Marine Geoscience Report 023

Loop Head

Overview

Loop Head is a wave-battered peninsula at the mouth of the Shannon Estuary in south-west County Clare, Ireland. Its steep sea cliffs expose Late Carboniferous bedrock belonging to the Clare Basin, notably the Ross Sandstone and Gull Island formations. This coastline is well known for clear outcrops of deep-water marine sediments, preserving features of ancient submarine fan systems and soft-sediment deformation structures. The geology and structure of Loop Head have been studied since the 1950s, as it provides an important record of a Late Carboniferous submarine delta-fan complex formed around 315 Ma.

Figure 1: Bathymetry around Loop Head. Depths are referenced to Lowest Astronomical Tide (LAT).

Dramatic coastal features, including sheer cliffs, sea stacks and natural rock arches, owe their form to the underlying geology and tectonic history. The area was deformed by the Variscan Orogeny (a continental collision and mountain-building event around 300 Ma), which folded and fractured the strata, creating weaknesses that the Atlantic Ocean has since exploited to carve arches, stacks, blowholes and cliffs. Today, Loop Head's geological heritage and coastal scenery make it an important site for understanding the link between bedrock structure, seabed geology and coastal erosion.

Regional Geology

The bedrock at Loop Head records a long geological history tied to the evolution of the Clare Basin (also called the Shannon Basin) during the Late Carboniferous, over 300 Ma. At that time, Ireland lay near the equator and was affected by glacio-eustatic sea-level fluctuations during ice ages. Glacio-eustasy refers to global sea-level change driven by the growth and melting of continental ice sheets: when ice volumes expand, seawater is stored on land and sea level falls; when ice melts, sea level rises. On timescales of tens to hundreds of thousands of years, these fluctuations shifted shorelines back and forth, alternately exposing and then drowning the shelf. Thick deposits of mud and sand were delivered by large river deltas into a subsiding marine trough, building a submarine fan system at the basin floor (Pracht & Feely, 2004).

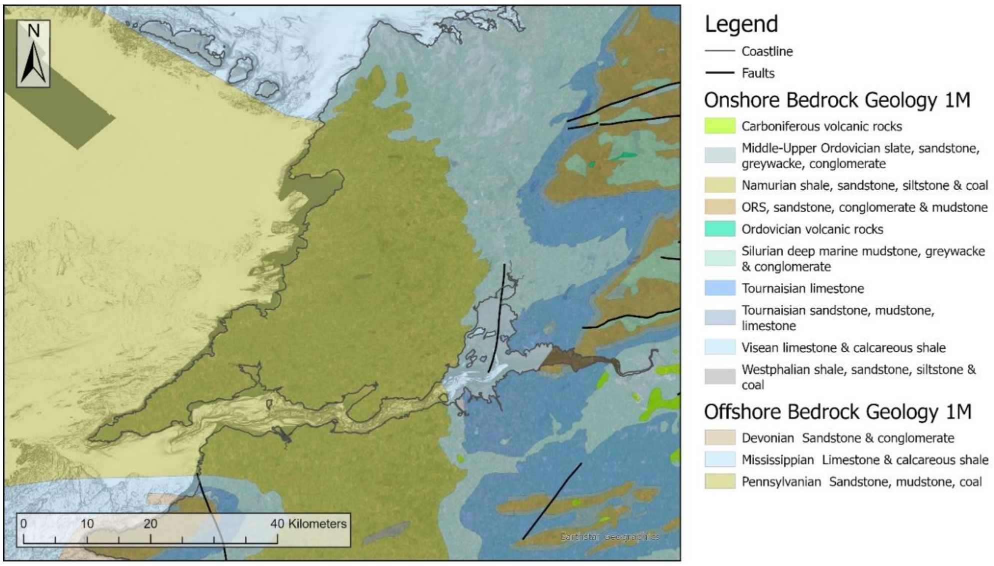

Figure 2: Regional geology of County Clare.

The stratigraphy in the Loop Head area is dominated by two major Late Carboniferous formations: the Ross Sandstone Formation and the Gull Island Formation.

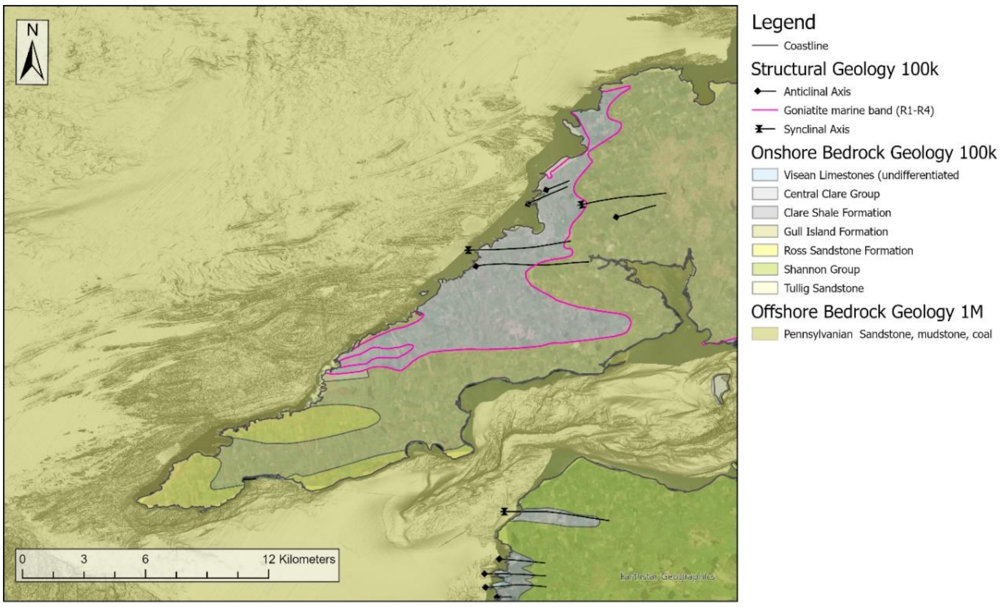

Figure 3: Detailed geology of the Loop Head Peninsula.

