Marine Geoscience Report 024

Cliffs of Moher

Overview

The Cliffs of Moher rise from the Atlantic Ocean, extending for nearly 8 km along the west coast of County Clare, from Doolin to Hag's Head, reaching heights of up to 214 m (McNamara, 2009). These vertical sea cliffs are among Ireland's most famous natural features, revealing a layered record of Carboniferous sedimentation and environmental change. They offer a continuous cross-section through deltaic sandstones, siltstones and shales deposited over 300 Ma, providing a geological archive of broader basin evolution, marine processes and glacial reshaping. Together, the geology and coastal setting make the Cliffs of Moher one of Ireland's best-known geosites.

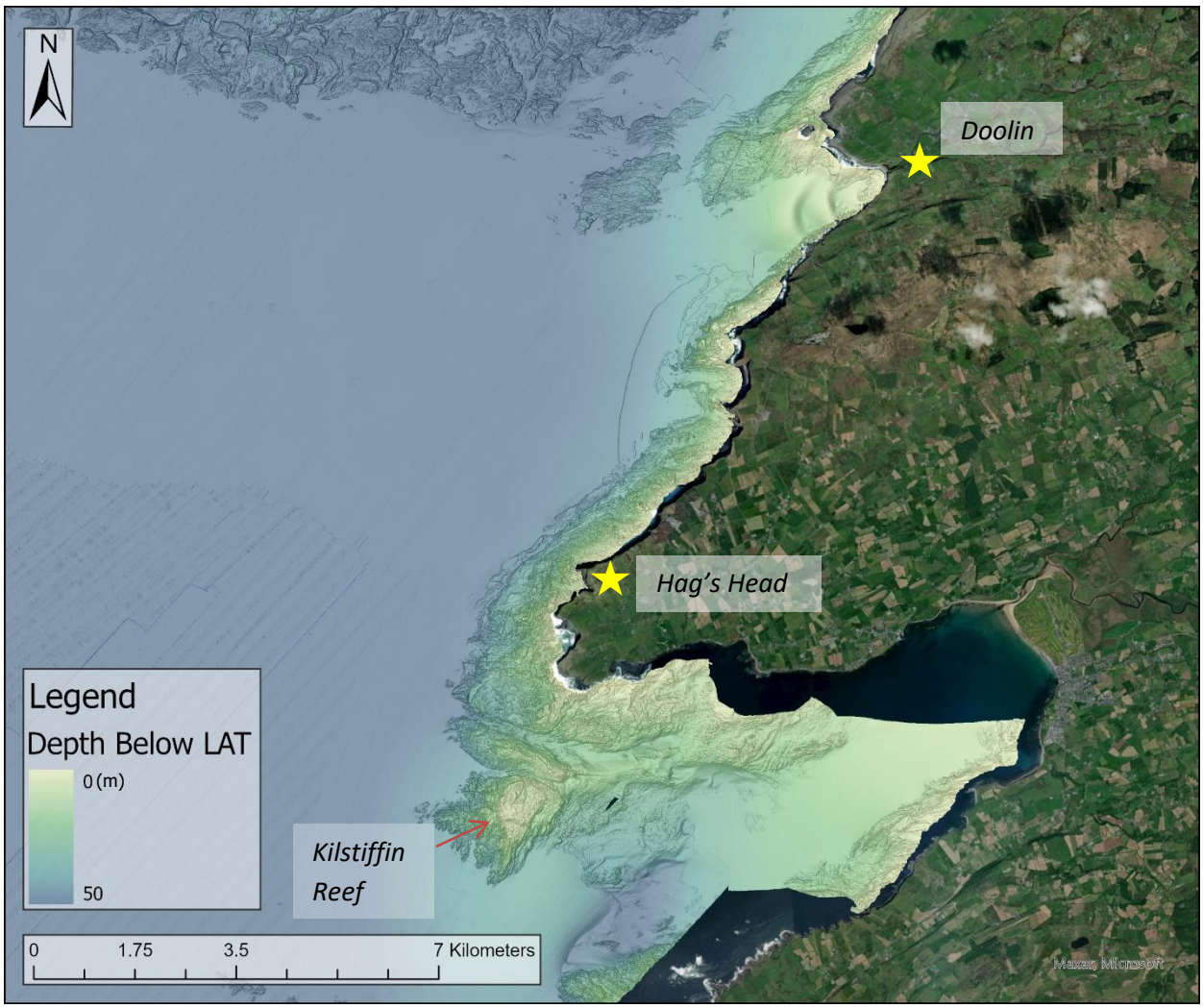

Figure 1: Bathymetry of the seabed off the Cliffs of Moher.

In addition to their geological significance, the cliffs are steeped in local mythology. According to legend, the sunken city of Kilstiffin lies beneath the waves, a golden city said to appear once every seven years, though those who see it are doomed never to see it again. Modern INFOMAR bathymetry data, however, does not show any obvious seabed feature corresponding to such a city.

