the terrestrial planets and the planetesimals is significantly less than the terrestrial planets' escape velocities, that gravitational focusing yields a mass accretion ratio Earth/Mars ~ $(\rho_{\oplus}/\rho_{mars})(R_{\oplus}/R_{mars})^4$ ~17, which agrees well with the mass accretion ratio inferred from HSEs of 12-23. For the Earth-Moon system, we find a mass accretion ratio of ~ 200, which, as we show, is consistent with the mass accretion ratio inferred from HSE abundances of 150-700. We conclude that small residual planetesimals containing about ~ 1% of the mass of the Earth could provide the dynamical friction needed to relax the terrestrial planets' eccentricities and inclinations after giant impacts, and also may have been the dominant sources for the relative and absolute amounts of late veneer added to Earth, Moon and Mars. We argue that the terrestrial planets volatile elements were also delivered by the late veneer in order to account for the ~4.4Ga old terrestrial hydosphere and early felsic crust of granitoids reflected in Hadean zircons [1]. [1] Harrison (2009) *Annual Review of Earth Planet. Sci.* **37,** 479–505.