The Ross Sandstone Formation is exposed extensively around the peninsula and represents deep-water fan deposits. It consists of thick-bedded sandstone sheets with minor siltstone and shale, interpreted as turbidites. These sediments were laid down by high-density turbidity currents in water depths of up to 1 km (Magee, n.d.). The sand-rich turbidite beds are laterally persistent, or sheet-like, and separated by thinner shales, indicating episodic flows across the basin floor. Slumping is common throughout the formation, occurring as sediment slid downslope and produced highly deformed structures within the unit (Parkes, et al., 2005).

Overlying the Ross Sandstone is the Gull Island Formation, a muddier unit that marks the transition to a slope environment. This formation is characterised by chaotic, highly deformed beds of mudstone, siltstone and sandstone, formed by soft-sediment slumping and slope instability as the submarine fan prograded outwards (Pracht & Feely, 2004). The Ross Sandstone turbidites are therefore overlain by a thick succession of unstable slope deposits of the Gull Island Formation, recording a shift from outer fan to delta-front slope conditions.

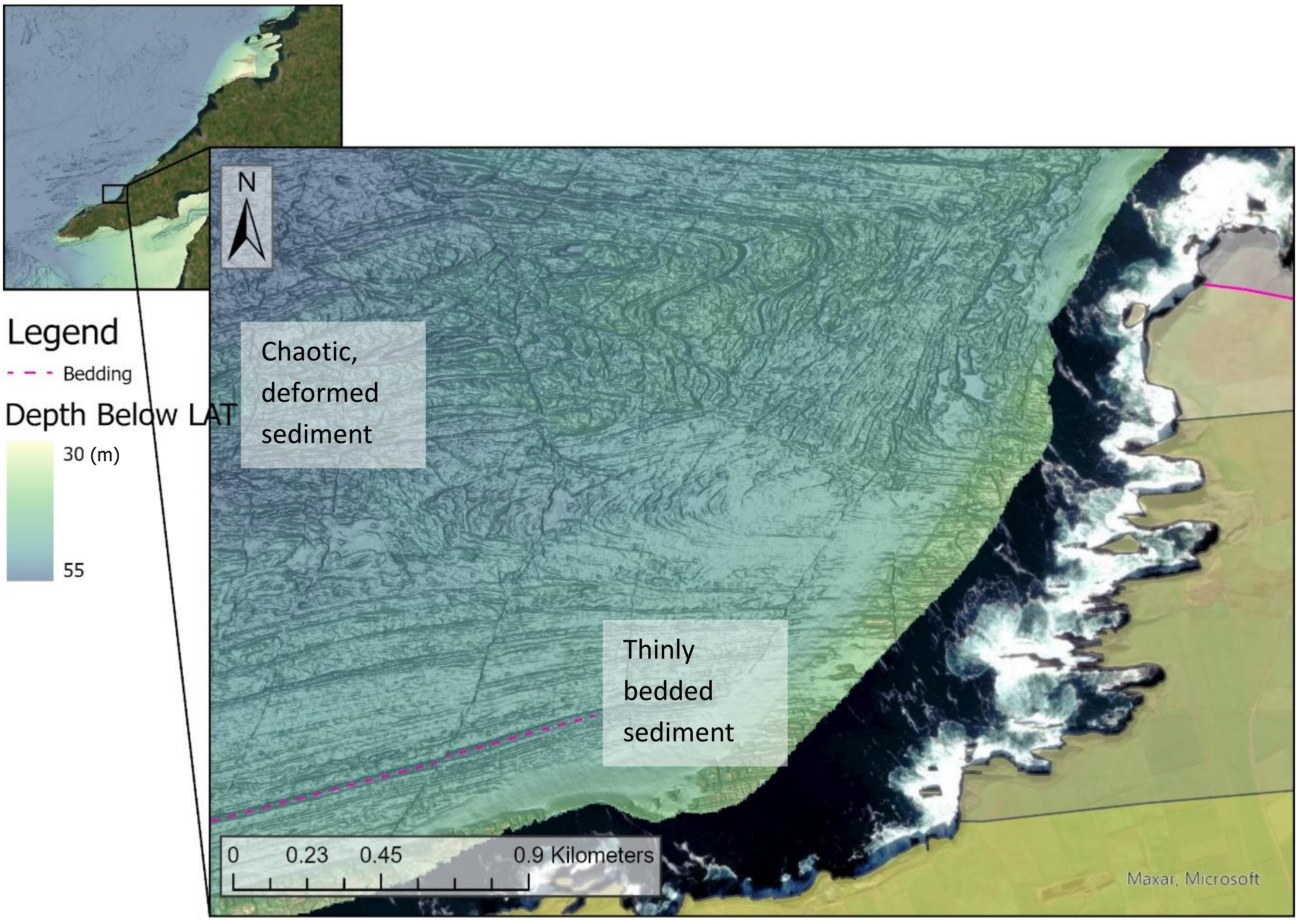

Figure 4: Bathymetry showing thinly bedded sandstone (Ross Sandstone Formation) to the south, and chaotic, deformed sediments (Gull Island Formation) to the north.

The deposition of these formations took place over several million years and was strongly controlled by sea-level change. Repeated glacial-interglacial cycles caused sea levels to fall and rise, leading to cyclic sedimentation patterns known as cyclothems. Each cyclothem typically consists of a vertical sequence from mudstone through siltstone to sandstone, reflecting a shallowing-upward cycle.

