DISCUSSION OF MEGACLAST TRANSPORT AND EROSION OF ROCKY SHORELINES: A COMMENT ON WILLIAMS (2010)

JASPER KNIGHT

A recent paper by Williams (2010) described very large boulders (megaclasts) from the Aran Islands, Galway Bay, and argued that wave overtopping of high cliffs caused clast detachment and landward transport by wave bores. Here I highlight limitations of Williams's arguments, and show that clast detachment and transport involves complex processes and conditions not considered in his paper.

Pre-detachment conditioning of rocky shorelines

It is important to consider clast properties (size, shape, strength, lithology, degree of weathering) prior to considering processes of clast detachment and transport. This is because pre-detachment history strongly influences clast susceptibility to detachment (Naylor and Stephenson 2010), the force required for detachment (Nott 2003), and processes of clast transport (Goto *et al*. 2009). Williams does not consider pre-detachment history, but it is significant for the Aran Islands because of its underlying Lower Carboniferous limestone. Weathering and karstification has led to joint widening and block destabilisation, evidenced by surface grikes, karren and dolines and subsurface caves. The Quaternary history of the region is also significant. Frozen ground during glaciations allowed meltwater erosion to cut channels and oversteepen slopes. Permafrost and meltwater erosion were both active in western Ireland during the late Midlandian glaciation (Orme 1967; Lewis 1985). Differential glacial erosion also led to exposure of some bedrock surfaces whilst others were protected by glacial sediment and/or preglacial weathered debris (Moles and Moles 2002). This variable sediment cover strongly influenced patterns of postglacial weathering. Although the extent of glaciation on the Aran Islands is unclear (McCarron 2007), glacially-influenced preconditioning of rock surfaces through weathering is extremely significant but was not considered by Williams (2010).

Processes of clast detachment

Williams (2010) was concerned with identifying the wave height required for clast transport, but did not first consider processes by which clasts are detached from rockhead. Limestone weathering decreases rock strength, widens joints and makes clasts more easily detachable. Recent studies show a close relationship between weathering, rock strength, and likelihood of clast detachment (e.g. Hall *et al*. 2008; Naylor and Stephenson 2010).

Williams (2010) assumes that all areas of the upper cliff face are potential sites for clast detachment. However, recent studies show that rocky shoreline erosion is highly selective, strongly lithologically controlled, and that clasts are detached preferentially from the intertidal zone (Naylor and Stephenson 2010; Knight and Burningham 2011). Williams (2010) applied Nott's (2003) equation for joint-bounded blocks in calculating the significant wave height required for clast detachment. However, Nott (2003) was concerned with sloping shore platforms rather than cliffs, and his equations have now been superseded (Nandasena *et al*. 2011).

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Wave conditions required for clast movement

Williams (2010) argued that a landward-moving bore formed as a result of cliff overtopping by white- (broken) or green-water (unbroken) waves. Bores can only form where waves are topographically funnelled across a shore platform or cliff-top (Hall *et al*. 2008). No topography was presented by Williams, hence it is unclear if bores are likely or not.

Williams' paper's title explicitly stated it would illustrate the storm versus tsunami wave debate, but failed to do that. Scheffers *et al*. (2010) presented radiocarbon ages from organics below megaclasts on the Aran Islands and County Clare. They showed clasts were emplaced episodically throughout the last 3,000 years and, although there may be correspondence with periods of high storminess (Hansom and Hall 2009), a tsunamigenic origin cannot be rejected. Knight and Burningham (2011) mapped the distribution of upper shoreface boulders in County Donegal and showed that, although clasts can be detached under contemporary wave conditions, there is a mismatch between the size of contemporary clasts and those that form ridges on the shore platform. This suggests that a spectrum of past and present wave sizes and therefore wave-generating mechanisms are responsible for clast detachment and transport.

