DISCOVERY AND RECOVERY OF AN EXCEPTIONAL ACCUMULATION OF CARBONIFEROUS ECHINOIDS AT HOOK HEAD, WEXFORD.

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ABSTRACT

Geoconservation is a burgeoning area of activity within the Earth sciences and the preservation of significant fossil finds remains crucial for the advancement of palaeontological knowledge and protection of geoheritage. Here, we report on the discovery of an unusually large and remarkably well-preserved cluster of Carboniferous echinoids at Hook Head in County Wexford, Ireland. The fossil accumulation was located in the upper part of the Ballysteen Limestone Formation, which is Tournaisian in age and records sedimentation on a mixed carbonate-siliciclastic shelf/ramp. The fossil record of Paleozoic echinoids is generally poorly sampled; however, the fossil cluster from Hook Head includes at least 250 partially imbricated echinoid specimens in close association and preserves features such as the spines, Aristotle's lantern and peristomal plates. The fossil-bearing surface was precariously located on a coastal outcrop and at serious risk of being removed by storm activity, prompting an emergency rescue operation. The successful recovery of this important fossil find, which included securing official permission for extraction of the slab and its lodgement with the National Museum of Ireland, represents something of a first for Irish geological conservation.

INTRODUCTION

Paleozoic echinoids are generally considered as forming only a minor component of epifaunal marine communities (e.g. Schneider 2008). This is largely due to their flexible construction, with their globular tests being comprised of loosely imbricating plates connected by soft tissue, leading to a high propensity for rapid post-mortem disarticulation prior to burial (e.g. Smith 1980, 1984; Donovan 1991; Ausich 2001). Thompson and Denayer (2017) noted that complete tests of Paleozoic echinoids are extremely rare and argued that the common occurrence of high levels of disarticulation has led to the perception of low echinoid abundance and/or diversity in Paleozoic benthic communities. After the Paleozoic, the palaeoecological prominence of echinoids fundamentally changed with the emergence of urchins with rigid tests and also the development of infaunal lifestyles, which enhanced their preservation potential even further (e.g. Kier 1977; Nebelsick 1999; Nebelsick and Kroh 2002; Kowalewski and Nebelsick 2003; Kroh and Smith 2010; Coppard *et al.* 2012; Hopkins and Smith 2015; Nebelsick and Mancosu 2015; Boivin *et al.* 2018).

This short contribution notes the discovery of a very large cluster of intact fossil echinoids preserved in Tournaisian (Carboniferous, Mississippian) carbonates at Hook Head, in County Wexford, southeast Ireland (Figs 1 and 2). The specimens, which are remarkably well-preserved (Figs 3 and 4), were discovered during the course of a geological mapping survey by the lead author (NÁ-A) in the summer of 2012. However, during follow-up field investigation in April 2014, it was found that a portion of the fossil-bearing surface had been removed by storm activity, resulting in a loss of several echinoid specimens. As the echinoid-bearing surface was quite exposed, lying close to the

high tide mark (Figs 1b-c and 2), and at very real risk of complete removal by further coastal erosion, it was decided that it was necessary to save and recover this important fossil accumulation. This set in motion a sequence of events, involving monitoring of the site at Hook Head until November 2014 when all of the necessary permissions were secured for rescue and removal of the fossil cluster. Successful recovery of the slab happened in December 2014, and it was immediately deposited with the National Museum of Ireland for safekeeping and conservation.

GEOLOGICAL CONTEXT OF THE FIND

The exceptionally well-preserved accumulation of fossil urchins was found in the upper part of the Ballysteen Limestone Formation, near the village of Slade at Hook Head (Irish grid reference SC 747987; Fig. 1b). The Tournaisian stratigraphy of the area was first described in detail by Smyth (1930), who defined a number of informal units based on lithology and palaeontological (principally brachiopod and coral) content. Subsequently, Sleeman *et al.* (1974, 1983) revised the entire Devonian-Carboniferous sequence on the Hook Peninsula and formally defined several lithostratigraphic units (e.g. see lower part of key in Fig. 1a), which record a transgression from terrestrial to marine sedimentary facies (e.g. Clayton and Higgs 1979; Sleeman 1977; Graham and Sevastopulo 2020). Sleeman *et al.* (1974) amalgamated the upper six of the informal divisions described by Smyth (1930) (representing the carbonate-dominant part of the succession) into the Hook Head Formation, which they estimated to be 335.5m thick.

