Short Contribution: Marine Erosion and Archaeological Landscapes: A Case Study of Stone Forts at Cliff-Top Locations in the Aran Islands, Ireland

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Two massively constructed stone forts exist on the edge of vertical coastal cliffs on the Aran Islands, Ireland. One of these, Dun Aonghusa, contains evidence of occupation that predates the main construction phases of the walls and broadly spans a time interval of 3300–2800 yr B.P. The other fort, Dun Duchathair, has been termed a promontory fort because its remaining wall crosses the neck of a small promontory marginal to the cliffs. Estimates of past rates of marine erosion in this part of Ireland may be made both by analogy with studies in other areas and comparison with present day rates of marine erosion. A working model for erosion rates of approximately 0.4 m of coastal recession per annum is suggested. By applying this rate to the cliffs of the Aran Islands, it can be shown that, assuming a construction date of approximately 2500 yr B.P. for these forts, they were originally built at a considerable distance from the coastline. Thus Dun Duchathair was not a promontory fort. The earliest recorded habitation at Dun Aonghusa, dated to the middle of the Bronze Age, was, therefore, at some distance inland and not on an exposed 70 m high cliff on the edge of the Atlantic Ocean.

INTRODUCTION

At a period of widespread rise in relative sea-level in many parts of the world, the present-day landscapes of archaeological sites may be misleading due to marine erosion. To demonstrate this, two sites in western Ireland were examined to determine their original position in a landscape. Many archaeologists have assumed that the present locations of these two sites, with respect to the coastline, have remained unchanged since their construction.

The Aran Islands off the west coast of Ireland (Figure 1) have a high density of large and elaborate stone forts. Among the best known are the cliff-top forts of Dun Aonghusa (L817097) and Dun Duchathair (The Black Fort, L870073), both situated on the largest of the three islands, Inishmore. The former is a complex of semicircular enclosures whose southwestern limit is a sea cliff some 70 m high (Figure 1). It is one of the best known archaeological monuments in Ireland and was described by Rathery (1984:45) as “one of the most astounding structures of its type in Europe.” Occupation at this site has been dated between ca. 3000 and...
Figure 1. (A) Location of the Aran Islands off the west coast of Ireland. (B) Map of Dun Aonghusa situated on the edge of a vertical 70-m-high sea cliff. (C) Map of Dun Duchathair, interpreted as a promontory fort, cliff height about 25 m.

2800 yr B.P. The innermost wall postdates ca. 2540 yr B.P. (Waddell, 1998). While some material has been dated to ca. 2200–2000 yr B.P. and to the early Historic period, these were not periods of extensive occupation. It would seem likely that at least some of the walls would have been extant over 2000 years ago.

The modern setting of the other cliff-top fort, Dun Duchathair (Figure 1), has resulted in its being described as a promontory fort (Gosling, 1994; Raftery, 1994). Similarly, the present setting of Dun Aonghusa has led to conjecture that it was constructed against the present day cliff. Raftery (1994:61), for example, compared the fort with others from Iron Age contexts in Iberia, all “built up against cliff edges in exactly the manner of Dun Aonghusa.” Also Waddell et al. (1994:25) surmised that it “was constructed in order to make full use of the defensive advantage of its cliff-top location . . . .” O’Riordain (1991:50) was convinced that the cliff-top forts
were in their original landscape when he said, “like other cliff edge sites some allowance must be made for erosion but any suggestion that these forts were once vastly greater in extent must be discounted.” The extensive construction of chevaux de frise outside the walls of these forts (Figure 1) strongly suggests a defensive purpose or an elaborate exhibition of status. However, the present location of these two forts, on the westerly facing cliffs, exposed to some of the most extreme sea and weather conditions in western Europe and without any permanent water supply, would not support such a defensive purpose.

COASTAL EROSION

Studies of Holocene sea-level changes around the Irish coast have shown (with localized exceptions) a progressive relative rise over the past 10,000 years (Carter et al., 1989; Lambeck, 1996). Such a rise must result in relatively progressive and continuous coastal erosion despite any intervals of regression due to isostatic crustal uplift. It is possible to partially quantify the extent of the erosion since the construction of the two forts on the Aran Islands.

