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A more complex deglaciation chronology of Southern Norway than previously thought. New geochronological constraints based on cosmogenic exposure ages of marginal moraines

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Glacial landforms from the last deglaciation in southern Norway were mapped by the famous glacial geologist Bjørn Andersen already in the early 1950s, using basic aerial photographs and topographic maps. Andersen reconstructed two distinct glacial sub-stages (the Lista stage and Spangereid stage) that were older than the Younger Dryas (YD), and one main glacial stage of assumed YD age (the Ra stage). This interpretation has remained largely untested and is still used in reconstructions of the Fennoscandian ice sheet. However, absolute chronological control has been lacking and only a handful radiocarbon dates has been used to support the deglaciation chronology.

In this study we test the reconstruction of Andersen by remapping the whole area using newly aquired LiDAR data (high resolution laser scanning of terrain), together with in-situ cosmogenic nuclide exposure ages of boulders on marginal moraines. The study comprises mapping of more than 6000 km2 of forested and dissected landscape, 53 10Be ages from boulders/bedrock, one cosmogenic 10Be depth profile in a coarse-grained glaciofluvial deposit, and finally one lake record.

Our study shows that the oldest of Andersen's glacial stages, the Lista stage right on the outermost Norwegian south coast, should likely be rejected since it consists of consolidated subglacial till and therefore is not an end moraine system. However, our cosmogenic depth profile indicates that this area might have been ice free already by around 19 ka BP, approximately 4000 years earlier than previously thought. At the same time the ice sheet surface slowly lowered, and the first inland hills of about 450 m. asl. became ice free at around 17 ka BP. Ice retreat continued slowly 10-15 km inland and halted as a calving fjord stage at the Spangereid stage with an approximate age of 15 ka BP. Then the deglaciation appears to have been very rapid and the ice front retreated 30-50 km inland to a position inside of the Ra stage, until a readvance in Older Dryas around 14.5 ka BP. The ice front might have retreated inland again in the Bølling-Allerød interstadial, but readvanced to almost exactly the same position in the early YD and with possible oscillations until late YD. The complexity of the cosmogenic exposure ages from the Ra moraine system is supported by LiDAR mapping that often shows multiple moraine ridges that sometimes onlap each other and sometimes are separated by as much as 5 km.

To conclude, our study shows that deglaciation of the south coast of Norway was more complex than previously thought. Ice retreat and readvances were episodic and only largely in concert with climate forcing. The Ra stage, which was previously thought to represent the YD in southern Norway, is in fact a complex moraine system spanning more than 2000 years including readvances both in the Older Dryas and the Younger Dryas stadials.