



Marine Geoscience Report 027

Aran Islands

Overview

The Aran Islands are three rugged Atlantic limestone islands off the west coast of Ireland, forming the western entrance to Galway Bay. Inishmore (*Inis Mór*) is the largest, Inishmaan (*Inis Meáin*) the middle, and Inisheer (*Inis Oírr*) the smallest, with a combined area of about 46 km².

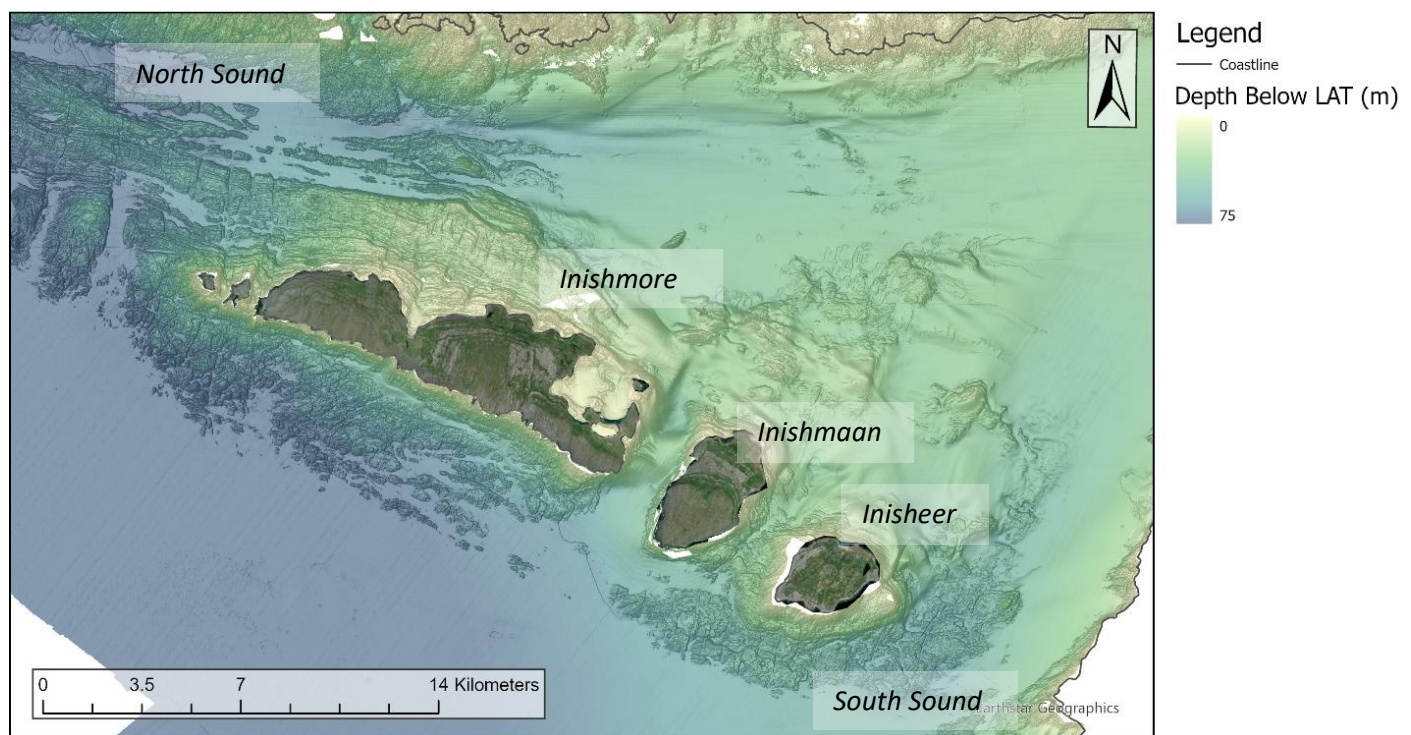


Figure 1: Overview of bathymetry around the Aran Islands. Depths are referenced to Lowest Astronomical Tide (LAT).

Geologically, the islands are an offshore continuation of County Clare's Burren plateau, consisting mainly of bedded Lower Carboniferous limestone deposited approximately 350 Ma. This hard karstic limestone, a continuation of the geology of the Burren rather than the granite of Connemara, dominates the landscape and coastline. Rainwater dissolution has widened vertical fissures, known as grikes, in the limestone pavement, leaving flat slabs, or clints, between them. The result is a stark terrain of bare grey rock with very thin soil, dotted with clints and grikes both on land and, as recent marine mapping has revealed, on the seabed. Sheer cliffs up to 100 m high line parts of the southern and western coasts of the islands, directly facing the Atlantic Ocean. These cliffs, limestone pavements and submerged karst features make the Aran Islands an important site for understanding the link between coastal geology, karst geomorphology and cultural heritage.

Geological History

The limestone bedrock of the Aran Islands formed in the Lower Carboniferous period (359-323 Ma) when this area was a tropical marine shelf near the equator. Over time, thick sequences of calcium-rich sediments (with occasional shale interbeds) were deposited and lithified into the grey Burren Limestone seen today (Meehan, et al., 2019). These strata are generally tilted gently to the south, giving Inishmore its stepped, terraced appearance (higher cliffs in the south, tapering lower to the north).

