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Determination of changes in the reservoir and cap rocks of the Chabowo Anticline caused by CO_2–brine–rock interactions

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ABSTRACT

The article describes the changes taking place in the rock matrix (reservoir and cap rock) due to the effect of carbon dioxide in the presence of brine. The experiment was carried out on samples of Lower Jurassic sandstones (reservoir rocks) and claystones (cap rocks) from Chabowo 1 and Chabowo 3 boreholes, Chabowo Anticline (NW Poland)—a potential structure for underground storage of carbon dioxide. Rock samples were placed for a period of 18 months in a designed apparatus system and the experiment was performed under the conditions of T = 25 °C and P = 6 MPa, by soaking the rock samples in a brine of simplified chemical composition similar to the brine present in the rock formation analysed. Mineral composition was determine by observation in transmitted light, XRD and SEM-EDS. In order to perform the changes in the individual mineral phases, using the SEM-EDS method, the results of mineralogical and petrographic observations of the same rock samples before and after the experiment are presented. Dissolution and precipitation processes of minerals were observed as the result of the experiment. Corrosion-prone minerals were feldspars, etchings were observed on pyrite and mica grains. The dominant mineral phase formed after the experiment was halite (which caused the precipitation of this mineral after the evaporation of brine). Precipitation of poorly developed kaolinite crystals was also observed. The long-term experiment conducted at low temperature and pressure showed similar changes that are obtained in the experiments carried out for the actual reservoir conditions, but on a smaller scale.

1. Introduction

Carbon dioxide is the main greenhouse gas emitted through industrialization and socioeconomic development of human society. Due to the fact that the consumption of fossil fuels has greatly increased, air pollution and greenhouse effect caused by CO_2 emission have become a major threat to the environment on a global scale, and CO_2 emission has still increased over recent decades (Shukla et al., 2010; Wdowin et al., 2012; Wang et al., 2013).

Carbon dioxide capture and consequently geological storage is the key strategy within the portfolio of actions to reduce CO_2 emission to the atmosphere. Amongst many options of geological storage, deep saline aquifers are the most promising on a regional to global scale because of their estimated storage capacities and their widespread distribution (Bachu et al., 1994).

In a CO_2 storage system, the formation rock will be in contact with carbon dioxide-saturated brine and CO_2 (Liu et al., 2012). CO_2 injection effects on rocks and reservoir fluids are mainly associated with CO_2 dissolution in reservoir fluids, mineral trapping, appearance of new mineral phases, migration of gas within the reservoir, evaluation of the geological storage capacity and sealing properties of caprocks (Tarkowski and Wdowin, 2011). Key problems concerning the storage of CO_2 in geological structures are its impact on rocks and reservoir fluids, as recognised during previous studies on the suitability of rocks and geological structures for underground CO_2 storage (Czernichowski-Lauriol et al., 1996; Enick and Lara, 1990; Fischer et al., 2010; Fischer et al., 2013; Wdowin et al., 2013, 2014). Studying these processes is very important for planning safe underground CO_2 storage operations. Therefore, CO_2–water–rock interaction experiments are considered to be one of the ways to understand and explore the mechanisms and processes of geological CO_2 storage (Ketzer et al., 2009). However such investigations should be supplemented by modelling of CO_2 sequestration to predict the rates and extents of subsurface rock–water–gas interactions (Labus et al., 2010; Tarkowski et al., 2011; Balashov et al., 2013).

The study focuses on the possibility of geological storage of CO_2 as well as evaluation of mineralogical alterations resulting from the interaction between CO_2-saturated brine and selected sandstone and claystone samples from the Chabowo Anticline in a long-term experiment.

2. Materials

Poland has favourable conditions for underground storage of carbon dioxide due to the occurrence of a thick (5–6 km) complex of Permo-

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Mesozoic sedimentary rocks in the Polish Lowlands. The geological structure of this complex shows a number of anticlines and salt-cored pillows and ridges related to salt tectonics. They are potential target areas of interest for large CO_2 emitters planning reduction of CO_2 emissions through CO_2 underground storage (Tarkowski, 2005, 2008, 2010; Tarkowski et al., 2009).