The geology of the islands is relatively simple. They are underlain by Carboniferous limestone with a gentle southerly dip. The limestones, like those of the Burren on the mainland to the southeast (Figure 1), are interbedded with rare thin beds of mudstone. Another common feature of these limestones is the presence of pronounced and pervasive joint systems, many of which have been enlarged by solution in their upper parts. Although the directions of these joints vary across the Burren, the two sets on the Aran Islands are relatively constant, one set striking approximately N–S and the other approximately NE–SW (Figure 2).

The rates of erosion of sea cliffs are determined by a number of factors, namely, wave heights and intensity, mechanical strength of the rock mass, and joint types and frequency. Wave intensities along the southwestern margins of the Aran Islands can be extreme. Thirty years of data from the meteorological station at Bellmullet, on the northwestern coast of Ireland, show that gales affect this coastline on more than 30 days per year on average. Gusts reached 95 knots during the 30 years of record, but winds speeds of about 150 knots are exceeded on average every 50 years. These winds drive waves with a fetch of thousands of kilometers. Some extreme waves striking the Aran Islands have been capable of moving clasts weighing over 5 tons at locations more than 50 m above sea level (Williams and Hall, 2003).

A recent study by Budetta et al. (2000) established a relationship between rates of coastal erosion and the mechanical strength of the rock masses involved. The sea cliffs in their study were situated in southern Italy, and the results quantify the rates of erosion under Italian wave conditions. It was shown that rates of marine erosion (cliff recession) have a linear logarithmic relationship to the compressive strength of the exposed rock mass. The strength of the rock mass is given by the equation \( \varepsilon_{RM} = 5\varepsilon_{Jp} \). Here \( \varepsilon_{RM} \) is the uniaxial compressive strength of the rock mass and \( \varepsilon_{Jp} \) is a joint parameter depending on the openness and roughness of the joint surfaces. Limestones almost invariably have very open joints in their upper levels.
dueto solution by meteoric waters, thereby reducing the strength (RM) of the rock mass. Although the Italian study did not assess limestones, it did analyze materials of varying strengths ranging from siltstones to concrete. The results indicate that rock with the unconfined compressive strength of jointed limestone would lie between the marine erosion rates of jointed siltstone and concrete. Under the sea conditions of southern Italy, such limestones would be susceptible to erosion rates of approximately 0.2 to 0.3 m/y. Weather conditions on this part of the Italian coast are not as severe as those experienced in the Aran Islands. In the Italian example, the waves have a maximum fetch of some 964 nautical miles, many factors less than those in the Irish study area. Strong gale frequencies (force 6–8) occur only 2.5% of the time in Italy but approximately 5% of the time in western Ireland. Erosion rates similar to those estimated in southern Italy are not uncommon. In Monterey Bay, California, erosion rates in jointed sandstones are between 0 and 0.46 m/y (Moore and Griggs, 2002). Along the Californian coast in general, present day erosion rates are as high as 0.75 m/y (Chernicoff and Fox, 1997). Modern erosion rates on the western coast of Ireland (Galway Bay, Connemara) vary from 0.1 to 0.4 m/y (Joyce, 2001).

The southwestern coasts of the Aran Islands exhibit all the features of a receding coastline, including sea arches, sea stacks, significant cliff undercutting, blow-
holes, caves, and embayments. They are the only heavily jointed limestone cliffs on the western seaboard of Ireland that face directly into the prevalent swell and storm direction. The pressure exerted by long-fetch Atlantic waves commonly exceeds 24,000 kg/m² during storms (Holmes, 1965). This pressure might be applied over 8000 times in 24 hours. About 600 m directly north of Dun Duchathair, in a large embayment, recent erosion is manifest by a major collapse of approximately 9000 m³ of limestone from the cliff (Figure 3). This collapse occurred between 1990 and 2002 (Robinson, 1990), and at this locality indicates an erosion rate of at least 6 m in 10 years, or 0.6 m/y.