Subsequent lithostratigraphic work by Geological Survey Ireland divided the Hook Head Formation into the Ballymartin Limestone and overlying Ballysteen Limestone formations (Sleeman and Tietzsch-Tyler 1988; Tietzsch-Tyler *et al.* 1994), which are more regionally correlatable entities (e.g. Philcox 1984; Somerville and Jones 1985; Sevastopulo and Wyse Jackson 2009; Somerville *et al.* 2011; see also Murray 2010). These two formations are predominantly composed of interbedded argillaceous limestones and calcareous shales, whilst conodont biostratigraphy indicates the presence of the *Pseudopolygnathus multistriatus* Biozone and lower part of the overlying *Polygnathus mehli* Biozone (Sleeman*, et al.* 1974; Johnston and Higgins 1981), which is equivalent to the *Polygnathus communis carina* Biozone of Belgium, confirming an upper Tournaisian age (Ivorian regional substage; see Varker and Sevastopulo 1985; Somerville 2008). A conspciuous 25m-thick unit of dolomitised crinoidal and oolitic cross-bedded grainstones (the Bullock Park Bay Dolomite Member; Fig. 1a) occurs within the Ballysteen Limestone Formation, *c*. 54m above the base (Tietzch-Tyler *et al.* 1994).

The Ballymartin Limestone and Ballysteen Limestone formations (= Hook Head Formation) at Hook peninsula have been interpreted as representing a mixed carbonate and siliciclastic shelf-ramp environment, which gradually deepened as marine transgression progressed (Ausich and Sevastopulo 1994; see also Kammer and Ausich 2006 for a broader perspective on the significance and impact of Mississippian carbonate ramp development). Much of the Hook Head succession was deposited below fair weather wave-base, with a temporary shallowing (minor regression) above this bathymetric level represented by the Bullock Park Bay Dolomite Member. Episodic storm events affected the Tournaisian seafloor, with tempestite deposition responsible for the high-quality preservation of numerous fossils due to rapid burial of the benthic community (Ausich and Sevastopulo 1994). Well-preserved macrofossils are common in the succession, particularly articulated crinoids (Ausich and Sevastopulo 1994, 2001), brachiopods (Mottequin 2010) and bryozoan faunas (Hageman *et al.* 2011; Wyse Jackson *et al.* 2017).

The horizon containing the echinoid cluster at Slade (Figs 2, 3 and 4) broadly equates to the gradational boundary interval between the '*supra-dolomite beds*' and overlying '*Linoproductus beds*' described by Smyth (1930), and it is positioned above the lithostratigraphic level of the Bullock Park Bay Dolomite Member. Ausich and Sevastopulo (1994) noted the presence of echinoid material in the uppermost '*supra-dolomite beds*' and also the '*Linoproductus beds*', along with preservation of rare complete echinoids in the overlying '*Chonetes beds*' (as defined by Smyth 1930). This latter informal subunit represents the top *c*. 50m of the Ballysteen Limestone Formation.

FIELD DESCRIPTION OF THE ECHINOID CLUSTER

At least 250 intact echinoid specimens are present in close association on the bedding surface, within an area of *c*. 1m^2 (Fig. 3). The immediately underlying portion of the host bed is a wackestone, although the urchins are overlain and draped by carbonate mudstone (calcilutite), which is variably bioturbated (Fig. 4a, c, d). All of the urchins are deflated, with test plating remaining in close association, and most specimens are preserved on their sides, with their primary and secondary spines still attached (Fig. 4). Pending further detailed taxonomic investigation, the specimens are interpreted as archaeocidarids (pers comm. George Sevastopulo 2016), principally on the basis of test plating and the relatively large size of spines (e.g. Thompson *et al.* 2020).

