



DEEP SUB-SEABED DISPOSAL OF CO₂ - THE MOST PROTECTIVE STORAGE -

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ABSTRACT

The sub-seabed disposal of CO₂ is safer than the disposal of CO₂ in inland aquifers. Even if small amounts of CO₂ seeped out of sea floor, CO₂ would disperse and dissolve into sea water. On the surface of the sea, there exist no depressions where CO₂ may concentrate. Sediments under deep sea floor are very cool because the deep oceanic water is usually at a few degrees centigrade. CO₂ hydrate is formed in sediments under wide areas of ocean floor deeper than about 300m. Virtually complete isolation of huge amounts of CO₂ is possible by the deep sub-seabed disposal. Liquid CO₂ with heavy suspension intrudes laterally under light unconsolidated sediments at sea floor deeper than about 3700m. Lateral intrusion technique for the super-deep sub-seabed disposal of CO₂ can protect the ecology on the sea floor. © 1997 Elsevier Science Ltd

KEYWORDS

CO₂; sub-seabed disposal; CO₂ hydrate; aquifer; unconsolidated sediments

INTRODUCTION

The principal cause of global warming is the huge amount of CO₂ emitted by burning fossil fuels extracted from underground deposits. Although the carbon dioxide is not very poisonous to animals and is even useful for plants, the enormous volume of manmade CO₂ emissions makes the development of effective mitigation technology extremely difficult. About 60% of CO₂ emissions in Japan are from fixed massive sources such as electric power plants, mills, etc. While intensive efforts are being made for the development of CO₂ recovery technology from flue gas of

power plants and mills, we should find suitable spaces for the disposal of separated CO₂. Oceanic disposal of CO₂ is still questionable due to the risk to the marine environment.

Depleted natural gas and oil fields have porous underground reservoir rocks and trap structures that can contain gas and liquids safely over several million years. Some natural gas deposits contain a large fraction of CO₂. It is possible to use depleted underground natural gas and oil reservoirs as storage sites for CO₂ because impermeable caprocks prevent the leakage of CO₂. Simple carbon dioxide is stored as a supercritical fluid in reservoirs deeper than about 800m. Cooler reservoirs having a low geothermal gradient can store more carbon dioxide than warmer reservoirs having a high geothermal gradient(Koide *et al.*, 1994).

Prediction of the fate of underground CO₂ is necessary for the safe subterranean disposal of CO₂. About 3 MPa of pressure at about 5°C is sufficient to form CO₂ hydrate in aquifers. Formation of CO₂ hydrate in the pores of rocks virtually completely prevents leakage of carbon dioxide(Koide *et al.*, 1995). Carbon dioxide injected in deep reservoirs may migrate upward in aquifer systems and forms a CO₂ hydrate cap at the depth range of 200m-400m below the water surface in cool sedimentary basins in high latitudes and in wide areas of cool marine sedimentary basins deeper than two or three hundred meters(Koide *et al.*, 1995).

In and around the Japanese islands, the Engineering Advancement Association of Japan (ENAA) estimated (Tanaka *et al.*,1994) that as much as 2 billion tons of CO₂ can be stored as a supercritical fluid in oil and gas reservoirs, as much as 1.5 billion tons in aquifers with trap structures, as much as 16 billion tons as solution in groundwater in other aquifers on land and as much as 72 billion tons in offshore aquifers. Koide *et al.*(1992) estimated that 320 billion tons of CO₂, at least, can be stored in aquifers in sedimentary basins in the world.

Artificial emission of CO₂ concentrates in urban areas and in industrial centers. However, it is very difficult in densely populated areas to find lands available for CO₂ injection-transportation