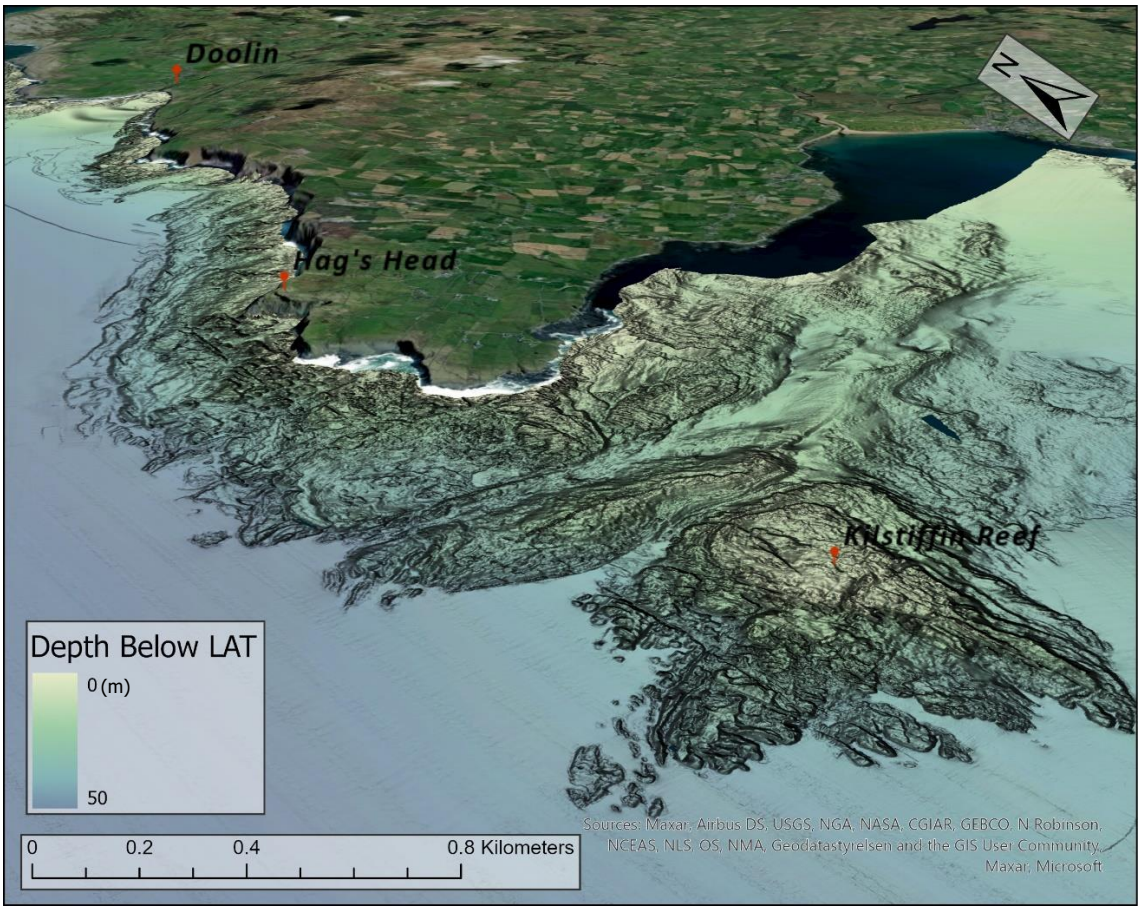

Figure 2: 3D bathymetry off the Cliffs of Moher, with Kilstiffin Reef in the foreground.

Regional Geology

The Cliffs of Moher are part of the Clare Basin, a sedimentary basin that developed during the Carboniferous Period between approximately 345 and 316 Ma, when Ireland lay near the equator (Parkes, et al., 2005). Following the erosion of the Caledonian mountain chain, a shallow sea transgressed (advanced landward over previously exposed land) across the region, depositing thick sequences of bioclastic limestones in warm, tropical conditions. These sediments formed a gently sloping marine carbonate platform, essentially a broad, shallow seabed where limestones built up, preserved today in the Burren region and parts of Galway Bay (McNamara, 2009).

Around 328 Ma, this shallow platform passed southwards into the deeper Shannon Trough basin, which was progressively filled with fine-grained shales, siltstones and sandstones. These deposits were delivered by a large delta system advancing from the south-west and are now preserved in the Shannon Group and Central Clare Group (SEPM STRATA Society for Sedimentary Geology, 2019). Later tectonic compression during the Variscan Orogeny, a continental collision and mountain building event, gently folded and faulted these strata and introduced vertical fractures (McNamara, 2009).

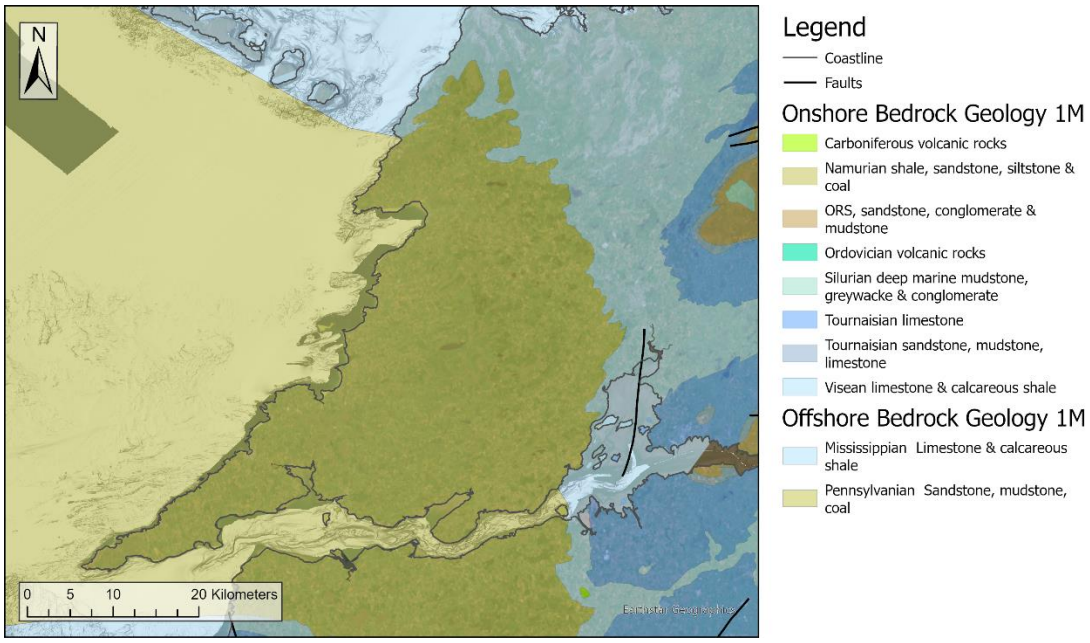

Figure 3: Regional geology of west Clare.