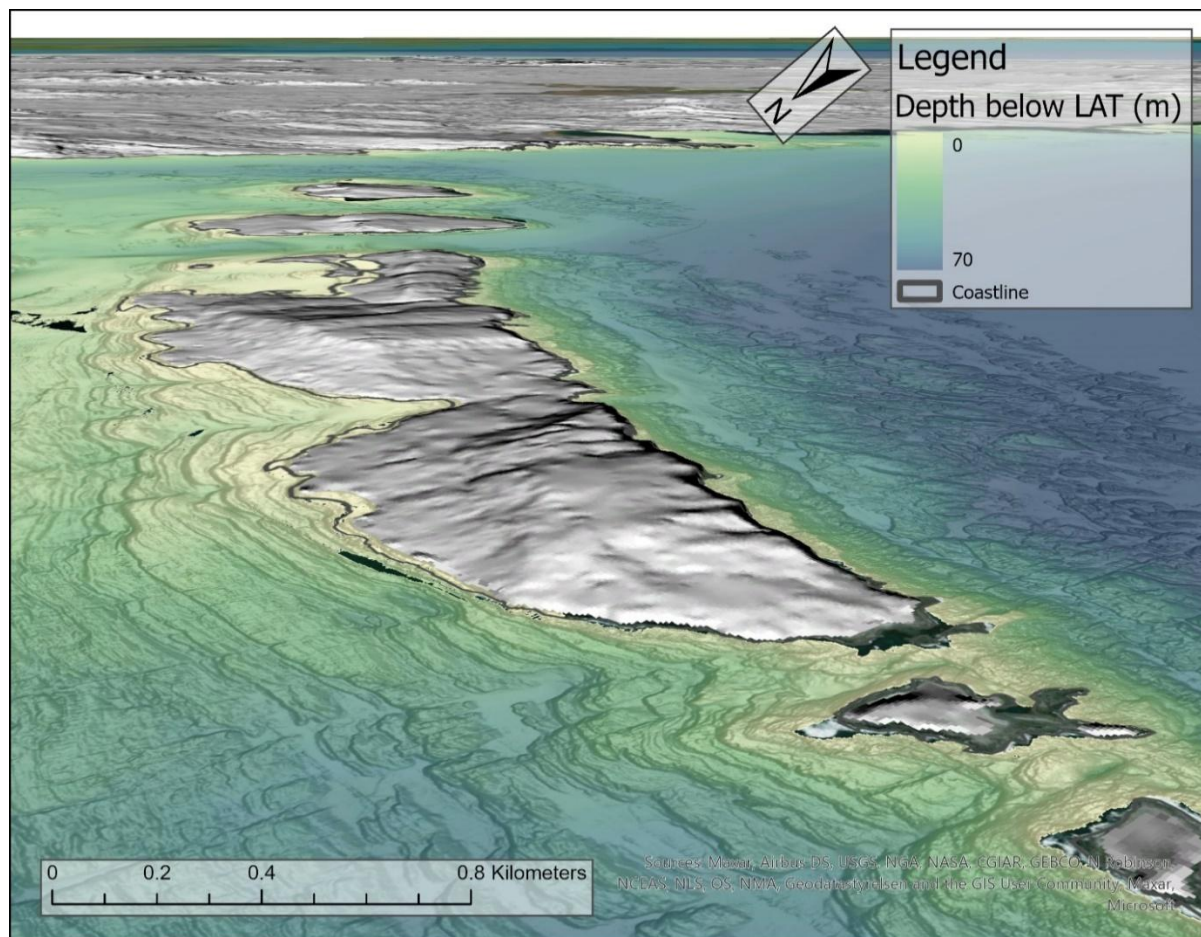


Figure 2: 3D imagery of the Aran Islands showing the terraced topography, with Inishmore and minor islets in foreground.

This limestone platform forms the southern geological framework at the mouth of Galway Bay. In contrast, to the north of Galway Bay the bedrock is older and more varied, dominated by Ordovician–Silurian metasedimentary rocks that were folded and metamorphosed during the Caledonian Orogeny, and intruded by the Galway Granite Batholith around 400 Ma (Pracht & Feely, 2004). Together, these contrasting provinces define a major regional boundary that is expressed offshore by east-west trending structures including the Galway Bay Fault zone.

Subsequent mild tectonic uplift and jointing during the Variscan Orogeny, a continental collision and mountain building event ~300 Ma, prepared the limestone for extensive chemical weathering. 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, beginning 2.58 Ma. This gap is largely due to prolonged uplift and erosion, which removed much of the deposited material from this time (Pracht & Feely, 2004).

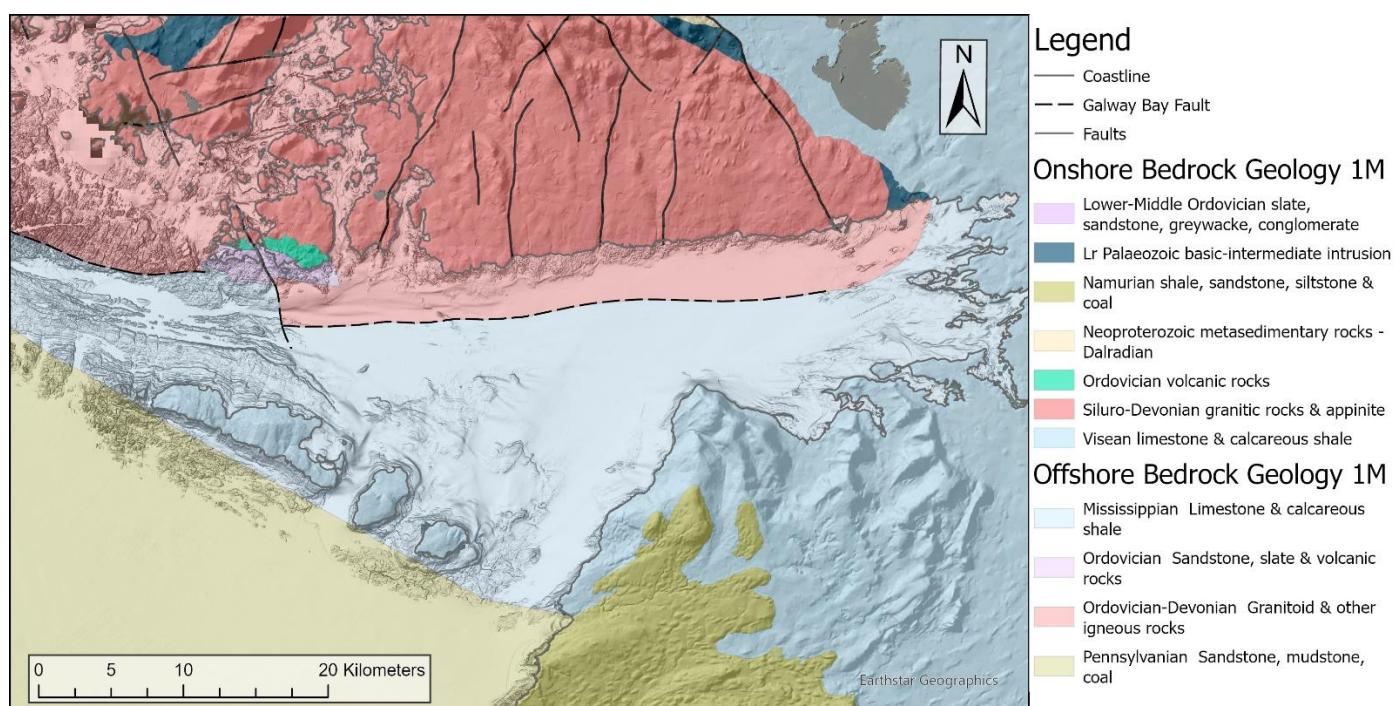


Figure 3: Regional Geology.

During the Quaternary period, the region was overridden by the British-Irish Ice Sheet. In the last glaciation, which reached a maximum around 24 ka, ice moved from the north and north-east across Galway Bay (Meehan, et al., 2019). Glacier abrasion smoothed and scoured the exposed limestone, producing streamlined pavements, drumlins and moraines from which the course of the ice sheet can be reconstructed (McCullagh, et al., 2020). The ice also carried exotic erratic boulders which were dropped on the islands: granite and metamorphic boulders derived from Connemara to the north, as well as sandstones from Clare, can be found perched on the limestone platform (Pracht & Feely, 2004). Unlike much of east Galway's lowland limestone (which retained a thicker glacial till cover and developed rich soils), the Aran Islands emerged from glaciation almost entirely stripped to bare rock.



Figure 4: Glacial erratic perched on a limestone platform on Inis Mór. Image from (Ding, 2013).

