Down by the river

Did you know that there are channels, very similar to rivers, on the seafloor, and that these channels can be kilometres wide and thousands of kilometres long? Our work, part of the Ocean Margins LINK programme, has shown how important these channels are to the oil industry.

These deep-sea channels are formed by dense underwater flows, like avalanches of mud, which hug the ocean floor. Just as water is more dense than air and flows through river channels, sediment can be suspended in water to form a flow that is more dense than the surrounding sea water. This flows along sea-floor channels. The dense flows come from muddy river floodwaters, or when sediment is mixed with sea water during underwater landslides.

Seafloor channels are extremely important. Once formed these convenient pathways move massive amounts of sediment – made up of topsoil, sand, minerals and associated pollutants - from rivers and shallow coastal waters to the deep sea. Sedimentary rocks formed from ancient seafloor deposits contain preserved seafloor channels, and these sandy deposits form some of the world's major oil and gas reservoirs.

Given their importance, you might be surprised to hear that until recently, very little was known about the behaviour of sediment-laden flows within these channels. In fact, until now, scientists had assumed that flows within these seafloor channels behave in almost exactly the same way as rivers. Recent research by our team at the University of Leeds has shown that flow in seafloor channels is dramatically and unexpectedly different, with the flow spiralling in the opposite direction to the flow of water in rivers – this has quite a bearing on where the sediment eventually settles, so it is useful information if you're trying to locate these kind of deposits.

Rivers can be quite easy to measure – you can wade or swim in some, float on others in boats, and deploy equipment from their banks and from bridges. In contrast, it is exceptionally difficult to measure flows in seafloor channels, due to the infrequent and highly

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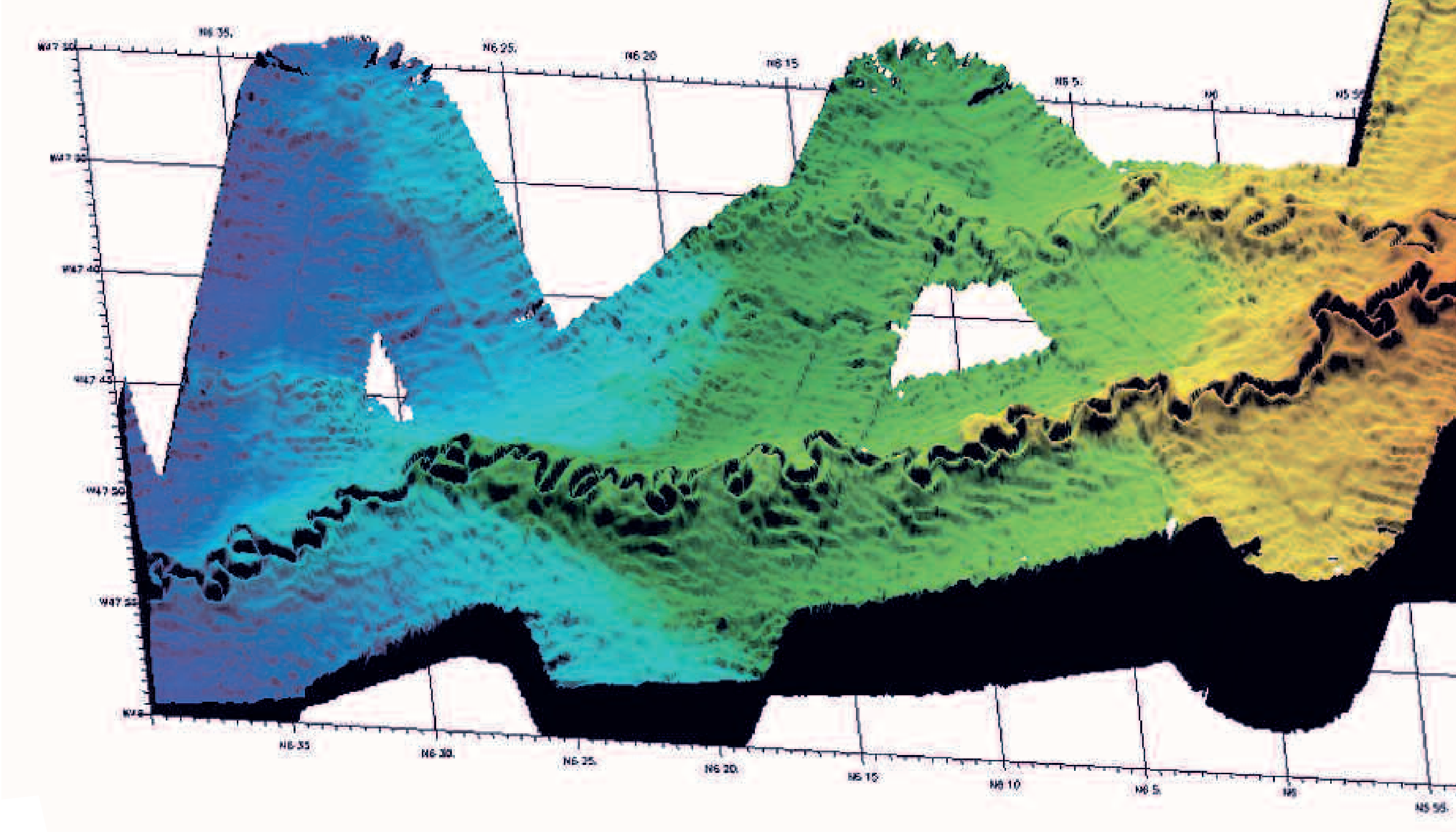
Over the last 75,000 years sediment from the Amazon River has created this 800km long channel beneath the Atlantic. The image shows a 200km long section of the channel, which is 4km wide with banks 100m high. Image courtesy of Bruno Savoye, IFREMER.



