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Sedimentological and H₂O-CO₂-rock interaction studies for a long-term geological CO₂ storage in the onshore Zululand Basin, South Africa

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South Africa has embarked on an ambitious goal to mitigate the climate change by reducing atmospheric CO₂ concentrations through CO₂ storage in deep geological formations. Integrated sedimentological, mineralogical and geochemical studies on the onshore Cretaceous Zululand Basin rocks in the KwaZulu Natal Province of South Africa are performed to provide information on the basin's suitability for long-term CO₂ sequestration. Three formations comprise the basin stratigraphy; the Makatini, Mzinene and St Lucia. According to [2], the Makatini Fm (125-115 Ma), is unconformably overlying the Lebombo Group volcanics, 80 m thick, with small-pebble conglomerates, sandstone, siltstone and limestone units. The Mzinene Fm is 95-120 Ma, c. 650 m thick, and made of glauconitic siltstone and cross-bedded sandstone, with rich calcareous invertebrate fauna, whereas the St Lucia Fm is recorded as 65-90 Ma, with a thickness of c. 900 m. The St Lucia Fm resembles the Mzinene Fm, but is separated by an angular unconformity from the Mzinene Fm, as conferred from seismic profiles.

Borehole cores ZA, ZB, ZC and NZA drilled through all three formations, were conventionally logged and samples of all lithologies were collected. Uncovered thin sections were studied by optical scanning electron microscopy, whereas energy dispersive spectroscopy, complemented by XRD and XRF provided additional mineralogical and geochemical information. To understand the behaviour of the rocks at the storage site, laboratory experiments close to reservoir conditions for geological CO₂ storage were performed. The samples were saturated with pure water for 48 hours and exposed to pure CO₂ for four weeks using a system of autoclaves under temperature of 100 °C and pressure of 100 bars.

Untreated samples (e.g. sample A20) comprising of clasts of 63 wt % of 85 µm sub-angular monocrystalline quartz and 15 wt % of 30 to 100 µm plagioclase grains embedded in a matrix of 12 wt % clay and 2 wt % mixture of calcite and zeolite. After CO₂ treatment, the samples showed degraded feldspars and rare lithic fragments, lesser amounts of kaolinite, smectite, mica flakes and alteration products such as chlorite and glauconite. Other samples (e.g. B28), a silicate siltstone consisting of 26 wt % quartz, 34 wt % carbonate, 17 wt % clay, 12 wt % plagioclase, 8 wt % chlorite and 2 wt % mica and traces of zeolite and microcline entirely disintegrated in pure water after 48 hours. Digital image analysis using photomicrographs for both pre- and post CO₂ treatment showed a significant alteration illustrated by textural changes, e.g. cracks, pitches and chipped surface of quartz grains, dissolution on plagioclase and fractures on clays minerals.

Mineral reactions during H₂O-CO₂-rock interaction experiments account for the observed differences in porosity and permeability between treated and untreated samples. Initially, the porosity and permeability increased through mineral dissolution, but reciprocated by precipitation of new phases as a result of geochemical reactions between CO₂, water and rocks. The net effects of the reaction could be advantageous for CO₂ storage whereby porosity and permeability are enlarged without negatively destabilising the rocks [1]. However, undesirable net effects are possible if the increase of porosity and

permeability reduce the rock strength, destabilising the wall rocks and leading to roof collapse which may eventually allow the stored CO₂ to escape.

References:

[1] Bachu S and Adams JJ (2003) *Energy Conversion and Management* 44: 3151–3175

[2] Shone RW (2006) In: Johnson MR et al. (Eds.): *Geol. Society of South Africa*, 541-552