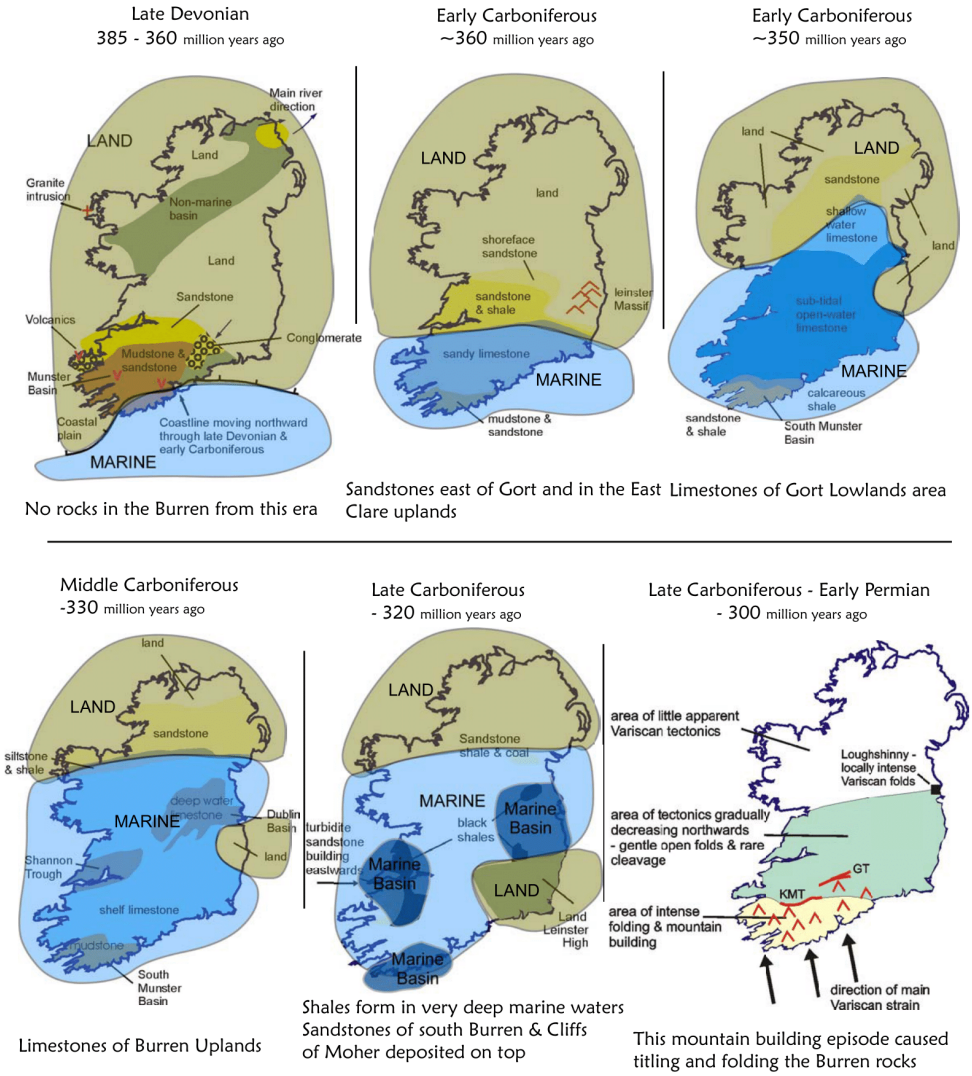

Figure 4: Palaeoenvironments in which the sediments of the Cliffs of Moher were deposited during the Carboniferous. Image from (GeoNEED, 2013).

Following the Variscan Orogeny, there is a significant gap in the geological record in the region from the end of the Carboniferous period until the Quaternary, around 2.58 Ma. This gap is largely due to prolonged uplift and erosion, which removed much of the material deposited during this interval. During the Quaternary, glacial activity further shaped the region, stripping away soil and weathered material and helping to expose the underlying bedrock (Pracht & Freely, 2004).

Formation of the Cliffs of Moher

The cliffs primarily expose Late Carboniferous sediments of the Shannon and Central Clare Groups. These include deep-marine black shales of the Clare Shale Formation, overlain by deltaic sandstones of the Ross Sandstone and Gull Island Formations. The vertical cliff faces expose features such as turbidite beds, slumped deposits and channel fills; all classic indicators of unstable delta-front environments (SEPM STRATA Society for Sedimentary Geology, 2019).

