A large rockfall avalanche in Oldedalen, inner Nordfjord, western Norway, dated by means of a sub-avalanche *Salix* sp. tree trunk

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Construction work in connection with tourist accommodation below a huge boulder (estimated volume of 270-300 m^3) in a rockfall-avalanche deposit in Oldedalen, western Norway, revealed tree trunks of *Betula* sp. and *Salix* sp. The trunks carried visible signs of damage (cracks and splintering) due to the avalanche. A piece of a *Salix* sp. trunk was dated at 5220 ± 80 ^{14}C yr BP [5940 (6010-5910) cal. yr BP (intercept age with one sigma)]. Since the rockfall most probably killed the trees, the date is considered to represent the age of the event.

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Introduction

Rockfall avalanches are formed by gravitational movement of a mass of disintegrated bedrock falling from a cliff or steep headwall (e.g. Blikra & Nemec 1998). If the volume is small, rocks tumble downslope by rolling, bouncing and sliding, and the run-out distance is relatively short. Larger-scale bedrock collapses, with a total disintegration into smaller pieces, commonly develop into true massflows with long runouts as a consequence (see review by Erismann & Abele 2001).

Radiocarbon data on rockfall deposits in Norway are relatively scarce (Blikra & Nesje 1997, Blikra & Nemec 1998). Some periods of frequent rockfalls have, however, been recognized. The oldest rockfall deposits date to the Younger Dryas Chronozone, a period characterized by cold climate and glacier re-advance along the western margin of the Fennoscandian ice sheet (e.g. Andersen et al. 1995). In the later half of the Holocene, three periods of increased rockfall activity have been recognized (Blikra & Nemec 1998; their Figure 39). Evidence suggests that there was an increase in activity subsequent to ca. 3800 cal. yr BP. Locally, the rockfall deposits are separated by palaeosols, which may indicate intermittent stable periods. Some attempts have been made to date large-scale rock avalanches. Nesje et al. (1994), for example, used Schmidt hammer rebound values to estimate the age of rockfalls in Norangsdalen, Sunnmøre to younger than 6000 cal. yr BP. Furthermore, studies in the Møre and Romsdal region demonstrate that many events are from the second half of the Holocene (Blikra & Anda 1997, Blikra et al. 1999).

The Oldedalen rockfall avalanche deposit and dating of an excavated tree trunk

In the southern part of Oldedalen, inner Nordfjord, western Norway, a rockfall deposit consisting of large boulders covers about 50,000 m^2 of the valley bottom (Figs. 1 and 2). The thickness of the rockfall deposit is difficult to estimate but a mean thickness of 5-10 metres gives a total volume of rock debris in the range of 250,000-500,000 m^3. The average slope of the valley side between the source and avalanche deposit is 36°. The fall-out area is located in a vertical cliff at about 600 m a.s.l. while the front of the rock-avalanche lobe is located at 120 m a.s.l. (Fig. 1), yielding a separation of 480 m (H) over a run-out distance of 750 metres (L), giving an H/L ratio of 0.64. The H/L vs volume relationship is comparable with large-scale rock avalanche deposits elsewhere (e.g. McEwen 1989). The bedrock in the area consists of augen gneiss with foliation planes dipping east towards the valley.

In connection with construction work and excavation for tourist accommodation several pieces of wood fragments buried in the finer rock debris were found beneath one of the largest boulders (estimated volume: 270-300 m^3, weight: 700-800 tonnes, Fig. 3), in the southern part of the deposit (see arrow in Fig. 1B). One of the largest fragments was identified as *Betula* sp. from preserved bark. This trunk was splintered at both ends (Fig. 4) and had deep cracks along it (Fig. 5). The splintering and cracks were not caused by excavation, but most likely by the rock-avalanche itself. A smaller tree fragment, also showing clear evidence of splintering, was

