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LIDAR-based coastal landscape reconstruction and harbour location: The Viking-age royal burial site of Borre (Norway)

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Airborne light detection and ranging (LIDAR) has found wide application in archaeological research for the detection and documentation of archaeological and palaeo-environmental features. In this study we demonstrate the analysis of an LIDAR derived 1x1 m digital elevation model (DTM) combined with geoarchaeological research of the coastal Viking-age burial site in Borre, Olso Fjord (Norway).

Borre is an exceptional burial site in Scandinavia, containing burial mounds up to 40 m in diameter and 6 m height, mentioned in Nordic Sagas, especially in the skaldic poem Ynglingatal, as the burial place of one or two kings of the Ynglinga dynasty. Archaeological findings and radiocarbon ages indicate that the Borre burial ground had been in use broadly between 600-1000 AD. Despite the reasonable expectation that a coastal site connected with the Viking kings of Vestfold, with hall buildings and ship graves demands a harbour, up to now no harbour has not been found with traditional archaeological surveys.

Since the area of Borre is affected by a continuous land uplift related to glacial rebound of Scandinavia, any former harbour site is expected to be exposed to the land surface today. The present day vertical crustal uplift is calculated around 2.5 mm/yr in the area of Borre.

Burial mounds and surrounding borrow pits as well as geomorphological features of the uplifted coast of Borre have been analysed by the 1x1 m LIDAR-DTM, using hillshade, slope and local relief model for visualisation. Altogether, 41 burial mounds and further 6 potential mounds are visible in the high-resolution DTM. A succession of more than 14 beach ridges, cross-cut by the burial mounds, is visible from the present shore line up to 18 m asl. They are more or less parallel and similar in size, except between at ca. 4-6 m asl, where the most prominent ridge is located, which probably has been enforced artificially. Using published shoreline displacement curves from nearby areas, the shore-line at Borre in the period 600-1000 AD was ca. 6-4 m higher than today, exactly at the position of the prominent beach ridge at the eastern boundary of the burial ground.

Below 4 m asl there are three, prominent, ca. 70 m, 150 m and 200 m long ridges, oriented at right angle to the general trend of the coast. All three structures cause considerable deflection of the beach ridges in this area and therefore must be older than the beach ridges below 4 m asl. These ridges comprise polymict, sub-rounded to rounded boulders up to 1 m in diameter, including porphyric volcanics, various types of gneisses, amphibolite, sandstone, etc. These boulders occur neither at the nearby beach areas nor in the beach ridges in the whole Borre area, but can be found in the Younger Dryas Ra moraine, some 1 km west of Borre.

In contrast to the strongly undulating shoreline at Borre, the nearby coast of the western Oslo Fjord between Åsgårdstrand and Horten, shows quite a straight shore line with hardly any natural harbours. The ridges seen in the LIDAR are exactly in the size range of the modern day jetties in this area and we believe that those between 4-0 m asl have been made for the same purpose, representing harbour structures for landing at Borre in Viking age.