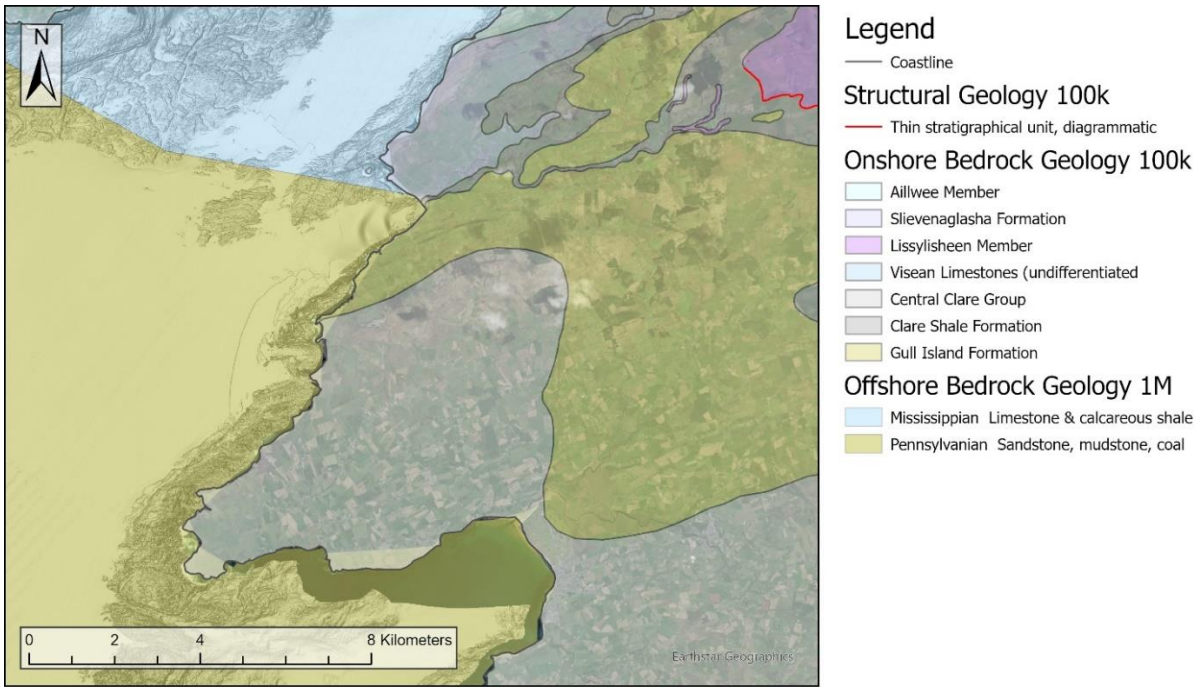

Figure 5: Detailed onshore geology of north-west Clare.

The formation of the cliffs involved several geological processes. Tectonic uplift raised the region, and prolonged exposure allowed erosion to wear down weaker beds and along the vertical fractures. During the Quaternary, glacial action and repeated marine undercutting further sculpted the coastline, ultimately producing the sheer cliff faces seen today (McNamara, 2009). These cliffs continue to retreat under the influence of wave action and weathering.

Rockfalls are common, contributing large volumes of debris to the base of the cliffs. The strata in the cliffs are almost horizontally bedded, and differential erosion between hard and soft rock layers has produced projecting sandstone ledges alternating with softer siltstone and shale beds (Doyle, 2022). These lighter-coloured sandstone layers form narrow shelves that are slightly more resistant to weathering and provide ideal nesting sites for seabirds. However, the sandstone ledges are still prone to failure over time and eventually collapse under their own weight into the sea below.

INFOMAR bathymetric data reveals a boulder-strewn seabed with slabs of sandstone at the foot of the cliffs, providing evidence of past and ongoing collapses that reflect the cliffs' geological instability and continued erosion by the Atlantic swell.

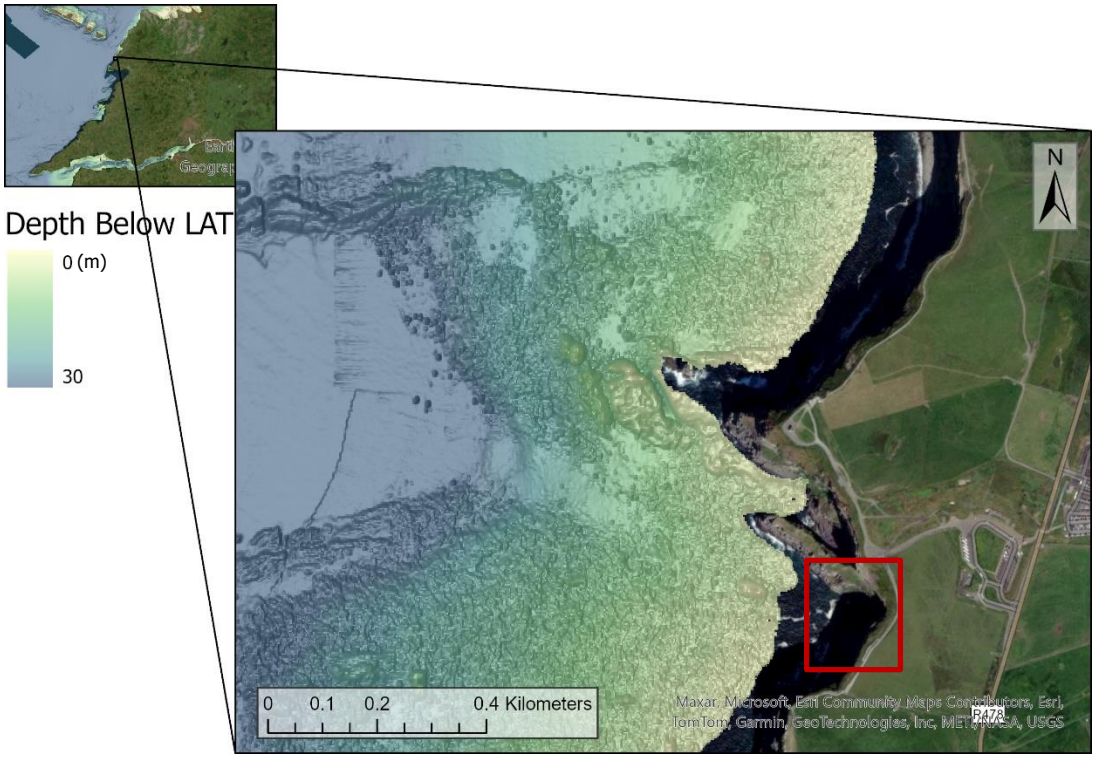

Figure 6: Bathymetric overview showing the location of the 3D model below.

Figure 7: 3D model of the cliffs, with rockfall at the base indicated. Model from (PGSimulation, 2022).