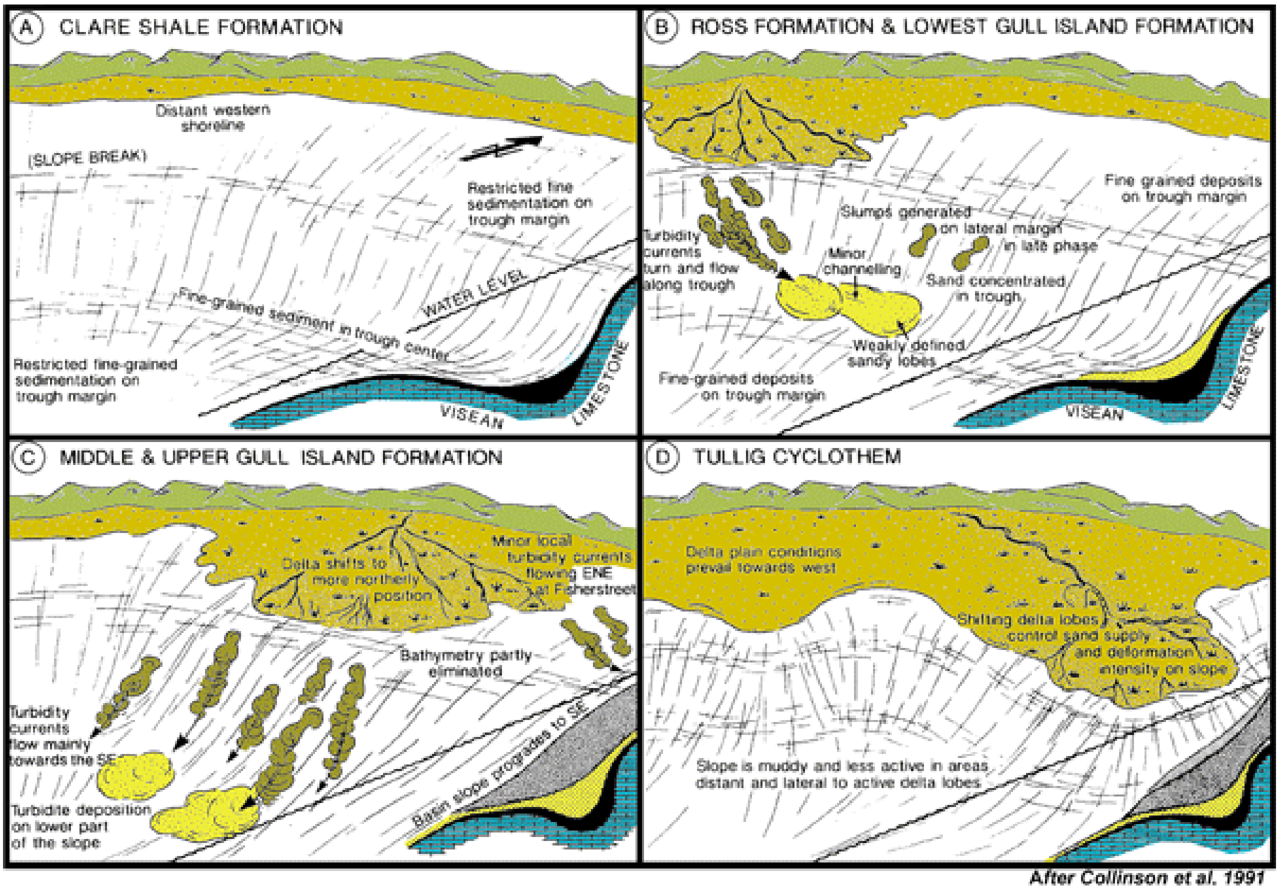

Figure 5: Depositional environments of the Clare Basin. Image from (SEPM STRATA Society for Sedimentary Geology, 2019).

During low sea-level stands, river deltas advanced across the basin, depositing shallow-water sands on top of previously deposited slope muds. During highstands, the delta retreated, and deeper-water conditions returned, sometimes depositing thin turbidite layers over the delta sands. These climate-driven cycles resulted in repeated, rhythmically stacked units seen in the coastal cliffs (SEPM STRATA Society for Sedimentary Geology, 2019).

The Loop Head Peninsula captures the earlier part of this succession: an upward transition from basin-floor turbidite sheets (Ross Formation) into deformed slope wedges (Gull Island Formation), ultimately overlain to the east by younger deltaic sandstones of the Central Clare Group (Magee, n.d.). This stratigraphy records a basin filling from below (deep marine) to above (deltaic), punctuated by episodic sea-level falls that caused channels to incise and sediment to temporarily bypass to the deep basin (SEPM STRATA Society for Sedimentary Geology, 2019).

Overall, the regional geology of Loop Head records the growth of a Carboniferous submarine fan-delta system, later preserved and exposed by uplift and erosion after the basin was infilled and tectonically inverted.

Structural Geology

The horizontal sedimentary layers at Loop Head were later deformed by tectonic forces. In the Late Carboniferous to early Permian, around 300 Ma, the Variscan Orogeny compressed Ireland's bedrock from the south. In County Clare, this produced east to west trending folds and associated joints and faults throughout the Carboniferous strata (Pracht & Feely, 2004).