The Slade assemblage is predominantly a monospecific association of archaeocidarids, and taphonomic investigation of the fossil cluster is ongoing. It remains unclear why these urchins congregated in such large numbers (to the exclusion of practically all other marine benthos). Elsewhere in the Carboniferous, the early Viséan Fort Payne Formation (Kentucky) and 'Black Marble' of Denée (Belgium) include polyspecific echinoid aggregations, which accumulated over time as composites of several depositional events (e.g. Mottequin 2008; Mottequin *et al.* 2015; Thompson and Ausich 2016). The Pennsylvanian (Kasimovian) Winchell Formation (Texas) records at least seven consecutive aggregations of autocthonous echinoids (e.g. Schneider 2003a, 2003b, 2008; Schneider *et al.* 2005). This particular shallow-marine estuarine-influenced nearshore unit has produced a largely monospecific echinoid assemblage dominated by *Archaeocidaris brownwoodensis*. At Hook Head, the urchin specimens are broadly similar in size to each other, they appear to be concentrated in a single, relatively thin, layer and there is a lack of additional taxa with similar hydrodynamic properties (Figs 3 and 4). These characteristics suggest that the Slade echinoids may have originally been gregarious in life and that, following a mass congregation on the seafloor, they were killed simultaneously by a sudden event, with relatively rapid burial facilitating articulation of tests and retention of spines. Test size of the Slade urchin specimens averages *c*. 10mm for the short axis and 14mm for the long axis, which is small for typical archaeocidarids (for example, the specimens of *A. brownwoodensis* described by Schneider *et al*. (2005) had test sizes ranging 34–60mm). Further detailed taxonomic and taphonomic investigation is in progress.

PROTECTION OF GEOHERITAGE IN IRELAND

As the limestone bed containing the fossil echinoid concentration at Slade was at real risk of being eroded and lost to science, intensive efforts were made by one of the co-authors (MAP) to secure the necessary official permissions to safely recover the slab. This action represented something of a first for Irish geological conservation and heritage, which had been developing since the late 1990s under the Geological Heritage programme in Geological Survey Ireland (e.g. Gatley and Parkes 2016, 2018; Parkes and Gatley 2018). During this time, the programme has identified and documented

important geological heritage sites for their protection and promotion. The Hook Head site is of national and international significance under the Carboniferous to Pliocene Palaeontology Theme and was recommended to National Parks and Wildlife Service (NPWS) for designation as a geological Natural Heritage Area (Meehan *et al*. 2018). Pending any potential future designation, identified sites such as Hook Head are classified as County Geological Sites, and are recognised in statutory County Development Plans. They are thus afforded a measure of protection in that they must be considered in the planning process.

The site on the Hook Peninsula (Fig. 1) adjoins a large area of seabed under the Special Area of Conservation (SAC) IE0000764 protection for vegetated sea cliffs, intertidal and offshore reefs and seabed; however, the fossil fauna was not specifically protected under this law. Regardless of the lack of formal protection, MAP made contact with the NPWS, with the aim of obtaining a licence for an extraction and rescue operation. A Notifiable Action Consent request was submitted, followed by an application for a Foreshore Licence (specifically a short event licence), as the fossil-bearing surface was located close to the high tide level (see Figs 1b-c, 2). This process was initiated in the hope of establishing a good precedent and enhancing collaborative relationships between the various State-level stakeholders (Geological Survey Ireland's Geological Heritage Programme, National Museum of Ireland and also the NPWS). Because the limestone bed dipped down beneath the mean high tide level, with the echinoid cluster positioned just slightly above this datum on the same surface (Fig. 2), the landowner of the farmland directly above the contiguous cliffs was deemed the owner of the specific area of the bedding surface containing the fossil accumulation (with the portion of the same horizon lying below the mean high tide level in State ownership). The local landowner was duly contacted and granted full permission for access and removal of the portion of the surface bearing the echinoid cluster.

RECOVERY OF THE ECHINOID-BEARING SURFACE

With the approval of the NPWS, Geological Heritage Programme (Geological Survey Ireland), National Museum of Ireland, Wexford County Council, relevant landowner and, indeed, local community, a multidisciplinary team (with experience in palaeontology, geological fieldwork, rock cutting/extraction methods and also geoheritage and conservation) travelled to Slade on 4 December 2014 (Fig. 5) to recover the limestone horizon containing the echinoid accumulation. The extraction was successfully achieved by cutting channels around certain portions of the periphery of the fossil cluster with a consaw and then using pry-bars to separate and carefully lift the entire slab, which was recovered in several large sections (Fig. 5a-c). These sections were then placed onto padded plastic pallets and transferred to a nearby van (Fig. 5d-f). Once the echinoid cluster had been safely removed, the area was carefully washed and cleaned to leave no visible trace of the extraction.

