CO_2 Storage as dispersed trapping in proximal areas of the Pearl River Mouth Basin offshore Guangdong, China

Niklas Heinemann[1], R. Stuart Haszeldine[1], Yutong Shu[1] and Mark Wilkinson[1]

[1]School of Geoscience, University of Edinburgh, Edinburgh EH9 3FE, UK

Abstract

Introduction

The effective CO_2 storage capacity of saline aquifers are estimations based mainly on the pore volume of large reservoir formations multiplied by a ‘storage efficiency factor’, a value defined by geological and engineering limitations (Bachu et al., 2007). The accuracy of the ‘storage efficiency factor’ requires a detailed knowledge of the geological environment and technical complexity of the storage operation. However, storage efficiency factors often do not exist and a published ‘average’ value is taken instead. By doing that, the CO_2 capacity study will be disconnected from determining factors concerning storage capacity such as the capability of local cap-rock to retain long CO_2 columns. In this study, we introduce CO_2 storage in the Pearl River Mouth Basin offshore Guangdong, China, an area where the capacity of conventional CO_2 storage is probably lower than previously anticipated (e.g. Zhou et al. 2011), but with additional storage space in overlying formations which have not been considered as storage targets so far.

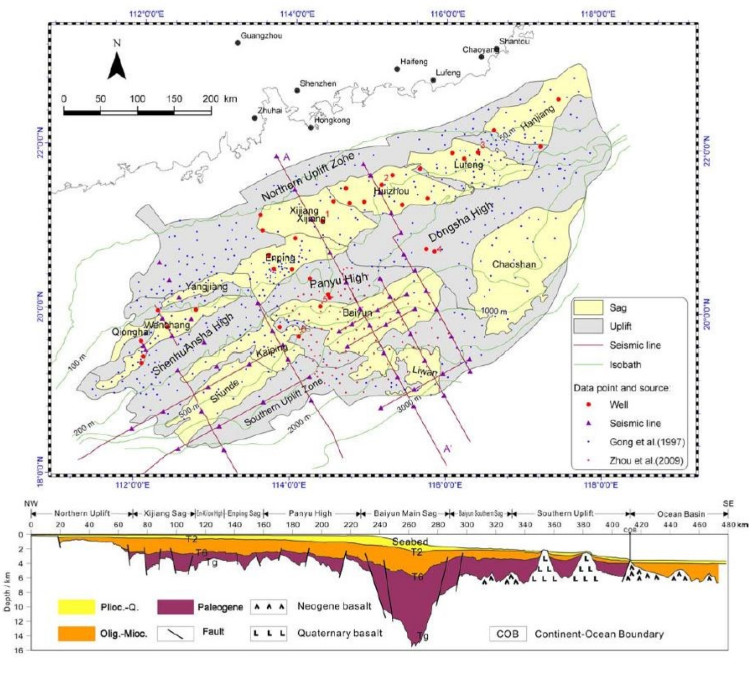

Figure 1: Simplified geological map and cross-section of the Pearl River Mouth Basin (Zhou et al. 2011).

The Pearl River Mouth Basin

The Pearl River Mouth Basin is located in the Guangdong Province in the northern South China Sea and is a Cenozoic sedimentary basin with a total area of nearly 200 000 km^2 and a maximum sediment thickness >6km in shelf and >14km in slope areas (Fig. 1; Chen et al., 2003; Zhou et al., 2009). Although several plays have been studied in the past, there is a distinct lack of large oil and gas fields in the proximal areas of the Pearl River Mouth Basin. Most oil fields are small except LH11-1 with a 75 m pay section in a carbonate platform (Tyrell & Christian, 1992). In more distal, deep water areas however, large gas fields have been found such as the Liwan 3-1 gas field, discovered in 2006 at a water depth of 1300 m.