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References

Goto, K., Okada, K. and Imamura, F. 2009 Characteristics and hydrodynamics of boulders transported by storm waves at Kudaka Island, Japan. *Marine Geology* **262**, 14–24.

Hall, A.M., Hansom, J.D. and Jarvis, J. 2008 Patterns and rates of erosion produced by high energy wave processes on hard rock headlands: the Grind of the Navir, Shetland, Scotland. *Marine Geology* **248**, 28–46.

Hansom, J.D. and Hall, A.M. 2009 Magnitude and frequency of extra-tropical North Atlantic cyclones: a chronology from cliff-top storm deposits. *Quaternary International* **195**, 42–52.

Knight, J. and Burningham, H. 2011 Boulder dynamics on an Atlantic-facing coastline, northwest Ireland. *Marine Geology* **283**, 56–65.

Lewis, C.A. 1985 Periglacial features. In K.J. Edwards and W.P. Warren (eds) *The Quaternary History of Ireland*, 95–113. London. Academic Press.

McCarron, S.G. (ed) 2007 *Aran Islands Field Guide*. IQUA, Dublin.

Moles, N.R. and Moles, R.T. 2002 Influence of geology, glacial processes and land use on soil composition and Quaternary landscape evolution in The Burren National Park, Ireland. *Catena* **47**, 291–321.

Nandasena, N.A.K., Paris, R. and Tanaka, N. 2011 Reassessment of hydrodynamic equations: minimum flow velocity to initiate boulder transport by high energy events (storms, tsunamis). *Marine Geology* **281**, 70–84.

Naylor, L.A. and Stephenson, W.J.S. 2010 On the role of discontinuities in mediating shore platform erosion. *Geomorphology* **114**, 89–100.

Nott, J. 2003 Waves, coastal boulder deposits and the importance of the pre-transport setting. *Earth and Planetary Science Letters* **210**, 269–76.

Orme, A.R. 1967 Drumlins and the Weichsel glaciation of Connemara. *Irish Geography* **5**, 262–74.

Scheffers, A., Kelletat, D., Haslett, S., Scheffers, S. and Browne, T. 2010 Coastal boulder deposits in Galway Bay and the Aran Islands, western Ireland. *Zeitschrift für Geomorphologie* **54**(Supplement **3**), 247–79.

Williams, D.M. 2010 Mechanisms of wave transport of megaclasts on elevated cliff-top platforms: examples from western Ireland relevant to the storm-wave versus tsunami controversy. *Irish Journal of Earth Sciences* **28**, 13–23.

REPLY TO KNIGHT

D. MICHAEL WILLIAMS

In his comment Knight makes points under three headings. I shall discuss these in his order.

Pre-detachment conditioning of rocky shorelines

Knight states that I did not consider the pre-detachment history of the megaclasts on the Aran Islands including the glacial erosion of the region. In the cause of brevity I shall list statements regarding the history of the clasts: Williams & Hall (2004), page 102, paragraph 4, glacial history of the islands; page 114, paragraph 7, pre-detachment form of the megaclasts is that of 'joint-bounded blocks'.

Williams (2010), page 1, paragraph 2, detailed descriptions of rock discontinuities framing the blocks; page 15, Fig. 3 clearly shows joint-bounded blocks liberated from bedrock prior to transport; page 16, Fig. 4 shows detached clast prior to transport; page 17, paragraph 1, blocks will be emplaced if $>60\%$ of discontinuities are open; page 17, paragraph 1, the clasts are classified as 'joint bounded blocks' or 'subaerial boulders' depending on the nature of their exposure to waves: page 19, paragraph 3 'detaching joint-bounded blocks'; page 20, paragraph 4, waves come into contact with already loosened clasts; page 21, paragraph 1, repeats a description of the pre-transport situation of the clasts.

Both papers therefore constantly and repeatedly refer to the pre-detachment situation of the megaclasts and Knight's comments in this regard are invalid.

