



How does fault-related alteration of basalt affect the potential for geological carbon sequestration in basalt formations?

Montserrat Recasens¹, Komal Nisar¹, Kitson Lim¹, M. Mercedes Maroto-Valer¹, Rachael Ellen²,
Susana Garcia¹

¹ Research centre for Carbon Solutions (RCCS), School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh EH14 4AS, United Kingdom

²BGS Scotland, The Lyell Centre, Research Avenue South, Edinburgh, EH14 4AP, UK.

Abstract

Basalt is one of the most abundant extrusive igneous rocks on Earth's surface, erupted in vast volumes during volcanic activity over time. As opposed to other geological carbon sinks considered for geological carbon sequestration, basaltic rocks are rich in divalent cations such as Ca^{2+} , Mg^{2+} and Fe^{2+} , which are highly reactive in contact with CO_2 -rich fluids. Therefore, they offer great potential to trap CO_2 via mineral trapping by forming stable carbonate minerals as calcite (CaCO_3), magnesite (MgCO_3) and siderite (FeCO_3). Furthermore, recent field studies have demonstrated the fast kinetics of the mineral carbonation process, which normally takes up to tens of thousands of years in other rock formations. For example, the CarbFix project in Iceland [1] and the Wallula basalt pilot project in Washington [2] have both proven that secondary carbonates derived from the reaction of injected CO_2 precipitate within two years when injected into basalt formations.

Most of the previous studies on basalt carbonation reactions have been performed on fresh basalt samples [3-5]. However, geologically old basalt formations are likely to have been subject to geological faulting since emplacement, with faults allowing fault-related fluids to interact with, and alter, the host basalt [6]. Nevertheless, very limited studies have been completed on the effect of fault-related alteration of basalt on CO_2 storage in faulted basalt formations, and it is unclear if such altered zones in faulted basalt formations may restrict, enhance, or indeed, have any effect on the potential for CO_2 storage. A recent study conducted by Adeoye and co-workers [7] investigated the role of fluid transport regimes on reaction products in fractures of serpentinized and unaltered basalt

cores. They highlight the importance of having diffusive mass transport conditions if CO₂ mineral carbonation is to be achieved.

The work presented here focuses on the improved understanding of CO₂-brine-basalt rock interactions and its solution chemistry evolution using fresh and faulted mugearite basalt, a type of oligoclase-bearing basalt, comprising olivine, plagioclase, pyroxene, clay and opaque oxides, sampled from a fault zone at Talisker Bay (Isle of Skye, Scotland). The samples are 'fresh basalt' (FB), which has not been altered due to fault activity, and its equivalent faulted and altered counterpart (AB). FB was collected from the undisturbed footwall of a 10 m displacement fault, and AB was collected from within the fault zone of this fault. The chemical and mineralogical composition of each sample was identical prior to faulting, but following faulting and subsequent interaction of fault-related fluids with the host rock, the mineralogy of AB and FB are distinct. For example, FB contains Mg-rich olivine, whereas in AB the olivines have been replaced by Fe-rich clays. AB contains an abundance of zeolite and clay mineralisation, whereas FB is relatively poor in these minerals. This distinction in mineralogy has the potential to influence the availability of divalent cations for mineral carbonation reactions.

Basalt samples were ground into powder and reacted during 30 days in two batch reactors under geological storage conditions (T=50°C and P_{CO2}=130 bar). The brine composition used in the experiments was prepared in order to represent water formation of the North Sea. The mugearite basalt was analysed using scanning electron microscopy (SEM) and X-ray diffraction (XRD), and the brine samples were analysed using inductively coupled plasma (ICP). The analysis identified that, prior to reaction, FB sample comprises of plagioclase feldspar (anorthite (Ca(Al,Si)₂O₆) and albite (Na(Si₃Al)O₈)), pyroxene (augite ((Ca,Mg,Fe)₂(Si,Al)₂O₆) and diopside (MgCaSi₂O₆)), olivine (Mg,Fe)₂SiO₄, iron titanium oxide (FeTiO) and some traces of quartz (SiO₂). AB comprises of plagioclase feldspars (anorthite and albite, as before), pyroxene (enstatite (Mg₂Si₂O₆) and augite ((Ca,Mg,Fe)₂(Si,Al)₂O₆)), clay (chlorite (Fe,Al,Mg,Mn)₆(Si,Al)₄O₁₀(OH)₈) and zeolites (natrolite (Na₂Al₂Si₃O₁₀(2H₂O)), chabazite (Ca,Na₂,K₂,Mg)Al₂Si₄O), and thomsonite (NaCa₂Al₅Si₅O₂₀(6H₂O))).

The preliminary ICP data shows that there has been a significant increase of Ca²⁺, Si⁴⁺, S²⁻ and Fe²⁺ concentration in the reacted brine samples from both experiments, probably caused by the dissolution of specific minerals from the original sample. Further analysis is required to identify these minerals: however, in the case of the increase in Ca²⁺ for example, it is likely that dissolution occurred of Ca-bearing minerals (e.g. anorthite, augite and chabazite). The ICP data also showed a

decrease of Na and Al concentration in the reacted brine samples, suggesting precipitation of new Na and Al bearing minerals following the experiment, although these have not yet been identified.

Preliminary XRD results found that new stable carbonate minerals of ankerite, burbankite, calcite, dawsonite and magnesite were formed in FB, and that magnesite, calcite, dawsonite and siderite were formed in AB following the experiment. These results show that both FB and AB reacted with the CO₂ dissolved in the brine, and that therefore both samples have the potential for mineral trapping of CO₂. Analyses are ongoing to quantify the potential of both rocks for mineral trapping, based on precipitation of secondary minerals, and in order to identify if FB or AB is a more or less suitable target for geological carbon sequestration.

References

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