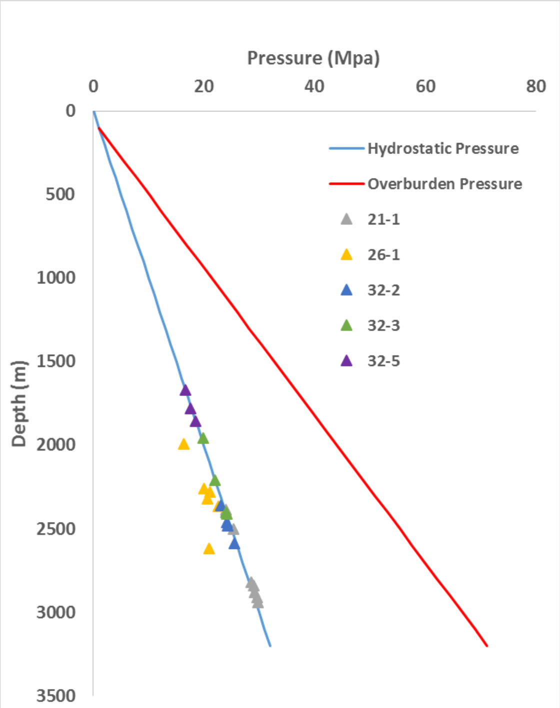

Figure 2: Pressure data from the Huizhou oil fields. Most of the data plot on a water gradient (Lui, 2011). The data suggest that there is no significant vertical oil phase connection. Also shown is a lithostatic (0.023 MPa/m) and a water gradient (0.01 MPa/m) calculated for a water depth of 100 m. Data extracted from Liu (2011).

Why are no large oil or gas fields present in the proximal siliciclastic stratigraphy when discoveries in carbonate platforms and more distal areas suggest that hydrocarbon supply was not a problem? A possible explanation arises when looking at the hydrocarbon accumulations in detail. The stratigraphy consists of a sequence of thin sand- and shale-rich layers forming relatively low amplitude anticlines (up to 52 m of vertical closure covering an area of 21.6 km^2 respectively for the Huizhou 21-1 oil field). Some of the sand-rich layers contain oil or condensate. Pressure data from the Huizhou oil fields do not line up on a typical oil gradient and suggest no vertical connection of the oil phases between the sand layers (Fig. 2). Additionally, some of the accumulations are not filled to spill and suggest that capillary leakage occurs (Fig. 3). Hence there is little proof that the shale-rich cap-rocks have been capable of retaining long hydrocarbon columns over geological times. Upward migration due to low threshold pressures of the hydrocarbons through the overburden towards the surface is likely while only a fraction has been trapped in the reservoirs.

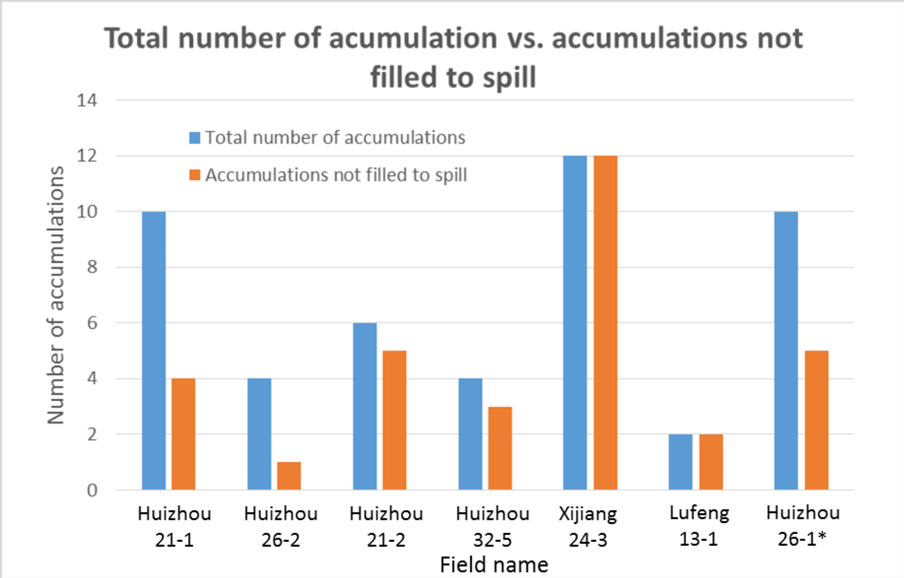

Figure 3: Comparison between the total number of accumulations and accumulations not filled to spill of some of the proximal hydrocarbon fields in the Pearl River Mouth Basin (water depth less than 200m. (*) The vertical closure of Huizhou 26-1 is unknown. Instead the layer thickness is compared with the oil columns. Data extracted from Liu (2011).

CO_2 storage as dispersed trapping

If CO_2 is injected into the sand layers for storage purposes, it will remain trapped as long as buoyancy pressure does not exceed the fairly low capillary entry pressure. When the entry pressure is reached, the CO_2 will migrate out of the reservoir into the layered overburden. Within the overburden, CO_2 will be migrate into small local traps, will be retained by capillary forces and will be exposed to under-saturated pore water and dissolve. The trapping mechanisms will progressively reduce the amount of free CO_2 while migrating towards the surface. Our simulations show that although the proximal parts of the Pearl River Mouth Basin are not capable of retaining large volumes of CO_2 in single reservoir layers, the stratigraphy consisting of several kilometers of sand and shale layers is still a storage target using dispersed trapping.

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