

## CO<sub>2</sub>-MINERAL SEQUESTRATION AND THE POTENTIAL FOR EXTRACTION OF ECONOMIC BY-PRODUCTS

WALDER, I.F.

Kjeøy Research & Education Center, Kjeøy, N-8412 Vestbygd, Norway

E-mail: ifwalder@kjeoy.no

There has been a lot of research development in recent years of different types of leaching techniques (acid leach, alkaline leaching, hydro-bio leaching, etc.). Most of this research has focused on leaching of sulphides and oxides for metal extraction. At the same time, there has been a lot of research taking place on CO<sub>2</sub>-mineral sequestration, which has enhanced the understanding of mineral leaching in general. CO<sub>2</sub>-mineral sequestration focuses on silicate minerals that release elements that can form (Ca, Mg, Fe) carbonate minerals for permanent CO<sub>2</sub>-storage.

Silicate minerals show a very large range of reaction rates, where olivine is one of the most reactive silicate minerals. The reaction rate of olivine is quite high. However, a common obstacle is that secondary minerals form on the surface of the olivine and inhibit a continuation of the high reaction rate. To maintain a high reaction rate, therefore, high pressure and temperature is implied.

The release of CO<sub>2</sub> from combustion of fossil fuels and from industrial processes such as cement production, roasting of ores, and steel production has gained much interest in recent years due to the influence of CO<sub>2</sub> on the environment and effects such as global warming. Many of the sources of CO<sub>2</sub> such as emissions from power plants comprise only a few percent CO<sub>2</sub> and accordingly huge emissions volumes have to be managed to separate the CO<sub>2</sub> formed during combustion. Much focus has been on methods for CO<sub>2</sub> capture using liquid absorbents. These processes, so far, have had a high energy demand and have resulted in a CO<sub>2</sub> stream for which permanent storage or reuse has to be secured in a secondary process. However, the increasing focus on CO<sub>2</sub> emission as a tradable commodity opens opportunities for utilizing the emission gases for mineral leaching not only for CO<sub>2</sub>-mineral sequestration, but also for element extraction.

The natural sequestration of atmospheric CO<sub>2</sub> in mine wastes has been studied with the focus to document the sequestration with respect to the total carbon dioxide impact of the mining process. The natural occurring passive reaction between atmospheric CO<sub>2</sub> and mine tailings may result in a reduction in the overall CO<sub>2</sub> impact of the mining (WILSON *et al.*, 2009). Natural sequestration of CO<sub>2</sub> is facilitated by silicate mineral weathering and carbonate precipitation, taking place *in-situ* in soils and rocks e.g. caliche, and *ex-situ* in oceans in soils e.g. limestone formations.

Investigations have also been carried out involving the mechanical activation by milling of rocks to increase the available surface area and, thereby, obtaining increased reaction between gas containing CO<sub>2</sub> and solid minerals. However the reactions rates have still been too slow for application in an industrial process (HAUG, 2010).

Leading researchers in the field (O'CONNOR *et al.*, 2005; GERDEMANN *et al.*, 2007) concluded that *ex-situ* mineral carbonatisation is too expensive (high energy consumption) to be viable even though considerable mineral dissolution and carbonate precipitation was obtained within a few hours by using olivine in some of their experiments. Different types of pre-treatment (ligands, preheating, mechanical activation by milling etc) were tried in high temperature high-pressure reaction chambers (O'CONNOR *et al.*, 2005). GERDEMANN *et al.* (2007) further evaluated dissolution rate of finely ground olivine and serpentine in a supercritical CO<sub>2</sub>-water solution in a high temperature and pressure vessel, and converted 81% of the olivine to magnesium carbonate in a few hours and 92% of preheated serpentine also to magnesium carbonate in one hour.

It is necessary, as described above, to dissolve (or alter with element release) minerals in order to achieve mineral CO<sub>2</sub> sequestration. When these mineral dissolve, there may be elements released that can form economically valuable products, e.g. calcite (CaCO<sub>3</sub>), magnesite (MgCO<sub>3</sub>), silica (SiO<sub>2</sub>), and nickel. Different rock types will have different leaching potentials depending upon both the reaction rate of the minerals and the mineral chemistry. Carbon dioxide is then used to precipitate carbonate minerals with the elements released (Ca, Mg, Fe).

Olivine rich rocks (dunite) may be iron or magnesium rich with little or no calcium, but with potentially high concentrations of nickel. Pyroxene and amphibole rich rocks have lower reaction rates than olivine, but may have relatively high calcium content in addition to iron and magnesium. Anorthite rich rocks (anorthosite) have high calcium and aluminium content but little or no magnesium and iron.

Carbonic acid has been shown to be effective for long-term leaching for actinolite and carbonate minerals (WALDER, 2011; WALDER & LUNDKVIST, *in prep*; TANGWA *et al.*, 2011). Further research is necessary for developing economically viable methods or processes for using CO<sub>2</sub> as a leaching agent at atmospheric conditions.

**References**

- GERDEMANN, S.J., O'CONNOR, W.K., DAHLIN, D.C., PENNER, L.R. & RUSH, H. (2007): *Environmental Science & Technology*, 41: 2587–2593.
- HAUG, T.A. (2010): Dissolution and carbonation of mechanically activated olivine. Investigating CO<sub>2</sub> sequestration possibilities. PhD thesis, NTNU.
- O'CONNOR, W.K., DAHLIN, D.C., RUSH, G.E., GERDEMANN, S.J., PENNER, L.R. & NILSEN, D.N. (2005): Aqueous mineral carbonation – Mineral availability, pre-treatment, Reaction parametric, and process studies. Final report. DOE/ARC-TR-04-002, Albany Research Center, US-DOE.
- TANGWA, E.K., WALDER, I.F. & LUNDKVIST, A. (2011): Mineral CO<sub>2</sub> sequestration in mine waste rocks, column experiments. Abstract for Goldschmidt, Conference, Prague, Czech Republic, August 2011.
- WALDER, I.F. (2011): CO<sub>2</sub> mineral leaching, Patent pending, No. 20110872.
- WALDER, I.F. & LUNDKVIST, A. (in prep): CO<sub>2</sub>-mineral sequestration using coarse crushed rocks from the extractive industry.