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A geological storage option for CO_2 in the Bohaiwan Basin, East China?

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Abstract

Geological assessment of the Bohaiwan Basin in eastern China for the COACH (Cooperation Action within CCS China-EU) project indicated that storing carbon dioxide (CO_2) in this region will be technically challenging and require a flexible storage solution. It is suggested that a pilot scheme within the Dagang oil field complex could prove the concept of Carbon Capture and Storage (CCS) and CO_2-Enhanced Oil Recovery (CO_2-EOR) in the challenging conditions of oil fields in this region of China. This could be followed by simultaneous injection of CO_2 into a nearby larger oil field and adjacent aquifers that would offer a potential storage option by combining the larger

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storage space anticipated for aquifers with the possible future financial incentives of CO_2-EOR.

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1. Current status of CCS in China

The concept of Carbon Capture and Storage (CCS) is gaining momentum in China with: in 2008, the successful addition of demonstration-scale post-combustion capture technology to the Huaneng Group Gaobeidian Power plant in Beijing [1,2]; the building of an IGCC (Integrated Gasification Combined Cycle) plant as part of a three-phase project to build a full scale commercial pre-combustion power plant (GREENGEN [3]); and the announcement of a full-chain CCS project in the Ordos Basin ([4]Chinadaily.com 2010). The Gaobeidian plant captures 3000 tonnes CO_2 per year using amine scrubbing of flue gases (capture began in June 2008). The CO_2 stream is 99% pure, food-grade and is sold to the beverage industry.

Geological storage options for CO_2 have been explored through the GeoCapacity (EU Framework 6), COACH (EU Framework 6) and China-UK NZEC (Near Zero Emission from Coal - phase I funded by UK Department of Energy and Climate Change) projects. These included the PetroChina-operated Dagang, Daqing, Huabei and Jilin oil field complexes, and the China Petroleum and Chemical Corporation (SINOPEC)-operated Shengli and Jiangsu oil field complexes. Aquifers in the Jiyang Depression adjacent to the Shengli oil field complex, the Jizhong Depression around the Huabei oil field complex and aquifers within the Jilin oil field complex were also assessed [5,6,7,8,9].

2. Sources

The main concentration of large point sources of CO_2 lies along the east coast of China. The emissions of the largest sources in the Shandong Province, eastern China, were assessed for the COACH project; annual emissions were estimated to be 201 $MtCO_2$ (million tonnes of CO_2). The power sector dominated the emissions, and the largest single source emits around 11 $MtCO_2$/year (million tonnes CO_2 per year) [10]. To store emissions from these industrial sources will require not only a site with a large capacity, but also with good injectivity and effective seals.

Retrofitting of power plants for CCS is expected to be technically challenging and potentially expensive, so where power stations can be built with CCS in the original design they may prove easier targets for capture. An example of this is the IGCC GREENGEN power plant which lies close to the storage sites studied in the COACH project (GREENGEN was a COACH project partner). Construction began in July 2009 on this 250 MW (Mega-Watt) IGCC power plant in Binhai Area, Tianjin, and this phase should be completed by 2011. It is intended that this plant will be followed by construction of another larger plant (400 MW IGCC) with pre-combustion CO_2 capture, most likely near the current Tianjin gasifier site (this will be GREENGEN phase II, planned for 2011-2015). Anticipated emissions from GREENGEN phase II are a little over 2 $MtCO_2$/year (million tonnes per year). Discussions are underway with China National Petroleum Corporation (CNPC) and PetroChina on storage sites for GREENGEN phase II. Additional funding and policy support is required for phase II. GREENGEN phase III (400 MW demonstration plant with hydrogen production and CCS ready for commercialization) is planned for 2013-2017. The location of GREENGEN phase III has not yet been confirmed.

3. Storage potential

Geological assessment of the Dagang and Shengli oil field complexes indicates that these fields are complex; being compartmentalized by faulting and highly variable lithology. Each field contains numerous individual reservoirs from which oil and/or gas are produced. The estimated capacity of the selected suitable reservoirs in the Dagang oil field complex was 22 $MtCO_2$, with the largest capacity found in the Gangdong oil field (8 $MtCO_2$ storage [5,6,7]). This oil field complex is evidently too small to contain large-scale emissions, but its proximity to CO_2 source, including the proposed Greengen phase II plant to be built at Tianjin, means that it could potentially be considered for an early pilot-scale scheme of storage and CO_2-EOR. A concern with this oil field is the number of boreholes already drilled; the Gangdong oil field alone contains over 600 wells within an area of 23.7 km^2. These wells would have to be considered in any evaluation of security of storage for their potential to permit CO_2 migration out of the reservoirs. Another issue is the compartmentalization of the fields; this could enable secure storage within each compartment but since numerous boreholes are required to effectively exploit the hydrocarbons trapped in this region, it is anticipated that if CO_2 were injected here, numerous boreholes with multiple perforations would be required to inject into the many compartments and reservoirs of these oil fields. Additionally, as the reservoirs are often divided into isolated compartments by faulting or lithology, it is almost certain that pressure relief wells would be required to produce oil and water (either utilizing pre-existing wells or new wells).