At many localities around the coasts of the islands, spectacular storm beach ridges are preserved. These often comprise large angular blocks of limestone with a pronounced imbricate fabric. The ridges can reach up to 5 m in thickness and are present at elevations of from 0 to 50 m above sea level and are the subject of a separate paper (Williams and Hall, 2003). They are the result of storm conditions generating waves powerful enough to move blocks weighing up to 250 tons at sea level, and attest to the extreme erosive nature of this Atlantic environment. Megablocks at higher elevations (> 20 m above sea level) are naturally moved less frequently than those at lower elevations. In 1839, during the “Night of The Big Wind” (Carr, 1993), ancient hut structures seaward of the wall of Dun Duchathair were...
buried under megaclasts weighing up to 5.8 tons. The storm “pushed enormous blocks (of rock) out of their places” (O’Donovan, 1839). This is the last known event to have moved megaclasts 25 m above sea level. This ridge is still extant but is now significantly eroded as is shown in Figure 4. The amount of coastal recession at these localities since 1839 may be calculated by measuring the distance from the seaward edge of the remaining beach ridge to the inner cliffs of the embayments, where the ridge is no longer present. Calculations of rates of erosion of the beach ridge in embayments around the area of Dun Duchathair give values of 0.3–0.8 m/y over the past 100 years. These values are conservative since they do not take into account the erosion of any wave-washed platform to the seaward margins of the ridge, such platforms being the norm at many places on the islands. These values bracket the erosion rate of 0.4 m/y obtained elsewhere in the Galway area, and make 0.4 m/y an average rate of erosion of the southeast coastal cliffs of the Aran Islands reasonable. The long-term erosion rate of the Aran Island cliffs is likely to be far greater than the average erosion rate for County Galway as a whole due to their extremely exposed position and the closely spaced and open joint system of the Carboniferous rocks. Such erosion would, of course, be episodic, being accelerated by the occurrence of major storm events.

ARCHAEOLOGICAL IMPLICATIONS

In order to reconstruct the landscape extant at the construction of these two forts, certain assumptions must be made. First, it is assumed, in the absence of contradictory evidence, that at least parts of these forts were constructed approximately 2500 years ago and, second, that present-day rates of coastal erosion in western Ireland and those derived from other studies are assumed to have remained more or less constant for the past 2500 years (possibly increasing slightly due to sea-level rise). Thus, a mean rate of erosion of 0.4 m/y for the sea cliffs of the Aran Islands would suggest that the southwest coastline of the islands has receded by approximately 1000 m since the construction of the forts. Figure 5 shows the estimated position of these forts with respect to the coastline 2500 years ago.

The revised positioning of the two forts shows that Dun Duchathair cannot be termed a promontory fort since it was not originally on a promontory. The sketch plan of Westropp (1910) shows the fort to have had a very pronounced curve to its main wall, a curvature still visible today despite erosion by wave action. It seems unlikely that a promontory fort would have had an unnecessary curvature involving an excess of labor and materials over a simple straight wall across a narrow promontory. This suggests that the structure was originally similar to Dun Aonghusa, but on a slightly smaller scale. This suggestion is supported by an early description of the fort by O’Donovan (1839) who stated: “To the northwest of this fortress (i.e., on the smaller promontory shown to the left of the fort in figure 4) are the evident traces of a similar one, but the cliff has fallen in and the storms have reduced the part remaining to a shapeless ruin.” Hence, it is likely that this shapeless ruin was...
Figure 4. Recession of the megaclast beach ridge in the vicinity of Dun Duchathair. The morphology of the ridge is outlined and the amount of erosion since 1839 is indicated by the white bars for the three embayments present here.
originally part of a circular or oval structure which has been so eroded as to leave only the wall segment today known as Dun Ducathair. In addition, Dun Aonghusa has produced evidence of occupation around 3000 yr B.P. (Waddell, 1998). It seems unlikely that a Bronze Age settlement would occur on a site as exposed as the present location. However, a site in a wooded environment, in an upland area, and perhaps 1 km away from the worst effects of the Atlantic storms would seem reasonable.

CONCLUSIONS

All archaeological sites exist in the modern landscape. In this paper, the modern coastal landscape of islands off the west coast of Ireland has been shown to be one of constant modification by erosional processes operating in a high-energy environment. Estimation of the rates of erosion has led to a reappraisal of both the original location, relative to a coastline, and function, of two prehistoric forts on one of these islands. While archaeologists are aware that floral and faunal changes may have occurred subsequent to the date of usage of a site, morphological changes due to erosion and deposition may not be so apparent to them. Such changes are not, of course, restricted to coastal sites, but may have considerably modified other landscapes, especially in mountainous, glacial, deltaic, or fluvial environments. Archaeological sites in coastal environments can also aid in the estimation of long-term rates of coastal erosion where the age and purpose of the site is known.
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REFERENCES


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