Following the ice retreat around 17 to 15 ka ago, the post-glacial sea-level rise gradually separated the Aran Islands from the mainland (INFOMAR, n.d.). What had been a continuous karst plateau extending from the Burren became isolated hill-like islands in the rising Atlantic. The Atlantic waters flooded the deep channels (Gregory's Sound, North Sound, and South Sound) that separate the islands from each other and from the mainland. The North Sound, north of Inishmore, reaches depths of 77 m and is associated with mapped bedrock structure, as illustrated in the below figure. This structural weakness, along with glacial erosion and marine currents, helped establish a conduit for Atlantic waters far into the bay. Coastal erosion by waves has since bitten into the edges of the islands, creating the sheer cliffs that define much of the southern coastline. Much of the modern coastal morphology has developed during the last 10,000 years, as sea level stabilised close to its present position.

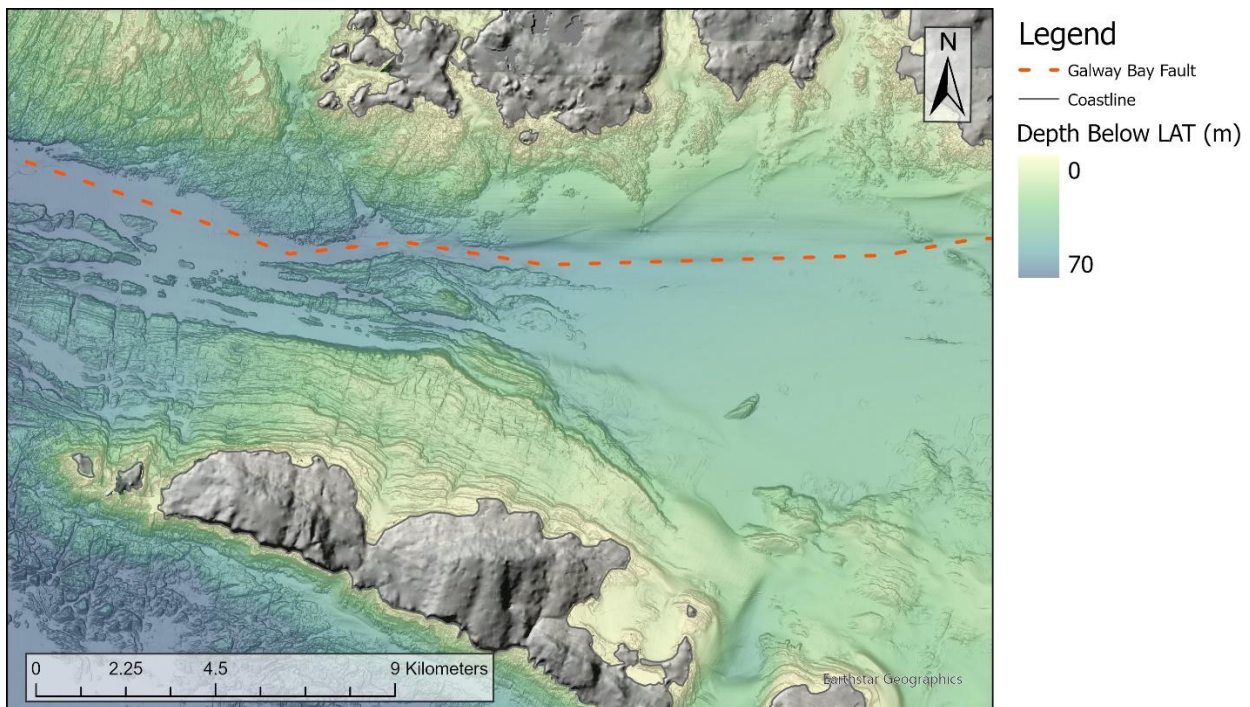


Figure 5: Bathymetry of the North Sound with the Galway Bay Fault indicated.

As the climate warmed in the Holocene, karst processes resumed on the freshly exposed limestone. The modern landscapes of Inis Mór, Inis Meáin and Inis Oírr, barren with rain-rilled limestone pavements and enlarged joints, largely reflect post-glacial karstification under thin or absent soil. The islands are notably streamless, and residents historically improved thin soils with seaweed and sand to create arable ground (Boitano, n.d.).

Karst Limestone

The term karst refers to landscapes formed by the dissolution of soluble rocks, especially limestone. The word originates from the Kras region of western Slovenia and north-eastern Italy, meaning “stony ground” (Drew, 2018). The Aran Islands exemplify classic karst terrain, displaying many features akin to the famous karst of the Burren just to their east. Like the Burren, the islands have extremely thin soils or none, and almost no permanent surface streams or lakes. Rainfall rapidly percolates into the ground through fractures instead of running off on the surface. This lack of surface drainage, combined with high rock permeability, means residents historically depended on rainwater catchment and a few springs for fresh water.

Beneath the surface, the Aran limestone is dissected by cavities and conduits characteristic of karst hydrology. Rain (which is slightly acidic) dissolves the calcium carbonate in limestone along joints and bedding planes, creating caves, sinkholes, and springs – though fewer caves are documented on Aran than in the Burren proper (Geological Survey Ireland, n.d.).

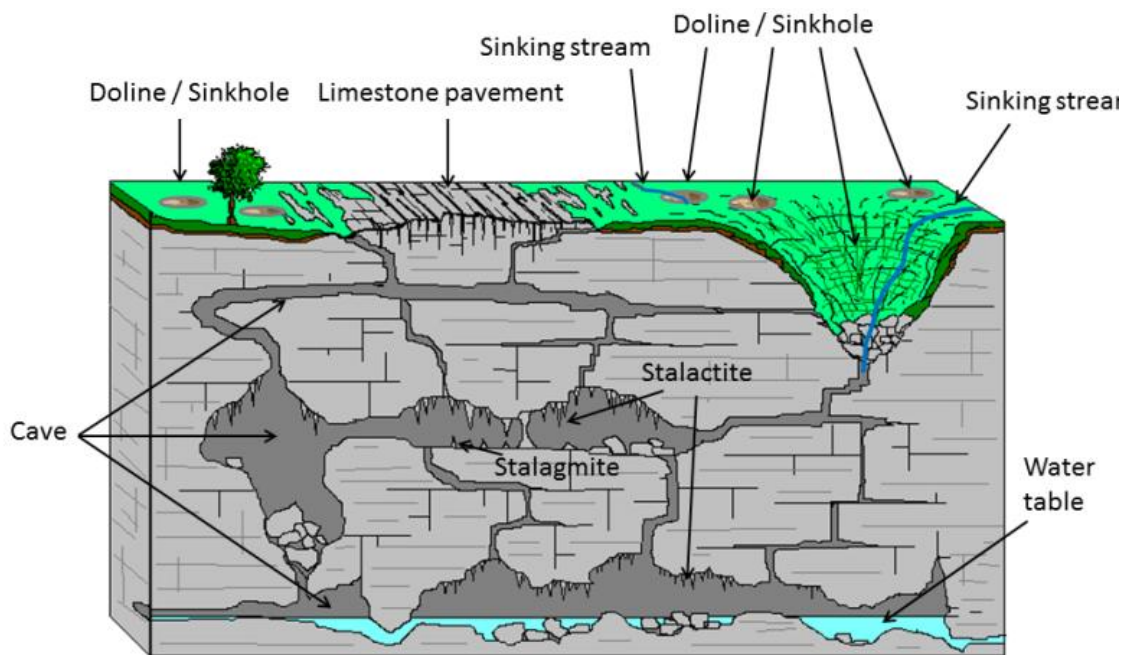


Figure 6: Diagram of karst landforms from (Geological Survey Ireland, n.d.).

