lasse.sander@awi.de

Characteristics of wave-built sedimentary archives in Buor Khaya Bay (71°N/130°E), Siberian Arctic, Russia

Lasse Sander[1], Rune Michaelis[1], Svenja Papenmeier[1], Sergey Pravkin[2], Karen H. Wiltshire[1]

[1]Alfred-Wegener-Institute (AWI), Helmholtz Centre for Polar and Marine Research, List/Sylt, Germany

[2]Arctic and Antarctic Research Institute (AARI), St. Petersburg, Russia

Prograded sequences of beach deposits preserve valuable paleoenvironmental information on the long-term variability of sea level, climate forcing and sediment supply driving centennial to millennial coastal evolution. Buor Khaya Bay, NE Siberian Arctic, is located at the transition between the Verkhoyansk mountain range and the southern Laptev Sea and is one of the few places along the Russian arctic coast, where wide beach-ridge systems exist. The area was visited during an expedition in August 2017 in order to obtain baseline information on the potential of five different coastal sedimentary systems (barriers, spits, lagoons, beach-ridge systems) for the reconstruction of Holocene relative sea level and past sea-ice extent. The project is at an early stage of investigation and we present first insight into a new and promising area of investigation. Work will be continued in summer 2018.

Sequences of prograded beach deposits (so-called beach-ridge systems) are a wave-built coastal geomorphological feature of global occurrence. The deposits may preserve information on the environmental conditions during their formation and have been used as archives for the reconstruction of parameters such as relative sea-level, wave climate, extreme events, sediment supply or sea-ice extent (*e.g.* Funder *et al.*, 2011; Tamura, 2012; Sander *et al.*, 2016). Other coastal sedimentary systems (such as barriers and lagoons) may provide useful insights into the sedimentary record of processes determining shoreline change *e.g.* overwash frequency or extreme events. In general, only limited information on Holocene coastal evolution exists for the coast of arctic Siberia and all visited sites are previously unstudied.

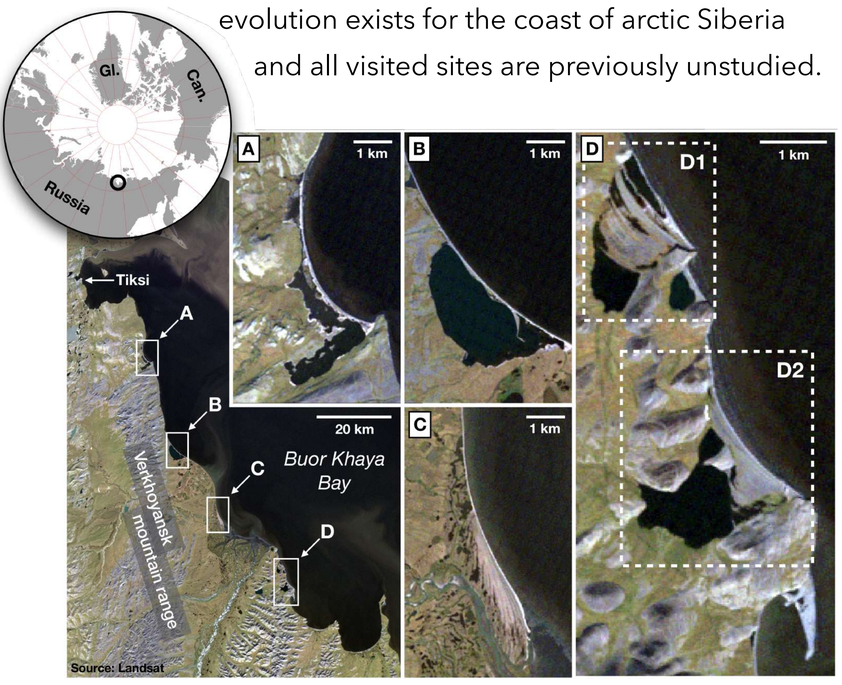

Figure 1: Overview of the south-western shoreline of Buor Khaya Bay (southern Laptev Sea) and the location of the investigated field sites. Site D is the focus area of this study.

