ST NINIAN'S TOMBOLO

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Introduction

St Ninian's tombolo, the largest geomorphologically active sand tombolo in Britain, is a classic geomorphological feature of national importance. The tombolo links the south-west Shetland Mainland to the small off-lying island of St Ninian's Isle (Figure 8.23). Although tombolos are by no means rare in an archipelago environment, they are numerically scarce relative to other classic forms of marine deposition (spits and bars). In the Northern Isles, tombolos (ayres) are generally formed of gravel, cobbles or occasionally boulders. St Ninian's tombolo is distinctive among its fellows in being composed mainly of sand. In addition, unlike many other ayres that are relict in terms of their evolution and relationship to contemporary sea level, St Ninian's tombolo is a geomorphologically active feature linked to a nearshore sediment circulatory system (Nature Conservancy Council, 1976; Smith, 1993; Bentley, 1996d). The tombolo is flanked on either end by areas of dunes and hill machair, enhancing the geomorphological interest. This almost perfectly formed feature set in a highly scenic part of the Shetland Isles must be one of the most outstanding tombolos in the world.

Figure 8.23: St Ninian's tombolo, looking south-west towards St Ninian's Isle. Dunes flank either extremity of the sandy tombolo. During the highest spring tides the central part may be completely covered in water. (Photo: G. Satterley/SNH.)

Description

St Ninian's tombolo is a large (*c*. 500 m in length along its central axis) sand tombolo linking St Ninian's Isle to the Shetland Mainland (Figures 8.23 and 8.24). By its very existence as a tombolo and its location, the beach is subject to wave activity from two completely opposing directions and is thus more liable to natural fluctuations of profile and beach area than a conventional arcuate beach. The beaches facing to the north and the south form long sweeping arcs stretching between the cliffs on either side of Bigton Wick to the north and St Ninian's Bay to the south (Figure 8.24). Waves approaching these beaches tend to break simultaneously along their entire length, suggesting that the planforms of each beach are in equilibrium with the approaching waves (Bentley, 1996d). The tombolo is strikingly symmetrical in plan (Smith, 1993; Bentley, 1996d) although it experiences changes in intertidal width and profile characteristics as a result of tidal and weather events. During low spring tides the tombolo is

60–70 m wide, while during the highest spring tides the central part may be completely covered in water. Typically the central part of the tombolo is 20–30 m wide at high tide (Figure 8.23).