At the base of the cliffs, wave-cut platforms have formed where repeated wave erosion has planed down resistant rock layers. These platforms are exposed at low tide and provide further insight into the interaction between geological structure and coastal processes. Their presence highlights the ongoing influence of marine erosion in shaping both the cliff face and the adjacent seafloor. Where wave-cut platforms occur at different elevations and can be dated, they may preserve evidence of former relative sea levels. Their elevation and any associated sediments or fossils can therefore help reconstruct past changes in sea level or land level, offering a valuable record of sea-level fluctuations.

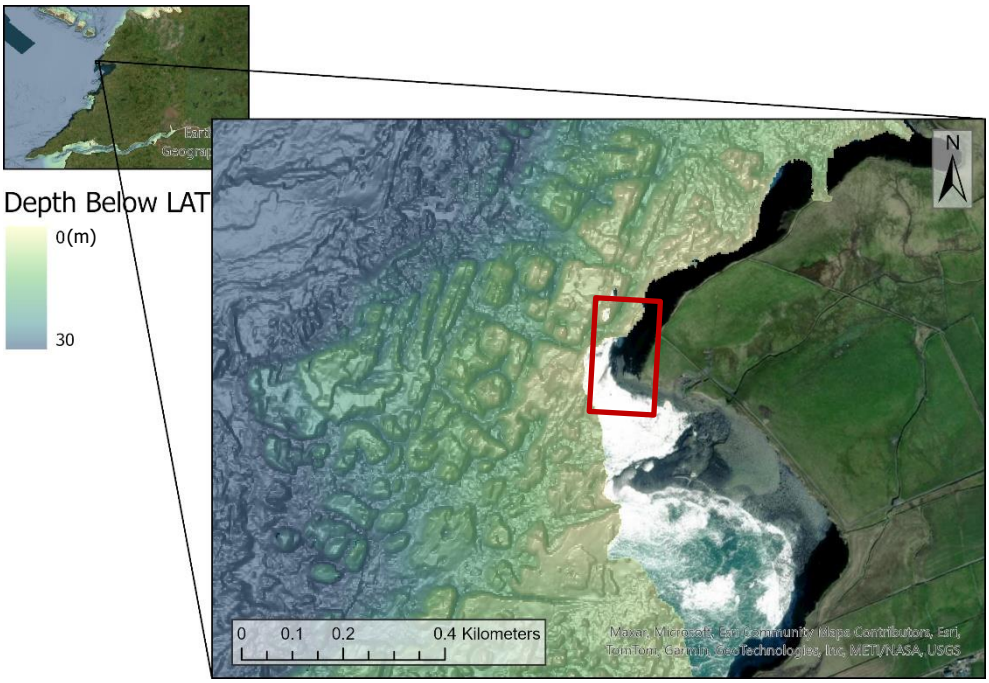

Figure 8: Bathymetric overview showing the location of 3D model below.

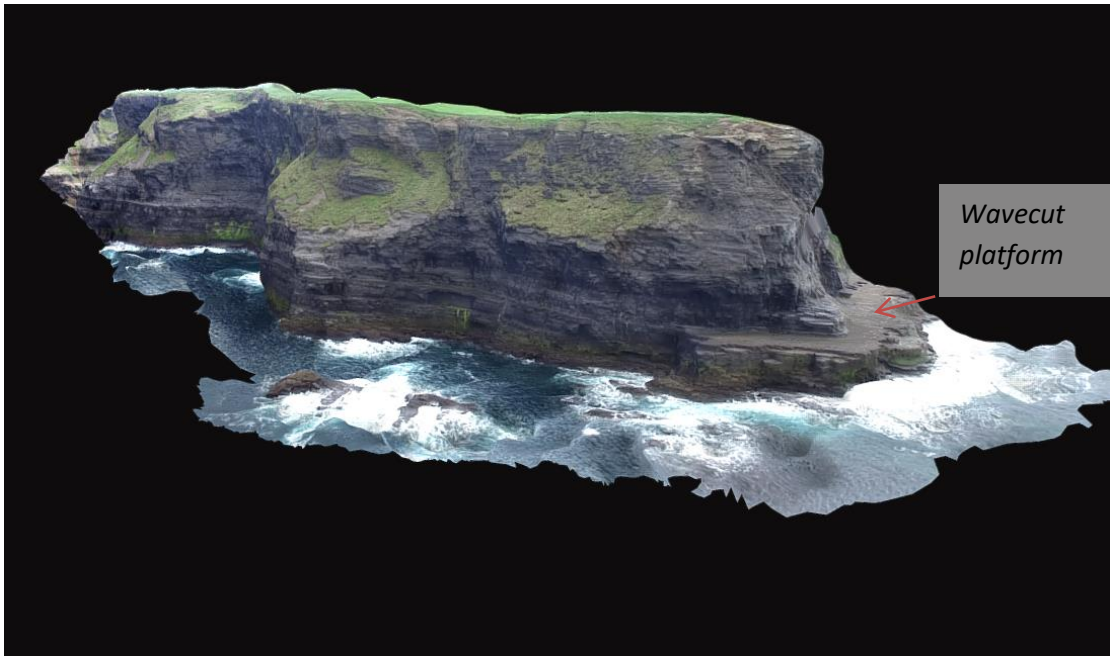

Figure 9: 3D model of the cliffs, with a wave-cut platform indicated. Model from (Carena, 2020).

Along the cliff base, wave action also carves sea caves into zones of weakness. Over time, the caves can deepen and break through to the other side of narrow headlands, forming sea arches through which tides flow freely. When the arches eventually collapse, they leave behind isolated sea stacks. These are tall rock pillars detached from the cliff face. Further erosion reduces these stacks to smaller stumps, which may also eventually disappear beneath the waves. These caves, stacks and stumps are clearly visible from the cliff-top paths and provide a clear example of ongoing coastal retreat.

