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Continental Saline Aquifers Suitable for CO_2 Sequestration

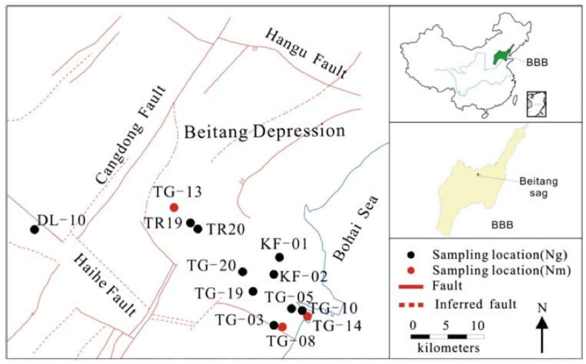
By SONG Jianlan (Staff Reporter)

Lately a group of hydrogeologists led by Prof. PANG Zhonghe at the CAS Institute of Geology and Geophysics (IGG) successfully assessed the suitability for CO_2 sequestration of the continental saline aquifers located in the Bohai Bay Basin (BBB) of northern China, and gave an optimistic prediction of its potential capacity based on studies of a series of scientific issues. This success will pave way for future commercial carbon sequestration in China.

This is among the intensive efforts made by CAS to combat global warming, which, according to IPCC Report, is mainly caused by emissions of greenhouse gases produced by human activities. Geologists at CAS have been trying for years to assess the prospects of turning some porous and well-closed geological formations into artificial carbon sinks. The main idea is to capture, inject and store greenhouse gases represented by CO_2 safely into such geological structures for future use. Possible structures for carbon sequestration include depleted oil/gas fields, unminable coal beds and deep saline aquifers; and among them saline aquifers, namely sedimentary rocks underground saturated with salt water, are believed to be very promising because of its large capacity and easy, wide availability.

Before developing into a commercial practice, however, this seemingly simple idea has to undergo serious examination and assessment to secure its viability and safety. Research on sequestration mechanisms of such structures and assessment of their storage capacity, for example, are required to help select the right sites for sequestration; careful appraisal of structural integrity is also critical to prevent potential leakage of the injected gas.

Research on the utilization of these structures for carbon sequestration started in the early 1990s in Canada, and soon the year 1996 saw the start of the Sleipner project in the North Sea of Norway, which emerged as the first successful commercial application of CO_2 sequestration in saline aquifers. By injecting the CO_2 extracted from locally produced natural gas into the saline aquifers in the



Location of the site and distribution of sampled wells from the Beitang sag in the Bohai Bay Basin (Ng: Guantao formation, Nm: Minghuazheng formation).(Image: By courtesy of Prof. PANG Zhonghe)

marine sandstone of Utsira at a rate of 1 million tons a year, it helps reduce the carbon emissions of the gas fields in an economical way. Due to the good integrity, homogeneity and closure of the strata, so far no sign of leakage is detected. The success of other commercial cases, though still very few in number, also proves the viability of this method.

The case of China is a bit different, however. Most available saline aquifers in this country are nested in continental deposits. Due to the difference in mineral compositions and hydrochemical characteristics, their responses to injected CO_2 might be a far cry from the marine ones; therefore their sequestration mechanisms are still poorly understood, and this made it difficult to assess their suitability for carbon sequestration. If properly studied and developed, however, such continental saline aquifers could make great storehouse for CO_2, as believed by scientists. "They might represent the real future of carbon sequestration in China," Prof. PANG comments: "especially those in the coastal east of this country."

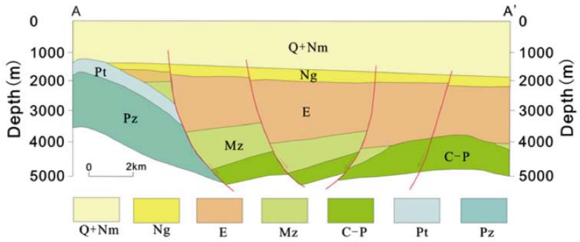
PANG's team took the lead to perform a field scale test at the Neogene Minghuazheng formation in the BBB, northern China to assess the suitability of the saline aquifers for CO_2 sequestration. Taking advantage of the existing geothermal and oil field wells, the researchers deployed a series of hydrogeological and geochemical investigations to understand the migration, reaction and trapping mechanism of injected CO_2 in the aquifers.