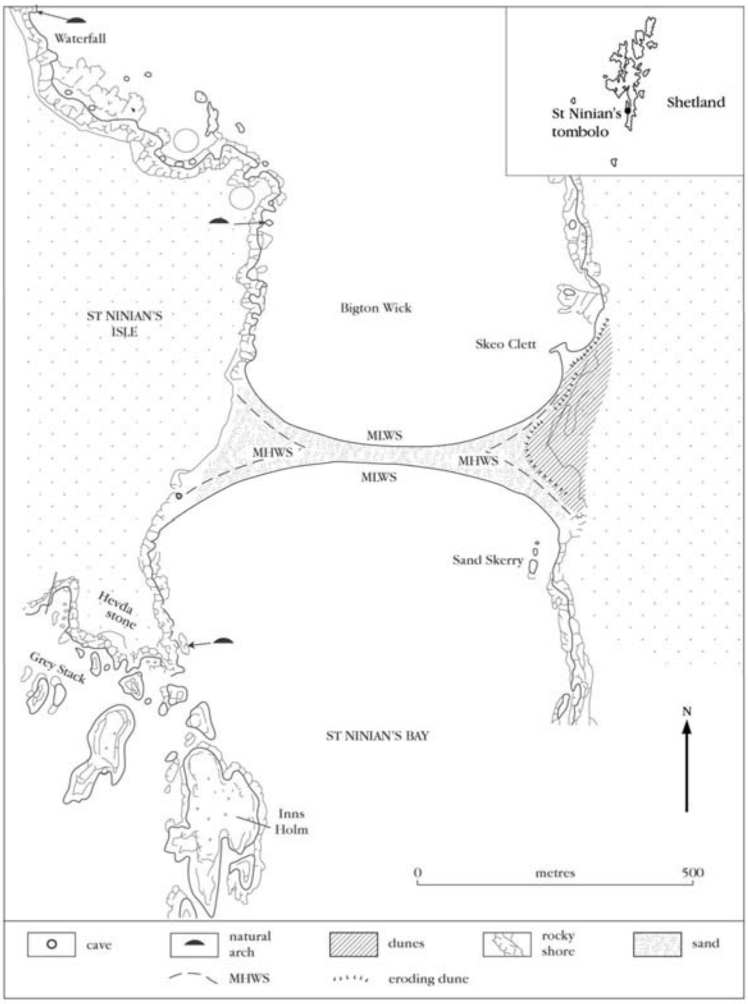

Figure 8.24: St Ninian's tombolo connects the Shetland mainland to an offshore island, and represents deposition from waves travelling south onto the north side, and vice versa in the south, in a very sheltered environment.

St Ninian's tombolo is composed almost entirely of medium-grained sand (D_{50} = 0.24 mm) with a carbonate content of around 50%. However, there is evidence that the beach sand overlies a gravel base (Flinn, 1974; Smith, 1993). Flinn (1974) identified ‘a rock base presumably of pebbles' at a depth of *c*. 2 m in two distinct locations using a probe and in several areas of the beach a scattering of flat pebbles lie on the surface. The tombolo appears to be nourished by nearshore sand sediment banks (Smith, 1993; Bentley, 1996d), although the exact mechanism of the sediment circulatory system at this site is imperfectly understood. The tombolo is a dynamic landform, repeatedly adjusting its form in response to tides and waves. During periods of constructive wave action sediment is transported from nearshore sources to the beach, raising the beach profile. The direction of sediment movement is reversed during periods of destructive wave action and the beach profile lowered. Changes in the height (and hence width) of the beach therefore occur with changing weather and marine conditions. In general, the tombolo is lower and narrower in winter, and is best-developed in summer (Mather and Smith, 1974). However short-term fluctuations, as a result of storms or periods of fine weather, can be imposed on this seasonal trend. For example, during the storms in which the oil tanker *Braer* ran aground (January 1993) the centre of the tombolo was totally underwater for several days. After such storms a temporary channel may form through the centre of the tombolo, with water typically flowing from north to south (Bentley, 1996d). There is also some evidence to suggest that the tombolo shifted slightly to the north following the January 1993 storms (Bentley, 1996d) although this may have been a temporary feature caused by predominantly southerly winds at the time.

Vegetated blown sand deposits veneer the slopes on either end of the isthmus resting on bedrock and a thin layer of till. Dunes (vegetated by marram *Ammophila arenaria*) adjacent to the beach at either end are backed by more extensive areas of hill machair blown sand that encroaches on pasture. The dunes and blown sand forms the sink for most of the sediment circulation system at St Ninian's tombolo. Once sand is incorporated into the sand plain it is unlikely to be re-incorporated into the system unless there is substantial erosion of the blown-sand areas (Bentley, 1996d). The dunes and machair have a relatively subdued topography, as a result of the influence of the underlying rock surfaces.

The volume of blown sand at the eastern end of the tombolo is much greater than that at the western end; a reflection of the dominance of westerly winds in Shetland (Smith, 1993). However, the morphology of this area has been altered dramatically by commercial sand extraction during the 1970s. A former extraction pit has since been naturally infilled by blown sand (Bentley, 1996d) and at present the dunes form low (<5 m) rolling mounds and hollows with small *Ammophila*-clad embryo dunes forming in a number of places. However, the coastal edge is distinctly erosional in character, particularly on the northern flank and there are a number of small blowthroughs within the dune system. The edge of the higher blown-sand area forms a prominent triangular-shaped bench landward of the dunes, backed by a thin cover of sand that is cut by a number of arcuate erosion scars. At the west end of the tombolo the dunes adjacent to the beach are heavily eroded. There are a number of active blowthroughs developing in the steep eroded and undercut dune face. However, despite this evidence of frontal erosion there was substantial sand accretion at the foot of the dune face in March 1996 (Bentley, 1996d). The hill dunes to landward have undergone advanced deflation (Smith, 1993, Bentley, 1996d), with low erosional scarps extending for several tens of metres often parallel to the contours of the slope.