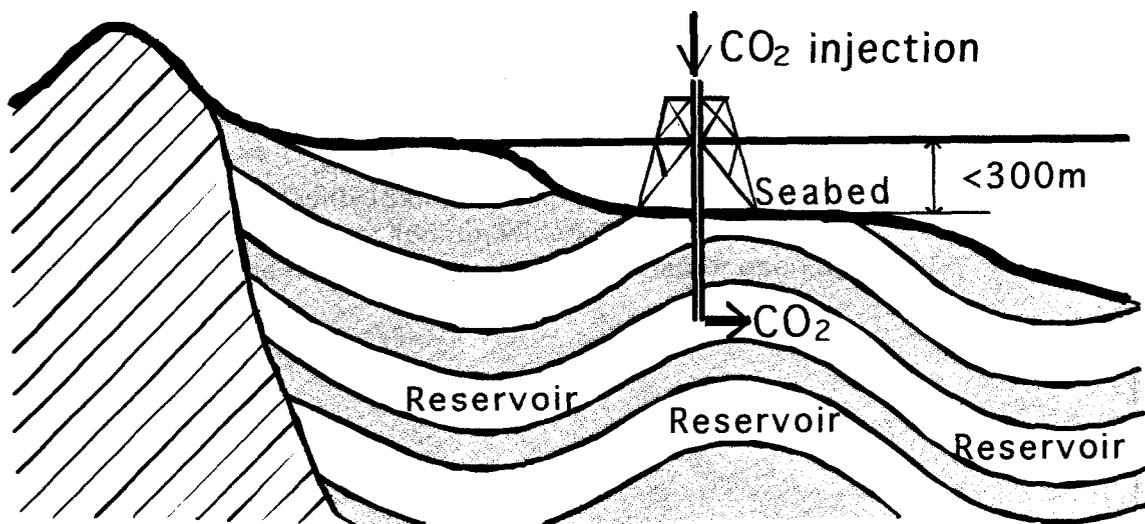


Fig.1 Shallow sub-seabed disposal of CO₂

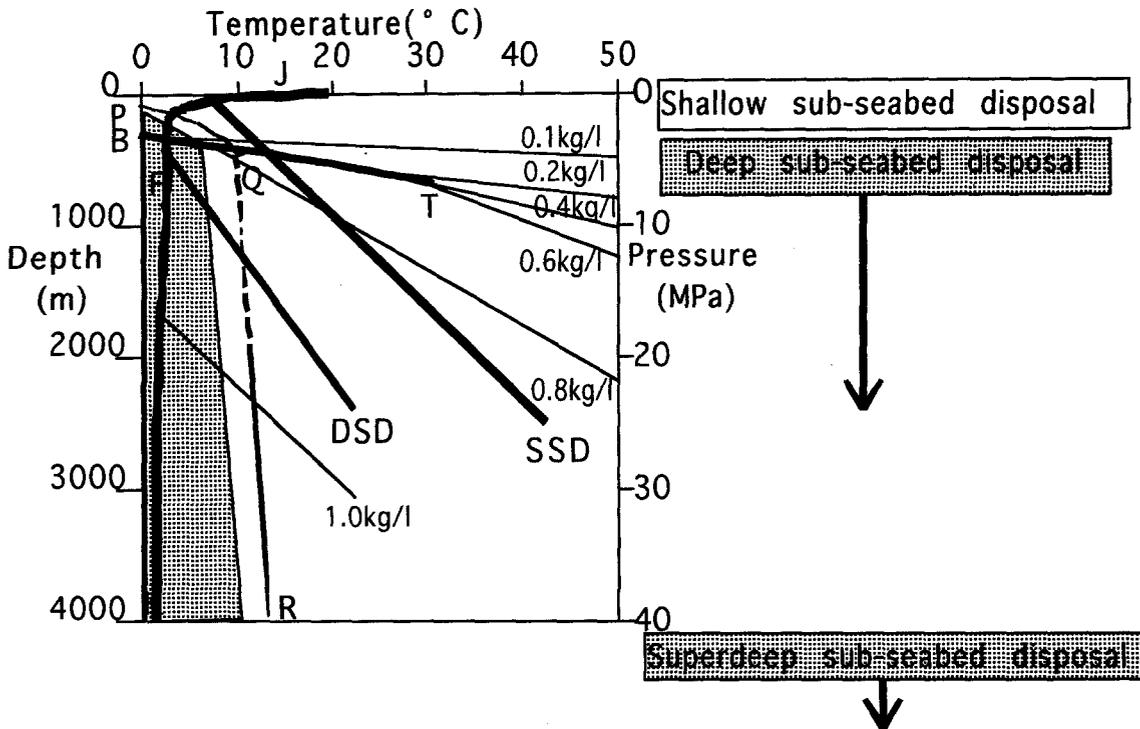


Fig.2 Sub-seabed disposal and state of CO₂ at temperatures and pressures below the seabed. B-Q-T is the boiling curve of CO₂, while T denotes the critical point at 31.1°C, 7.39MPa. P-Q-R is the decomposition criterion of CO₂ hydrate. The dotted area is the temperature-pressure range where CO₂ hydrate may be formed in marine sediments. J-F-K is a temperature profile in the northern Pacific Ocean. The lines SSD and DSD are simplified examples of possible temperature-pressure increase with depth in marine sediments in cases of shallow and deep sub-seabed disposal, respectively.

facilities. The sub-seabed disposal of CO₂ has great advantage for safety and for accessibility in Japan that consists of small islands.

SHALLOW SUB-SEABED DISPOSAL OF CO₂

The sub-seabed disposal of CO₂(Fig.1) is technically and economically feasible for submarine aquifers below shallow seabed(Korbøl and Kaddour, 1995). The cost for construction of injection facilities is reduced where offshore platforms for oil or gas production are available. The disposal of CO₂ in submarine aquifers is safer than the disposal of CO₂ in inland aquifers. Even if small amounts of CO₂ seeped out of sea floor, CO₂ would disperse and dissolve into sea water. On the surface of the sea, there exist no depressions where CO₂ may concentrate. CO₂ disposal in aquifers under sea floors shallower than 200 or 300m is safe and economically reasonable technology for CO₂ mitigation. Huge volumes of CO₂ storage are expected in sedimentary basins under continental shelves in the world.

