# ‘Weathering Extremes’ at Caerlaverock in Scotland: reconstructing climate change and its impacts

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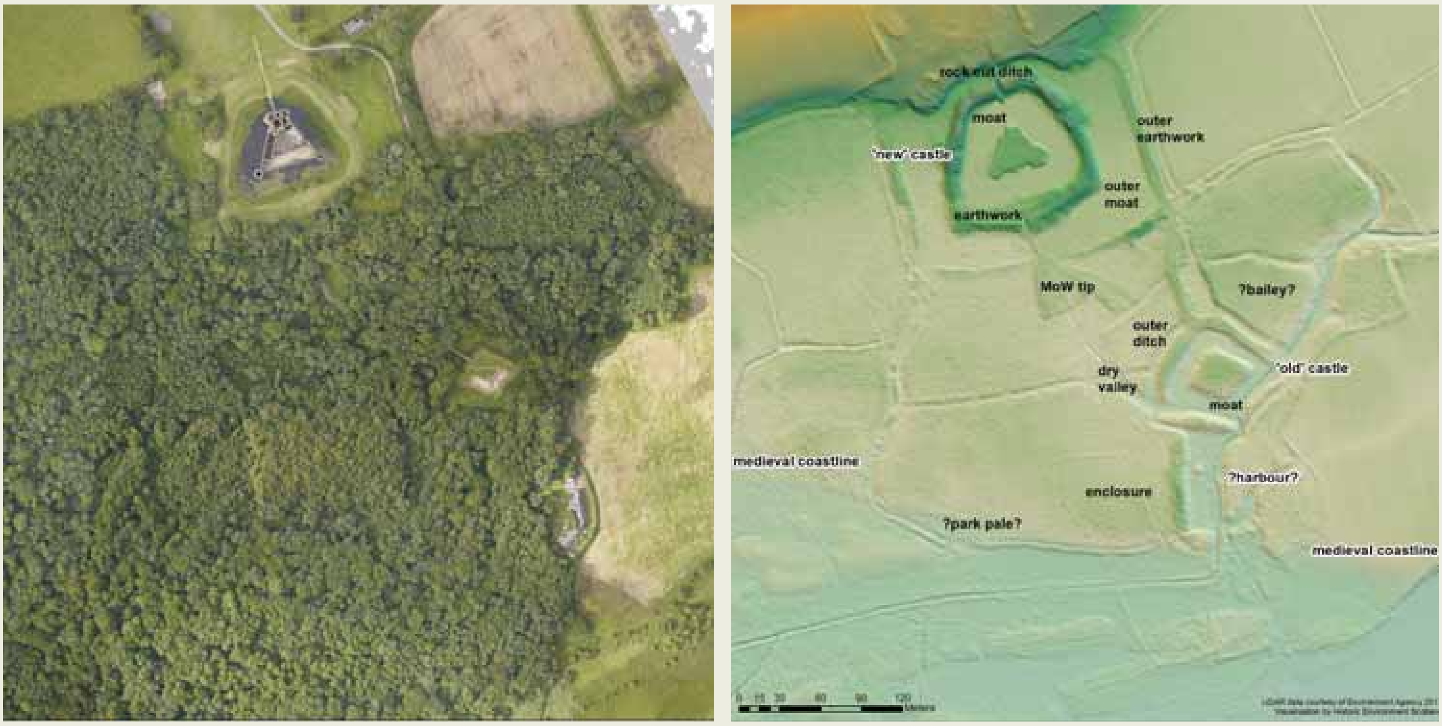
**‘Weathering Extremes’ was a research project jointly funded by HES and the Castle Studies Trust, in which we explored the impacts of huge storm surges on the landscape and the medieval castles at Caerlaverock.**

The ‘old’ (bottom) and ‘new’ (top) castles at Caerlaverock. Credit: HES

There are two medieval castles at Caerlaverock, on the north shore of the Solway Firth, eight kilometres south of Dumfries. One was constructed in 1229–30; the other, inland, was begun in 1277. Today they are separated from the firth by 800 metres of salt marsh and, at low tide, by two kilometres of intertidal sand.

The rural setting and isolation give the castles a tranquil feel, and Caerlaverock is one of the most-visited HES properties. When they were built, the older castle stood right on the coast, only a few metres above the contemporary sea level, and had a ‘harbour’. The castles looked across the firth to the ‘auld enemy’ across the water in Cumbria. Indeed, the later castle was besieged in 1300 by the ‘hammer of the Scots’, Edward I, described in rich detail at the time and brought to life in the interpretation centre at Caerlaverock. But Caerlaverock also faced an older, more implacable enemy, the sea itself.