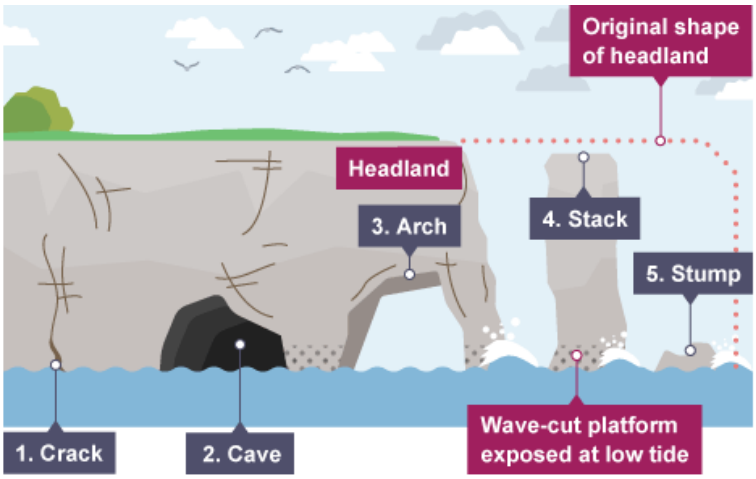

Figure 10: Diagram showing the formation of sea caves, arches, stacks and stumps. Image from (BBC, n.d.).

Kilstiffin Reef

Located at the southern end of the Cliffs of Moher, approximately 2 km offshore, Kilstiffin Reef is a submerged geological feature composed of Late Carboniferous sandstones, siltstones and shales, belonging to the same Central Clare Group that forms much of the coastal cliffs.

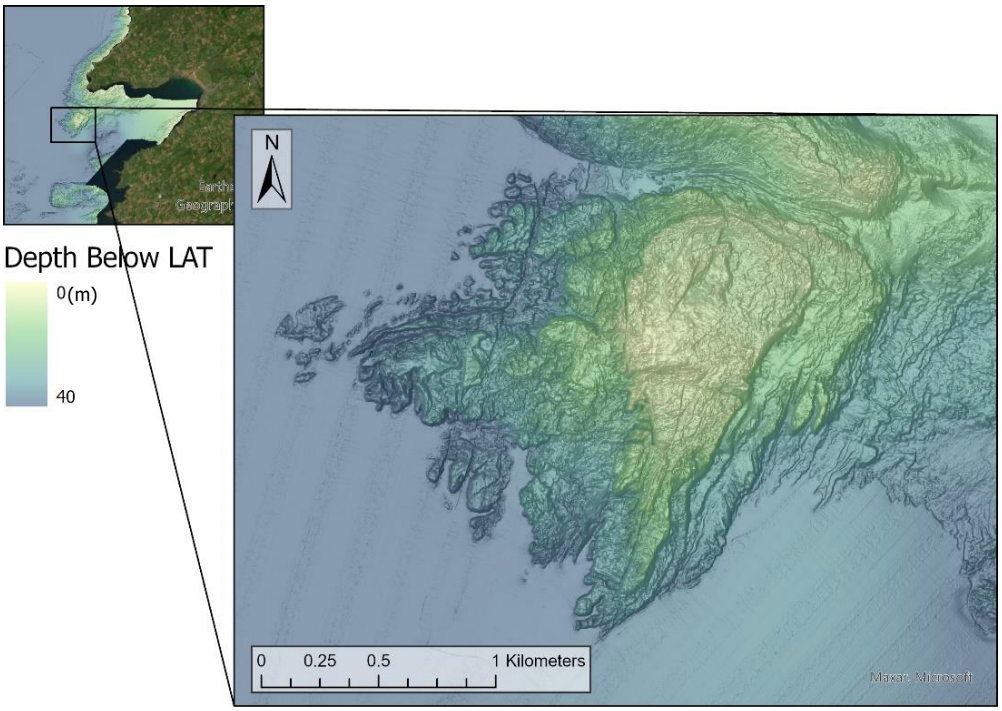

Figure 11: Bathymetry of Kilstiffin Reef.

INFOMAR bathymetry data reveals huge slabs of rock and undulating reefs rising steeply from deeper waters, offering insight into past deltaic sedimentation and structural deformation on the edge of the Clare Basin (INFOMAR, 2023). The reef is relatively flat-topped, rising from depths of about 40 m to just 5 m below the sea surface.