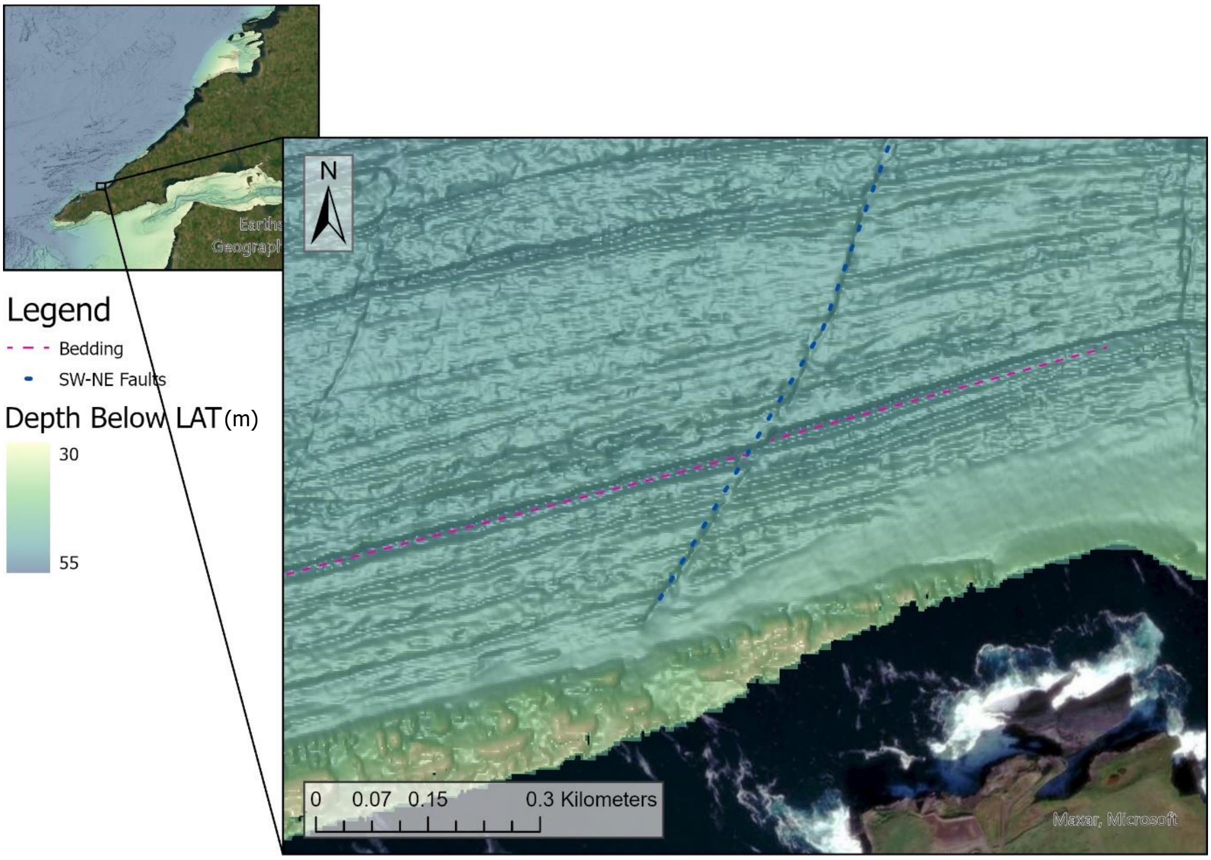

Figure 6: Bathymetry showing faulting causing displacement between bedding.

Many of these folds are exposed in the sea cliffs. At Loop Head itself, the cliffs reveal the cross-section of a large box fold (Magee, n.d.), a broad, symmetrical fold with a flat crest and steep limbs (Fossen, 2015).

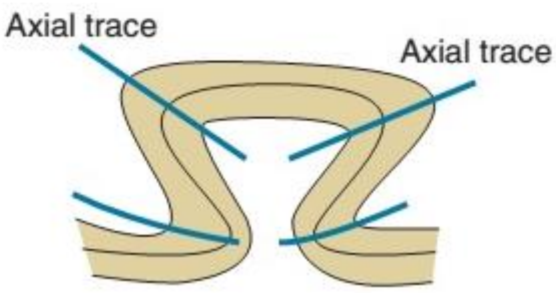

Figure 7: Diagram of a box fold. Image from (Fossen, 2015).

One limb of this fold is seen on the north side of Loop Head as an impressive vertical wall of sandstone beds rising from sea level to the cliff top, while the other limb outcrops on the south side of the headland (Sheehan, 1984).

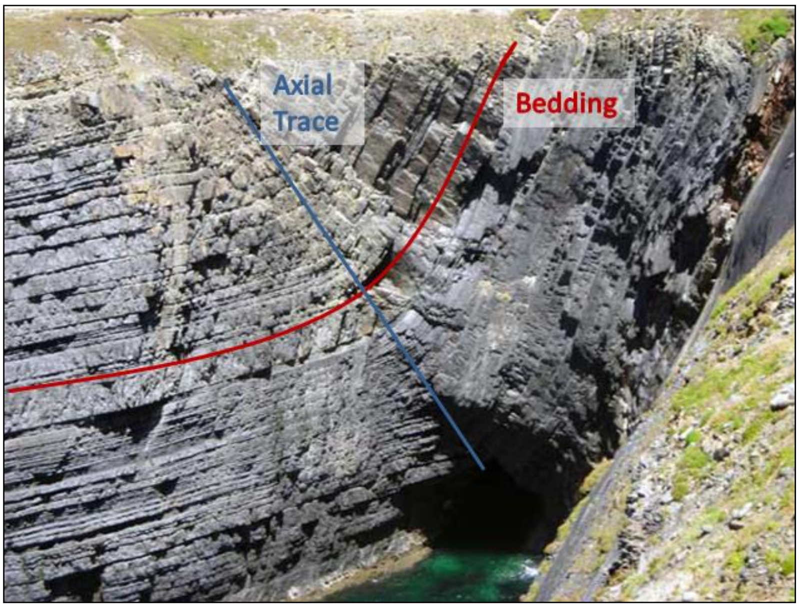

Figure 8: Image showing limb of box fold at the Bridges of Ross, with bedding and axial trace indicated. Image from (SEPM STRATA Society for Sedimentary Geology, 2019).

The fold's hinge lies offshore near a prominent sea stack, Diarmuid and Gráinne's Rock, which is separated from the mainland by Cúchulainn's Leap, a south-west to north-east trending fault (Sheehan, 1984).