The Aran landscape is dominated by bare, grey limestone pavement: flat slabs of bedrock (called *clints*) separated by a grid of deep, vertical fissures known as *grikes*. These grikes are enlarged vertical joints in the limestone that have been widened by solution over time, essentially making the island's pattern a combination of tectonic structure and chemical weathering (INFOMAR, 2023).

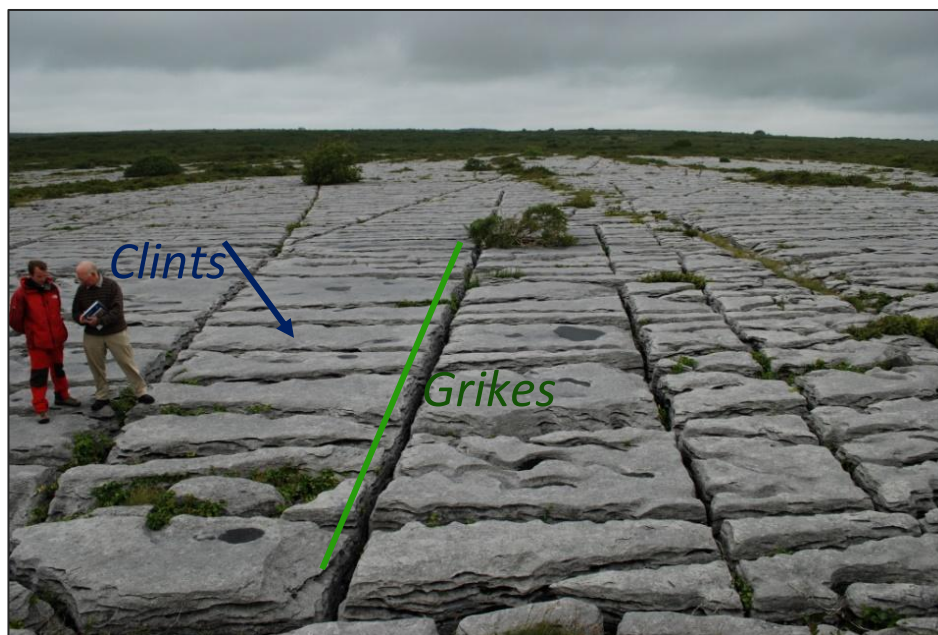


Figure 7: Clints and grikes in the Burren, with humans for scale. Image from (SEPM Strata, 2013).

The result is a rectilinear pattern of blocks and chasms that give the land a blocky, pavement-like appearance. Barren as it looks, this pavement supports rare alpine and Mediterranean flora in the grikes' microclimate, one of the ecological surprises of karst landscapes (National Parks, n.d.). In the absence of thick glacial drift or soil, the Aran Islands preserve a clear example of temperate limestone pavement and active karst development.

The southern and western sides of the Aran Islands face the Atlantic and are regularly exposed to storm waves. These waves break against the cliffs and shoreline, contributing to erosion of the limestone platform. On the south-west side of the islands, the seabed is covered in places by fragmented limestone slabs, reflecting ongoing mechanical breakdown and reworking along this exposed margin (INFOMAR, n.d.).

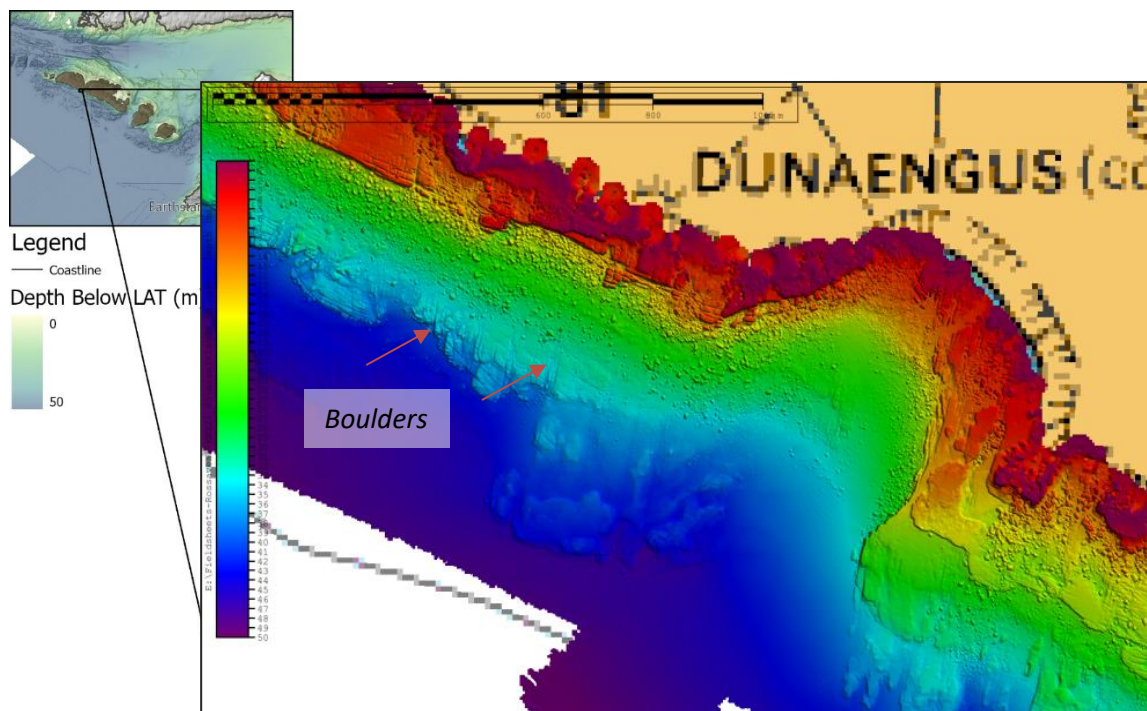


Figure 8: Bathymetry showing boulders and loose material at the foot of the Inishmore cliffs.

Seabed Features

The underwater geology around the Aran Islands preserves the same karst signature seen on land. Surrounding the islands, the seabed is characterised by limestone pavement with well-developed joint systems, where clints and grikes are expressed in submerged bedrock. The limestone is also locally weathered into terraces, producing a stepped morphology that mirrors the layered outcrops onshore.

Most of this karstification developed when these limestone surfaces were subaerially exposed during periods of lower relative sea level. During glacial lowstands most notably around the Last Glacial Maximum (approximately 24,000 years ago) – sea level was substantially lower than today, and areas that are now seabed would have formed part of an exposed limestone landscape (Ó Cofaigh, et al., 2012). The submerged pavements and associated solution features are therefore interpreted as relict karst landforms and provide evidence of formerly emergent terrain that has since been drowned by sea-level rise.