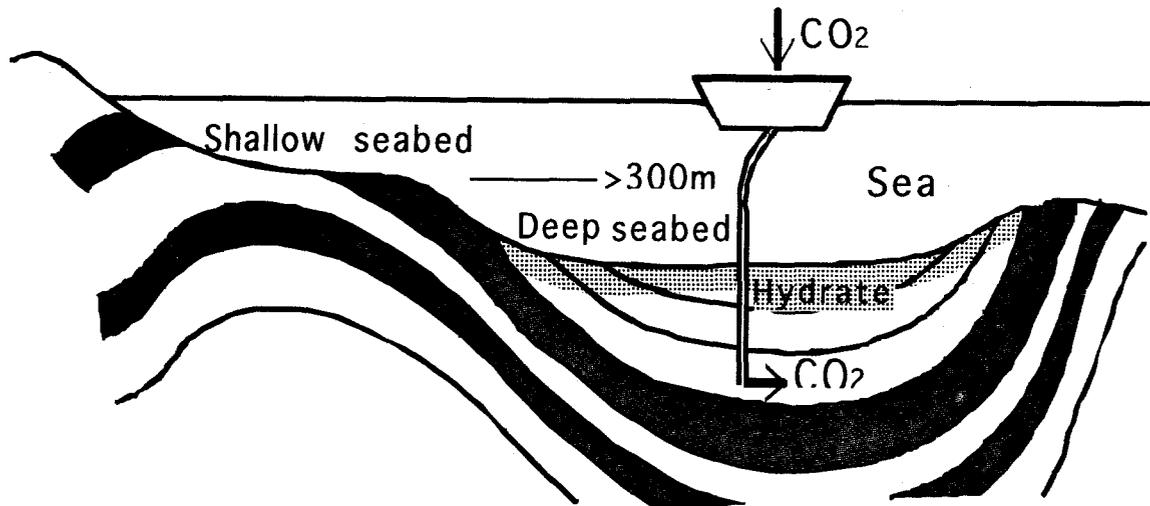


Fig.3 Deep sub-seabed disposal of CO₂.

DEEP SUB-SEABED DISPOSAL OF CO₂

Sediments under deep sea floor are very cool because the deep oceanic water is usually at only a few degrees centigrade. CO₂ hydrate is formed in sediments under wide areas of ocean floor deeper than about 300m where the temperature of sediments is lower than about 5°C (Fig.2). CO₂ injected in submarine aquifers migrates and forms CO₂ hydrate cap in cool sediments just below deep ocean floor (Fig.3). Virtually complete isolation of huge amounts of CO₂ is possible by the deep sub-seabed disposal in sedimentary basins under sea floor deeper than about 300m. Deep drilling at deep seabed is technically difficult and expensive. Deep sub-seabed aquifers provide the most protective but less accessible storage for CO₂.

SUPERDEEP SUB-SEABED DISPOSAL OF CO₂

Shindo *et al.* (1993) proposed long-term storage of liquid CO₂ in depressions of very deep seabed. Thin film of CO₂ hydrate and layer of CO₂ saturated sea water protect heavy CO₂ liquid in depressions of seabed deeper than 3700m (Fig.4). However, some ecological impacts are inevitable even at very deep seabed.

Thick unconsolidated sediments fill some depressions of seabed. Effective density of some shallow unconsolidated sediments is only a little higher than seawater. Effective density of liquid CO₂ can easily be made higher with mixture of heavy suspension such as clay or ash than shallow unconsolidated sediments under seabed deeper than 3700m. Falling steel penetrator can easily penetrate some 10 meters into unconsolidated sediments under deep sea floor. Liquid CO₂ with heavy suspension can be injected laterally under lighter unconsolidated sediments without serious damages to sea floor (Fig.5). Lateral intrusion technique for the super-deep sub-seabed disposal of CO₂ hardly affect the ecology on the seabed.

