

Patterns of Holocene Coastal Development in Eastern Scotland



Callum Firth¹, Phillip Teasdale¹ and David Smith²

¹University of Brighton & ²University of Oxford

Introduction: The coastline of eastern Scotland is characterised by a wide variety of relict depositional marine features which include extensive estuarine deposits (Carse), complex shingle/sand spits/forelands and dune fields. The earlier features (Lateglacial – circa 17,000 to 10,000 years ago) formed as the Scottish ice sheet retreated and as a consequence their development was often controlled by the availability of sediments during a period of rapidly relative falling sea level. Later (Holocene) depositional features are often more extensive and they reflect the complex interaction between glacio-isostatic uplift, eustatic sea level rise, sediment supply and wave energy. In general three contrasting zones of Holocene depositional coastlines can be identified (Fig. 1) each dominated by different processes. Within these zones variations in sediment supply and wave energy control the distribution of coastal landforms. The three zones are:

- Carse Lands -dominated by uplift and rapid estuarine sedimentation
- Large sand and shingle complexes – dominated by mid Holocene sea level stability
- Small barriers - dominated by Late Holocene sea level stability



Fig 2: Forvie Dunes at the mouth of the Ythan

Small Barriers: This zone is characterised by small barriers and bay head beaches with dune systems and fragmentary raised estuarine flats located behind them. Examples include the Ythan (Fig. 2, Smith *et al.* 1999) and Wick (Dawson and Smith, 1997) estuaries and Sandend Bay. The zone experienced low rates of glacio-isostatic uplift and as a consequence eustatic rates of sea level rise have exceeded uplift for most of the Holocene (Fig. 3). The small coastal barriers and associated dune systems have been pushed inland often over-riding earlier estuarine deposits (e.g. Philorth – Smith *et al.*, 1982) or where relative sea level has fallen (e.g. Ythan) extensive dune systems have developed.