The Slade echinoid cluster was deposited with the National Museum of Ireland (specimen number NMING:F35254) immediately following recovery, where it is presently awaiting cleaning, preparation and restoration. It represents a very significant find in palaeontology (both nationally and internationally) and the action taken to save it represents an important development in Irish geological heritage and conservation. Since December 2014, the remaining bedding surface at Slade, on which these echinoids came to be so well-preserved and in such remarkably large numbers, has not survived winter storms.

ACKNOWLEDGEMENTS

We dedicate this contribution to the memory of our co-author Matthew Parkes, who worked tirelessly and very effectively to secure all the necessary permissions to ensure the safe recovery of this important piece of Irish geological heritage. Matthew always sought to improve the management of geological and palaeontological interests within the existing frameworks of protection. At Hook Head, he envisaged a local Fossil Collecting Code within a conservation message, contingent upon local community support, in particular with the Hook Lighthouse Visitor Centre.

We are also very grateful for immense support and advice from George Sevastopulo, who also recently left us. When first notified about the find in 2012, George remarked *"I remember a similar surface that I found that did not last the winter; we should not let this one go."* He immediately recognised the extraordinary significance of this fossil find and the need for its preservation for future generations.

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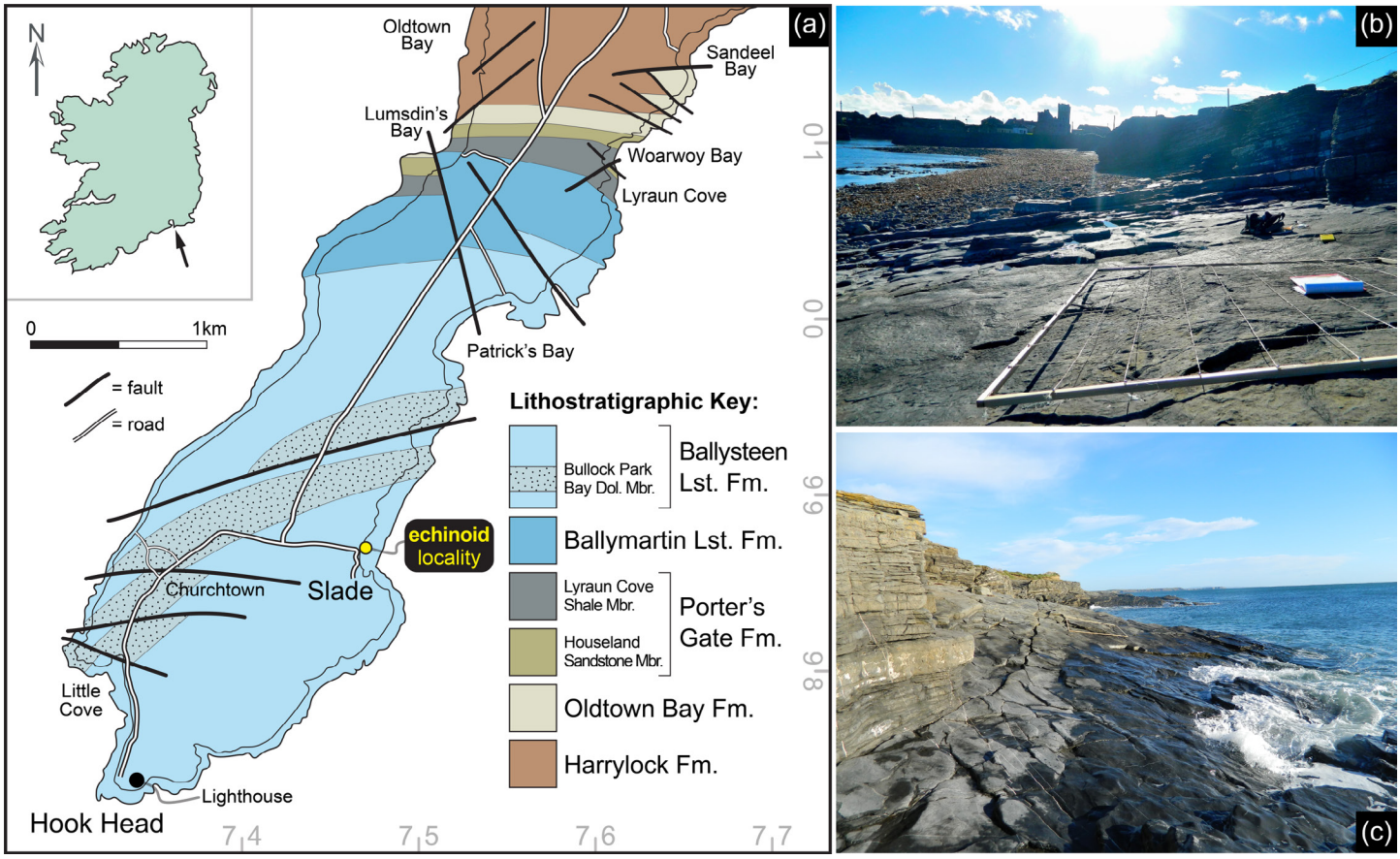

