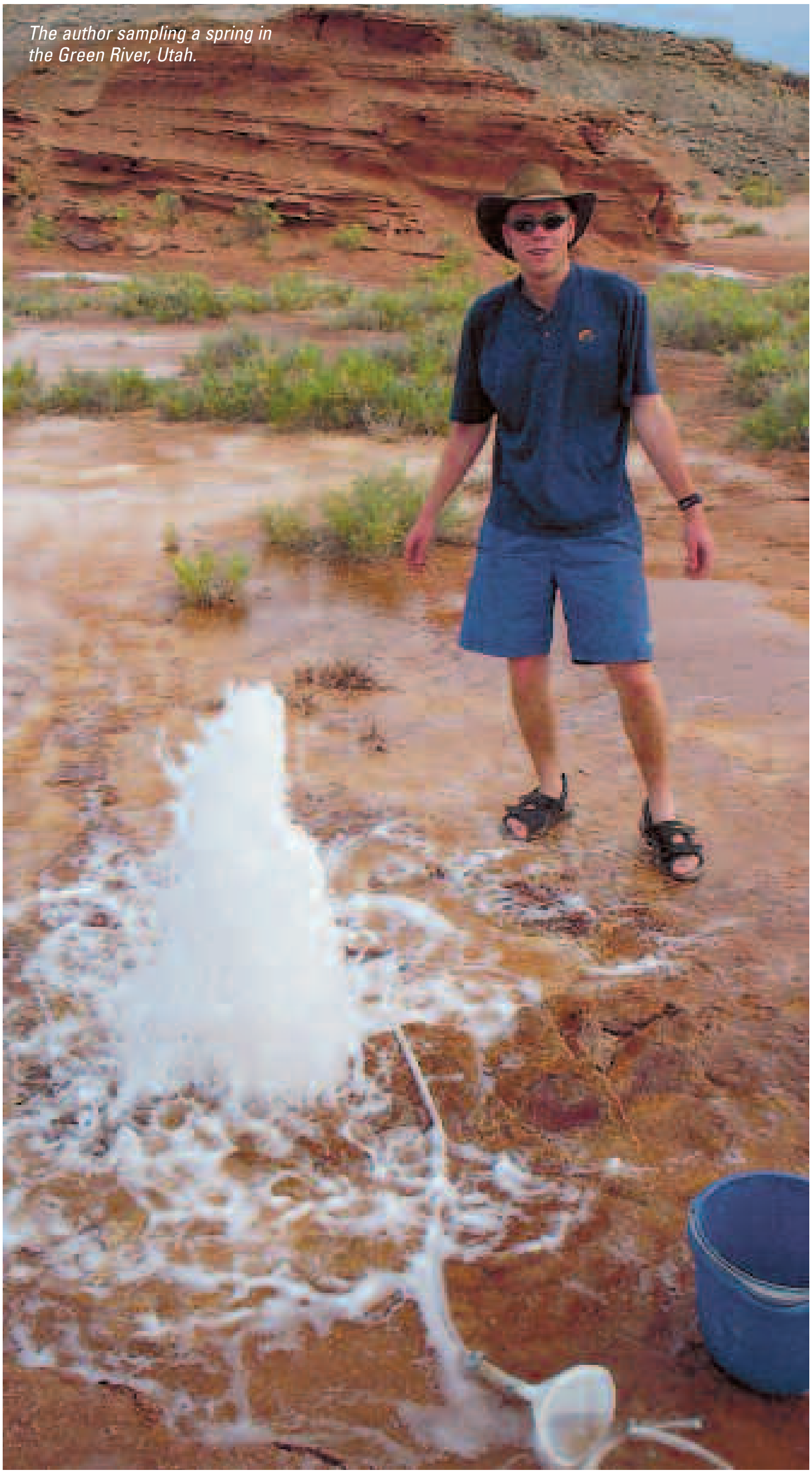
Colorado's captured **carbon**



The author sampling a spring in the Green River, Utah.