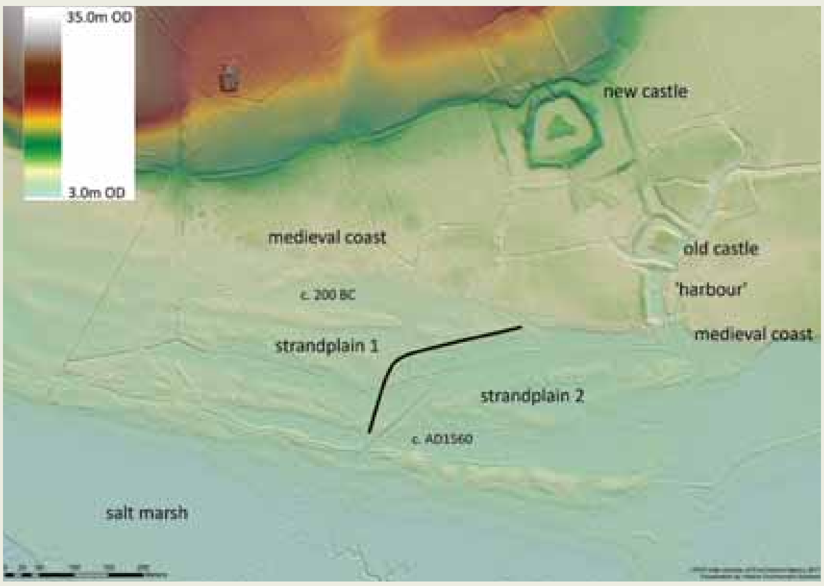
The landscape and coast of Caerlaverock. The white splash in the wood is the ‘old’ castle. The medieval coast lay where the hedge to the left is, and the yellow gorse bushes in the centre. Castle Wood conceals the geomorphological evidence for storm surges. The salt marsh formed in the early 18th century. Credit: HES




Side-by-side of aerial photograph and visualisation of the lidar data with vegetation removed (Digital Terrain Model). Credit: HES

In updating what was known about Caerlaverock for visitors, we revisited work we did 20 years ago. Then, we tentatively suggested that the older castle had been hit by storm surges, and that maybe this was why the later castle was built (Brann 2004). But we never fully got to grips with what was happening on the coast itself, the old coastline being concealed beneath Castle Wood. New lidar images, providing detailed maps of the coastline, showed us what we'd only glimpsed before.

From the lidar images we identified a coastal landform known as a strandplain, made up of a succession of storm beach ridges some 200m wide in total. The ridges are enormous, each traceable east–west for several hundred metres parallel to a low cliff, and each




Visualisation of lidar data with vegetation removed (Digital Terrain Model) showing strandplain identified by the project team. Credit: HES

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10–20 metres wide. Some have preserved lower-lying lagoonal basins, trapped during the surge and filled with re-deposited mud. The ridges stand proud of these by some two metres; it's still quite an effort to climb up one or two of these. The beaches are made of sand and gravel. Storm beaches are only created by very large storm surges; nothing like these form in the Solway today. They are unambiguous indicators of major storms, or perhaps a series of storms over a few weeks. They are invariably a result of a storm coinciding with a very high tide. A rough and minimal guide to the size of the surges comes from the altitudes of the lagoonal sediments: some of these exceeded contemporary high tides by 3–4 metres. At least one surge topped the cliff, eroded archaeological features and threw gravel 20 or so metres shoreward.

It looked at first as if there'd been maybe six or seven such surges, but when we recorded the different rock types represented in the gravel, we realised that ridges in the west were formed of different rock types to those in the east, and that we actually had two separate strandplains, side by side, formed at different times. We have evidence of at least 16 storm surges. Beaches in the west were older than those in the east. They formed as spits, extending eastward. Then at least one storm surge partially destroyed these earlier ridges, ripping into the Permian bedrock underlying these and lowering it by a metre and a half. Then the second strandplain had formed, the gravel composed of this bedrock to the virtual exclusion of rock types found in the earlier ridges. And this second strandplain formed, not as a series of spits, but from waves heading straight at the cliff – and the older castle.