The coastal geomorphology of the area is determined by the relief of the Verkhoyansk mountain range (*cf*. Figure 1). The bay is brackish, microtidal and ice-free for 3–4 months. Sites A and B are composed of slim and low-lying barriers that separate coastal lagoons from the open waters of the southern Laptev Sea. Site C is a wide barrier spit composed of wave-built deposits. Sites D1 and D2 comprise several sets of prograded beach ridges separating coastal lagoons from the open water of the bay and are surrounded by wave-cut cliffs in elongated morphological depressions. While sites A and B are subject to frequent overwash activity, sites C and D are characterised by the preservation of deposits and a steep modern storm berm. All sites are dominated by sand- to cobble-sized sediment. Apart from the sites described, most of the shoreline of south western Buor Khaya Bay is dominated by active bedrock cliffs.

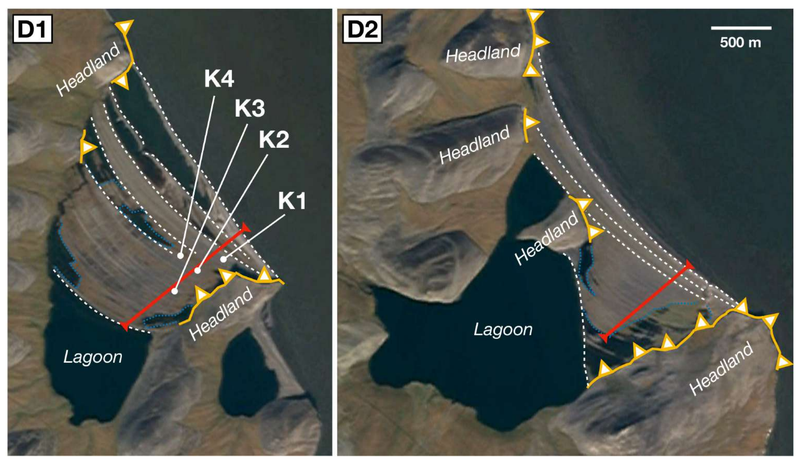

Figure 2: Field sites D1 and D2 are prograded beach-ridge systems located in topographic depressions within the denudated relief of the Verkhoyansk mountain range. Both sites are surrounded by marine (paleo-) cliffs (yellow signature) and can be divided into different sets of ridges, separated by unconformities (dashed white lines). Arrows indicate the locations of the ^{14}C samples (K1-4; cf. Table 1). Red line indicates the location of the shown GPS-RTK profiles (Fig. 4)

Methods

All field sites were accessed by boat. At each field site, GPS-RTK elevation profiles were recorded in a cross-ridge direction, perpendicular to the modern shoreline. Data on beach morphology and the surface properties of the elevated marine deposits (grain size, vegetation, debris) were collected in the field and supported by kite aerial photography (KAP) surveys. Age control (for system D1 only) was established using the ^{14}C-dating of buried drift wood (dated at MICADAS Laboratory, Alfred-Wegener-Institute, Bremerhaven; *cf.* Table 1). Preparation of the campaign and the interpretation of field data are supported by Landsat satellite imagery, medium-resolution digital elevation models and archived topographical maps.

Table 1: Overview of ^{14}C samples from site D1

Sample	Coordinate	Lab. code	Age (yr)
K1	71°1.728′N/130°11.991′E	1288.2.3	3234±177
K2	71°1.670′N/130°11.656′E	1289.2.3	3540±177
K3	71°1.593′N/130°11.402′E	1290.2.3	4028±177
K4	71°1.738′N/130°11.466′E	1291.2.3	3826±177