Interpretation

St Ninian's tombolo most likely formed during a period of rising relative sea level (Smith, 1993; Bentley, 1996d). The relative sea level history of Shetland is one of progressive submergence since the decay of the late Devensian ice-sheet (Mykura, 1976). Dating of submerged peats in many of the sheltered voes and sounds indicate that *c.* 5500 years BP relative sea level stood around 9 m lower than at present (Hoppe, 1965). Depositional features such as tombolos, spits and bars are relatively common along recently submerged coasts (Johnson, 1919), although in the Northern Isles tombolos (ayres) are typically formed of shingle (e.g. the Ayres of Swinister, see GCR site report, this volume). The extensive sand tombolo of St Ninian's Isle, which is linked to the contemporary nearshore sediment circulation system, is distinctive in terms of its scale, composition and dynamism, and thus forms an unique component in the sand spit/tombolo GCR network.

There remains much scope for scientific research at the St Ninian's site, particularly to determine the evolution of this outstanding tombolo and investigate the complex relationship between sediment dynamics and relative sea-level change. At present, little is known concerning the exact evolution of the tombolo, except that it formed some time during the period of Holocene submergence of the Shetland coastline. The tombolo of St Ninian's Isle may have formed in a similar way to the South Ayre of Swinister. In this model, waves approaching from the west are diffracted and refracted around St Ninian's Isle, and eventually meet in the lee of the island. As the waves lose energy and deposit their load, sediment gradually builds up and eventually forms a connecting isthmus between St Ninian's Isle and the Shetland Mainland. Flinn (1997) also argues that the position of the tombolo is mainly related to diffraction around the island. It has been suggested that the tombolo has been in existence since at least the medieval times (Smith, 1993) when St Ninian's Isle was the site of a church. Smith (1993) attributes the quasi-permanency of this sand tombolo to the likelihood that the beach sand overlies a gravel base. If indeed it overlies a gravel core the implication is that at some time in the past, gravel was a relatively more important sediment source than at present. Although there is some evidence of a gravel core (Flinn, 1974; Smith, 1993; Bentley, 1996d), there is potential for further research using coring techniques and shallow seismic survey to determine the extent of the gravel base.

The earliest definitive evidence of the tombolo's existence is its depiction on an old chart drawn around 1700. The tombolo is clearly shown on a later chart drawn in 1743–1744, and George Thomas's 1830 map shows a feature similar to that of the present day. A comparison of old maps and aerial photographs suggests that although overtopping has occurred since 1822 (Flinn, 1997), the tombolo narrowed during the 20th century (Bentley, 1996d; Figure 8.25) and now has an increased frequency of overtopping of its centre. Beach profiles have been surveyed bi-annually since 1993 in order to determine any trends in the tombolo evolution. Although the record is too short to identify any long- or medium-term trends, some seasonal and inter-annual changes have been identified (Bentley, 1996d). Each winter there tends to be a loss of sand from the centre of the tombolo and a slight gain at the ends. This appears to be largely reversed during the summer when sand appears to return to the centre. However, in the interval between April 1993 and April 1994 there was a net loss of material from the centre of the tombolo, but at each end there were both localized gains and losses.