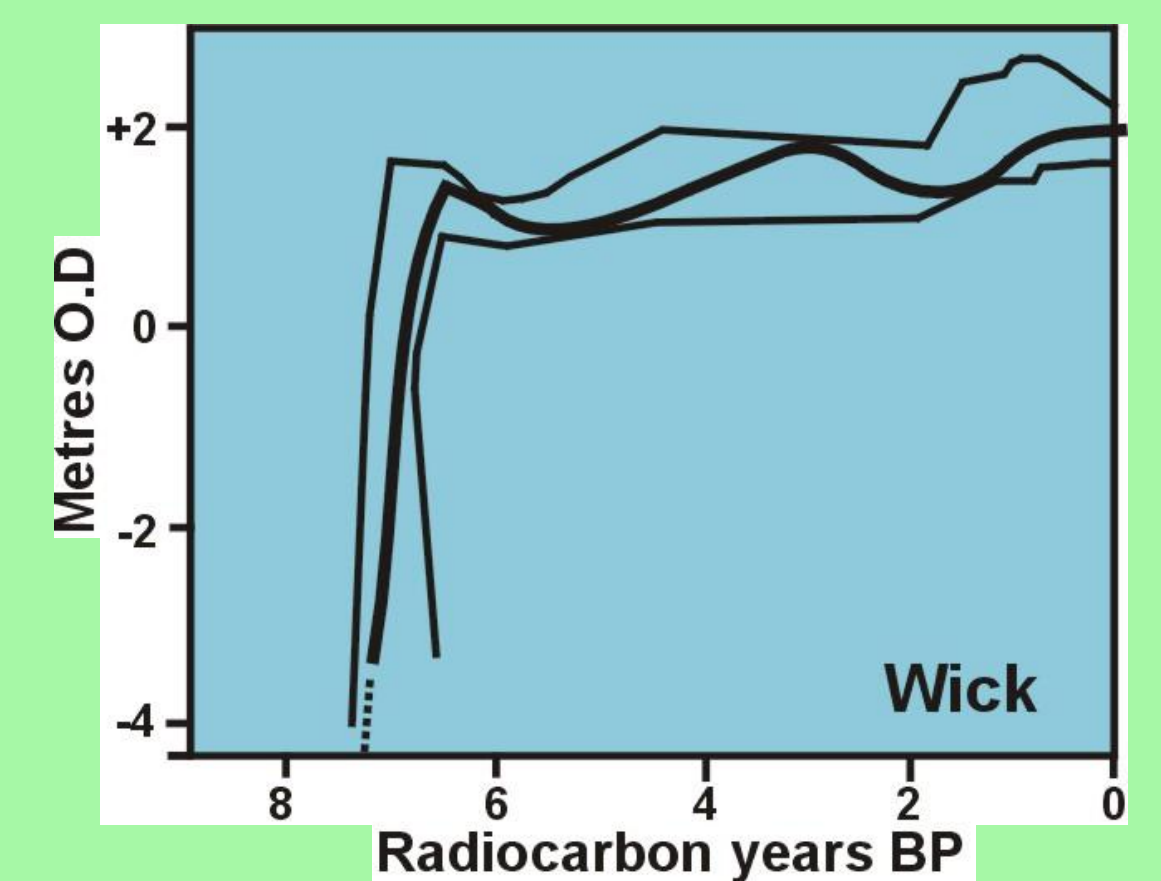


Fig 3: Relative sea level curve for Wick (after Dawson and Smith, 1997)



Figure 1: The three zones of coastal deposition that characterise eastern Scotland.

