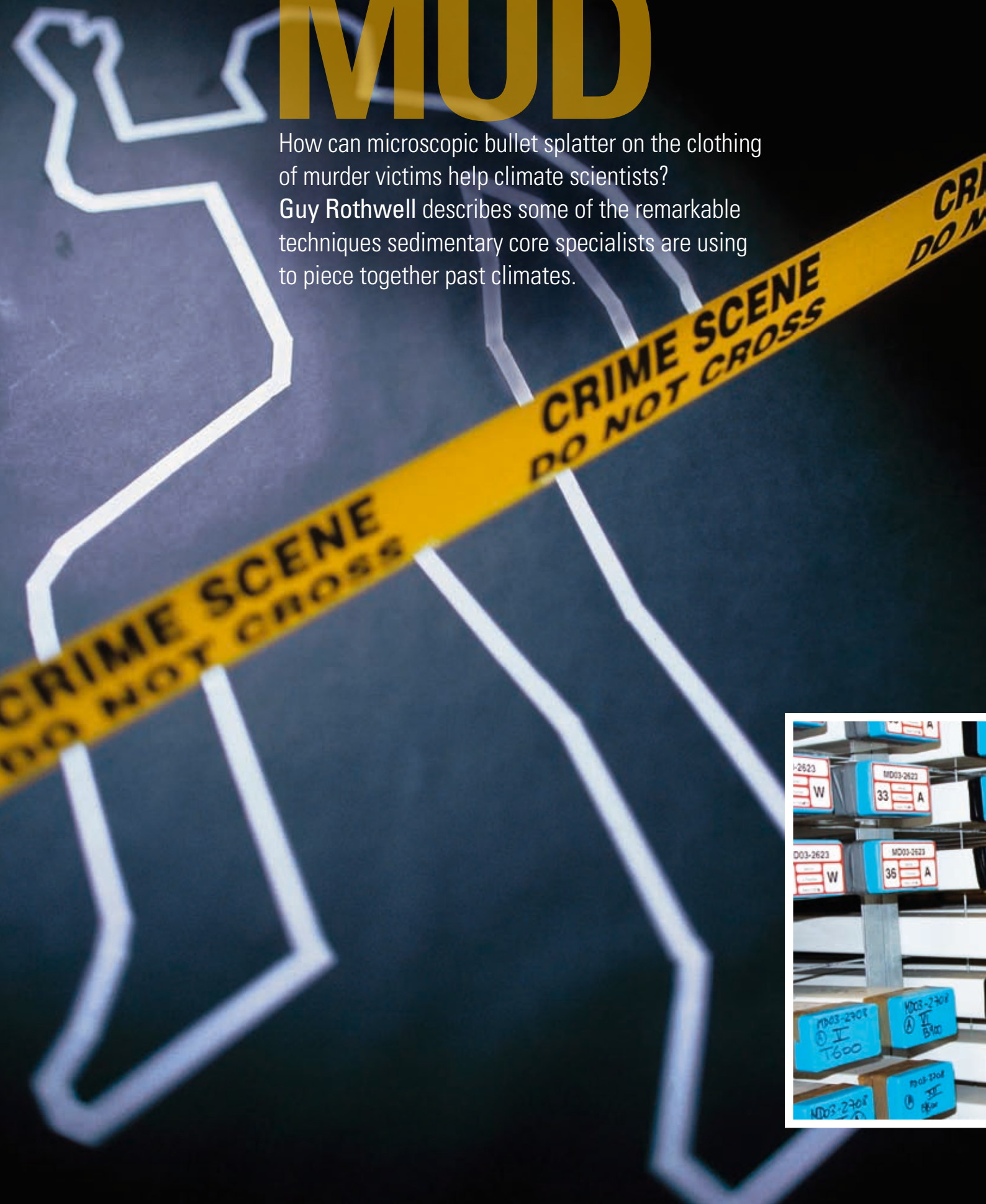


Stuck in the **MUD**

How can microscopic bullet splatter on the clothing of murder victims help climate scientists?

Guy Rothwell describes some of the remarkable techniques sedimentary core specialists are using to piece together past climates.