INFOMAR high-resolution bathymetry data show extensive areas of flat limestone bedrock on the seabed. These appear as underwater pavement surfaces with joint patterns comparable to those on land.

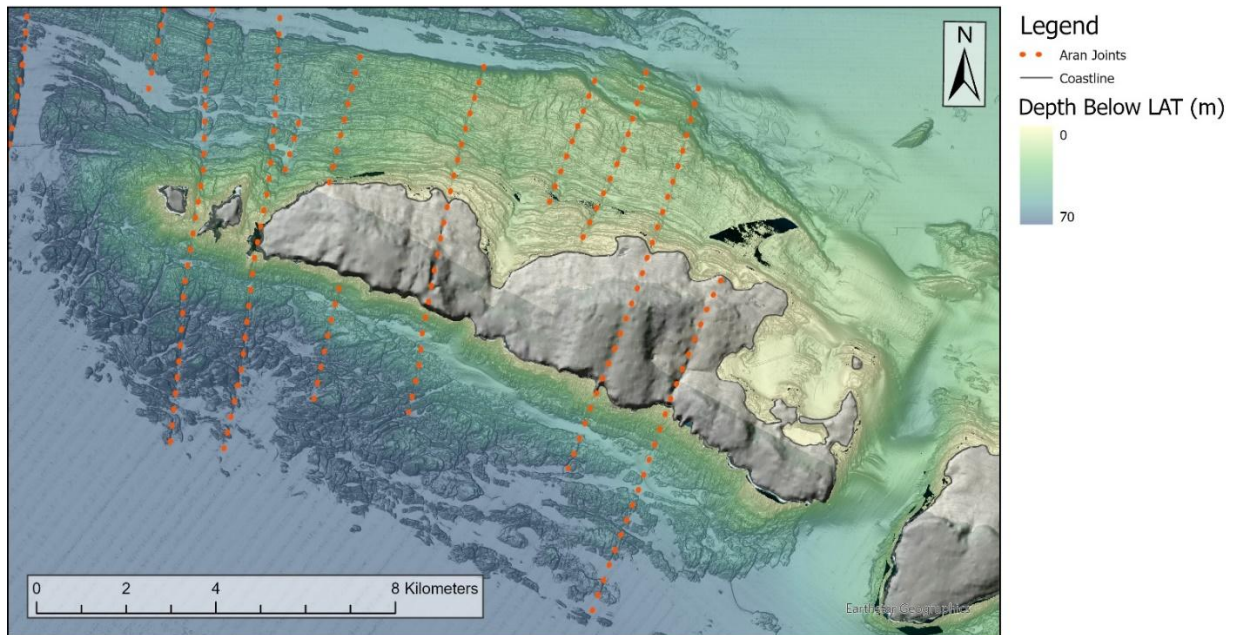


Figure 9: Offshore limestone pavement showing joint-controlled fissures.

Solutional processes widened and deepened the grikes along pre-existing lines of weakness (vertical joints), forming extensive fissures separated by clints (flat, pavement-like slabs).

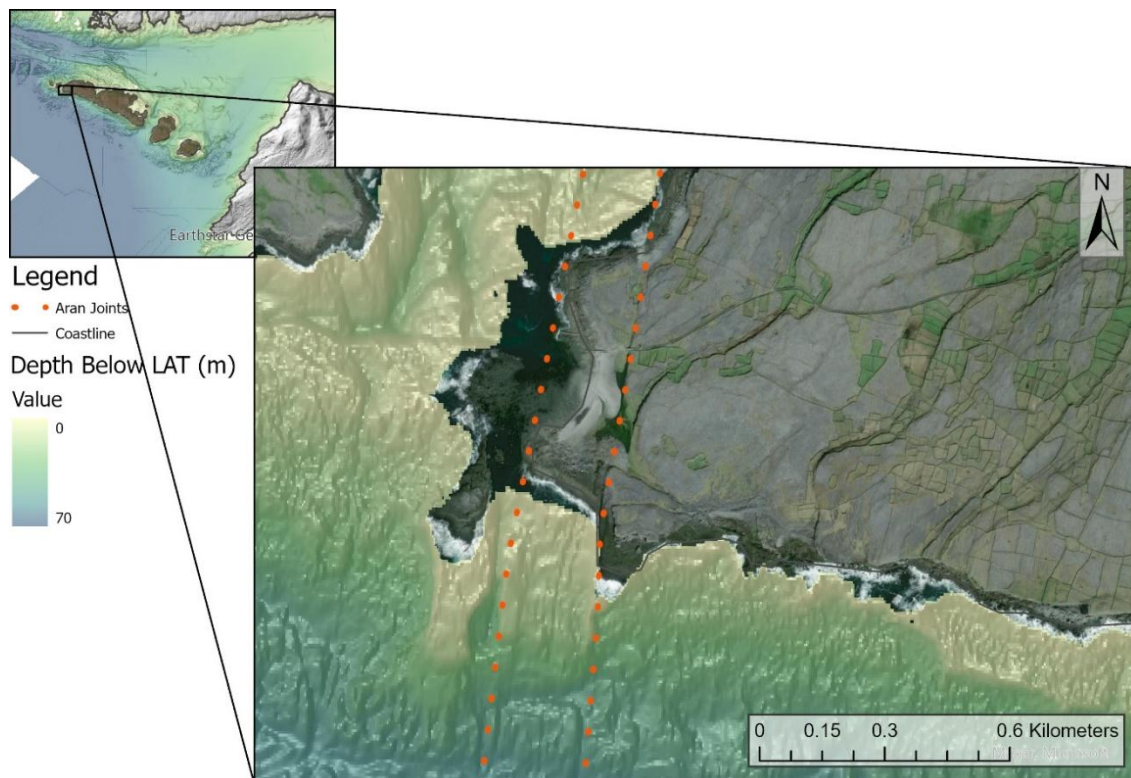


Figure 10: Detailed imagery of the offshore/onshore expression of joints.

In some areas, dissolution and local collapse have produced shallow depressions or pits – interpreted as small sinkholes formed by karst processes during earlier low sea-level stands.