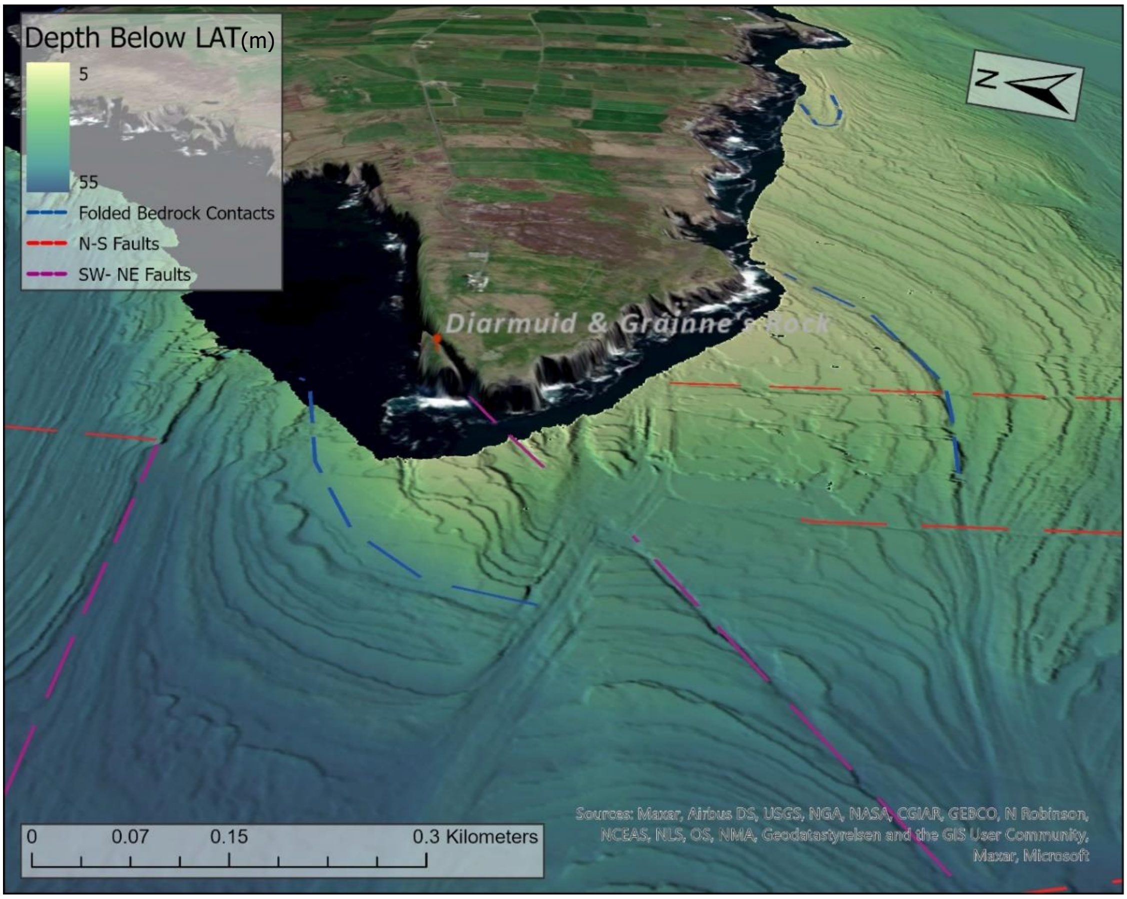

Figure 9: 3D imagery of bathymetry around Diarmuid & Gráinne's Rock, with faults and folded contact indicated.

Numerous smaller folds, including tight upright folds, gentle warps and recumbent, or overturned, folds, are seen along the coast. Some are related to tectonic compression, while others formed through soft-sediment slumping. Within the slump units of the Gull Island and upper Ross formations, beds were contorted while still unconsolidated, producing recumbent fold structures in places. These soft-sediment folds tend to have chaotic orientations and are often truncated by the overlying undisturbed strata, indicating they formed due to gravity-driven sliding before lithification (Parkes, et al., 2005).

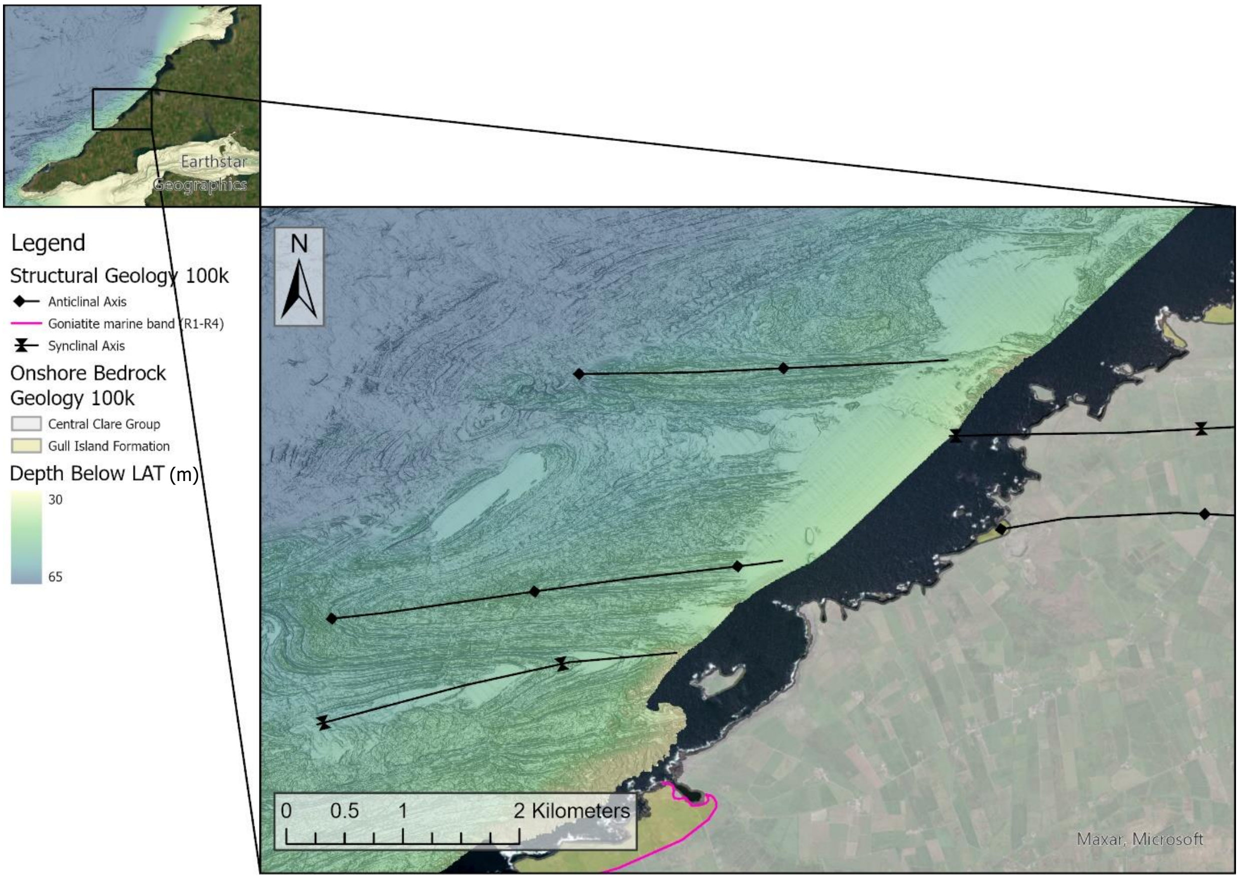

Figure 10: Bathymetric and geological image of onshore and offshore folds.