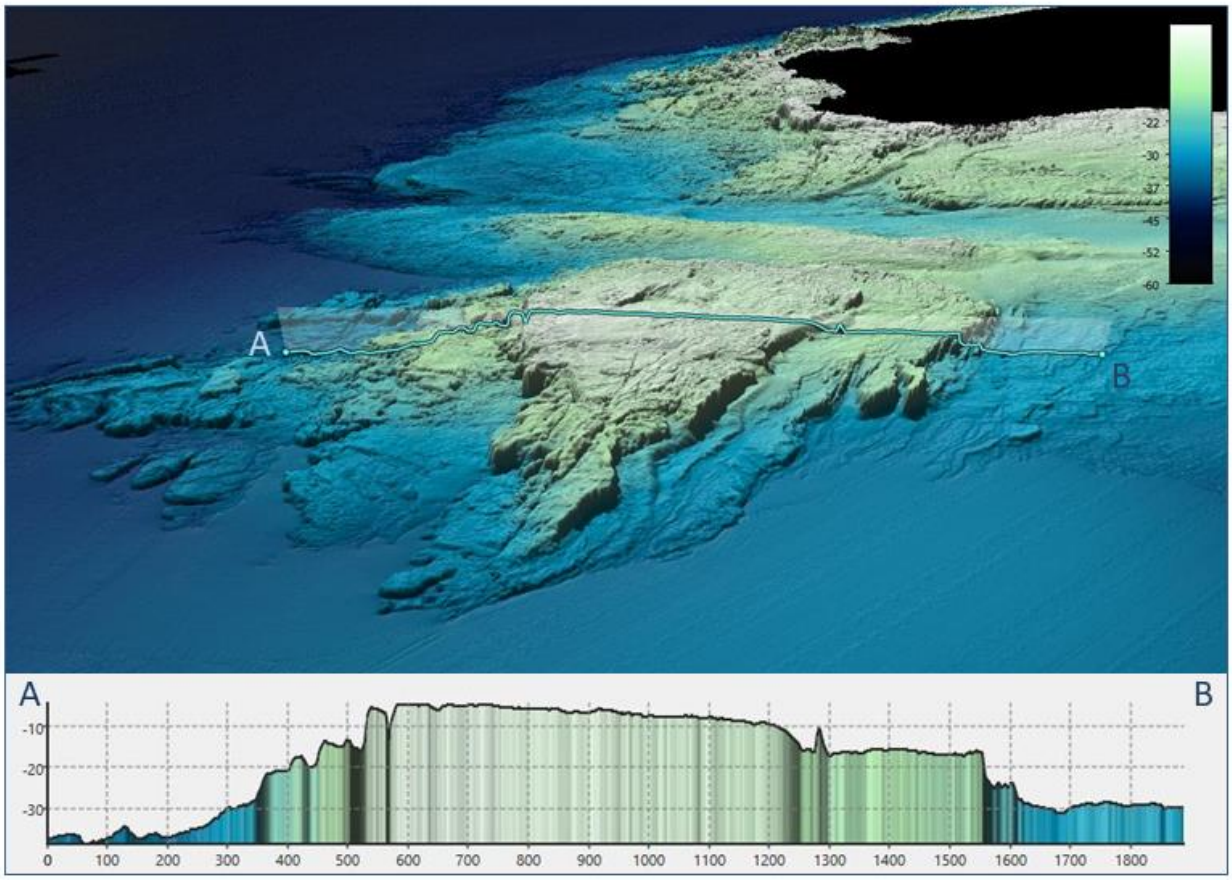

Figure 12: 3D bathymetry of Kilstiffin Reef, with elevation profile inset.

Kilstiffin Reef is also associated with the legend of the sunken city of Kilstiffin. As the tale goes, the city, adorned with golden roofs, palaces and churches, was lost to the sea when its chieftain dropped a magical key in battle. Every seven years, the city is said to rise above the surface, glowing beneath the waves. Those who see it, however, are said to perish before its next appearance (Chavis, n.d.).

Aill na Searrach

Aill na Searrach, meaning "The Leap of the Foals," is a prominent headland near the northern end of the Cliffs of Moher. Just offshore, beneath this lookout point, lies a reef system responsible for producing Aileen's wave, one of the most renowned big-wave surf breaks in Europe (INFOMAR, 2023)

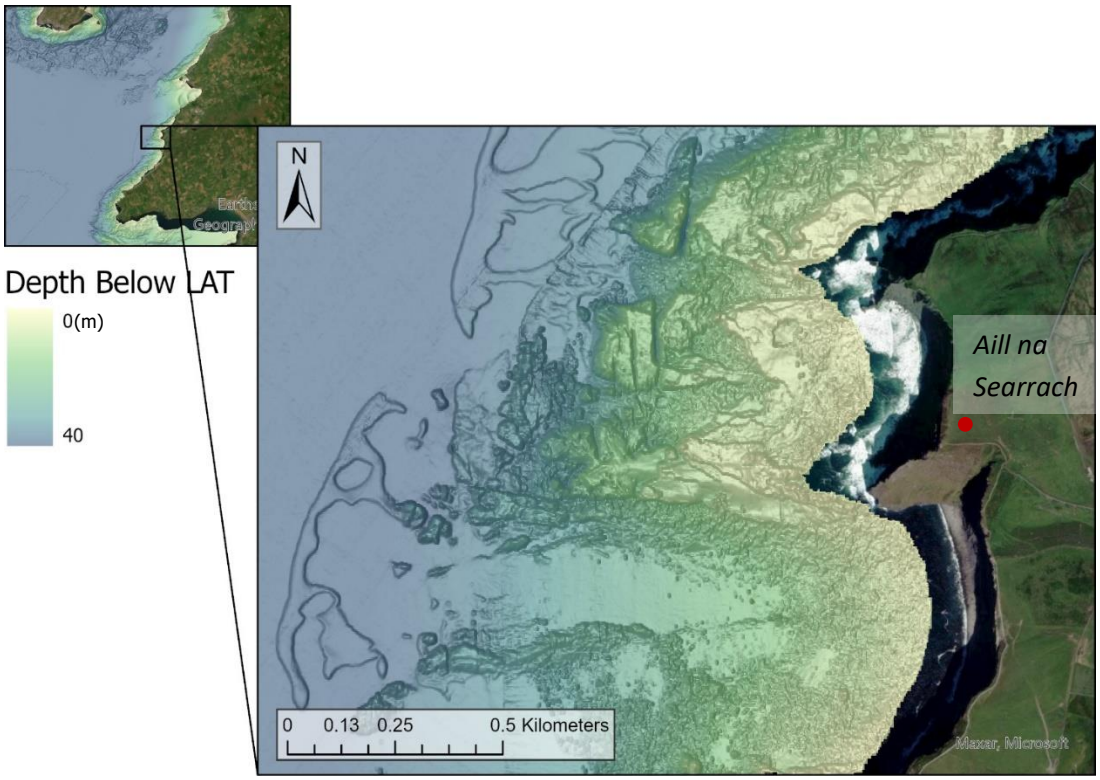

Figure 13: Bathymetry below Aill na Searrach.

INFOMAR bathymetry shows steeply rising slabs of Carboniferous rock and undulating reef features that extend out from the base of the cliffs into deeper Atlantic water. These rock formations abruptly shoal incoming swell energy, causing the massive waves that define Aileen's. When powerful Atlantic storms generate the right swell direction and period, the reef focuses that energy into a steep, clean wall with waves that can reach over 10 m (MP, n.d.). The location has become a destination for big-wave surfers from around the world.