In the Polish Lowlands, some tens of potential geological formations suitable for underground storage of carbon dioxide have been recognised and preliminarily characterised. The Chabowo Anticline is amongst 36 potential structures selected in Poland for underground storage of CO_2 (Tarkowski, 2010). This anticline is located in NW Poland in the Szczecin–Mogilno–Uniejów Trough (Tarkowski et al., 2014). It was explored by three boreholes: Chabowo 1, Chabowo 2 and Chabowo 3, and by semi-detailed reflection seismic surveying (the study in which the seismic profiles are at a distance of 4–5 km from one another). The Chabowo Anticline is 14–15 km long and 5–7 km wide, and its amplitude is approximately 350 m. Its acreage is approximately 90 km^2. The Chabowo 1 borehole is located in the centre of

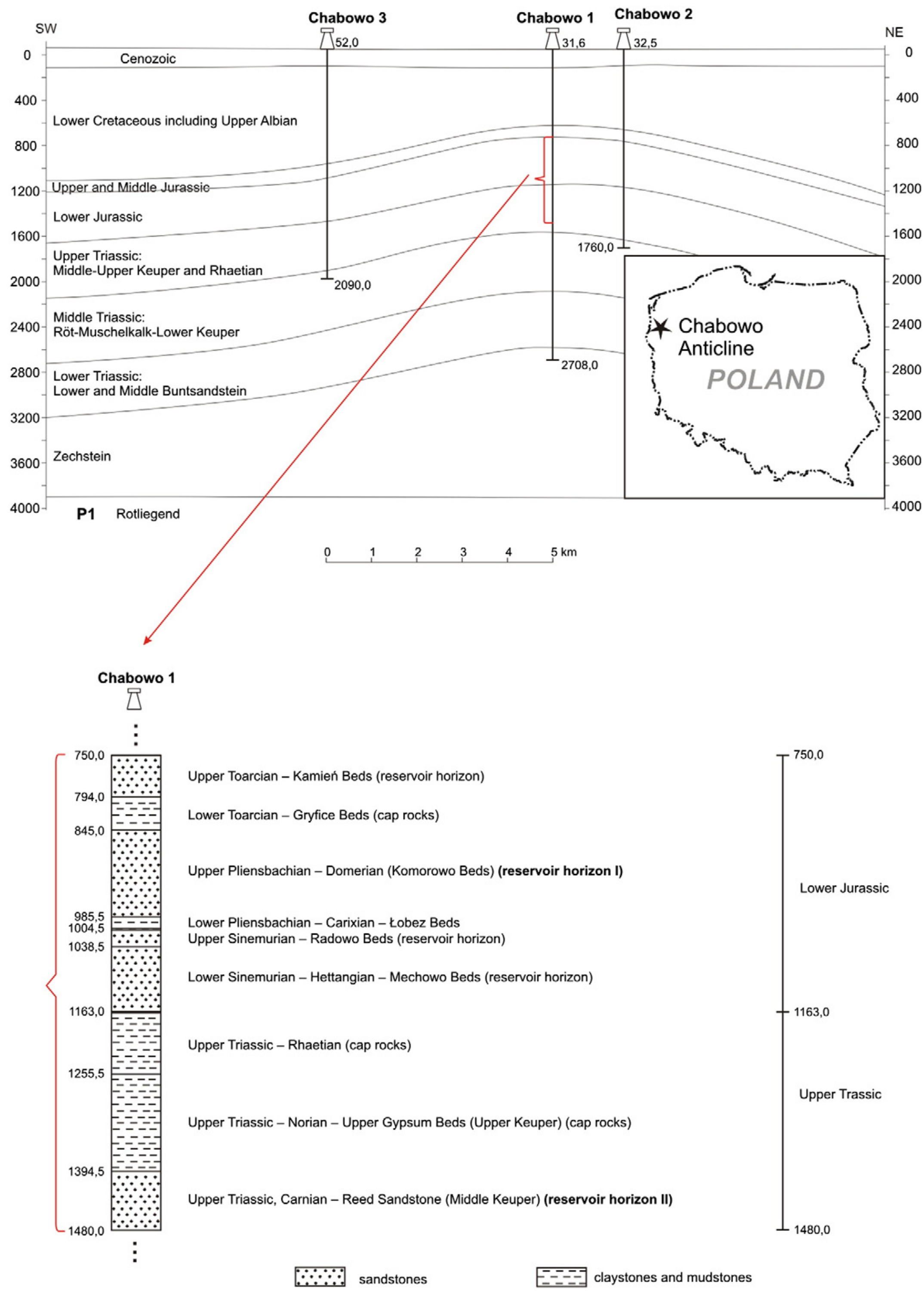

Fig. 1. Location and geological cross-section of the Chabowo Anticline, trending SW–NE along the line connecting the boreholes of Chabowo 1, Chabowo 2 and Chabowo 3.