Magma recharge and eruption processes at Volcán Llaima (Andean Southern Volcanic Zone, 38.7°S)

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Volcán Llaima (38.7°S) is one of the most active volcanoes in Chile with over 50 eruptions since 1640. Periods of eruptive activity are generally characterized by a combination of violent Strombolian explosions and voluminous lava flows. A previous study based on whole-rock, mineral, and olivine-hosted melt inclusion compositions of basaltic-andesitic magma erupted during three different episodes revealed shallow magma storage (2-3 km depth) as mush (>50 vol% crystals) in multiple dike-like reservoirs. Further characterization of the olivine compositions and comparison of the lava and tephra yield information on magma recharge time scales and eruption triggering. Multi-element zoning patterns (Fe, Mg, Mn, Ca, Ni, Cr, Ti, Co, Sc, V, Y, Al, P) were measured by LA-ICP-MS in olivine crystals from tephra. Coherence in the zoning patterns between various traverses and crystals from the same eruption allow us to reliably identify multiple magma replenishment events and the time scales at which they occur. Most elements record the latest recharge event, which took place between 100 and 600 days before eruption, while others (e.g. V, Ti, and Sc) also preserve compositional oscillations in the crystal core which we interpret as older recharge events. Comparison of the lava and tephra reveal higher crystallinities (~50 vol% vs. ~30 vol%) and a greater fraction of more evolved (mush-derived) crystals in the lava than in the tephra. This suggests that shifts in eruptive style at Volcán Llaima are strongly affected by the ratio of volatile-rich magma recharge to resident mush. When this ratio is low, the crystallinity of the erupted magma is high, which implies that (1) the resistance to flow is large, and (2) a permeable volatile network is achieved early, thereby promoting volatile-loss and diminishing the magma buoyancy. When the fraction of recharge magma is large, the crystallinity of erupted magma is lower and bubbles will tend to couple with the magma, entraining it rapidly toward the surface and producing a Strombolian eruption.

The first 10 million years of the Solar System

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The initial conditions of the solar nebula and subsequent formation and evolution of the protoplanetary disk can be constrained using chronological and isotopic studies of meteorites and samples returned from space missions. Chronology of early Solar System processes at a sub-My resolution is based on the long-lived U-Pb and short-lived (e.g., ^{26}Al-^{26}Mg) radiogenic systems. The precision of isotopic dating has dramatically increased over the last decade with the development of new mass spectrometry techniques. The accuracy, nevertheless, relies on knowledge of the initial composition, the distribution of the isotope pairs throughout the nebula, possible late additions, and disturbances during planetary processes. The degree of heterogeneity of the solar nebula can be evaluated from isotopic variations found for some elements (e.g., Nd, Ni) in chondritic and differentiated meteorites. Recently, U isotopic variations measured in CAIs [1] revealed the presence of ^{247}Cm in the early Solar System and consequently required the adjustment of previous U-Pb dates. For example, the U-Pb and Al-Mg chronologies of the formation of CAIs relative to chondrules are important constraints for the lifetime of the protoplanetary disk but are discordant [e.g., 2,3]. This brings into question the use of some meteoritic samples as reference materials, and reinforces the need for high-precision U-Pb isotopic studies of planetary materials.

The presence of short-lived radionuclides (SLR) has implications for the astrophysical environment of the Solar System. It is essential to determine the initial abundances and distribution of SLR in the Solar System to understand their origin and transfer within the nebula and possibly the protoplanetary disk. In particular, the source(s) of ^{26}Al and ^{60}Fe in the Solar System need to be constrained more tightly. As the major initial radiogenic heat sources, these two isotopes played a crucial role in the formation and evolution of habitable planetary worlds. I will discuss the most recent advances in the chronology of primitive and differentiated meteoritic objects using the U-Pb and extinct radioactivities and how they affect our models for Solar System formation and planetary evolution.

[1] Brennecka *et al.* (2010), *Science* **327**, 449-451. [2] Amelin *et al.* (2010), *Earth Planet. Sci. Lett.* **300**, 343-350. [3] Bouvier and Wadhwa (2010), *Nature Geosci.* **3**, 637-641.