Figure 14: Image of Aileen's wave from (Surf Forecast, n.d.).

The name Aill na Searrach, or Leap of the Foals, derives from local folklore. One version of the legend tells that, when Christianity arrived in Ireland, the Tuatha Dé Danann, a mythological tribe of pagan deities, resisted the change. After losing an argument about Christianity to St Patrick, they transformed themselves into foals and hid in sea caves near the cliffs. After centuries, seven of these foals emerged, only to be startled by the daylight. Spooked, they galloped along the cliff edge and ultimately plunged from the headland at Aill na Searrach (Cliffs of Moher, 2026).

Biodiversity

The Cliffs of Moher are designated as a Special Protection Area (SPA) under the EU Birds Directive because of their internationally important seabird populations.

More than 20,000 seabirds breed here each year. The site supports Ireland's largest colonies of razorbills and kittiwakes, as well as significant numbers of guillemots, fulmars, puffins and choughs. Two pairs of peregrine falcons, a protected species, also nest on the cliffs. The horizontal bedding provides ideal nesting ledges, while nearby sea areas offer rich feeding grounds. Inland, choughs forage within 350 m of the cliff edge (National Parks & Wildlife, 2015).

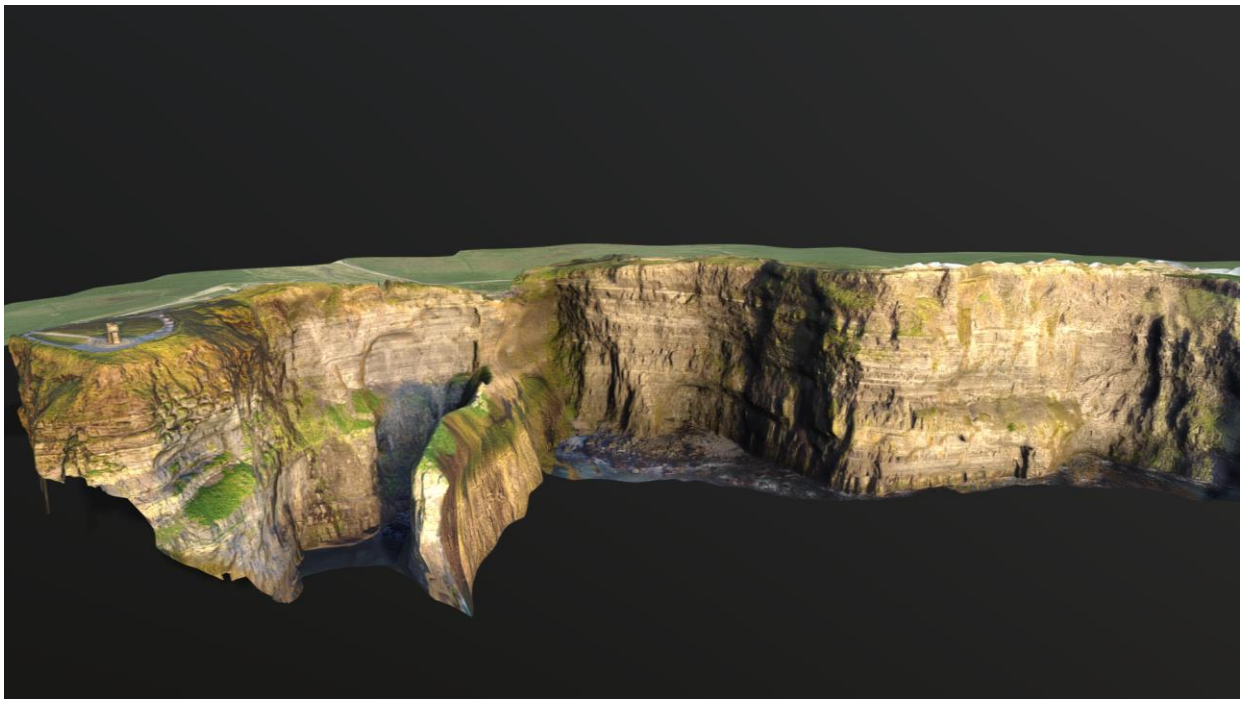

Figure 15: 3D model of the cliffs with horizontal bedding and patches of vegetation evident. Model from (PGSimulation, 2022).

Although vegetation is sparse on the cliff faces themselves, the slopes and tops support a mosaic of maritime grassland. Species such as thrift, sea campion, buck's-horn plantain, rock samphire, and the rare roseroot grow in crevices and exposed areas. A diverse lichen flora reflects the clean, saline-rich air and minimal disturbance (National Parks & Wildlife, 2015).

Conclusion

The Cliffs of Moher preserve an important Late Carboniferous sedimentary succession within the Clare Basin. Deep-marine shales and overlying deltaic sandstones record the progressive filling of the basin, while later tectonic deformation, glacial erosion and marine processes have helped shape the modern cliffs.

Offshore, Kilstiffin Reef and the reef at Aill na Searrach show that the same geological framework continues beneath the Atlantic. INFOMAR bathymetry links these submerged rock platforms to present-day seabed morphology, coastal erosion and wave behaviour. At Aill na Searrach, the reef shoals incoming Atlantic swell, helping to create one of Europe's best-known big-wave surf breaks. The cliffs also support internationally important seabird populations and maritime vegetation, with protected birds nesting on stratified ledges and specialist plants growing on exposed cliff-top grasslands.

The cliffs remain an active erosional coastline, where weathering, wave attack and rockfalls continue to modify the cliff face and adjacent seabed. Future sea-level rise and more frequent or intense storms may increase erosion pressure, potentially leading to more frequent cliff collapses, loss of sea stacks and changes in shoreline configuration over the coming decades.

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