Hunting the last ice sheet

The seabed around Scotland is giving up the secrets of the last ice age. Kate McIntyre and John Howe explain how.

Rannach Moor.

Scotland has been subject to repeated glaciations over the past 2 million years – the evidence is all around in the wild and rugged landscape, the ice-carved glens and dramatic sea lochs. Yet the landscape beneath the sea is now also beginning to reveal further clues as to the extent and dynamics of the British Ice Sheet.

We are re-evaluating the extent and effect of the last northern ice cap to have occurred in the UK. The ice cap existed in Scotland during a cold period termed the Younger Dryas. This rapid cooling at the end of the last glaciation may have been caused by a temporary slowing of ocean circulation, or even perhaps by a meteorite impact in North America that led to a decrease in global temperature. Such short, cold climatic events are called stadials; the Younger Dryas stadial occurred between 12,800 and 11,500 years ago – very recently, geologically speaking!

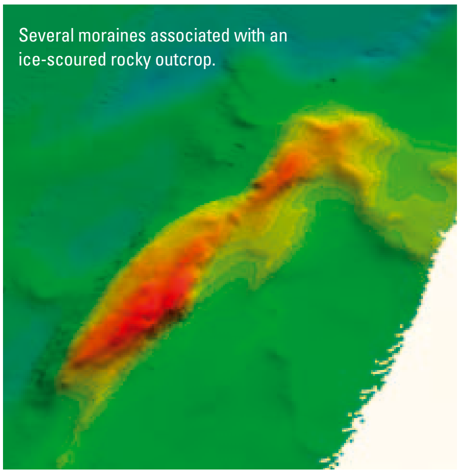
During this time a large ice cap covered much of western Scotland. Modelling studies and onshore fieldwork in the area have established the assumed limits of the ice cap. And with the development of more advanced geophysical techniques, we are now examining the offshore marine record. Studying the marine environment has many advantages; the main one is its ability to preserve ancient climates, both in the shape of the seabed and in the layers of sediments that accumulate there.

My PhD project, funded by NERC and based at the Scottish Association for Marine Science (SAMS) in Oban, investigates the offshore records of Scotland's last ice cap. This involves examining sediment records, and mapping the underwater limits of the ice cap by collecting and interpreting multibeam sonar data. Multibeam systems use multiple beams of sound directed at the seabed to build an accurate acoustic map of the underwater landscape. We used SAMS' new Reson Seabat multibeam system to carry out the mapping from research vessel R/V *Calanus*.

Fjords – better known in Scotland as sea lochs – are carved into the landscape by glaciers, and act as outlet conduits for ice and water draining seaward from their main ice caps. This means they often preserve moraines – ridges of gravel, sand and rock left behind as the glacier retreats – within their basins. We can identify these moraines on the seabed by multibeam mapping.

Loch Linnhe is the south-westerly end of the Great Glen Fault which cuts across Scotland to the Moray Firth on the east coast. During past ice ages, the loch was a major outlet for glaciers from the Rannoch Moor area, where ice built up in the initial stages of development. Our recent multibeam survey of Loch Linnhe discovered moraines that suggest that the Younger Dryas glacier may have advanced significantly further down the loch than was previously thought from onshore field mapping evidence.

Further evidence for a more southerly limit is contained in sediments from the sea floor. We have found very heavily compacted sediment in a core sample taken much further south than the mapped onshore limit of the glacier. The only way for the sediment to become so compacted is by the crushing weight of ice passing over the top of it, so the glacier must have reached at least as far south as the position of this core.



Several moraines associated with an ice-scoured rocky outcrop.

The glacier seems to have retreated in several stages, each being marked by a recessional moraine deposited at the front of the glacier when it paused in its long retreat, or even returned briefly to advancing. This stepped pattern of retreat has also been observed in the Summer Isles region in north-west Scotland. Here, a multibeam survey by the British Geological Survey in 2005 revealed a similar pattern of recessional moraines preserved on the seabed.