Generally at the first stage of sequestration, CO_2 is physically captured by the strata and trapped in the structural micro-cavities; while time goes on, more and more CO_2 molecules will gradually dissolve in the saline water and combine with the saline compositions to form an acid, corrosive solution. This corrosive liquid will react with the minerals of the rocks and produce more stable chemicals — theoretically, in the end the injected CO_2 will be safely "locked" in the saline water and/or rocks in the form of stable minerals and reach a long-term water-rock equilibrium.

But capture and trapping mechanisms vary across different sites. To determine the capacity of a site, one needs to know the locality-specific sequestration process and mechanism. The team hence collected water samples and drill cores of the Guantao and Minghuazheng formations for measurements of mineralogy, water chemistry and isotopes. Tests indicated that the formations had a low salinity. It means the saline aquifers would allow a high CO_2 solubility. Encouragingly, data showed that the strata also have high porosity and permeability, both of which are favorable for carbon storage. A subsequent geochemical modeling based on previous tests demonstrated that the water and rocks, which contained a lot of carbonates, strongly reacted with the injected CO_2. A ^{14}C dating revealed that the age of the formation water was as old as 15 to 20 thousand years, suggesting that the formation is a quasi-closed system over large time scales, though its lateral sealing mechanism for CO_2 sequestration still needed further investigation. Hydrochemical and isotopic evidence showed that the formation had little connection with the upper strata, which further confirms its safety for carbon storage once CO_2 is injected. All these would assure good conditions for carbon sequestration.

Examination of the logging materials also indicated that the site could offer desirable temperature and pressure conditions for carbon sequestration. Aside from good storage conditions derived from combination of high porosity, permeability and low salinity, the site was also revealed to be capped and locked out by several clay layers of Neogene and Quaternary, which would work as good sealers because of their low permeability and great thickness.

The combination of the above favorable conditions, as reported by the team in the *Applied Geochemistry*, might lead to a potential capacity for CO_2 storage as high as 17.03 Mt, if estimated by the solubility trapping of the aquifers. Due to the complexity of the conditions involved in sequestration and errors from the calculation, the authors warned, uncertainties existed in the estimation.



A cross-section of the Beitang sag. The porous and permeable sandstone and mudstones of Neogene, Eocene, Carboniferous and Permian, Proterozoic, Paleozoic and Mesozoic periods are capped by a thick structure formed by clay layers of Quaternary period, which are hard to permeate by water and gas. (Q: Quaternary, Nm: Neogene Minghuazheng formation, Ng: Neogene Guantao formation, E: Eocene, C–P: Carboniferous and Permian, Pt: Proterozoic, Pz: Paleozoic, Mz: Mesozoic.) (Image: By courtesy of Prof. PANG Zhonghe)

"There are abundant CO_2 sources in this area as a result from the adjacent coal-burning thermal power plants, therefore it is a cost-wise choice to sequestrate the CO_2 emissions locally," PANG explains when asked about the economic significance of the sequestration techniques, with an optimistic view of future applications for them. He introduces that techniques for saline aquifer utilization can also be applied to other industries, including oil/gas and geothermal development. "Towards a longer temporal dimension, CO_2 will mostly dissolve in the saline waters and combine with local minerals in stable forms with a certain acidity," he continues: "Such corrosive liquid, if permeates in carbonate strata, will increase the porosity of the strata and hence prevent clogging of the paths through which the oil/water travels to the surface or spreads around."

Local oilfields will directly benefit from this technique, PANG told the reporter. These oilfields are experiencing a drop in production because the oil is too thick or the reservoir is being exhausted. Existence of CO_2 in the strata can decrease the viscosity and improve the fluidity of oil. "Therefore it will help increase the production, the so-called enhanced oil recovery," he says.

According to PANG, the BBB has a long history of geothermal development and utilization, but these years it is encountering with difficulty in reinjection of wastewater due to clogging. This plight has caused the dropping of water table and rising of worries. Pumping CO_2 into the saline aquifers beneath can improve the permeability of the strata, and speed up the flowing of thermal water.

Funded by the China National High-tech R&D (863) Program, the team seeks to perform larger tests of CO_2 sequestration in the near future, aiming at a commercial scale application of such techniques for carbon sequestration and generate economic revenues in North China.