The Shengli oil field complex has an estimated storage capacity of 472 $MtCO_2$, contained in numerous porous layers and lenses, surrounded by and sealed by impermeable mudstone and claystone layers [5,6,7]. This initial estimate suggests this field could contain the emissions from the lifetime of the GREENGEN phase II plant (around 2 $MtCO_2$/year, this phase is planned for 2011-2015). Porosity and permeability of the formations is highly variable and injectivity is expected to be low. As in the Dagang oil field complex, these fields are compartmentalized and so the same concerns over the number of boreholes required apply. CO_2–EOR could be considered in the Shengli oil field complex, offsetting some of the financial cost of CO_2 capture.

The largest capacity of the sites investigated was identified in the aquifers of the Huimin sub-basin within the Jiyang Depression, adjacent to the Shengli oil field complex. The Guantao Formation is hydrocarbon bearing in the Shengli oil field complex but generally non-hydrocarbon bearing in the adjacent Huimin sub-basin due to immaturity of source rocks. If the sealing formations are equally effective in the Huimin sub-basin as in the oil fields, then the Guantao Formation could offer copious potential storage. Areas where the Guantao Formation has thick sandstone layers were selected in the Huimin sub-basin (Figure 1~~Figure 1~~). These areas had an estimated storage capacity of 700 MtCO_2 [5,6,7]. As yet, sufficient data are not available to identify antiformal closures and so assessment has focused on regions of thick sandstone with the aspiration that later work will identify closures suitable for storage. This storage estimate needs to be considered with caution as there are less data available than in the oil field areas and so the potential aquifer storage sites are less well understood, and there remains the possibility that they may also be compartmentalized by faulting and lithological variations as in the adjacent oil fields.

4. A potential storage solution

The Dagang oil field complex could be exploited for a pilot scale CO_2-EOR project, continuing from this, CO_2 could be transported further to the Jiyang Depression and injected into the Shengli oil field complex for CO_2-EOR and storage and simultaneously into the adjacent aquifers for large-scale storage (Figure 1~~Figure 1~~). A pilot project in the Dagang oil field complex would build expertise and experience of CCS in China. This knowledge and experience could then be transferred to a larger-scale project in the Shengli oil field complex and Huimin sub-basin aquifers. Simultaneous CO_2 storage in the aquifer and supply for EOR in the Shengli oil field complex would provide CO_2 as needed for the oil field (the amount would vary through the lifetime of a EOR project, for example, CO_2 produced after breakthrough at the wells could be recycled and as a result, lower amounts of new CO_2 would be required from the source). As CCS became more widely deployed, CO_2 from other sources in this industrial region could be brought to this joint EOR and storage project creating a 'CO_2 network'

The next step for this potential storage solution is detailed investigation of the storage capacity of the aquifer and oil fields. This requires modeling of the aquifer based on seismic and borehole data, testing of seal properties and analysis of sandstone for its reservoir properties (for example, see work undertaken for the Sleipner storage site 11,12,13,14,15]. Pilot schemes and storage/CO_2-EOR in the oil field complexes requires collaboration with PetroChina and SINOPEC; their knowledge and experience of these fields gained through decades of hydrocarbon extraction and re-use of exploration data will allow detailed modeling of the potential for CO_2 storage and CO_2-EOR.

5. Future of CCS in China

Two major barriers to CCS in China are the financial cost of CCS and access to detailed scientific data. The former can be overcome through collaboration and developments in CCS technologies driving down the price of implementation. Unfortunately, at present, the cost of CCS makes it unattractive for large scale deployment; changes in policy are required to stimulate investment, not just in China, but worldwide. Access to data remains difficult partly because data are acquired by oil companies and held as confidential in perpetuity. Other data are acquired and held by state-level geological surveys or mineral companies. Both the COACH and China-UK NZEC projects shared publicly available data which permitted the initial assessment of these storage sites. However, for more detailed work, primary data such as seismic and borehole data and results of geochemical testing are required. An exception to this was the COACH project assessment of the Dagang oil field complex where PetroChina, a project partner, shared oil field data they had acquired including oil reserves, reservoir properties and maps through their subsidiary company the Research Institute of Petroleum Exploration and Development (RIPED).