Climate change and global warming are never far from the headlines these days, and for good reason. The UK government is committed to addressing the problem of greenhouse gases and signed the Kyoto Protocol in 1997. This is a legally binding contract to reduce greenhouse gas emissions to 12.5% below 1990 levels by the year 2012. In the UK alone, carbon dioxide emissions account for 85% of greenhouse gases, and at present 30% of this is from burning oil, coal and gas in power stations.

Unfortunately, renewable energy (wind, solar and wave power) will not be able to replace traditional energy sources within the next few years. But if carbon dioxide can be separated off from power station emissions and stored safely, short-term targets can be met without radically changing our energy culture. This will cut greenhouse gas emissions and give more time to develop efficient renewable energy.

Capturing and storing carbon dioxide is called sequestration. Carbon dioxide could be sequestered in the deep oceans as solid carbonate precipitate (lime), but the most practical and environmentally acceptable option, given current technology, is to store it deep underground (see *Planet Earth*, summer 2002, p18).

So can deep geological structures safely store carbon dioxide over hundreds or thousands of years without it leaking to the surface? The best way to investigate

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Carbon dioxide stored deep underground won't leak out says Stuart Gilfillan, provided it's in the right place.

Overall, global carbon dioxide levels in our atmosphere have increased by 31% since the industrial revolution. At best, concentrations of this greenhouse gas are set to be double pre-industrial levels by 2100. At worst, they could double by 2045. In fact, emissions today are already 12 times higher than in 1991. Scientists expect this to raise global temperatures between 1.4 and 5.8°C over the next century, melting polar ice, raising global sea level, and causing widespread flooding and more frequent extreme weather.

this is to study natural carbon dioxide gas fields. These form in the same way as a normal oil or gas field, by trapping natural carbon dioxide in geological structures below the ground surface. The Colorado Plateau area in the south-west United States contains the highest number of natural carbon dioxide fields in the world. My colleagues and I have collected gas samples from five different fields and several natural springs from this part of the United States.

We know that oil and gas have been stored safely in normal fields over millions of years, but when it comes to carbon dioxide our knowledge is limited. This is because there are several different ways carbon dioxide is produced within the Earth's crust. Without knowing how the gas formed, it's difficult to be sure how long it has been stored underground. There are two main mechanisms that produce enough carbon dioxide to form these gas fields: 'degassing' from magma (lava which doesn't reach the surface), and the breakdown of carbonates (such as limestone) through heating. The ratio of heavy and light carbon atoms (isotopes ^{13}C and ^{12}C) within the gas can usually tell these two origins apart, as both sources have a distinct range of isotope ratios. However, these ranges overlap slightly, so this method doesn't work every time.

A better way is to use helium—the lighter-than-air gas you find in fun-fair balloons. It's one of the noble gases, renowned for being unreactive, or inert, and it's this property that makes it useful for tracing the origins of underground carbon dioxide. A light isotope, ^{3}He, comes only from deep within the Earth, and is transported within magma. So if a lot is present in the carbon dioxide, then the gas came from magma. If there is only a small amount, then the carbon dioxide came from carbonates.

Noble gases don't just tell us where the carbon dioxide has come from—they also give an idea of what happens to it in the crust. Careful measurements of other noble gases such as neon, argon, krypton and xenon can help us distinguish how the Earth's crust, mantle and groundwater contributed to and affect carbon dioxide and other gases in the reservoir.

By measuring the noble gases within the Colorado carbon dioxide, we have been able to confirm for the first time that the gas in all of the fields comes from degassing magma within the crust. In all but one of these gas fields, the last known magmatic activity was well over a million years ago (and in one it was at least 40 million years ago). This clearly means that carbon dioxide has been stored naturally and safely for a very long time in these fields. So, underground sequestration, in the correct place, should be a safe option to help us cope with emissions until we can develop cleaner energy sources.

Chris Ballentine and Greg Holland sampling at Sheep Mountain carbon dioxide field, Colorado.

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