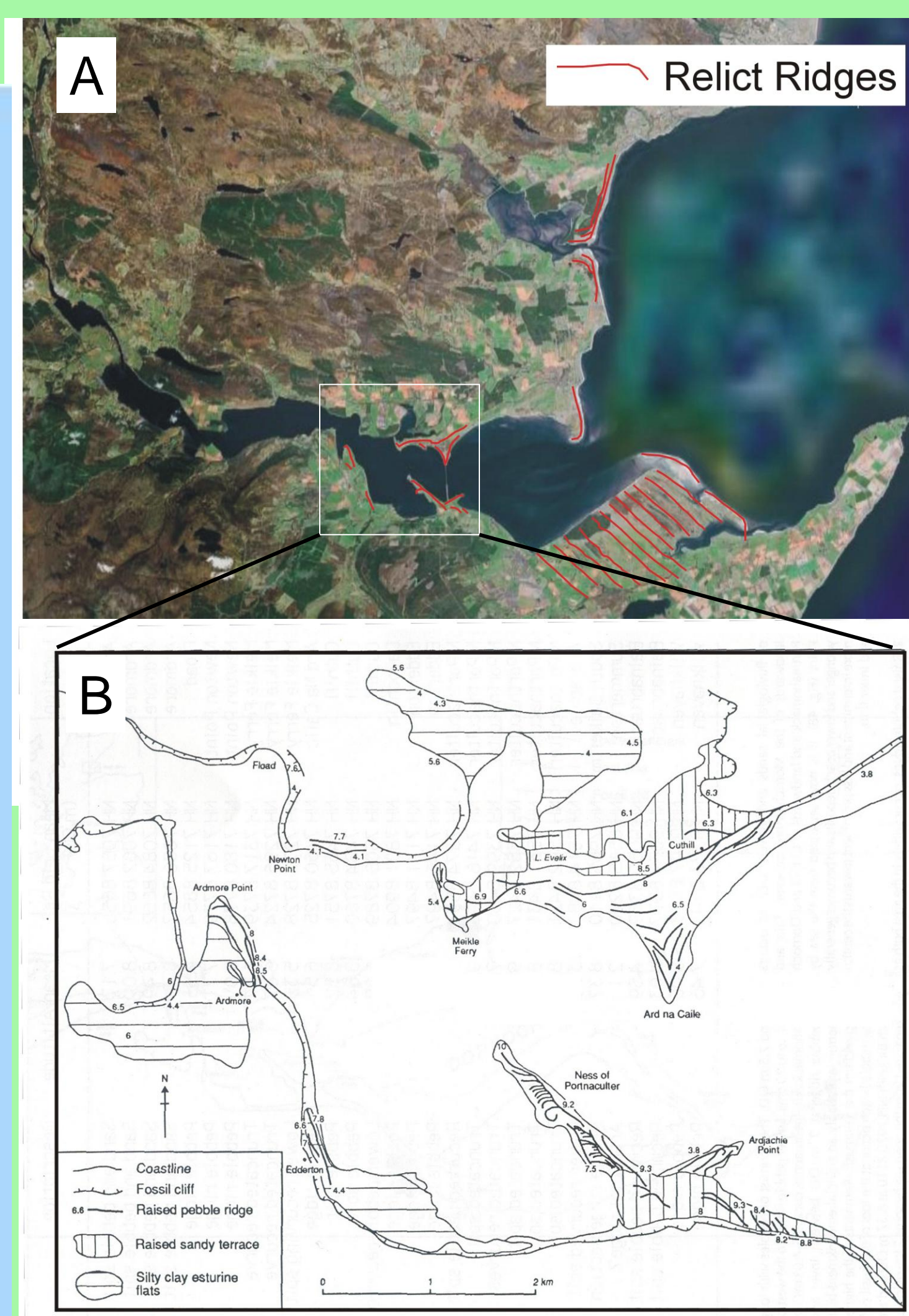


Fig. 4: A -Sand and shingle complexes in the Dornoch Firth area. B- Detail of the central Dornoch Firth.

Sand & Shingle Complexes: This zone is characterised by staircases of mid to late Holocene raised sand/shingle ridges which form complex spit and foreland systems in the outer sections of the Firths/embayments. Behind these complexes raised estuarine mudflats and sandflats are present. The relict ridges are often covered by later dune systems. Examples include, Loch Fleet, the Dornoch Firth (Fig. 4, Firth *et al.*, 1995), Montrose (Smith & Cullingford, 1985) and the Burghead – Findhorn coastline (Fig 5 -Ogilvie 1923). Relative sea level curves from this zone (Fig. 6) indicate that rates of uplift and eustatic sea level rise were very similar during the mid Holocene. As a consequence there was a 3,000 year period of sea level stability which allowed the spit and foreland systems to develop. As relative sea level fell these spit and foreland systems were reworked and extended at lower levels. In the Late Holocene the systems were covered by dunes.