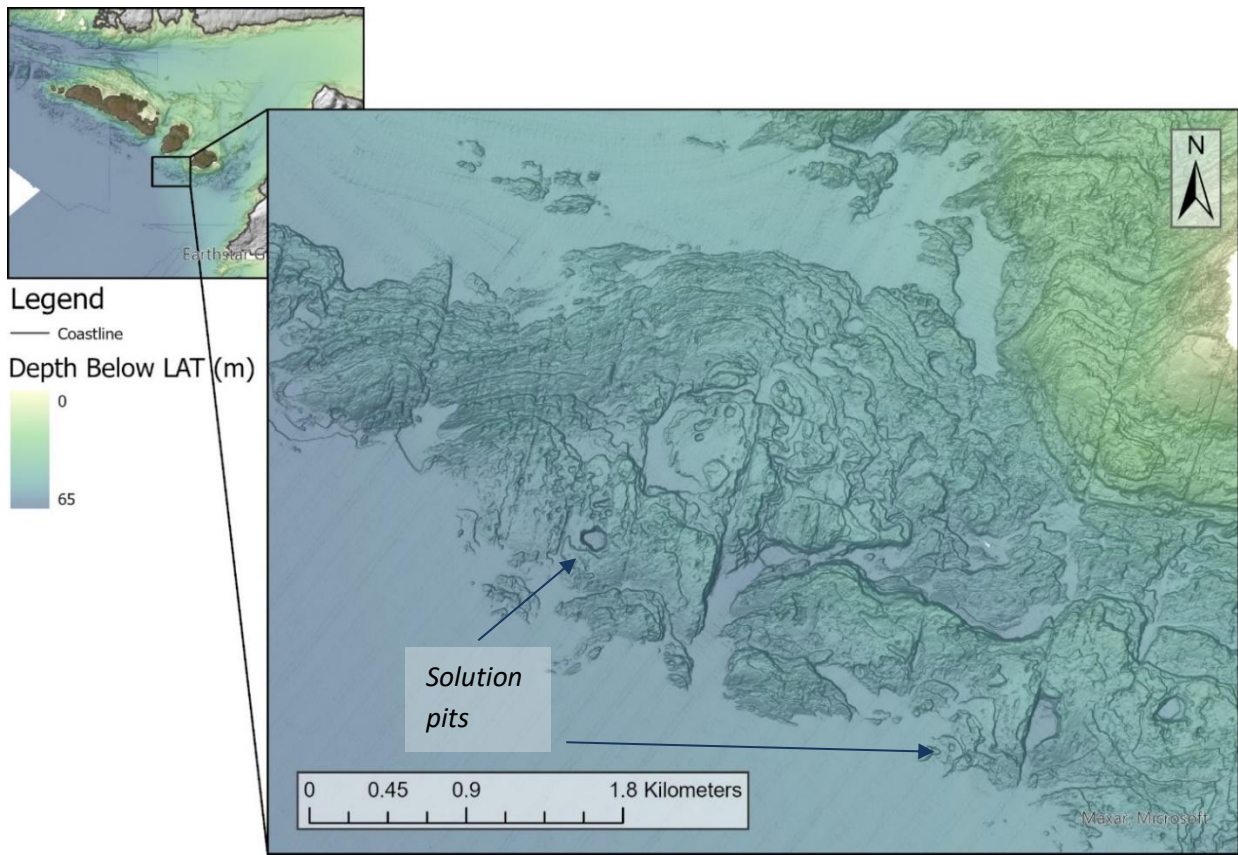


Figure 11: Solution pits in limestone on the south side of the islands, interpreted as relict karst depressions formed during lower sea levels.

The solution pits can reach up to 5 m in depth and 120 m in diameter.

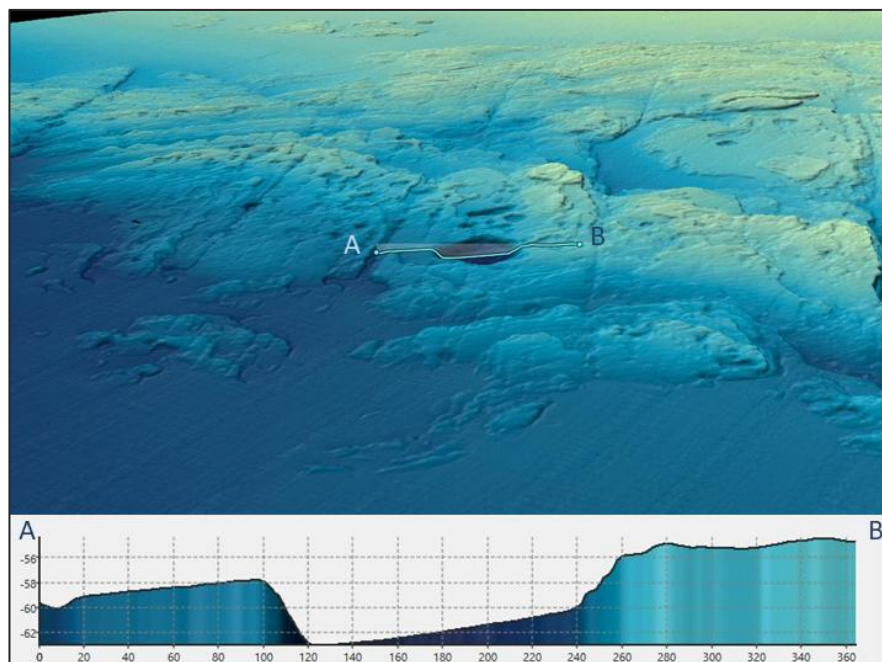


Figure 12: Elevation profile of the largest solution pit.

Between the Aran Islands and the mainland lie narrow channels (the North Sound, South Sound, Gregory Sound & Foul Sound) that act as funnels for Atlantic tides. In these constricted passages, the narrow geometry of the passages amplifies tidal speeds, and the fast-moving water carves out and maintains deep, scoured troughs in the seafloor (McCullagh, et al., 2020).

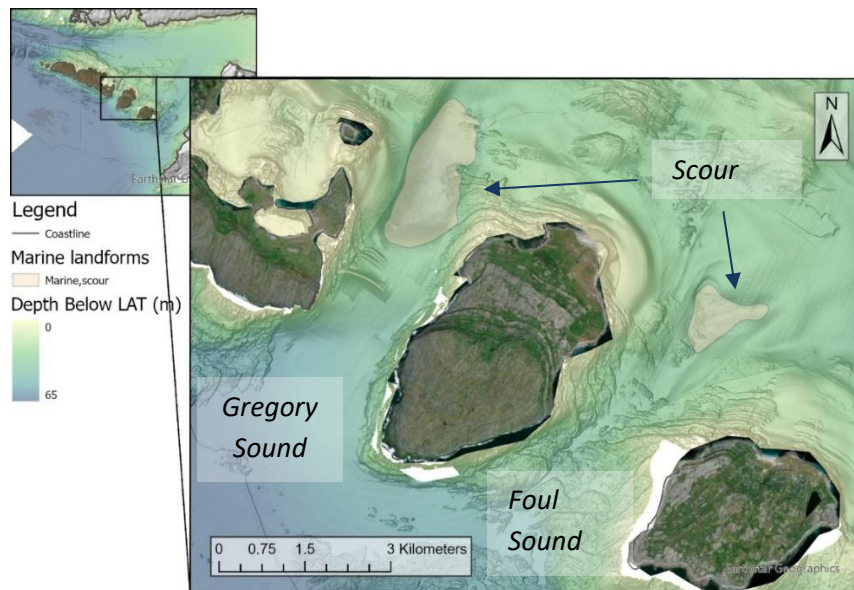


Figure 13: Bathymetry of Gregory and Foul Sound, with scoured areas indicated.

Backscatter data, which measure the strength of the returning signal and provide an indication of seabed hardness, show coarser, higher-backscatter material concentrated within the scour depression in Gregory Sound, consistent with winnowing of fine-grained sediment by strong currents. In contrast, Foul Sound is dominated by exposed bedrock, and backscatter values there largely reflect the presence of hard rock rather than a coarse sediment infill. Generally, darker tones indicate harder seabed and/or coarser material, while lighter tones indicate finer-grained sediments.