Fig. 1—Location of Slade echinoid fossil cluster in County Wexford. (a) Geological sketch map of Hook Penninsula showing the location of the echinoid fossil locality, immediately north of Slade. Inset map (top left) shows general location in Ireland. The lithostratigraphic key of the main geological map compilation is based on the scheme proposed by Tietzsch-Tyler *et al.* (1994). The Famennian-Tournaisian (Devonian-Carboniferous) boundary occurs close to the top of the Harrylock Formation (Sleeman *et al.* 1983; Higgs *et al.* 1988) and the overlying Tournaisian succession generally youngs in a southerly direction on the peninsula. Geological map adapted from MacCarthy and Higgs (2013) and also Geological Survey Ireland data. Fm. = Formation, Mbr. = Member, Dol. = Dolomite, (b) View looking southwards from the fossil locality towards Slade Castle, taken at low tide. The quadrant measures 2m^2 and rests directly on the echinoid cluster, (c) View from same location as (b) taken at high tide and looking northwards along the coast.

Fig. 2—View of the Slade echinoid-bearing surface (immediately beneath the quadrant, which measures 2m^2) taken at high tide. This photograph was taken looking eastwards and emphasises the precarious position of the fossil accumulation prior to recovery.

Fig. 3—General plan view of the echinoid cluster on the bedding surface at Slade, prior to recovery. White box indicates area shown in Fig. 4a. Black arrow (top left) points to geographic north.

Fig. 4—Detailed views of the echinoid cluster at Slade. (a) General view of imbricated echinoids with attached spines. Bioturbation is evident in the interstitial calcilutite matrix. Approximate locations of more close-up views in Fig. 4(b), (c) and (d) are shown with white boxes. The width of the white box for Fig. 4(b) is 9cm, (b) Imbricated echinoids with at least two fossil specimens showing Aristotle's lantern and peristomal plates (white arrows), (c) Partially covered echinoids exposing aristotle's lantern and peristomal plates (white arrows), (d) Abundant trace fossils associated with echinoids, one particularly good example is indicated by the yellow arrow. Diameter of 2 Euro coin in (c) and (d) is 26mm.

Fig. 5—Recovery of the echinoid-bearing limestone surface at Slade in December 2014. (a)-(c) Cutting, lifting and freeing the slab using pry-bars, (d)-(f) Transfer of the slab sections on padded plastic pallets to nearby vehicle. The pallets made it easier and safer for the recovery team to lift and transport the slab sections. (g) The recovery team (minus Sarah Gatley, who took the photograph; from left to right: Maite Zabaltza-Jimeno, Jake Ciborowski, John Murray, Matthew Parkes, Barry Walsh, Philip Cassidy and Barry O'Rourke, with Nidia Álvarez-Armada kneeling in front). The group is standing at the point of successful extraction at the end of the day, with Slade Castle in the background. The area had been carefully cleaned to leave no trace of disturbance.