Observations and inferences on coastal evolution

The modern shoreline at both beach-ridge sites (Fig. 2) is composed of a low gradient upper shoreface with longshore intertidal bars primarily composed of sands and gravels, and a steeply inclined beachface characterized by pebble- to cobble-sized material and the presence of ample amounts of debris (driftwood, anthropogenic debris; Fig. 3). The steep angle of the modern berm ridge (storm berm elevation: 3–4 m) and the presence of overtopped debris suggest the occurrence of increased water levels under high energy conditions. The fossil beach ridges have elevations of 2.5–4.5 m (*cf.* Fig. 4) with surfaces composed of pebble- to cobble-sized material. Swales are mostly vegetated and locally water-logged. The surrounding headlands show clear indication of wave erosion (in the form of active and paleocliffs) and thick layers of regolith cover the slopes. The minerogenic beach deposits are composed of flat subangular to rounded shales. These are probably of local origin, given their high degree of similarity (color, lithology) with the weathering products from adjacent bedrock cliffs. No aeolian deposits were observed.

The elevation and composition of the beach deposits suggest a construction during (storm-)wave conditions. Both systems can be divided into distinct sets of ridges, suggesting (1) continuous progradation under conditions of high sediment availability over mid-Holocene time scales, and (2) unconformities evidencing periods of increase in allogenic perturbation or reduced sediment supply.

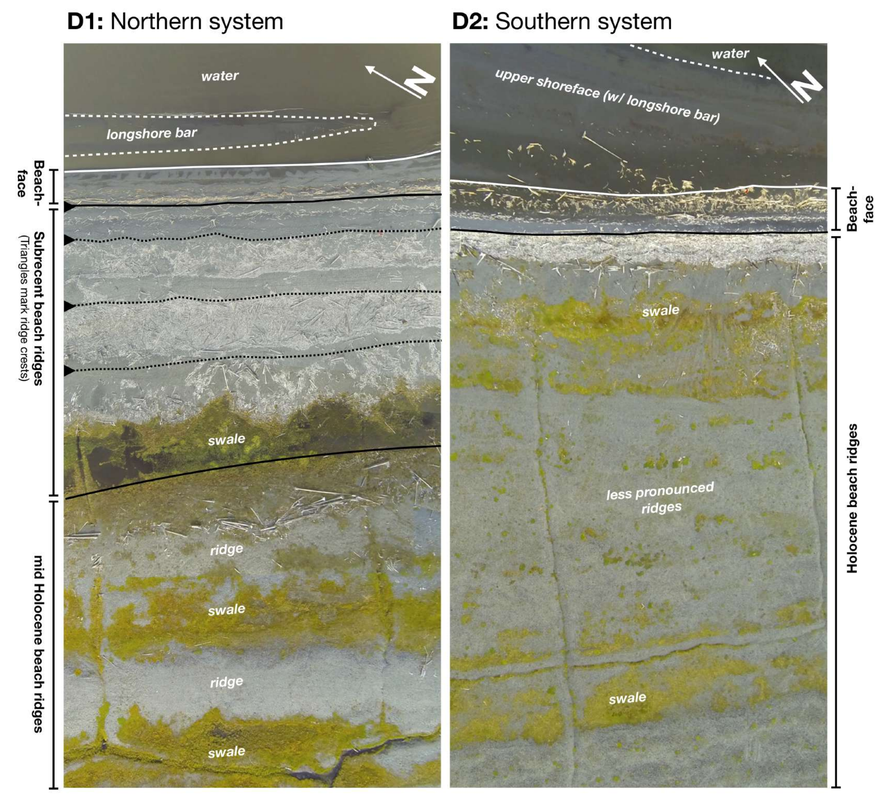

Figure 3: Aerial images of the proximal parts of both systems along the GPS-RTK profiles indicated in Fig. 2 and Fig. 4 (image height: ~ 350 m). The image of site D1 shows an unconformity between mid-Holocene deposits and younger beach ridges separated by a deep swale (*cf.* Fig. 4). The presence of large amounts of debris suggests subrecent perturbation of the younger and lower-lying ridges. The image of site D2 shows the modern beach and a denudated beach-ridge topography. This setting suggests a hiatus in progradation likely caused by a limitation of space due to the consecutive infill of the embayment.

