Trapped in ICE

Ameena Camps investigates carbon dioxide hydrates – a new way to store carbon dioxide underground in a cage of ice.

As greenhouse gas emissions continue to rise and global warming begins to take effect, it is clear that it will be difficult to meet Kyoto targets and to make the much larger cuts in carbon dioxide emissions that many scientists now believe are needed to avoid dangerous climate change.

At the British Geological Survey and the University of Leicester we are researching a novel way to reduce the amount of carbon dioxide going into the atmosphere – by storing it in a frozen form in a geological reservoir where it will remain safely trapped for many thousands of years in cold sediments under the deep ocean.

Currently, carbon dioxide extracted from natural gas is being stored in warm, deep sediments at the Sleipner gas field in the North Sea. At this high temperature (over 30°C) and pressure, carbon dioxide becomes a supercritical fluid, which has properties somewhere between a gas and a liquid. But we are looking at the possibility of storing it in colder sediments as a frozen hydrate instead, because 30-40 per cent more carbon dioxide can be stored inside the same volume of rock in this solid form, and it is less likely to leak out than the supercritical fluid. As much as $160m^3$ of gas can be trapped in $1m^3$ of hydrate, making it a very effective store.

Hydrates (also known as clathrates) are ice-like crystalline minerals that look like normal ice and form when gas and water freeze together at low temperature and high pressure. They are made of a cage of frozen water molecules with the gas molecules trapped inside.

Since their discovery in 1810 by Sir Humphrey Davy, hydrates have been researched in the laboratory, with rapidly growing interest in more recent years. Natural hydrates on Earth are dominated by methane hydrates (see 'Burps that warmed the world', *Planet Earth* Spring 2006, p25), though natural carbon dioxide hydrates have been discovered off Japan, and could exist on Mars and Jupiter's moon Europa.

After their discovery, hydrates were regarded as a mere curiosity until gas hydrate formation was discovered as a cause of pipeline blockage in Kazakhstan in the 1930s. In the 1960s, a Russian drilling crew discovered natural methane hydrates in a Siberian gas field, and in the 1970s they were discovered in deep water sediments at outer and polar continental margins. In more recent years gas hydrates are moving into the foreground of global climate debates. Current worldwide interest includes their role in past and present climate change, in the carbon cycle, as a future energy resource (for natural gas extraction), as a desalination agent, as a cause of submarine landslides, and as a carbon dioxide store.

As part of my PhD project I have been making carbon dioxide hydrate in the laboratory, using high-pressure equipment to recreate the storage conditions you would find under the ocean. Using a scanning electron microscope, at very low temperatures, I can enter the micro-world of hydrates, producing some fascinatingly detailed images of how hydrates form in different sediments and at different temperatures.

My experiments have shown that carbon dioxide hydrate forms rapidly, filling the gaps between sediment grains and cementing the grains together. This means that the hydrate is likely to form stable structures in sediments under the oceans.

With the additional use of geophysical techniques and computer modelling, a vast amount of knowledge is at our fingertips. Using a computer program developed to predict carbon dioxide hydrate thickness, I have identified many regions off Western Europe with pressures and temperatures suitable for carbon dioxide hydrate formation. These areas have the potential to store large volumes of carbon dioxide if this storage technology was to be developed further.

Our laboratory investigations could have many wider applications. They can aid geophysical modelling of the stability of underwater slopes, for example, and can help desalination plants by understanding how salt is excluded when a hydrate forms. This exciting research is rapidly gaining pace, with many avenues to follow, and I look forward to unfolding more secrets hidden within these little crystals.

Ameena Camps is a research student at the British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottinghamshire, NG12 5GG, email: apcamps@bgs.ac.uk. She works with Chris Rochelle at BGS and Mike Lovell at the Department of Geology, University of Leicester.

1 *Ameena Camps investigating hydrates in the hydrothermal lab.*

2 *A single hydrate crystal grown in sand. The crystal is about 0.08mm across.*

3 *Large areas off Western Europe have a pressure and temperature which are right for hydrate formation. Countries such as Portugal and Norway could potentially store significant amounts of CO_2 offshore. The scale is in metres thick and the grey zone is outside the study area.*

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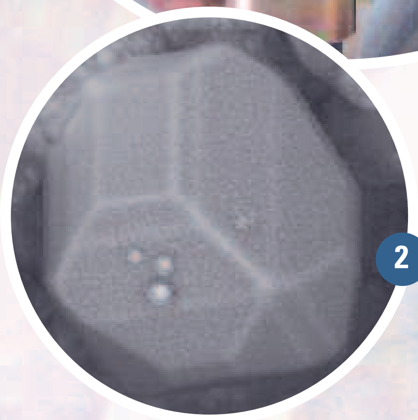

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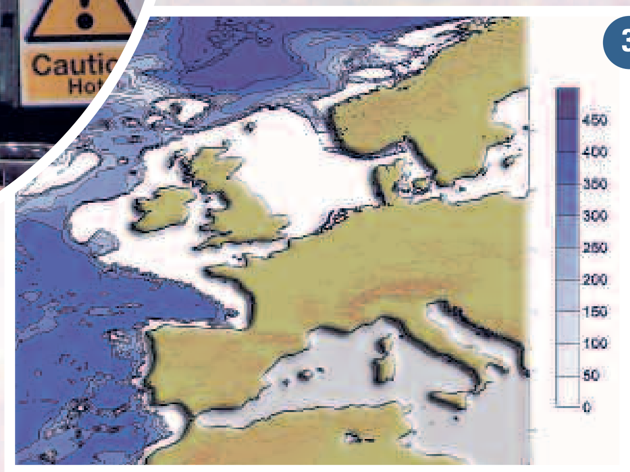

Towards zero emissions

The British Geological Survey has taken a leading role in the international development of carbon dioxide capture and storage (CCS) technology since 2000. These efforts are now being translated into policy. In the UK, the government endorsed CCS with the launch in June 2005 of '*A strategy for developing carbon abatement technologies for fossil fuel use*'.

An exciting European project, launched in 2005, is the '*Technology platform for zero-emission power from fossil fuels*'. This brings together all the industrial and research stakeholders across Europe, and aims to build Europe's first zero-emission coal-fired power station by 2015. BGS is on the project's advisory council and working groups.

BGS also took a lead on the international promotion of CCS. The plan of action agreed last year by the G8 countries said: 'We will work to accelerate the development and commercialisation of CCS technology.'

Contact: Nick Riley, njr@bgs.ac.uk