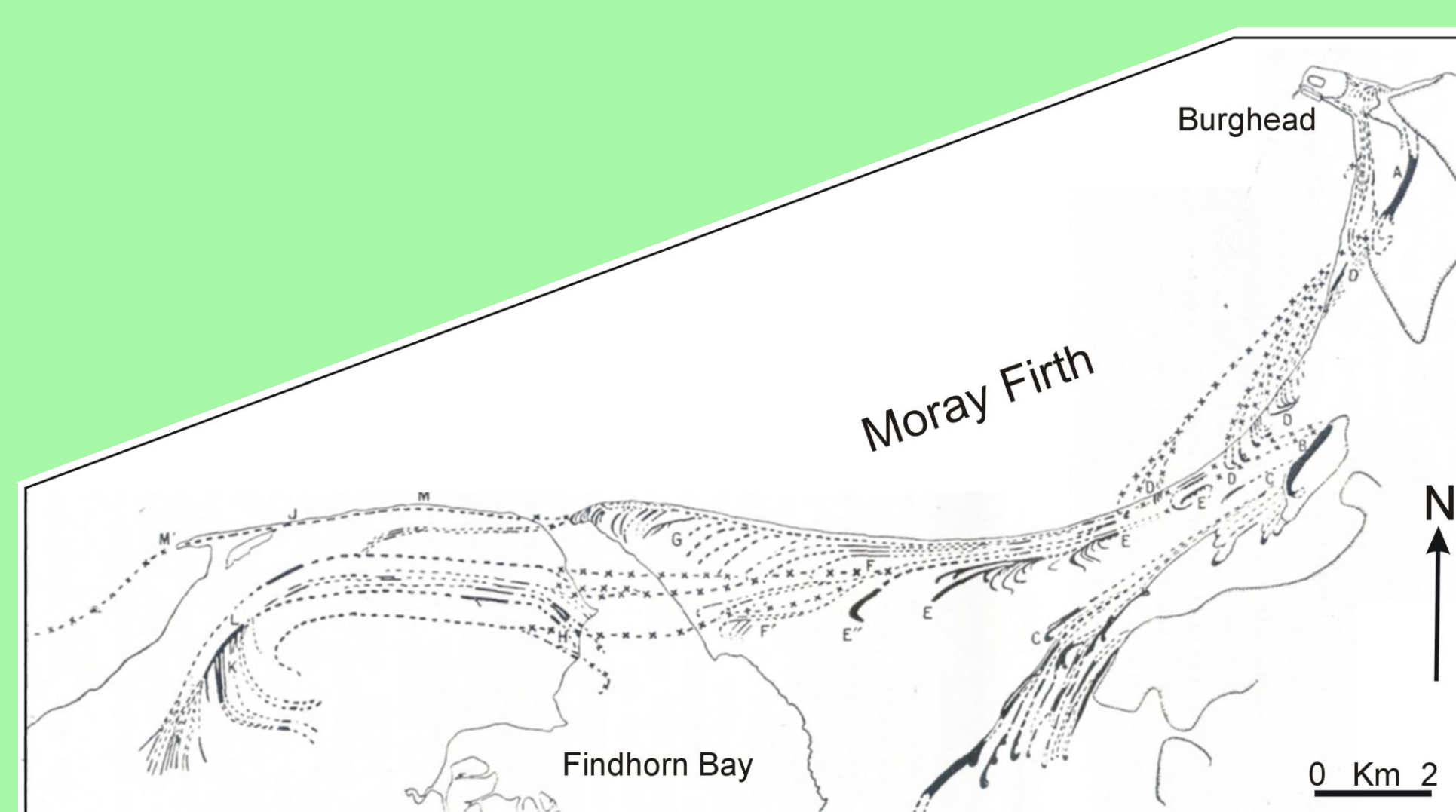


Fig. 5: The sand and shingle complexes between Burghead and Findhorn Bay (after Olgvie, 1923)