Fractures and joints are another widespread structural feature at Loop Head. Variscan compression and subsequent stress regimes produced orthogonal joint sets cutting through the bedrock, with a notable set of near-vertical joints striking roughly north-south (Coakley & McCarthy, 2014). These fractures, along with occasional small faults, dissect the rock and often guide erosion. Straight sea-inlets and clefts can align with joint directions. INFOMAR bathymetry data confirms that the structures seen on land continue beneath the sea. North of Loop Head, faulted and folded bedrock outcrop on the seabed, with several prominent north to south striking faults and concentric fold patterns evident in the relief. In the shaded seafloor imagery, the fold outcrops appear as arcuate, eye-shaped concentric structures created by erosion of the plunging fold hinges (Arosio, et al., 2024).

The offshore geology follows the same structural grain as the onshore cliffs, with east-west folds cut by near-vertical fractures. This continuity shows that the Variscan deformation fabric extends across the Shannon Estuary and beyond, partly concealed by the waters of the Atlantic. The deformation at Loop Head, from the large box fold to smaller fractures and joints, has had a strong control on the landscape and is central to understanding how the area has evolved since Carboniferous times.

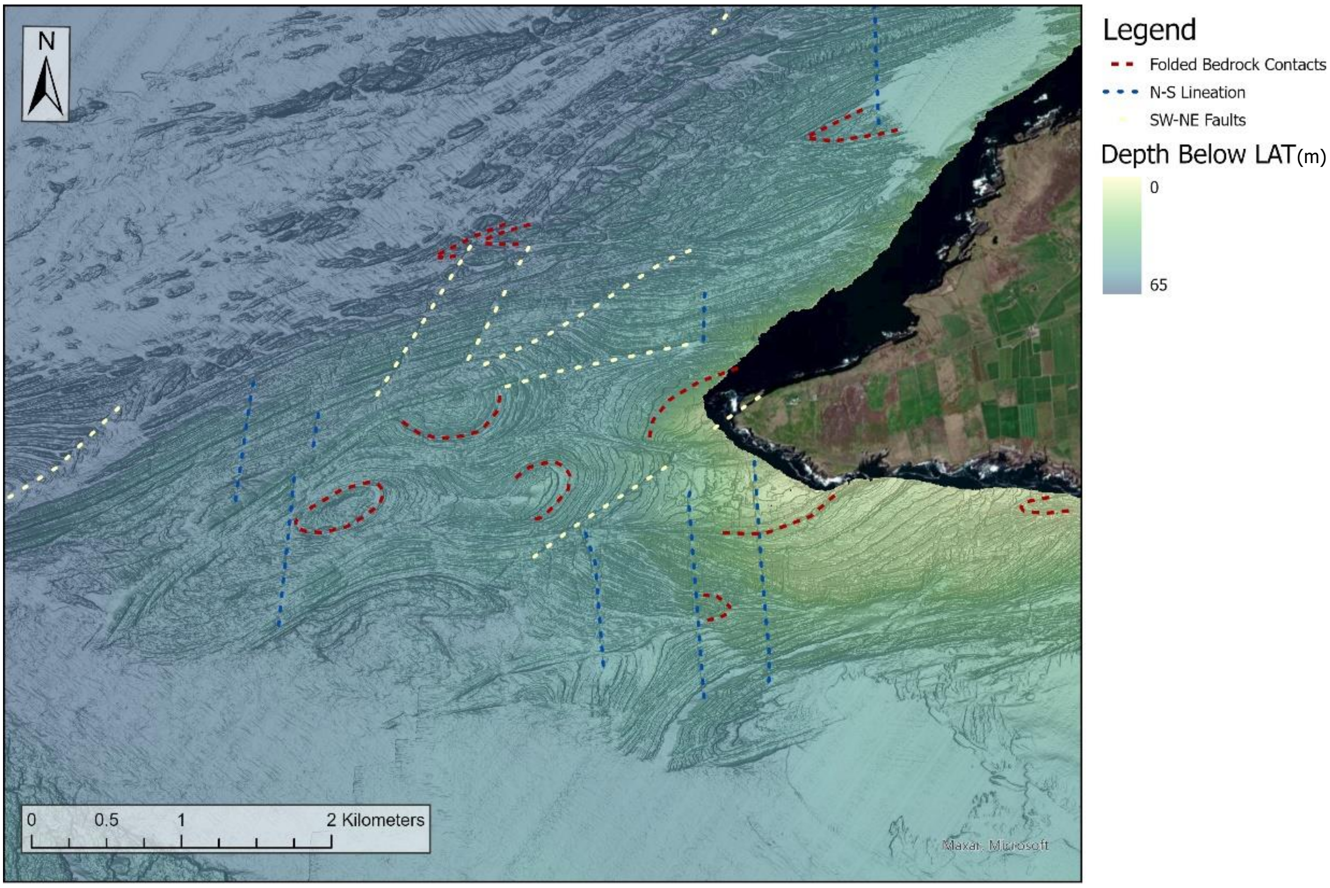

Figure 11: Bathymetry of Loop Head with faults and folded bedrock contacts indicated.

Bridges of Ross

One of Loop Head's best-known features is the Bridges of Ross, located on the north shore of the peninsula near Ross Bay. The name is plural because there were originally three adjacent sea arches here, spanning coastal chasms like rocky bridges. However, two of the bridges are believed to have collapsed in the 19th century, leaving only one robust arch still intact (Wild Atlantic Way, n.d.).