In the summer of 1773, Captain John Phipps aboard HMS *Racehorse*, an eight-gun privateer captured from the French in 1757, led a two-ship expedition to Arctic waters in an attempt to discover a north-eastern passage to India. Accompanied by HMS *Carcass*, whose crew included a 15-year-old midshipman called Horatio Nelson, Phipps abandoned his quest after becoming trapped in ice north of the Norwegian island of Spitsbergen.

One day on this British naval expedition marked the beginning of a new kind of scientific exploration that continues to this day at the British Ocean Sediment Core Research Facility (BOSCORF). This is a NERC-funded community facility located at the National Oceanography Centre, Southampton.

On the historic day, the two ships crossed the southern margin of the Vøring Plateau north of Norway. Above the plateau, the crew on board made one of the earliest attempts at a deep-sea sounding, achieving a depth of 683 fathoms (1249 metres).

They were successful and recovered a sample of 'fine soft blue clay' – the first recorded description of sediment from the deep-sea floor. Today, sediments from the deep-sea floor form the basis for a whole range of scientific and industrial investigations, on which our world's well-being depends.

Information obtained from these types of sediments is used for mapping and surveys, oil and gas exploration, national resource assessment, pollution studies, laying submarine cables and the siting of seafloor structures. Life within these sediments – and there is more life here than you could possibly imagine – may

provide the antibiotics of the future. And, perhaps most pertinently, trapped in these sediments, if you know how to look, is a long history of the Earth's climate and the resulting environmental change.

Journey back in time

Climate researchers often use ice cores and tree rings to determine past climate histories. Tree rings give accurate dates going back maybe hundreds or thousands of years. Ice cores delve deeper; the longest stretches 800,000 years into the past. In contrast, deep-sea sediment cores are one of the few records of past climate that can extend back on timescales of millions of years. One of the world's most ambitious collaborative research programmes – the Ocean Drilling

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Program* – has recovered sediment cores ranging in age from the last decade back to the Triassic Period, nearly 227 million years ago.

The Triassic may have been one of the hottest times in Earth history. During this period, Earth was dominated by an enormous super-continent called Pangaea. The continent's vast size limited the climatic effects brought about by oceans, so the interior suffered very hot summers and cold winters. Ocean Drilling Program cores show the climate was predominantly hot and dry. There was no ice at, or near, either

pole, which were warm and temperate – a veritable 'hot house' Earth.

The significance of this kind of research is underlined in the fourth report from the Intergovernmental Panel on Climate Change, published in 2007. This report forms the basis of global climate policy. For the first time, it contained a dedicated chapter on palaeoclimate, or the study of the ancient climate. The reason is clear: knowing how the climate changed naturally in the past, and what caused this, is improving future predictions. It allows researchers to separate out human influence from natural variability.

Deep-sea sediments can provide long, undisturbed and continuous records that are ideally suited for climate studies,

unlike terrestrial sediments which can be incomplete because of erosion or other processes.

Cores are delicate and can dry out and fracture within months unless stored under optimum conditions. If they are damaged this limits their value for further research. NERC has spent many millions of pounds collecting sediment cores from the deep-sea floor. Previously there was a tendency for scientists to retain ownership of cores. But many cores, and the valuable environmental records they contained, were lost or damaged.

Now BOSCORF stores and helps preserve these assets. If cores are moisture sealed and refrigerated, they can remain pristine for decades. This means researchers in the future, equipped with yet-to-be-thought-of technologies and concepts, can resample the cores and make new discoveries about the past.

Our large refrigerated stores keep cores in perfect condition. But we also provide UK researchers with access to the most comprehensive suite of state-of-the-art core logging instruments available in Europe.

Taking samples from cores is destructive – eventually there may be nothing left. But now we can analyse cores without physically cutting into them, and use the data to help focus where to take future samples for analysis.

Ideally, climate researchers need high-resolution information about past environmental change on timescales of a



Cores are stored at 4°C and sealed against moisture loss.

year, or even less. Realistically, centennial and decadal timescales have been achievable in the past. BOSCORF's quest to provide researchers with the tools needed to analyse palaeoenvironmental records at the highest possible resolution has led us to team up with a Swedish Company, Cox Analytical Systems based in Gothenburg.

Crime scene investigation

This collaboration may not be an obvious one. Cox was more at home dealing with all manner of criminal forensics. Police call its experts in to identify bullets and determine shooting distance from microscopic bullet splatter on the clothing of murder victims. They also helped in identifying forged and altered documents through geochemical changes in ink composition.

