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Cosmogenic exposure dating of boulders and bedrock in Denmark: wide range in ages reflect strong dependence of post-depositional stability related to specific glacial landforms

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The timing of ice-sheet fluctuations, as indicated by glacier advances and retreats, is detected from a wide range of geochronological techniques, including varve counting, and radiocarbon and luminescence dating of proglacial and inter till sediments. A robust Late Weichselian chronology of deglacial ice sheet fluctuations in southwestern Scandinavia indicates that the decline of the Scandinavian Ice Sheet from the Last Glacial Maximum position at c. 23-21 kyr (thousands of years) ago in central Denmark occurred through recessional stages and readvances. Active glaciers withdrew from eastern Denmark 17-16 kyr ago and left the southwestern Baltic basin ice free at the beginning of the Bølling interstade c. 14.5 kyr ago. The withdrawal left behind belts of elongate end moraines and streamlined ground moraine as large ice masses were successively isolated causing massive down wasting until c. 12 - 11 kyr ago. In Eastern Denmark and southernmost Sweden this lead to formation of complex superimposed glacial landscapes originally covered with a wealth of erratic boulders. Hitherto untried cosmogenic nuclide surface exposure dating was applied to sites in Eastern Denmark to test the method against independent chronologies.

Samples collected from erratics, moraines and ice-sculpted bedrock were prepared at the Cosmogenic Nuclide Laboratory at the University of Glasgow and AMS measurements were carried out at the Scottish Universities Environmental Research Centre (SUERC) AMS facility. Procedural blank corrected 10Be concentrations were converted to in situ 10Be surface exposure ages using the online CRONUS-Earth 10Be-26Al exposure age calculator Version 2.2.

Exposure ages from 35 samples range between 11.5 and 20 kyr, 18 of which lie within the expected age envelope. Two samples show overestimated ages apparently due to cosmogenic nuclide inheritance from previous exposure episodes. The remaining 17, two of which have suffered from exhumation, are younger than predicted. Dating of boulders and adjacent bedrock on the island of Bornholm in the western Baltic reveal almost similar ages and fit the independent chronology. This indicates that very little if any inherited nuclides are present in the boulders. Moreover, ages from Bornholm seem to become younger with descending height above sea level, suggesting that the island was progressively exposed as glaciers in the Baltic downwasted. In mainland Denmark ages that fit the age model are situated on top of end moraines or located on streamlined ground moraine. Boulders with underestimated ages were sampled in dead ice moraines and down wasting landscapes. These results are interpreted as providing landform stabilisation ages since these boulders appear to have first melted out of dead ice and came to rest after 15 until about 12 kyr ago.

We conclude that cosmogenic nuclide surface exposure dating is very sensitive to landscape stability, and that when used for dating glacier fluctuations surface stability should be thoroughly evaluated before sampling.