Evaluation of the CO_2-sequestration capacity of sandstone aquifers in the Campine Basin (NE-Belgium) based on autoclave experiments and numerical modelling

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The Campine Basin in NE-Belgium houses important CO_2-emitting industries. Injection of CO_2 in sandstone aquifers in this sedimentary basin could significantly reduce emissions towards the atmosphere.

An integrated study was set up to evaluate the effects of CO_2-water-rock interactions on the reservoir properties of 3 sandstone aquifers in the basin, i.e. the fluvial sandstones of the Westphalian C, Westphalian D and the Lower Triassic (Buntsandstein). A number of representative samples, from boreholes, of each reservoir were characterised by means of a broad spectrum of petrographical, geochemical and petrophysical methods. Five samples of each reservoir were exposed for a period of 6 months to the conditions prevailing in the reservoirs during and after CO_2 injection, in high temperature - high pressure autoclaves. CO_2-water-rock interactions were inferred from the evolution of the chemical composition of the brine in the autoclaves and comparison of the treated and untreated samples after the experiments.

Data from the detailed characterisation of the experimentally treated samples was used to construct a reaction model in PHREEQC. Reaction kinetics of 17 rockforming minerals are based on user-defined rate laws and parameters. CO_2-water-rock interactions inferred from the experiments were used to adjust reaction progress.

Numerical modelling confirms that the sequestration capacity of the studied reservoirs will be greatly enhanced by CO_2-water-rock interactions. During injection carbonate dissolution can enhance permeability of the reservoirs. In the first 15 years after injection alteration of Al-silicates (feldspars and clays) to kaolinite and illite buffers the pH-drop caused by CO_2-injection. Higher pH and release of K and Na promote ionic trapping, i.e. sequestration as dissolved bicarbonate species. Slow release of Fe and Mg from altering Al-silicates offers some potential for mineral trapping, i.e. sequestration of CO_2 as carbonate minerals. Dissolution of hematite and pyrite causes reduction of Fe^{3+} and precipitation of siderite. Substantial siderite precipitation occurs after more than 25 years and is initiated when a certain pH is reached due to Al-silicate reactions.

These numerical simulations illustrate that the sequestration capacity offered by CO_2-water-rock interactions is highly variable, depending on the reservoir mineralogy. The sequestration capacity of the studied reservoirs ranges from approximately 100-500 gCO_2/kgw.

$^{40}Ar/^{39}Ar$ ages of the sill complex of the Karoo large igneous province: Implications for the Pliensbachian-Toarcian climate change.

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Reliable geochronological results gathered (n=76) so far have considerably constrained the timing of the emplacement of the Karoo large igneous province. Yet strikingly missing from this dating effort is the huge sill complex cropping out in the $>0.6x10^6$ km² main Karoo sedimentary basin. We present sixteen new $^{40}Ar/^{39}Ar$ analyses carried out on fresh plagioclase and biotite separates from fifteen sill samples collected along a N-S trend in the eastern part of the basin. The results show a large range of plateau and mini-plateau ages (176.2 ± 1.3 to 183.8 ± 2.4 Ma) with most dates suggesting a ~3 Ma (181-184 Ma) duration for the main sill events and confirming the relatively long emplacement duration of the main volume of the province. The youngest plateau age at 176.2 ± 1.3 Ma obtained on a sill and two plateau ages at ~176 Ma obtained by [1] on the neighbouring Uderberg dyke swarm, unambiguously define a young "hot line" extending from the eastern Lesotho to the coast. This possibly illustrates important and late stress constraints related to the continental breakup near the future rifted margin.

The available age database of the Karoo province allows to correlate the Karoo CFB emplacement with the Pliensbachian-Toarcian second order biotic extinction and associated global warming and with the Toarcian anoxic event (providing that adequate calibration between the ^{40}K and ^{238}U decay constant is made). The mass extinction and the isotopic excursions recorded at the base of the Toarcian appear to be synchronous with both the increase of magmatic production rate of the Karoo province and the emplacement of the sills. Field evidences and $^{40}Ar/^{39}Ar$ ages suggest that the sills intruding carbon-rich sedimentary layers filling the souther Africa Karoo basins might be one of the main culprits of the global warming and oceanic anoxic conditions recorded at this time. However, the long duration of the igneous activity is not easily reconcilable with the shorter time scales required by recent climate models derived from sill-sediment interaction [2,3]. We propose that the relatively low eruption rate of the Karoo province is one of the main reasons explaining why its impact on the biosphere is relatively low contrary to e.g. the CAMP (Triassic-Jurassic) and Siberia (Permo-Triassic) provinces.

References

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