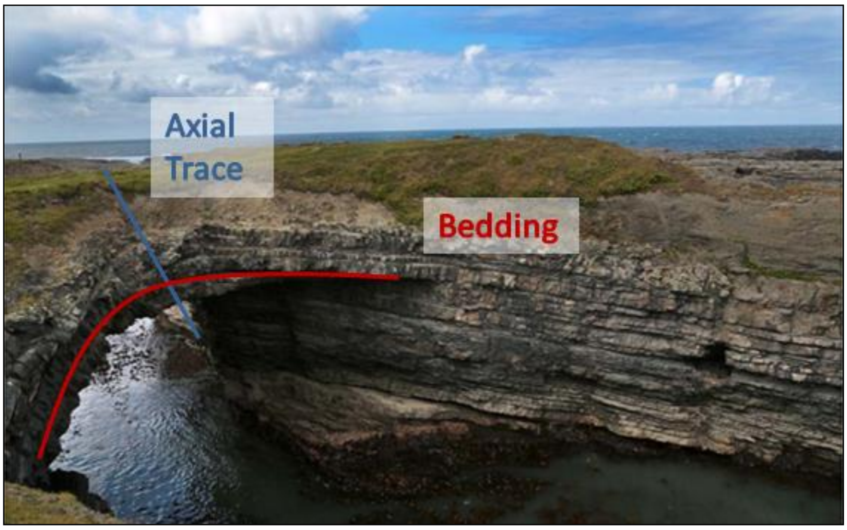

Figure 12: Image of the Bridges of Ross showing a fold, with bedding planes and axial trace indicated. Image from (Loop Head Tourism, 2021).

This surviving arch (pictured above) has been sculpted by relentless wave action along zones of weakness in the rock. These weaknesses correspond to geological structures in the underlying Upper Carboniferous strata. The remaining arch reflects both marine erosion and the structure of the underlying bedrock. It follows the line of a fold hinge, while its roof is formed by a more resistant sandstone layer that capped the slump.

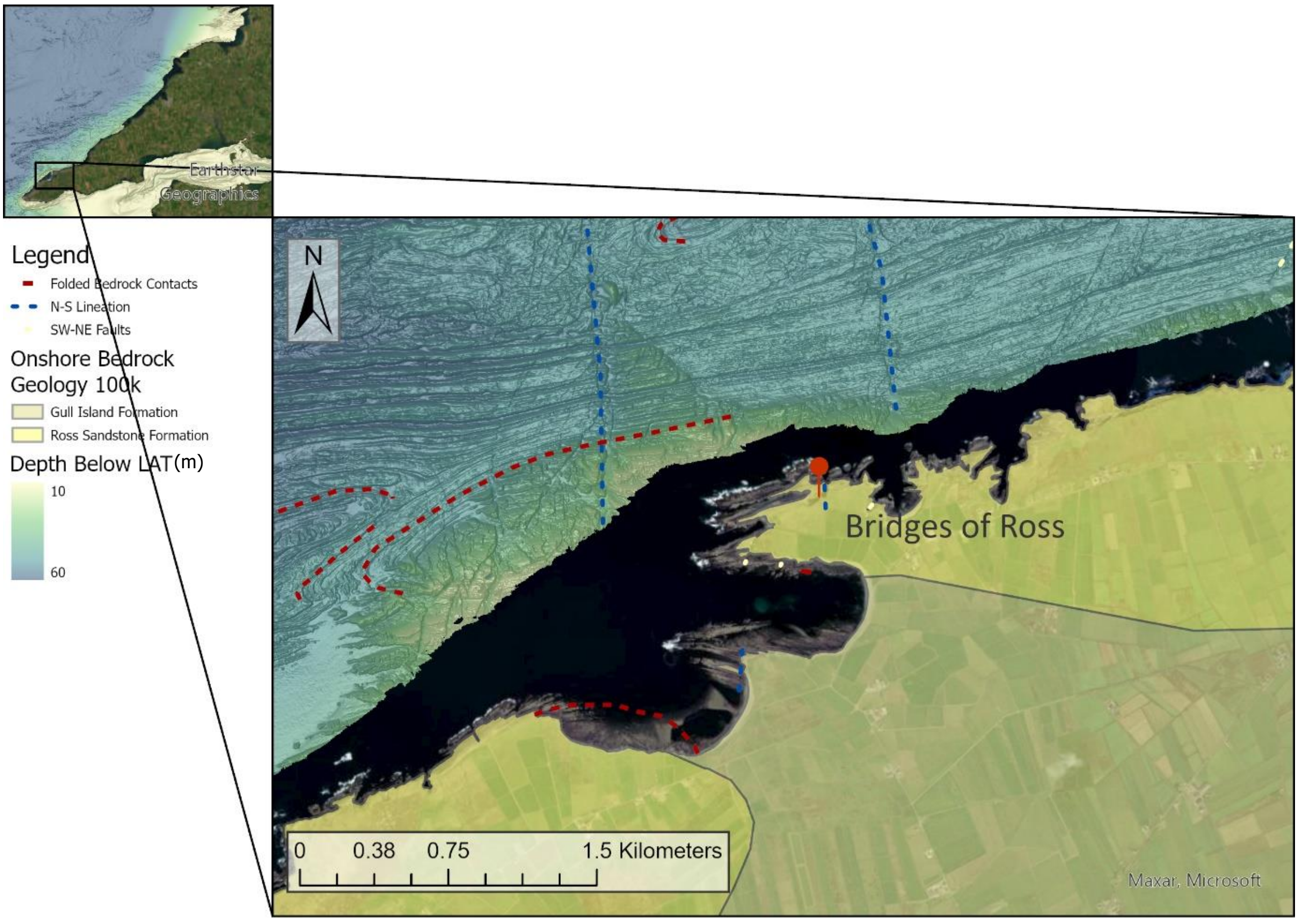

Figure 13: Bathymetry around the Bridges of Ross, with faults and folded bedrock contacts indicated.

At the Bridges of Ross, part of the Ross Sandstone Formation is exposed, but here the otherwise sheet-like sandstone and siltstone beds are heavily deformed. Slumping, or gravity-driven sliding of sediment, occurred repeatedly during deposition of the Ross Sandstone. Ross Bay is the site of an ancient slump deposit known as the Ross Slide, which has given the rocks a chaotic internal structure that has influenced later erosion.

The Ross Slide is several metres thick and consists of a lower interval of contorted siltstone overlain by sandstone. When this slump took place, semi-consolidated sediment on the ancient delta slope became unstable and moved downslope, folding and faulting itself in the process. Some of the fold hinges were rotated into near-horizontal, recumbent orientations during the slippage. At the top of the slumped unit, geologists have identified sand volcanoes. These are small conical mounds of sandstone that formed when water and liquefied sand were forced upwards through cracks, erupting onto the surface of the slump as it settled (SEPM STRATA Society for Sedimentary Geology, 2019).

