

Mineral dissolution observed in real time and *in situ* by liquid cell TEM: a new frontier

ROLAND HELLMANN^{1*}, DONOVAN LEONARD²

¹ISTerre, Université Grenoble Alpes, CNRS, Grenoble, France (*correspondence: roland.hellmann@univ-grenoble-alpes.fr

² Materials Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge, TN USA (leonarddn@ornl.gov)

Until now, probing chemical weathering mechanisms of minerals and glasses has relied in large part on solid-state investigations of the interfacial region that characterizes the fluid-solid interface. Typical state-of-the-art analytical tools with high spatial and/or high mass resolution that have been used include advanced transmission electron microscopy techniques (STEM-HAADF, HRTEM, EFTEM, EELS), atom probe tomography (APT), and nano- and time-of-flight secondary ion mass spectrometry (nanoSIMS and ToF-SIMS) (see, e.g., [1, 2]). However, the use of these techniques is based on dry postmortem samples that are typically subjected to high vacuum conditions within the instrument(s) during the analyses. Such conditions may have a deleterious effect on surface altered layers, which in general are very hydrated. Of particular importance is the fact that the altered surfaces that form during chemical alteration are no longer in contact with the aqueous fluid that led to their creation in the first place. The drying out process may in fact change the physical and chemical properties of altered surfaces, and thus may influence the analytical results that are measured. The use of a new technique, liquid cell TEM (LC TEM), represents a new frontier in the study of dissolution (and precipitation) processes. In fact, there is probably no better technique for studying dynamic reactions *in situ* between a solid and liquid at nm-scale resolution [3]. Using LC TEM, we have measured surface dynamic processes on wollastonite in deionized water at ambient temperature. Our preliminary results indicate that step edge and terrace movement are not constant with time, but rather show complex behavior. In addition, there is evidence for ephemeral precipitation processes occurring, even though the liquid cell volume was completely undersaturated with respect to secondary phases, such as amorphous silica.

[1] Hellmann et al. (2015) *Nature Mater.* **14**, 307-311; Hellmann et al., *Chem. Geol.* 2012. [2] Hellmann et al. (2012) *Chem. Geol.* **294-295**, 203-216. [3] de Jonge and Ross (2011) *Nature Nanotech.* **6**, 695-704.