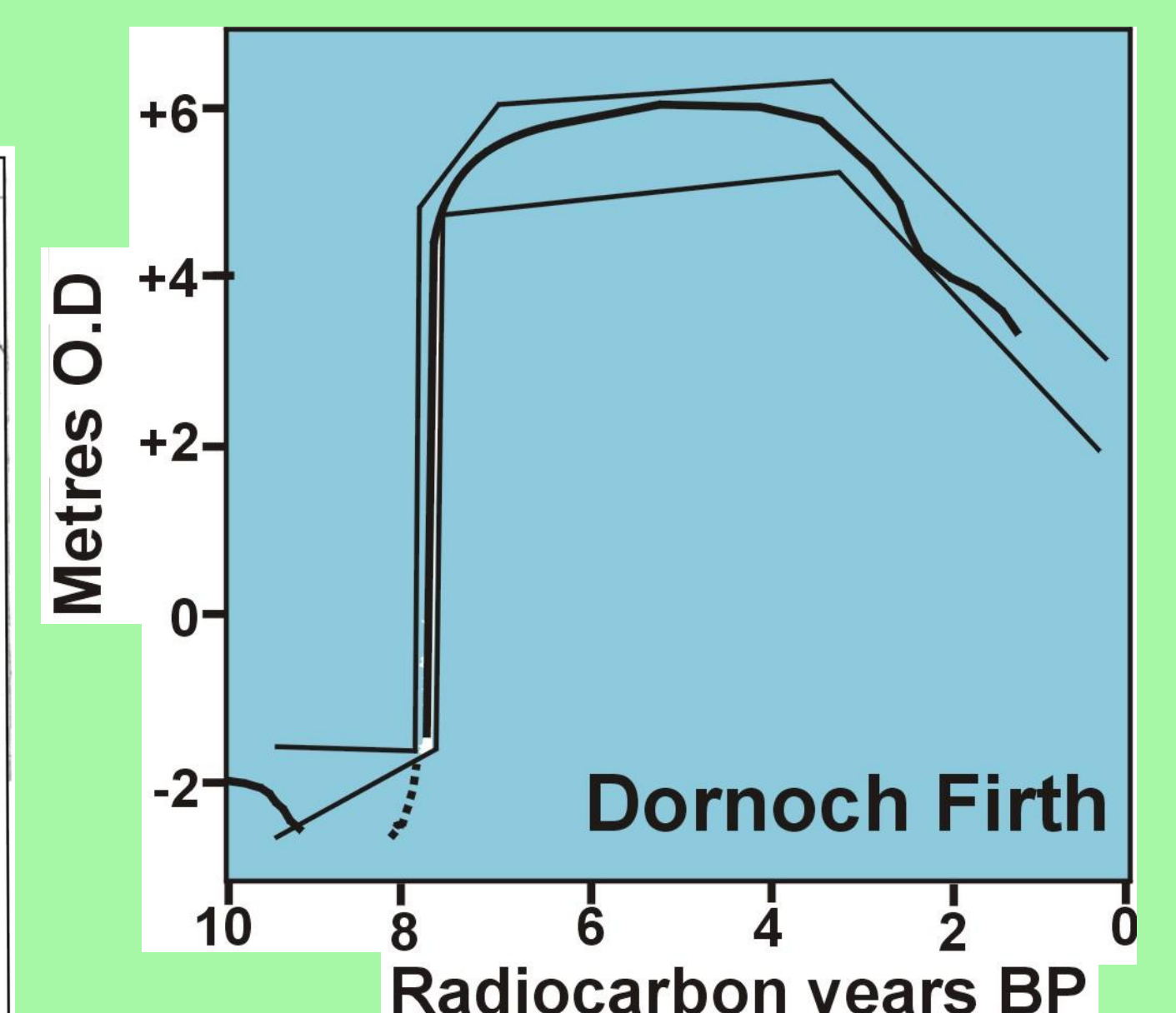


Fig 6: Relative sea level curve for Dornoch Firth (after Smith *et al.*, 1992)



Fig 7: The carselands of the Beaulie Firth.

The Carselands: This zone is characterised by extensive relict estuarine flats (Fig 7) with relatively few high energy features. Examples include the head of the Forth (Smith 1968), Tay and Beaulie Firths (Firth and Haggart, 1989). The zone experienced relatively high rates of glacio-isostatic uplift which were only exceeded by the rapid rise in sea level during the early to mid-Holocene (Fig 8). As a consequence periods of sea level stability were rare and the opportunity to develop spits and sand/shingle complexes was limited. Isolated sand barriers associated with the culmination of the mid Holocene rise in sea level are however present at the forward margin of the highest (Menteith/Main Postglacial Shoreline) (Firth and Haggart, 1989). As relative sea level fell the estuarine flats were extended further seaward individual surfaces/ shorelines being associated with brief periods of sea level stability