What interested us was that Cox had developed an X-ray fluorescence (XRF) microscope. This is a non-destructive method – the sample does not need to be sliced – of mapping element distributions at very high resolution. It is ideally suited to forensic applications, like identifying bullet types; identifying and recovering textile fibres and paint chips; and detecting forgeries and alterations to documents. From our point of view, it is also perfect for geological research.

Before this technology, we had to do geochemical analysis of sediment cores at low resolution because of the difficulties of manually slicing the sample any thinner than about a centimetre. And it took several weeks to process. The new instrument, called the ITRAX corescanner, can get down to an impressive, and previously unheard of, 0.1 millimetres. It does this by

Our large refrigerated stores keep cores in perfect condition.

tightly focusing an X-ray beam onto the sample through a glass capillary wave guide. What's more, the instrument can analyse cores unattended on overnight runs, giving scientists the data they need while they sleep.

The element data generated can indicate ancient or palaeorainfall, land water run-off, wind strength and how dusty the climate was, how life in surface waters changed over time (from barium content) and a wide range of other environmental data. The ITRAX corescanner is now an essential tool for palaeoceanographers and researchers studying climate change and environmental pollution. BOSCORF holds the only instrument in England available to researchers.

Medicines from the deep

The value of deep-sea cores goes beyond climate and Earth science. Indications are that new life-saving antibiotics may come from substances found in deep-sea sediments.

One of the most exciting marine science discoveries of the last decade is that the sediments of the deep ocean are home to a thriving microbial habitat. Some say these habitats account for ten per cent of the world's total biomass and more than 60 per cent of all bacterial biomass on Earth.

Like all microbe communities, these

microorganisms compete with each other for space and energy. They produce compounds to limit or destroy rivals. Because these bacteria have evolved largely in isolation from the bacteria that cause disease in animals and people, terrestrial bacteria have no resistance to some of them. This makes them likely candidates for the next generation of antibiotics.

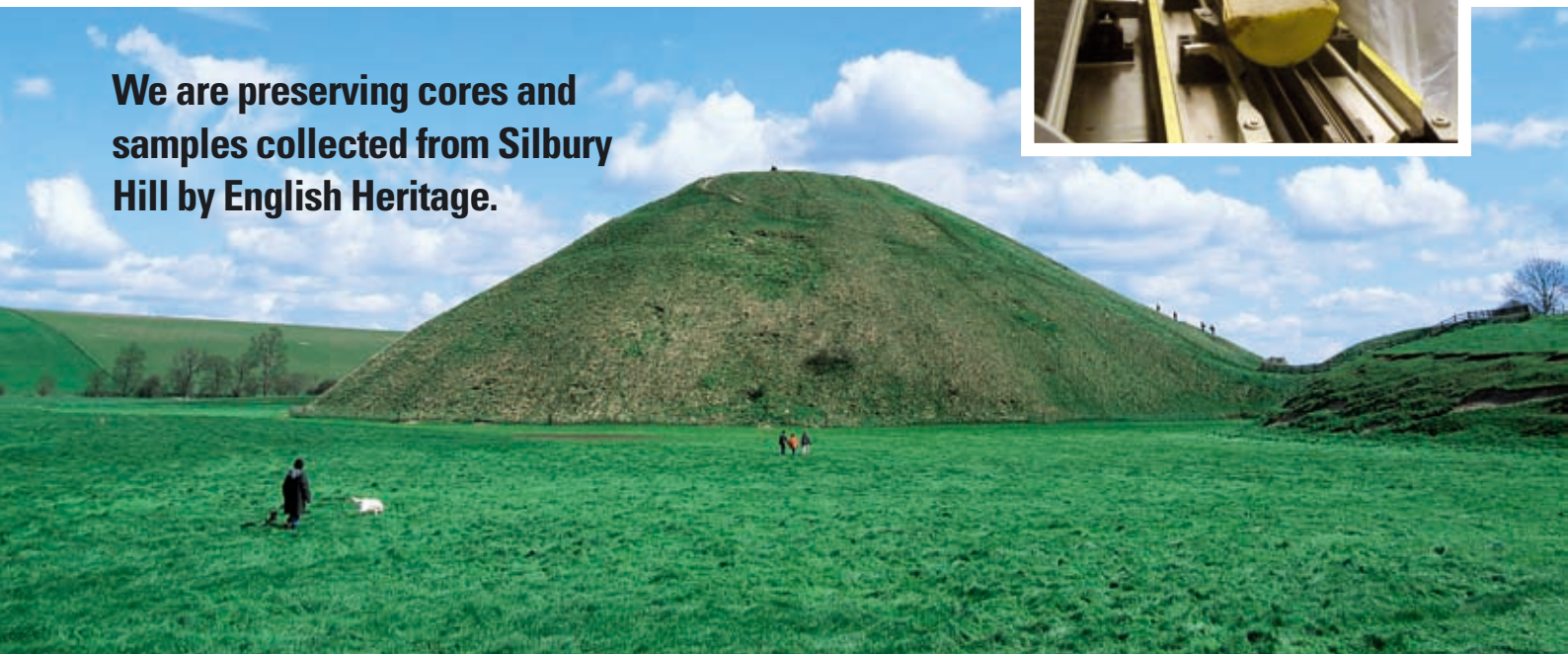
In 2005, scientists on NERC's £5 million Marine and Freshwater Microbial Biodiversity programme announced that they had found a microbe, *Verrucosipora maris*, in sediments from the Sea of Japan. The microbe produces a unique antibiotic, abyssomicin C, which has properties that seem to inhibit the hospital 'super bug' MRSA.