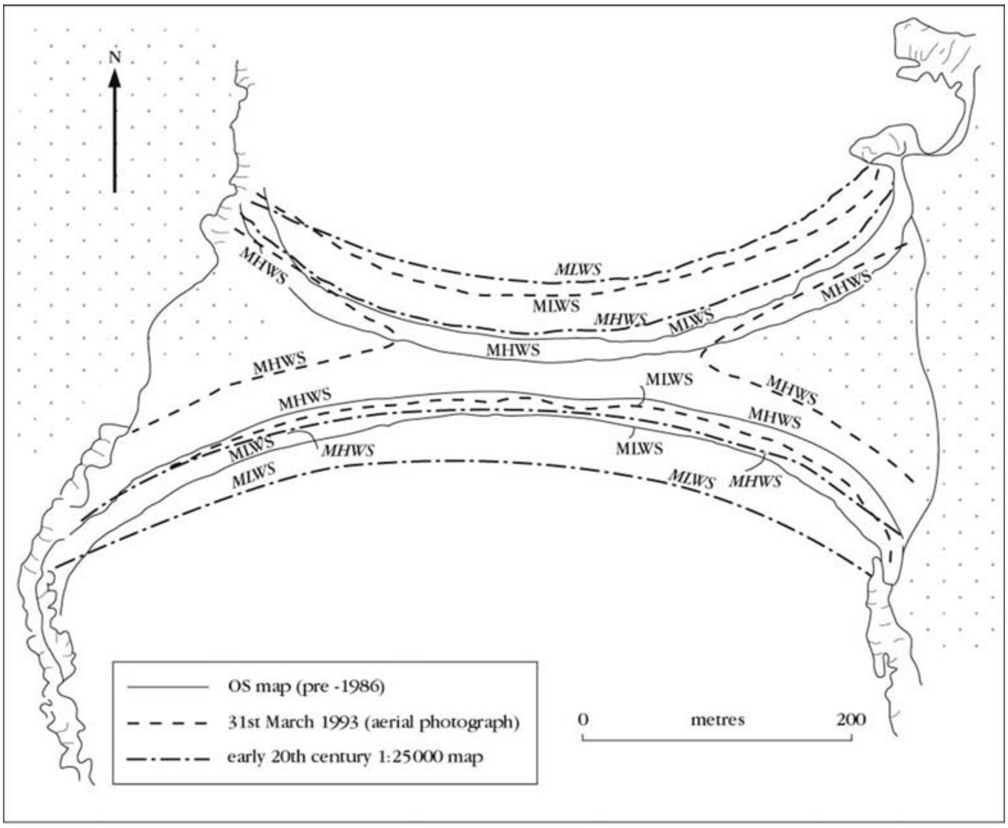

Figure 8.25: Change in tombolo position. In the early 20th century the tombolo was wider than at present, but with its axis in a similar position. Aerial photographs taken in March 1993 showed that the tombolo had migrated northwards by about 30 to 40 m. Subsequent topographical surveys later in the same year showed that the tombolo was migrating back southwards, suggesting that the northward shift was a temporary feature caused by southerly winds. MLWS, MHWS represent the position of mean low- and high-water springs, respectively. (Source: J. Swale, SNH.)

St Ninian's tombolo is linked to a nearshore sediment circulation system (Smith, 1993; Bentley, 1996d) where beach sediment is supplied from accumulations of sediment in the bays to the north and south. Smith (1993) expresses concern that the nearshore sediment bank has minimal possibilities of replenishment from nearby land sources, other than by wave erosion of blown-sand deposits at both the eastern and western ends. The seasonally wave-trimmed nature of the dunes at the western end and the sand extraction that substantially reduced the sand stocks at the eastern end in the 1970s may imply that the whole system is operating on a finite, and possibly decreasing, volume of sediment (Smith, 1993). In the context of continuing submergence, the supplies of sand via the nearshore and longshore sediment circulatory system that feed the tombolo are critical to its continued existence. In this respect any form of sand-extraction from the beach and surrounding windblown deposits is detrimental to the long-term existence of this outstanding tombolo.

Conclusions

St Ninian's tombolo, which connects St Ninian's Isle with the south-west Shetland Mainland, is the largest geomorphologically active sand tombolo in Britain. The size (*c*. 500 m long) and almost perfect symmetry of the tombolo is unique. The tombolo, composed of a shelly sand overlying a shingle base, is part of a dynamic and complex nearshore sediment circulation system. Although tombolos are relatively common along submerged coasts such as the Shetland Isles, it is the exceptional scale, composition and dynamism of St Ninian's tombolo that are of particular scientific interest. This interest is enhanced by the flanking windblown deposits of dunes and dune grassland. Conservation of this key site for coastal geomorphology is of the utmost importance; any disturbance of the sediment dynamics of the system may be critical to the tombolo's long-term existence.

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