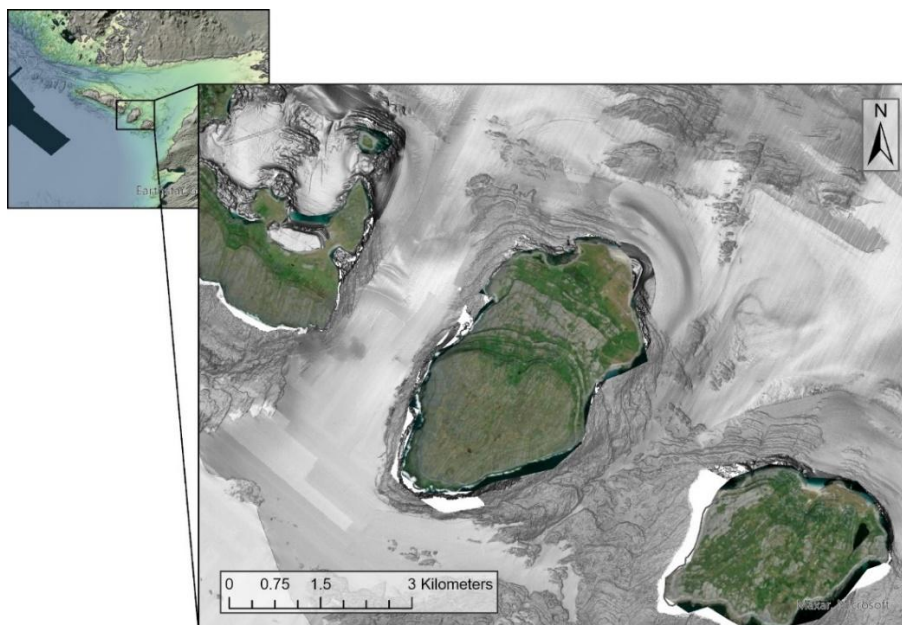


Figure 14: Backscatter data indicating coarser material (darker) is within the Gregory Sound scour depression.

Where currents are strong but sediment is abundant, underwater dunes or sandwaves form on the seabed. These are large, rhythmic sand ridges that are oriented transverse to the dominant flow. Between the Aran Islands, several sand-wave fields have been mapped. In the shallow channel between Inis Meáin and Inis Mór, Gregory Sound, survey profiles reveal at least four sand dunes a few meters high. A field of smaller sandwaves can also be seen further north, in the higher resolution bathymetry data.

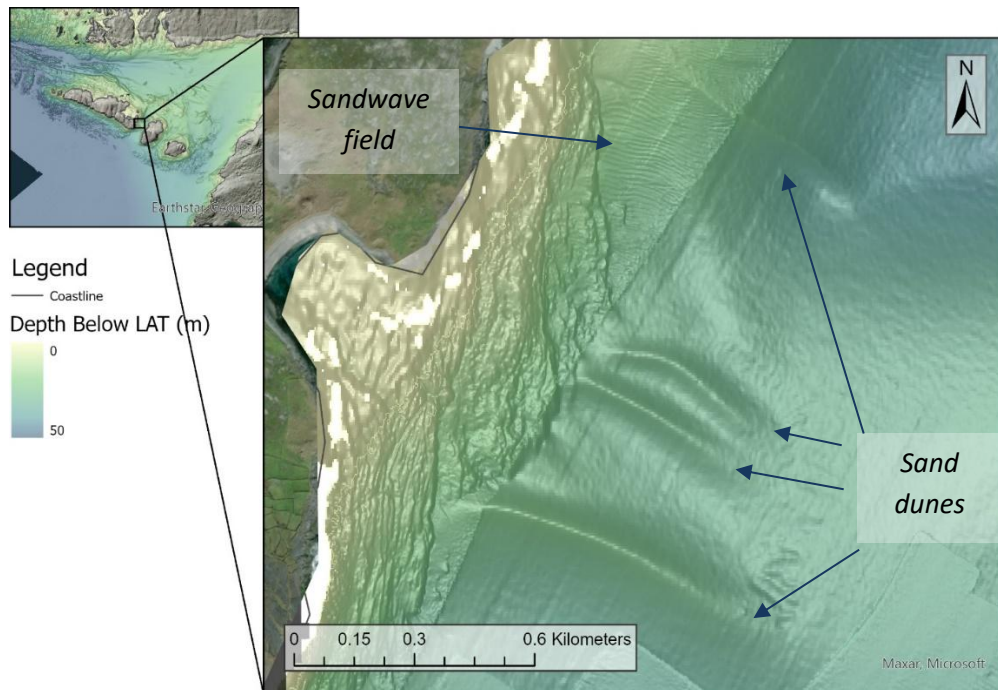


Figure 15: Bathymetry of sandwaves and sand dunes in Gregory Sound.

Some have crescent-shaped crests, typical of high-velocity, reversing tidal currents. These sand waves can be tens to hundreds of meters apart (wavelengths of order 100–200 m) and are composed of well-sorted sand (McCullagh, et al., 2020). Their presence indicates that alternating tidal flows carry sand back and forth, building symmetrical or slightly asymmetric ridges on the seafloor.

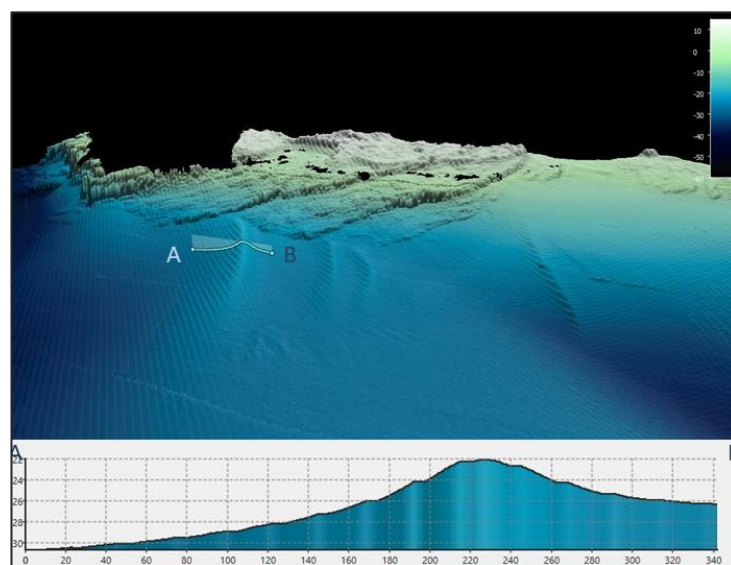


Figure 16: Elevation profile of a sand dune in Gregory Sound.

Dún Aonghasa (Dún Aengus) and Boulder Ridges

Perched dramatically on the edge of 100-metre-high sea cliffs, Dún Aonghasa (also spelled Dún Aengus) is the most iconic prehistoric fort on the islands. The stone fort dates back to the Bronze Age (1100 BC) and was expanded in later centuries, with thick dry-stone ramparts enclosing a semi-circular area that opens westward to the Atlantic Ocean (Tuatha, n.d.).