Processes of clast detachment

Knight states that in quoting Nott's analysis (2003) of wave emplacement of clasts I was incorrect and Nott's equations have been superseded.

Williams (2010) page 21, paragraph 1 stated that Nott's analysis (2003) cannot be applied to the Aran Islands situation of cliff-top emplacement of megaclasts. The whole point of this section was to show that Nott's equations only apply under certain restricted conditions and it is stated (page 21, paragraph 1) that these equations have been criticized by others.

Wave conditions required for clast movement

Knight quotes Scheffers *et al*. (2010) who postulate a tsunamigenic origin for the emplacement of the Aran megaclasts occurring over a period of 3,000 years based on radiocarbon dating of shell material within the megaclast ridges. He also states that I have not thrown any light on the storm waves versus tsunami debate.

Both Knight and Scheffers *et al*. (2010) seem unaware of numerous time averaging studies of marine shells which discuss the survival periods of marine shells in various marine environments. I will mention a few of these: Meldahl *et al*. (1997) showed that shells from present day surficial marine sediment (U.S.A.) had a half life in the taphonomic active zone of nearly 700 years and that some shells were thousands of years old. They also noted that the physical state of the shells was not necessarily related to their age; Carroll *et al*. (2003) studying brachiopods from recent surficial sediment in Brazil found they ranged in age from modern to 3,000 years old; Stride *et al*. (1999) in a study of modern surficial marine sediment around the coasts of the British Isles and France found shell ages ranging from 158 B.P. to 23,600 B.P.

It is apparent from these and other studies that shell hash emplaced by waves from a marine

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setting into an aerially exposed setting within the megaclast ridges such as those on the Aran Islands cannot be relied on to represent the time of emplacement of the clasts. This method is scientifically unsound and the results with their wide variation of ages are best explained as periodic sampling by extreme waves of natural shell populations from offshore environments in western Ireland. The authors present no other unequivocal evidence for tsunami emplacement of the megaclasts of the Aran Islands. Williams and Hall (2004) described the witnessed, and relatively common, emplacement of megaclasts by storms without the presence of tsunamis in Ireland and Scotland over 170 years. My 2010 paper illuminates the debate by postulating an emplacement mechanism for such deposits by extreme storm waves in a zone of the earth where tsunamis have been virtually absent since 1755.

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References

Carroll, M., Kowalewski, M., Simoes, M. and Goodfriend, G.A. 2003 Quantitative estimates of time-averaging in terebratulid brachiopod shell accumulations from a modern tropical shelf. *Palaeobiology* **29**, 381–402.

Meldahl, K.H., Flessa, K.W. and Cutter, A.H. 1997 Time-averaging and post-mortem skeletal survival in benthic fossil assemblages: quantitative comparisons among Holocene environments. *Palaeobiology* **23**, 207–29.

Nott, J. 2003 Waves, coastal boulder deposits and the importance of pre-transport setting. *Earth and Planetary Science Letters* **210**, 269–76.

Scheffers, A., Kelletat, D., Haslett, S., Scheffers, S. and Browne, T. 2010 Coastal boulder deposits in Galway Bay and the Aran Islands, western Ireland. *Zeitschrift fur Geomorphologie* **54**, Supplement 3, 247–79.

Stride, A.H., Wilson, J.B. and Curry, D. 1999 Accumulation of late Pleistocene and Holocene biogenic sands and gravels on the continental shelf between northern Scotland and western France. *Marine Geology* **159**, 273–85.

Williams, D.M. 2010 Mechanisms of wave transport of megaclasts on elevated cliff-top platforms: examples from western Ireland relevant to the storm wave versus tsunami controversy. *Irish Journal of Earth Sciences* **28**, 13–23.

Williams, D.M. and Hall, A.M. 2004 Cliff-top megaclast deposits of Ireland, a record of extreme waves in the North Atlantic—storms or tsunamis? *Marine Geology* **206**, 101–17.