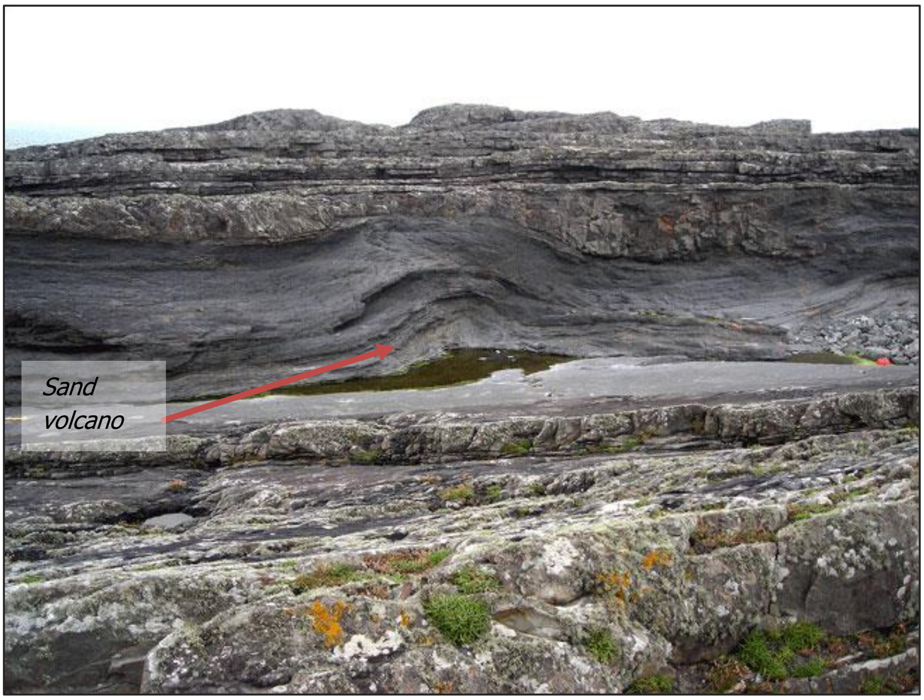

Figure 14: Image of the Ross Slide from (SEPM STRATA Society for Sedimentary Geology, 2019)

The Bridges of Ross therefore provide a three-dimensional view of a large ancient submarine mass-wasting event and its modern erosional expression. The chasm beneath the arch exposes contorted strata in the rock walls, showing how a sedimentary event that took place around 315 Ma still influences the coastal landscape today.

Figure 15: 3D Imagery of the Bridges of Ross with faults indicated.

Conclusion

Loop Head records the development of an Upper Carboniferous submarine fan and slope system within the Clare Basin. The Ross Sandstone Formation records deep-water turbidity currents and sheet-like sandstone deposition, while the overlying Gull Island Formation records slope instability, soft-sediment deformation and slumping. These rocks were later folded, fractured and uplifted during the Variscan Orogeny.

The same geological structure that is visible in the cliffs continues offshore, where INFOMAR bathymetry data show folded bedrock contacts, faults and eye-shaped fold outcrops on the seabed. This onshore-offshore continuity shows that the structural grain of Loop Head extends beneath the Atlantic.

The peninsula's cliffs, sea stacks, arches and inlets have been shaped by the interaction of bedrock structure, jointing, faulting and wave erosion. At the Bridges of Ross, marine erosion has exploited folded and slumped Carboniferous strata, leaving a coastal arch that reflects both the sedimentary history of the Ross Sandstone Formation and later structural deformation.

Bibliography

- Arosio, R., Wheeler, A., Sacchetti, F. & Lim, A., 2024. *Hidden landscapes: the mapping of Ireland's shelf geomorphology.* [Online]
  Available at: https://www.hydro-international.com/content/article/hidden-landscapes-the-mapping-of-ireland-s-shelf-geomorphology#:~:text=on%20bedrock.%20D%29%20%E2%80%98Eye,in%20bedrock%20offshore%20Loop%20Head

- Coakley, B. & McCarthy, D., 2014. *Loop Head and Kilkee Heritage Trail on the Wild Atlantic Way,* s.l.: The Heritage Council; Clare County Council; Fáilte Ireland.

- Fossen, H., 2015. *Geometric description of folds.* [Online]
  Available at: https://geologylearn.blogspot.com/2015/08/geometric-description-of-folds.html

- Loop Head Tourism, 2021. *The Bridges of Ross.* [Online]
  Available at: https://loveloophead.com/the-bridges-of-ross/

- Magee, G., n.d. *Guide to the Geology of the Loop Head Peninsula.* [Online]
  Available at: https://www.dolphinwatch.ie/site/uploads/geology/guide-to-the-geology-of-the-loop-head-peninsula-.pdf

- Parkes, M., McAteer, C. & Engering, S., 2005. *The Geological Heritage of Clare: An audit of County Geological Sites in Clare ,* s.l.: Geological Survey Ireland .

- Pracht, M. & Feely, M., 2004. *Geology of Galway Bay: A Geological Description to Accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 14, Galway Bay,* s.l.: Geological Survey Ireland.

- SEPM STRATA Society for Sedimentary Geology, 2019. *Bridges of Ross Ross Fm.* [Online]
  Available at:

https://www.sepmstrata.org/page.aspx?pageid=470#:~:text=Deepwater%20Bridges%20of%20Ross%20Formation,wings%20(Elliot%2C%202000a).

- SEPM STRATA Society for Sedimentary Geology, 2019. *Clare Basin Upper Carboniferous Deepwater Sediments.* [Online]
  Available at: https://www.sepmstrata.org/page.aspx?pageid=154

- Sheehan, G. C. L., 1984. *The Geology of Loop Head, Co. Clare.* [Online]
  Available at: https://www.geoschol.com/more/iga_field_guide_loop_head.pdf

- Wild Atlantic Way, n.d. *Bridges of Ross.* [Online]
  Available at: https://www.thewildatlanticway.com/sight/bridges-of-ross/