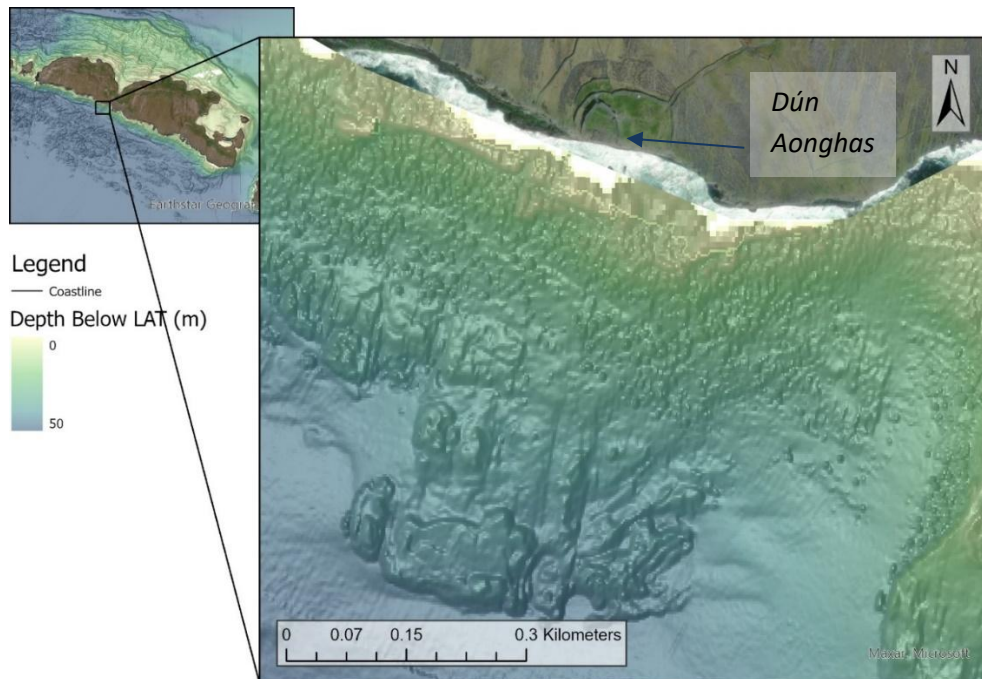


Figure 17: Bathymetry of the seabed below Dún Aonghasa.

Geologically and geomorphologically, the surrounding cliff-top hosts spectacular ridges of storm-thrown limestone boulders—naturally quarried blocks detached from the cliff face and hurled inland by extreme Atlantic waves (Cox, et al., 2018). Mapping has documented >1,000 such boulders on the Aran Islands; during the 2013–2014 winter storms many were moved, with individual blocks of 10s–100s of tonnes displaced. These movements challenge our assumptions about storm wave energy and the mechanics of boulder transport. Some of these displaced blocks rest atop the cliffs, 30 m metres above high tide, far beyond the reach of regular storm surge or wave splash. The largest boulder moved during those storms weighs an astonishing 620 t (Cox, et al., 2018).

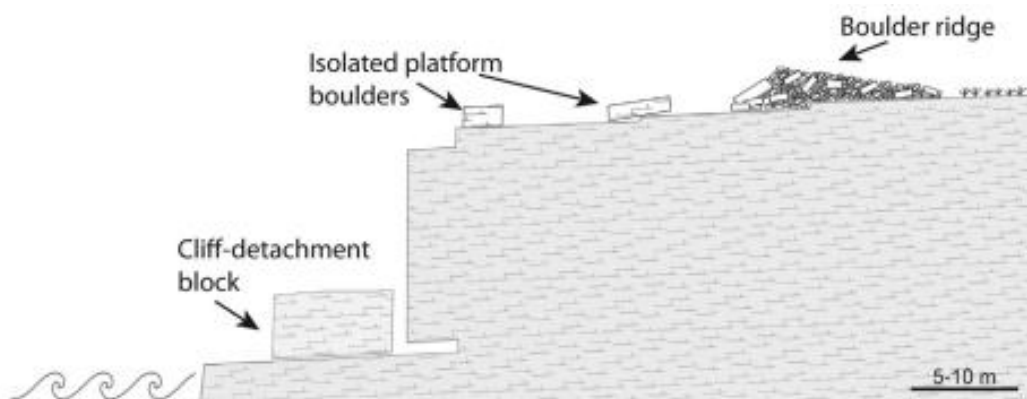


Figure 18: Diagram showing the formation of boulder ridges. Image from (Cox, et al., 2018).



Figure 19: Before-and-after photographs show creation of new boulders as well as movement of existing ones. The site is 10 m above high water and 50 m inland. Numbers in the 2013 photograph correspond to the numbers in the 2014 image, and yellow arrows point to the same horseshoe shaped puddle in both photos. Image from (Cox, 2020).

Regular monitoring showed sections of boulder ridges creeping landward (roughly 3 m per decade) since the 19th century, highlighting the continuing dynamism of these rocky coasts (University of Chicago Press Journals, 2012). Their position raises key questions: how can waves lift such enormous rocks up sheer cliffs, and what does this imply for future coastal vulnerability?



Figure 20: 3D model of demonstrating the scale of the sheer cliffs below Dún Aonghasa. Model from (LibanCiel, 2023).

Multidisciplinary research involving wave-tank modelling, field measurements, and numerical simulations shows that non-linear wave amplification, caused by waves shoaling and interacting with irregular seabed topography, can greatly enhance wave energy as it reaches the cliff base. The presence of narrow inlets or submarine ridges offshore can focus wave energy and leads to sudden explosive surges. In such events, water pressures equivalent to several tonnes per square metre can be exerted on coastal rock platforms, enough to quarry and hurl limestone slabs inland (Cox, et al., 2018).

The boulder deposits near Dún Aonghasa are active geomorphological features that record high-energy coastal processes. They show that even resistant rocky coastlines can change rapidly during major storm events, particularly where cliff faces, shore platforms and nearshore bathymetry focus wave energy. This has implications for understanding future coastal risk as sea level rises and storm impacts change.

Conclusion

The Aran Islands' marine geology reflects the combined influence of Carboniferous limestone bedrock, Quaternary glaciation, karstification and ongoing marine processes. The islands form part of the same limestone platform as the Burren, but their exposed Atlantic setting has produced a distinctive coastal and seabed landscape.

Onshore and offshore, limestone pavements, joints, grikes and solution pits record former periods of subaerial exposure and later drowning by post-glacial sea-level rise. Between the islands, strong tidal currents maintain deep channels, scour depressions and sand waves where mobile sediment is available. Along the exposed Atlantic margins, wave erosion continues to break down the limestone cliffs and shore platforms, while storm-emplaced boulder ridges show the power of high-energy events to move large coastal blocks.

Continued seabed mapping and geological investigation provide an evidence base for habitat management, conservation planning, and coastal risk assessment across this karst archipelago.

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