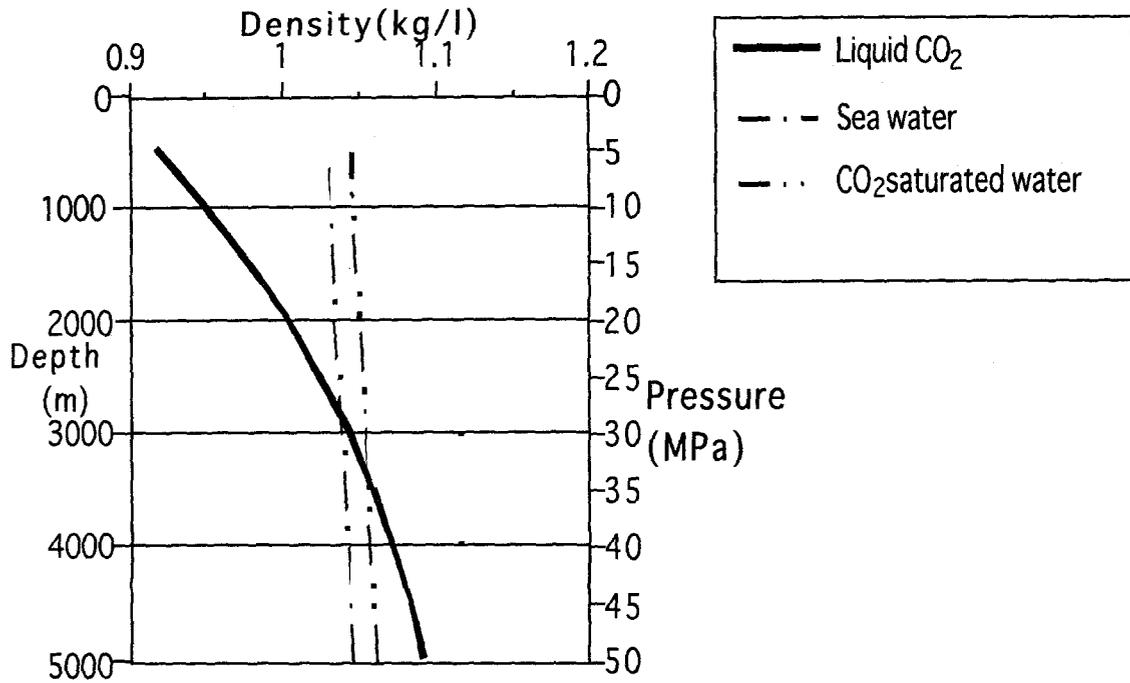


Fig.4. Approximate relation between pressure and density of CO₂, sea water and CO₂ saturated sea water at 3°C.

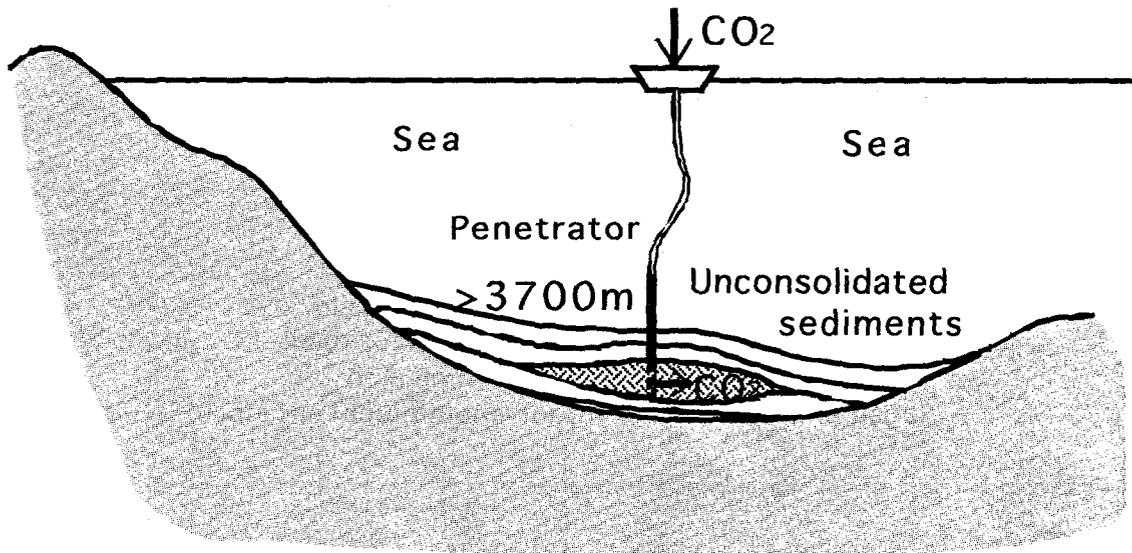


Fig.5 Superdeep sub-seabed disposal of CO₂

CONCLUSION

Shallow sub-seabed disposal of CO₂ in aquifers under seabeds shallower than 200 or 300m is technically and economically feasible and safer than inland aquifer disposal. Deep sub-seabed disposal of CO₂ in aquifers under seabeds deeper than 300m provide the most protective storage for CO₂ thanks to formation of CO₂ hydrate in sub-seabed sediments. Superdeep sub-seabed disposal of CO₂ under light unconsolidated sediments also hardly affect the ecology on the seabed. Three types of sub-seabed disposal of CO₂ - shallow, deep and super-deep sub-seabed disposal - can realize CO₂ emission free fossil fuel power generation.

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