6. Conclusion

From the geological assessment of the Bohaiwan Basin in eastern China, the Shengli oil field complex and adjacent Jiyang Depression were identified as being of interest for geological storage of CO_2 but require more detailed evaluation. The Dagang oil field complex was identified as having potential for a pilot-scale project but also requires further detailed investigation. It is suggested that simultaneous utilization of these sites could offer a more complete storage solution; the Dagang oil field complex, closest to the planned GREENGEN phase II plant at Tianjin could be used to prove the concept of CCS and CO_2-EOR in the geologically challenging conditions of these Chinese oil fields. This could then be followed by CO_2-EOR in the Shengli oil field complex, with additional injection and storage in the adjacent aquifer formations of the Huimin sub-basin. Such operations would allow largescale storage not only from the GREENGEN phase II plant (and possibly GREENGEN phase III if nearby), but also potentially from other large CO_2 sources in this industrial region. They would also support security of energy supply and offset some of the financial costs of a CCS project.

There is great interest in implementing CCS in China, from both Chinese and external parties, however, there are barriers to this which need to be overcome through future collaboration, global technology development and knowledge sharing.

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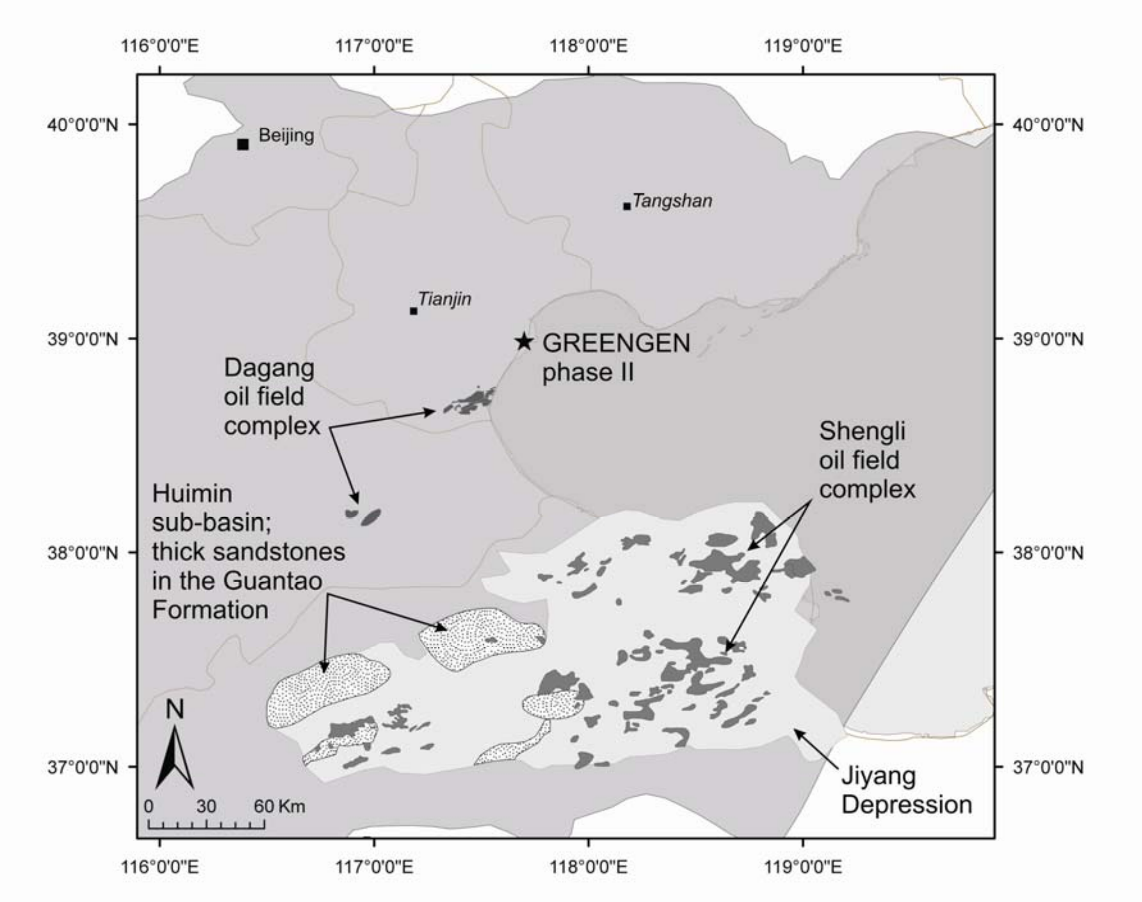

Figure 1: Location of GREENGEN phase II plant and potential storage sites. Basemap data taken from the Digital Chart of the World (1:1 million data), State province and basin outline reproduced with the kind permission of the USGS.