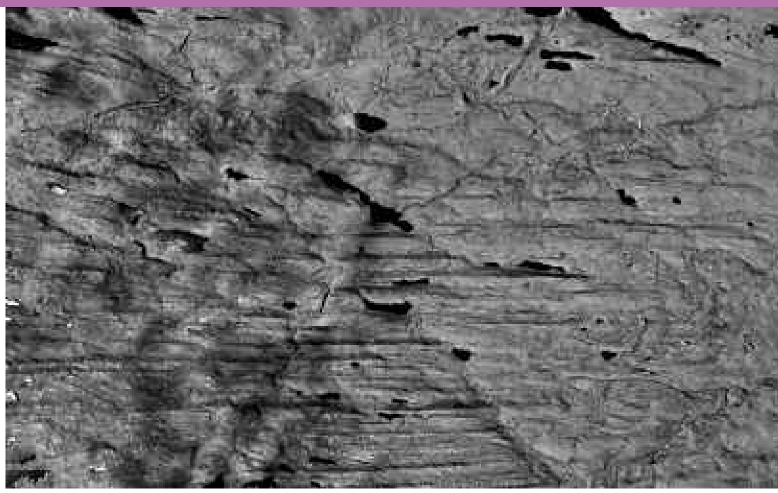
Scratching the surface

Martyn Stoker and colleagues use remote sensing techniques to reconstruct just how far offshore the Pleistocene British Ice Sheet extended.



Huge grooves in the bedrock in north-west Scotland.

During the last 500,000 years the British ice sheet grew and decayed several times. During ice ages, ice masses grew in the mountains of northern Britain, spread out and met up to form ice sheets that covered the lowland landscape, including parts of the continental shelf that are now underwater. The position of the ice sheet's farthest reaches on land are reasonably well known, particularly for when the ice was last at its greatest, during the last glacial maximum between 25,000 and 18,000 years ago. But no one is sure how far the ice reached under today's sea. Conflicting models argue for scenarios ranging from ice advancing to where the continental shelf plunges to the deep, to ice terminating only a short way offshore. If we can reconstruct the volume of the ice-sheet, the corresponding drops and rises in sea level and how the melt-water affected the major current in the North Atlantic (the thermohaline circulation), we will better understand how the oceans, atmosphere and frozen environment interact as a system, and so better understand worldwide environmental change.

But to reconstruct ice sheets accurately, we need clear images of the seabed and of how the glaciers scoured it and shaped it into forms such as piles of rock and rubble dumped at the end of a glacier (moraines). Scratch marks and moraines would provide unequivocal evidence of where the ice reached during the last glacial maximum.

> At times the British ice sheet pulsed with fast-flowing glaciers as its arteries

Recent evidence for ancient glaciers on the continental shelf off north-west Scotland and in the North Sea has livened up the debate over ice limits. At the British Geological Survey and Imperial College, we have combined evidence of glaciers on land with new images of the seabed to investigate the glaciers' direction from onshore to offshore. Geophysical imaging techniques provide the equivalent of aerial photographs of the seabed, as well as former seabed surfaces that are now buried.

In the Assynt region of north-west Scotland, aerial photographs show a streamlined crystalline bedrock surface cut by deep, wide parallel grooves, covering an area of about $150km^2$. Under the sea, between Assynt and Lewis, marine side-scan sonar investigations revealed that the softer, sedimentary, seabed is covered in closely spaced, very long ridges and grooves. These ridges and grooves show where the ice moved fastest. The sea-bed scratches run along a trough extending away from north-west Scotland and across the continental shelf. This trough feeds into a big fan, like a delta, in deep water, called the Sula Sgeir Fan. Map-form seabed images (from 3D seismic reflection data) and seismic reflection profiles, which give a cross-section through the seabed, show moraines preserved at the end of the ice sheet on this sea-floor trough. Thus, it is likely that ice streams emanating from north-west Scotland throughout the last 500,000 years have, from time to time, fed the Sula Sgeir Fan.

Meanwhile, off the coast of eastern Scotland, much discussion has centred on whether the British and Fennoscandian ice sheets joined together in the North Sea during the last glacial maximum. By 'stripping off' the surface layers, 3D seismic reflection surveys show ancient seabed surfaces covered in huge glacial scratches. These provide the strongest evidence yet for extensive ice cover across the North Sea when the various ice ages were at their heights.

Whilst we continue to get a better idea of how the shape of these Pleistocene ice sheets evolved, our regional geomorphic approach to marine landscape evolution is leading to an improved understanding of how the glaciers in the British ice sheet behaved. Our results, so far, suggest that during the last glacial maximum the British ice sheet was constantly advancing and retreating and at times pulsed with fast-flowing glaciers like arteries. It also extended a considerable distance offshore.

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