Conclusions and outlook

This study has for the first time established the elevation and Holocene age of two prograded beach-ridge systems in NE Siberia. The arrangement of landforms suggest fluctuations in the parameters determining their long-term evolution, specifically sediment supply, relative sea-level and the direction of wave approach. In the next field season, we will continue our work on site D in order to complement the dataset with additional age control, georadar profiles and photogrammetric survey data. The aim is to gain more detailed insight into the past and present processes that influence the formation and preservation of wave-built deposits in the Arctic settings of northern Siberia as well as to unravel the indication they contain on the climate and sea-level history of the southern Laptev Sea.

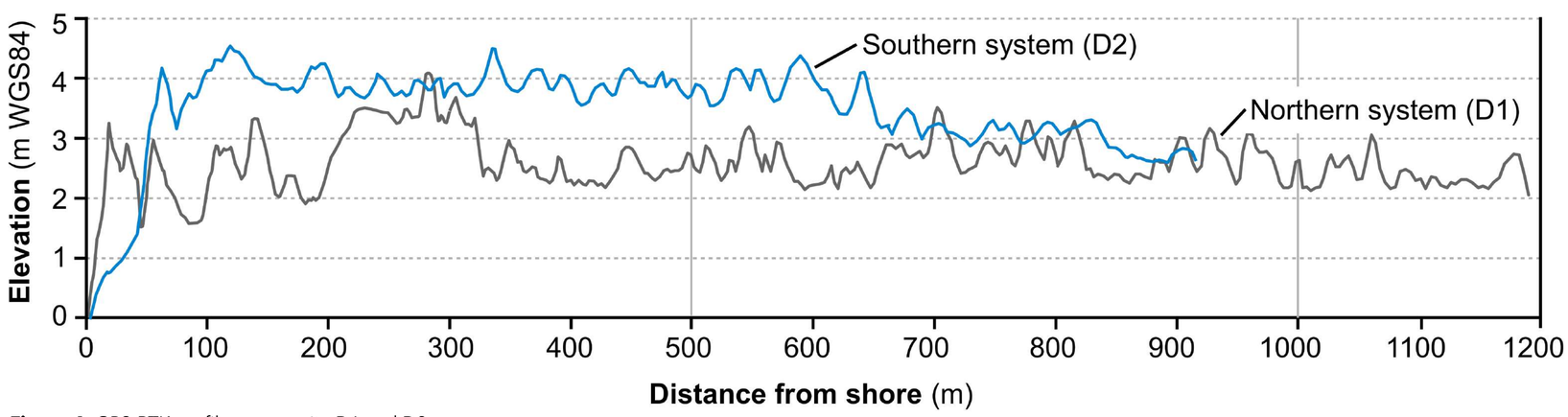

Figure 4: GPS-RTK profiles across site D1 and D2.

Acknowledgements: Field work was conducted as part of the expedition "LENA 2017". We would like to express our gratitude for the indispensable logistical support of Waldemar Schneider and Volkmar Aßmann (both AWI, Potsdam). The crew of RV "Nicole" is thanked for facilitating access to the field sites as well as for their hospitality during the field campaign. Torben Gentz and Gesine Mollenhauer (MICADAS Lab, AWI Bremerhaven) conducted the radiocarbon dating.

References

Funder, S., Goosse, H., Jepsen, H., Kaas, E., Kjær, K.H., Korsgaard, N.J., Larsen, N.K., Linderson, H., Lysså, A., Möller, P., Olsen, J. & Willerslev, E. (2011): A 10,000-Year Record of Arctic Ocean Sea-Ice Variability–View from the Beach. *Science* 333: 747- 750.

Sander, L., Hede, M.U., Fruergaard, M., Nielsen, L., Clemmensen, L.B., Kroon, A., Johannessen, P.N., Nielsen, L.H. & Pejrup, M. (2016): Coastal lagoons and beach ridges as complementary sedimentary archives for the reconstruction of Holocene relative sea–level changes. *Terra Nova* 28(1): 43-49.

Tamura, T. (2012): Beach ridges and prograded beach deposits as palaeoenvironment records. *Earth- Science Reviews* 114(3), 279-297.

HELMHOLTZ