Scientists have identified other deep marine bacterial strains, producing chemically diverse antibiotics from BOSCORF cores, showing our scientific value now extends into medicine and


The ITRAX corescanner. This gives unprecedented detail down to 0.1mm and is the only one in England.



We are preserving cores and samples collected from Silbury Hill by English Heritage.



A mud core being retrieved from the deep ocean during an expedition with the Integrated Ocean Drilling Program.



Many cores in our store are regarded as internationally important, attracting researchers from all over the world.

William Crawford/IODP/TAMU

pharmacy. Indeed, recent advances in coring technology, such as the development of pressurised corers that can recover deep-sea sediments and preserve them at in situ pressures, allowing deep-sea sediment-dwelling microbes to be cultured, promise a new generation of treatments and possibly cures for a variety of medical conditions.

Our core collection, currently some 1400 cores, continues to grow by about 100 more cores each year. Many cores in our store are regarded as internationally important, attracting researchers from all over the world.

Besides deep-sea sediment cores, researchers are collecting large numbers of cores from lakes, peat and loess (windblown silt deposits). These often give even higher-resolution information on past environments.

Sediment cores from lake bottoms have unrivalled temporal resolution compared with other archives of environmental change. We've resolved seasonal changes within a single year using the ITRAX core-scanner on lake cores collected in Scotland as part of NERC's Rapid Climate Change programme. Different ratios of calcium to iron can distinguish the clays deposited in the winter months from the silts laid down

during the summer melt season. Analysis at such high resolution helps us establish whether climate events in Britain occurred at the same time as those in other parts of the north Atlantic region and continental Europe.

Unravelling prehistoric mysteries

Silbury Hill in Wiltshire is the largest prehistoric man-made mound in Europe. The hill was built about 4400 years ago. It took an estimated four million man-hours of hard labour to complete – a remarkable feat of prehistoric organisation and engineering. Beyond that, little is known.

We are preserving cores and samples collected from the hill by English Heritage. These cores and sediment samples, collected during vital stabilisation works in 2007-8, will help answer more precisely key questions such as how the hill was built, when it was built, and how long its construction took.

Increasingly, archaeologists are collecting cores like these through prehistoric landscapes before they are destroyed by climate change and development.

Sediment cores are ultimately the only true record of environmental history. They

can be put to many uses, and these uses are constantly changing as new technologies develop.

We can only validate models of past environmental changes by examining the record of the past preserved in sediment cores. Right now we really need this information. The environment is changing fast. The consequences of human activities, such as increasing carbon dioxide concentrations, are now affecting the world in ways unprecedented in our history.

Sediment cores are often the only way to get a glimpse of global conditions when carbon dioxide concentrations were this high, and of how the environment changed as a result. National core analysis and storage facilities, such as BOSCORF, are fundamental both to understanding the world of the past and to predicting the world of the future. ❖

**Currently the Integrated Ocean Drilling Program involves collaboration between 21 countries.*

MORE INFORMATION

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