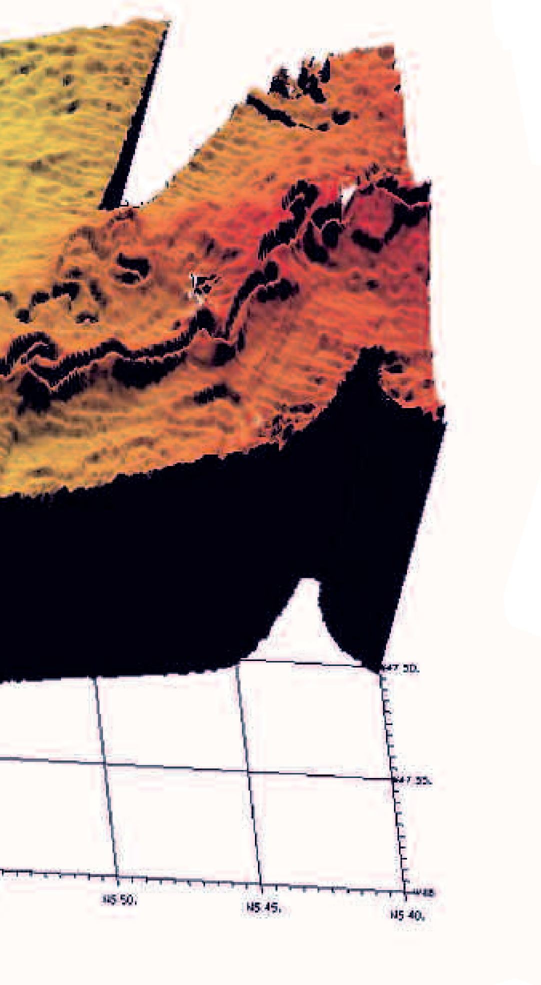
Deep-sea rivers flowing through troughs and valleys on the seafloor behave in the most unusual way, and hold a key to improved oil and gas extraction, say **Kathryn Amos** and **Jeff Peakall**.

This work was part of NERC's Ocean Margins LINK Programme – see page 24. The team hold their end of programme event on Thursday, 15 February 2007, at the Royal Society, London. See www.nerc.ac.uk for more information.

Find out more
http://earth.leeds.ac.uk/~earjp/bends

destructive nature of the flows themselves and the difficulty of measuring hundreds of metres below the surface of the sea and tens to thousands of kilometres from land. Consequently, data from these channels is very limited and insufficient to investigate the dynamics of flow. To overcome this limitation we built a meandering channel out of fibreglass, to fit into a large, two-metre-square tank. We filled this tank with water, and pumped a dense salt-water flow into the channel, to simulate the flow of muddy water on the seafloor.

We measured flow velocities using equipment with probes like underwater speed cameras that measure the speed of tiny particles within the flow. This allowed us to put together a three-dimensional picture of the movement of the fluid as it flowed along the channel. To simulate sediment transport and deposition by these flows, we placed a bed of plastic particles in the channel, and ran salt-water flows over the top.



When water in a river flows around a bend, different forces combine to control the movement of the water. The main forces are the centrifugal force – the force that pushes you sideways when you drive quickly around a bend in a car – and a pressure force from the weight of water in the channel. At different depths below the water surface, these forces combine with the speed of the water to control the direction the water moves in. In rivers, this results in an overall spiralling of water as it flows downstream. Close to the riverbed, water flows from the outside of the bend to the inside of the bend as it moves downstream, and close to the water surface, there is an overall movement of flow from the inside of the bend to the outside of the bend as it moves downstream.

The results from our experimental models of seafloor channels showed that in these channels, this spiralling of flow moved in the opposite direction to that in rivers. Using mathematical modelling that was originally used to describe flow in rivers we were able to explain why this happens. In the dense flows that form seafloor channels, the highest downstream velocities occur close to the bed, whereas in rivers, the highest downstream velocities occur close to the water surface. This alters the balance of the forces that control fluid motion, and causes flow in seafloor channels to rotate in the opposite direction to rivers.

We were stunned. In over a hundred years of studying flow around bends, scientists have only observed flows to spiral in one direction. The results are important as they will allow scientists to better understand the formation of seafloor channels, and the ways in which sediments and other materials such as pollutants are transported to the deep sea. It also has a wider importance, because it increases our understanding of the controls on flows within all types of channel. For example, some rivers have velocity changes with depth that are different to that observed in a typical river profile (see 'Sounding out our coastlines and rivers, *Planet Earth*, Spring 2006), and our results might help to explain observed differences in flow patterns within these rivers. Our results will also help to understand the dynamics of volcanic eruptions that flow along river valleys.

Interestingly, the sedimentary deposits formed by these flows share some broad similarities to the deposits which form in rivers. They had a deep pool towards the outside bend, and a build-up of particles towards the inside bend, similar to point-bar deposits of sand and pebbles that form in rivers. However, the reversal of the spiralling motion of the flow causes a number of key differences compared to river deposits, with variations in the shape, position, and sediment distribution of these point-bars. Our new found understanding of these sedimentary deposits, and the differences compared with rivers, has real potential for improving oil and gas extraction from the deposits of seafloor channels.

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