Mapping beneath the waves

As well as the Loch Linnhe research, my fieldwork has involved sea-floor mapping in the Sound of Sleat and further out to sea, west of the Isle of Muck. Scotland's west coast, with its many lochs, glens, mountains and islands, is well known for its outstanding natural beauty, and it has been a huge privilege to have the opportunity to carry out my fieldwork in this area. The Linnhe survey was carried out in

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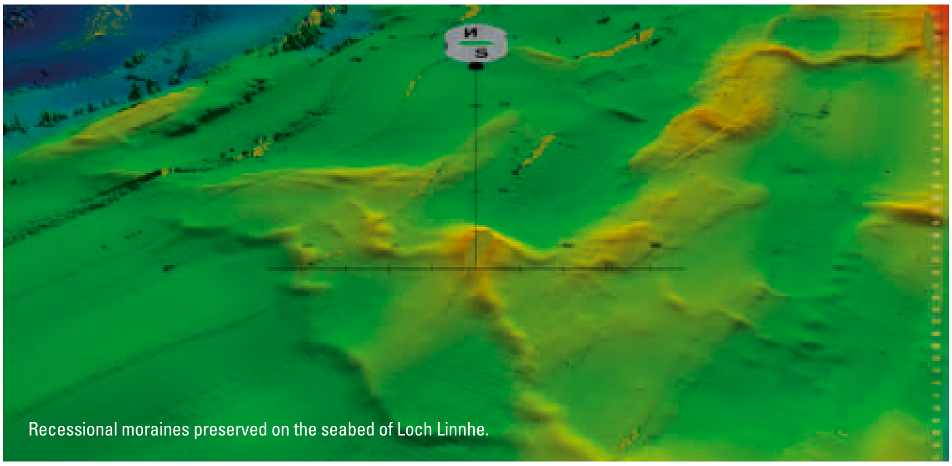

Recessional moraines preserved on the seabed of Loch Linnhe.

February, but we were blessed with beautiful weather and calm conditions. The *Calanus* made her way up and down the loch at a sedate surveying speed of three to four knots, offering alternate views of the snowy mountain peaks of Glencoe to the north-east and the raised shorelines around the Firth of Lorne and the island of Lismore to the south-west.

Meanwhile the multibeam transducers beneath the boat were pinging away, picking up the returning echoes of sound and translating them into a beautiful seafloor image on our onboard computer screen. It was fascinating to watch as features such as moraines and ice-scoured rocky outcrops appeared on the screen, revealing a hitherto unseen complex underwater landscape. Later in the Sound of Sleat, we weren't so lucky – a storm blew up in the middle of our first day's survey and we were forced to batten down the hatches and make our way back to Mallaig harbour through the mountainous waves. Fortunately we had already mapped a large moraine outside the mouth of Loch Hourn, demonstrating that, as in Loch Linnhe, the ice here extended further seawards than the onshore evidence suggests.

The raging weather trapped us in the harbour for the rest of the week, but the following Monday dawned blue and sunny. We steamed out past the islands of Rum, Eigg and Muck and surveyed the Muck Deep – a long, narrow depression in the seabed carved out during earlier ice ages, when ice sheets much bigger than the Younger Dryas ice cap covered vast areas of North America and Europe. At 320 metres, the Muck Deep is one of the deepest points on the UK continental shelf (the area of shallow sea surrounding land, which rarely exceeds 200 metres in depth). The survey was carried out over three days of silky seas and utter tranquillity; we were even briefly joined by a pod of bottlenose dolphins which swam around and underneath the bow of the boat, much to the delight of crew and scientists alike.

At present there is considerable debate over the extent and timing of the short-lived Younger Dryas event. The stadial interrupted a period of warming at the end of the last ice age, plunging the northern hemisphere back into glacial climate conditions. The big question that is vexing glaciologists is whether or not the Younger Dryas ice cap grew from nothing after the main ice sheet disintegrated. Numerical models predict that it could have done – but this disagrees with the recent offshore evidence, which shows that the glens and sea lochs of western Scotland were filled with glaciers to some extent even during the warm period before the stadial.

Questions like these might seem a little esoteric and only of interest to academics, but modern and recent climate models are being used to predict climatic change over short timescales measured in decades. To test these models, it is vital that we have as much information as possible about how climate has changed in the past and how these changes have affected our environment. If the models can accurately 'predict' climate change that we know has already occurred, then we can have much more confidence in predictions they make about the future. Studies like ours provide the evidence for past climate change, against which ice-sheet and climate models can be tested.

MORE INFORMATION

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