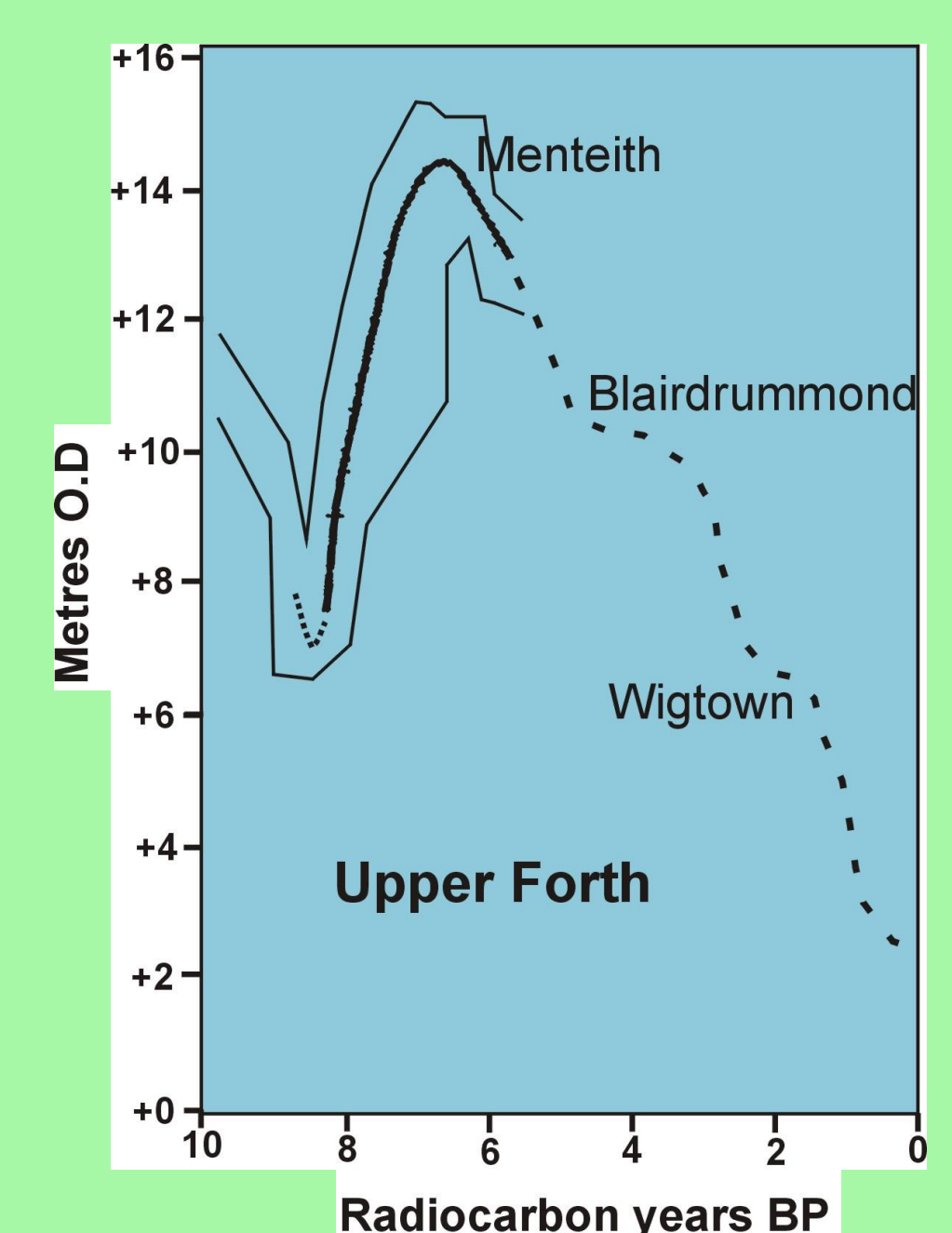


Fig 8: Relative sea level curve for the Upper Forth

Conclusions: The interaction between glacio-isostatic uplift and eustatic changes in sea level have played a significant role in the formation and distribution of coastal depositional features in eastern Scotland. As a consequence despite the abundance of sediment and wave energy levels extensive sand and shingle complexes are restricted to the zone where there was a prolonged period of relative sea level stability from around 6,500 – 3,400 yrs. B.P.

References:

Dawson S. & Smith D.E. 1997: Holocene relative sea-level changes on the margin of a glacio-isostatically uplifted area: an example from northern Caithness, Scotland. *The Holocene*, 7, 59-77.

Firth C.R. & Haggart B.A. 1989: Loch Lomond Stadial and Flandrian shorelines in the inner Moray Firth area, Scotland. *Journal of Quaternary Science*, 4, 37-50.

Firth C.R., Smith D.E., Hansom J.D. & Pearson S.G. 1995: Holocene spit development on a regressive shoreline, Dornoch Firth, Scotland. *Marine Geology*, 124, 203-214.

Ogilvie A.G. 1923: The physiography of the Moray Firth coast. *Transactions of the Royal Society of Edinburgh*, 53, 377-409.

Smith D.E. 1968: postglacial displaced shorelines in the surface of the carse clay on the north bank of the River Forth, in Scotland. *Zeitschrift Geomorphologie*, 12, 388-408.

Smith D.E. & Cullingford R.A. 1985: Flandrian relative sea-level changes in the Montrose Basin area. *Scottish Geographical Magazine*, 46, 91-105.

Smith D.E., Cullingford R.A. & Seymour W.P. 1982: Flandrian relative sea-level changes in the Philorth valley, north-east Scotland. *Transactions of the Institute of British Geographers*, 7, 321-336.

Smith D.E., Firth C.R., Brooks C.L., Robertson M. & Collins P.E.F. 1999: Relative sea-level rise during the Main Postglacial transgression in NE Scotland, U.K. *Transactions of the Royal Society of Edinburgh: earth Sciences*, 90, 1-27.

Smith D.E., Firth C.R., Turbayne S.C. & Brooks C.L. 1992: Holocene relative sea-level changes and shoreline displacement in the Dornoch Firth area, Scotland. *Proceedings of the Geologists Association*, 103, 237-257.