We hadn't expected such wonderful preservation of these coastal features: as well as concealing the evidence, the centuries-old woodland had also protected it. We, with additional support from HES, dated the sediments in the oldest and youngest lagoons; we're currently seeking funding to date all the events recorded. We used optically stimulated luminescence (OSL) dating because all the sediment is inorganic, working with Tim Kinnaird and Aayush Srivastava at the University of St Andrews. The earliest event is Late Iron Age in date, formed around 200 BC; the youngest formed around AD 1560 as a final spit seaward that wrapped around both strandplains. But we think we have two clusters of storms, separated by a currently unknown interval. They both represent prolonged periods, when Atlantic westerly winds were much more vigorous than they are now, generated by a complex network of relationships between solar irradiance, the vigour of Atlantic Ocean circulation, the extent of Arctic sea-ice, and atmospheric circulation. Workers have for decades sought to define such storm-rich periods along the Atlantic coast; recent syntheses of medieval evidence include those by Brown (2015) and Griffiths (2015). Chronologies of dune sand construction are most frequently cited but there is real uncertainty whether wind-blown sand is always a reliable indicator of climate change. This is just one reason why strandplains and storm beaches are so valuable; they are unambiguous.

But what of the Caerlaverock castles, facing the storms? We cored the sediments filling the moat and a network of negative features around the older castle. We found organic mud only in the quadrant furthest from the sea and sparingly elsewhere; silt and sand filled everywhere else. Jason Jordan and Busie Gigranin at Coventry University undertook diatom analyses of the sediments; diatom species are sensitive to different salinities. Radiocarbon-dated and Bayesian-modelled sediment and diatom analyses combined to show that the surroundings of the older castle had been impacted on at least five occasions, around 1300, 1350, tentatively around 1400, around 1475 and around 1545. These dates make us think that the second cluster of storm beaches that formed south of the older castle began in the high Middle Ages. We still cannot say whether these surges forced abandonment of the older castle. They are later than construction of the new castle in 1277, but because the earliest recorded storm surge to impact the older castle inevitably post-dated construction of the moat in 1229–30, this may not have been the earliest impact. In a previously overlooked rectangular human-made basin west of the 'bailey', the earliest storm surge sediment signature was deposited soon after a radiocarbon date of cal AD 1158–1265. Storm surges may even have reached the newer castle, which was inland but not significantly higher.

And the 'harbour' south of the older castle? This remains an enigma. We think from OSL dating that it was constructed at the same time as the older castle, but it can't have been a harbour because its floor is higher than even spring tides reached then. It may never have been open to the sea because sediment analyses showed that still-water sediment accumulated in it when all around, storms raged.

Tim Kinnaird and Aayush Srivastava of the University of St Andrews wrapping a core taken for OSL dating. Credit: Morvern French

Flags marking the transect of cores taken in the west moat of the 'old' castle. Credit: Stefan Sagrott

Richard Tipping extracting a core in the moat of the 'old' castle. Credit: Stefan Sagrott

What do we do with all these interpretations? For one, the palaeoenvironmental data we have collected provides completely unsuspected insights into the vulnerability of this coast to past climatic impacts. Fairly diligent searching of the literature failed to detect this succession of events. Caerlaverock was home to the Maxwell family, very powerful magnates with rich documentation, yet no one seems to have noticed or mentioned what we found. When we can date all the storm surge events, we will have the most securely dated unambiguous record for Britain's west coast and will be able to embed the events in an increasingly well-understood North Atlantic palaeoclimatic context. But perhaps more important, we can show visitors to Caerlaverock the physical evidence, encourage them to explore and reflect on what they can each do to limit what might be coming in the near future.

## References

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**Morvern French**

Dr Morvern French is Properties Historian at Historic Environment Scotland, working on medieval and early modern interpretation across the estate. She is the research manager for the Caerlaverock Castle interpretation project.

**Eileen Tisdall**

Dr Eileen Tisdall is a lecturer in environmental geography at the University of Stirling. Eileen's research career has focused on the development of methodological approaches that generate palaeoenvironmental data sets tied to human activity in the landscape, which can be used to determine drivers of environmental change and people's responses to it. Much of Eileen's research is as part of an interdisciplinary team, working collaboratively with academics, specialists and archaeologists, and has included several successful projects with Historic Environment Scotland.

**Stefan Sagrott**

Stefan is a Senior Cultural Resources Advisor in the Cultural Resources team at Historic Environment Scotland, where his work contributes towards developing greater understanding of and the management and conservation of the HES estate and its cultural significance. His job necessitates him having a broad range of research interests across many periods and he is particularly keen on the use of geophysics, airborne laser scanning and photogrammetry for cultural heritage survey and protection. Stefan is Treasurer of the CIfA Scottish Group.

**Richard Tipping**

Dr Richard Tipping is a palaeoecologist and geomorphologist, who retired in 2016 from the University of Stirling. He has worked at the interface between people and the environment for nearly 40 years, largely in Scotland where environmental pressures and climatic stresses constrain much of what people can do.