Paper Number: 4564

Petrography, Mineralogy and Geochemistry of Rocks in the Borehole ZA, Onshore Zululand Basin: Evaluation for Carbon Dioxide Storage

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The Cretaceous Zululand Basin of South Africa is one of the possible sites proposed for geological CO_2 sequestration [1]. This contribution aims to investigate the suitability of the sedimentary rocks of the onshore Zululand Basin in KwaZulu Natal, South Africa, for a permanent sequestration of CO_2. Unfortunately the bottom part of the 1779.96 m deep drill core ZA, drilled by SOEKOR in the 1960s is not preserved and the core starts only at 1602 m depth.

The onshore Zululand Basin covers an area of 7500 km^2, extending from St Lucia northwards into Mozambique. The preserved core from 1602 to 1041m is characterised by dark grey coloured calcareous siltstone beds, rich in formanifera and algae fossils, a greyish brown medium to coarse grained glauconitic intercalations, overlain by the succession of siltstone layers with some interbeds of calcareous and glauconitic siltstones (Makatini and Mzinene Formations). The middle part of the sequence (Mzinene Formation) shows brownish sandstone layers interbedded with limestone rich in algae and calcareous sandstone layers. Invertebrate fossils are common throughout the formation. The St Lucia Formation closing-up the Zululand Group, is similar to the Mzinene Formation, except that it is thicker, more fossil rich and contains more glauconite [2]. In the core, above 675m depth, it displays an alternation of siltstone and sandstone layers followed by 245 m thick calcareous siltstone overlain by glauconitic sandstone and algae limestone layers.

The middle sandstone strata between 1035 to 678 m, meet the criteria for a suitable reservoir. It is bounded on top by a 42 m thick siltstone and sandstone layers as a possible cap rocks, covered by 242 m thick calcareous siltstone and sandstone. Petrographically, the middle sandstone rocks are characterised as subarkose, arkosic wackes and calcareous sandstone and they contain mostly quartz, calcite and plagioclase minerals with a respective average of 47, 21 and 15%. Other minerals such as smectite, mica, hematite, zeolite, glauconite and lithic fragments also occur. The geochemical investigation of these sandstones reflects their mineralogical contents and shows the predominance of SiO_2 (55wt%), CaO (11wt%), Al_2O_3 (10wt%) and Fe_2O_3 (7wt%) contents followed by other major oxides such as MgO, Na_2O, K_2O, H_2O, MnO, TiO_2, P_2O_5 and Cr_2O_3 summing up to c. 8%. The porosity and the permeability of the middle sandstone rocks are respectively over 30% and 30mD. The predominance of quartz, calcite and plagioclase minerals are also evident in the possible cap rock layer. However, there is an increase of clay mineral contents, which is supported by the spectral results (mineral and index chemical results) showing the evidence of aforementioned different clay minerals at this depth.

The treatment of the rock samples with CO_2 under supercritical conditions of 100^{o}C and pressure of 100 bars, during a period of two weeks shows a dissolution reaction on the surface of quartz grains and the calcite cement has reacted creating secondary porosity and changing permeability of the rock.

Therefore, the middle sandstone and the overlying siltstone rocks are unsuitable for injecting carbon dioxide because of the important amount of calcite content and authigenic minerals which may be dissolved during the scCO_2 - mineral reaction, creating secondary porosity. The progressive increase of the pore pressure may lead to the disintegration of the entire layers [3].

References:

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