Enhancing CO_2 sequestration in Mg-rich mine tailings

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Mineralization of atmospheric CO_2 within carbonate minerals occurs passively in Mg-rich mine tailings via weathering of Mg-bearing primary minerals [1]. Passive carbon mineralization has been documented at the Mount Keith Nickel mine (MKM) in Western Australia [1]. Field data and reactive transport modeling indicate that passive mineralization occurs primarily via carbonation of brucite [$Mg(OH)_2$], and is limited by the supply of CO_2. MKM produces ~0.1-0.3 Mt brucite/yr in tailings; complete carbonation of this brucite would sequester up to 60% of mine emissions [2]. Thus, modification of tailings management practices to enhance brucite carbonation rates could provide a significant offset of emissions.

Two strategies are proposed to enhance CO_2 sequestration. First, passive carbonation could be accelerated by maximizing the exposure of brucite to atmospheric CO_2. Mineral abundance profiles from tailings of different ages at MKM and reactive transport modeling with MIN3P [1,3] were used to calculate the rate of brucite carbonation with depth below the tailings surface. It is estimated that passive sequestration would be maximized if brucite remained at the surface for twice the current duration (i.e., burial rates decreased).

A second strategy is to actively supply CO_2-rich gas streams into tailings [2]. Column experiments containing brucite were conducted to assess carbonation efficiency with injection of CO_2-rich gas into partially saturated systems akin to mine tailings. The effect of brucite grain size, water content, and reaction path length were assessed. Experimental and modeling results indicated that brucite grain size should be minimized to prevent the development of a passivating surface layer. Moreover, tailings water content should be maintained above residual saturation to optimize carbonation. The experimental rates suggest that the CO_2 sequestration potential in tailings would become limited by the brucite content rather than the reaction rate if CO_2-rich gas were supplied. These results will guide implementation of accelerated CO_2 sequestration strategies at mine sites.

[1] Bea *et al* (2012) *Vadose Zone J*. **11**. [2] Harrison *et al* (2013) *Environ. Sci. Technol*. **47**, 126-134. [3] Molins & Mayer (2007) *Water Resour. Res.* **43**, W05435.

Magnetic nanostructures in meteorites: A window on the early solar system

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Paleomagnetic signals recorded by meteorites are a potent source of information about processes occuring during the early solar system. This talk sets out the challenges that we face when attempting to extract meaningful magnetic information from such ancient and complex materials. To overcome these challenges we must search for the most ideal carriers of magnetic remanence (i.e. those displaying the highest magnetic stability and the highest resistance to thermochemical alteration and shock demagnetistion) – a search that leads us away from the conventional bulk paleomagnetic methods that have served us so well over the past 60 years, and towards the development of spatially resolved measurments that will take paleomagnetism to the micrometre scale and beyond.

Using a combination of state-of-the-art electron and X-ray imaging methods, we show that Fe-Ni metal carries a chemical transformation remanent magnetisation (CTRM) encoded within a spinodal decomposition nanostructure that formed continuously during slow cooling. This nanostructure is comprised of nanoscale islands of a magnetically hard phase (chemically ordered FeNi) coherently intergrown with a hitherto unobserved soft magnetic phase (chemically ordered Fe_3Ni), that developed progressively along pre-existing Ni concentration gradients. Dramatic variations in magnetic behaviour are observed across a lateral traverse of the spinodal region, which can be related to variations in the underying nanostructure that developed during progressive cooling. Asteroid cooling models predict that spinodal nanostructures within chondritic meteorites formed during a time when the proposed asteroid core dynamo was active. We argue that microstructures forming in Fe-Ni metal from chondritic meteorites have the potential to reveal a time-resolved record of asteroid dynamo activity during the first 100-200 Ma of the asteroid's history – a record that would be the nanometre scale equivalent of the kilometre scale magnetic anomalies recorded by oceanic crust on Earth.

DOI:10.1180/minmag.2013.077.5.8