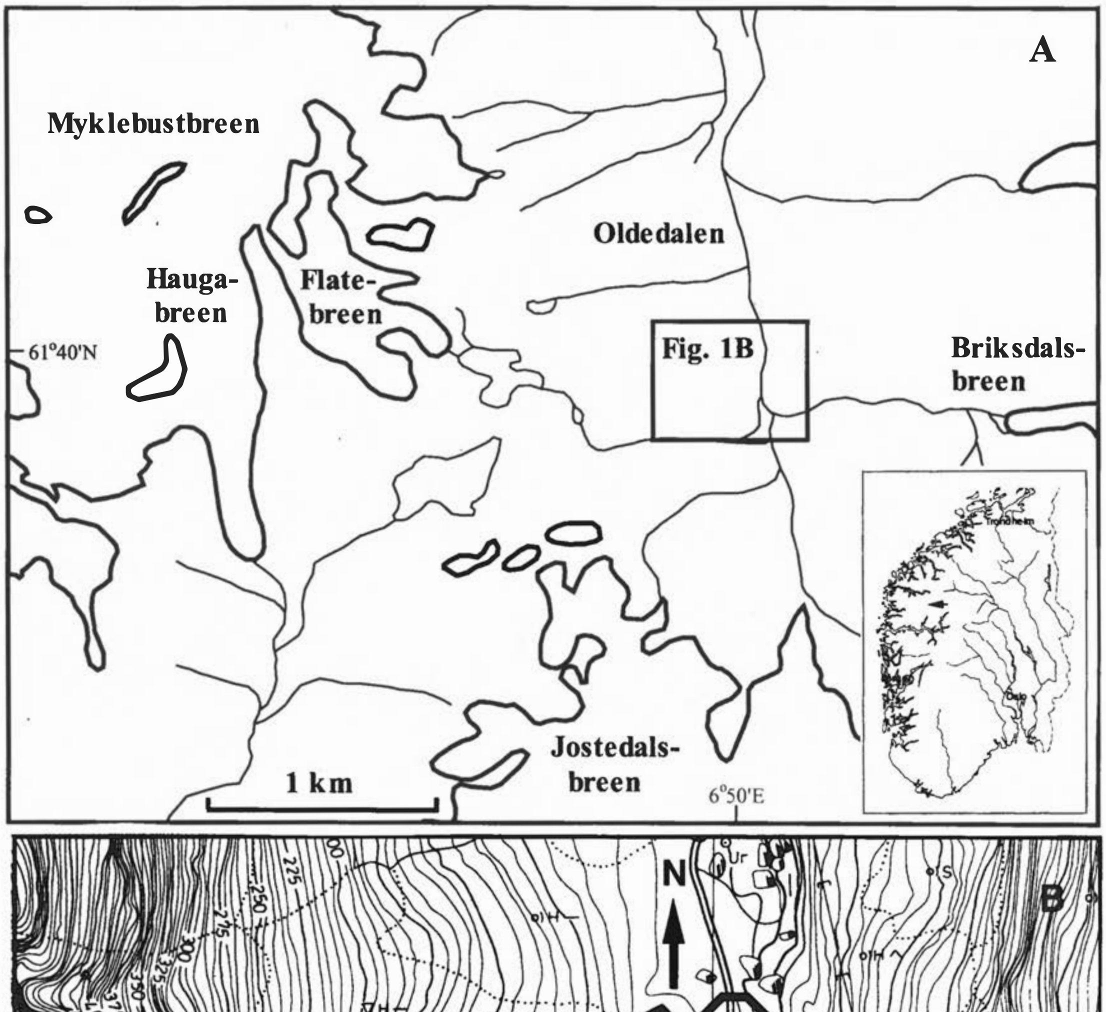

Fig. 1A. The study area in Oldedalen, western Norway (see index map). B. The rock avalanche deposit (the front lobe marked with the bold line). The boulder, below which the radiocarbon date is obtained, is indicated by an arrow.

identified as *Salix* sp. This piece of wood was subject to 'conventional' radiocarbon dating and yielded an age of 5220 ± 80 ^{14}C yr BP [5940 (6010-5910) cal. yr BP)] (Beta-155582) (Table 1). As the splintering and cracking of the tree trunks are interpreted to have occurred during the rockfall avalanche, the date indicates the age of the event. The date of the rockfall avalanche was considerably younger than expected. It did not occur immediately after the retreat of the last continental ice sheet at approximately 10,000 cal. yr BP (Rye et al. 1987, Nesje et al. 2000). The age approximately coincides with the age of the formation of the Jostedalsbreen ice cap at ~6000 cal. yr BP (Nesje et al. 2000, 2001), and the avalanche may have been triggered by this early phase of regeneration of local ice caps (Myklebustbreen/Flatebreen, Fig. 1A) in the area. This might have contributed to a change in the distribution of water in the source area, with an increase in pore-water pressure in the failure zone causing collapse.

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Fig. 2. The rockfall deposit seen from the eastern valley side. Note the large boulders along the avalanche front lobe. Photo: Atle Nesje.

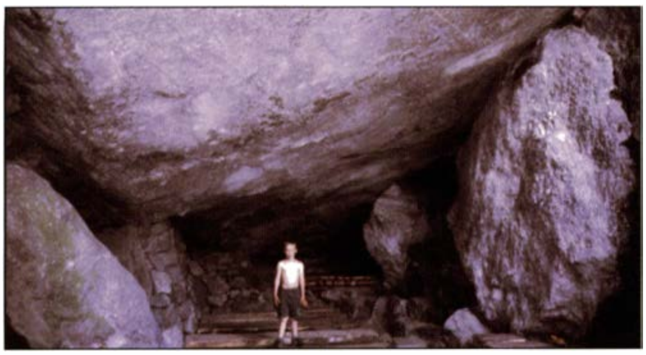

Fig. 3. The tree trunks, included the dated one, were found in connection with construction work below this huge boulder (for location, see arrow in Figure 1B). Photo: Atle Nesje.

Fig. 4. Detail of one of the splintered ends of a Betula sp. trunk. Photo: Markus Hahn.

Fig. 5. Surface detail of the tree trunk in Figure 4 showing a deep crack into the wood (arrow). Photo: Markus Hahn.

Table 1. The radiocarbon date. Calibration of the radiocarbon age to calendar years BP (BP = AD 1950) is according to the INTCAL98 age calibration program of Stuiver et al. (1998).

Dated material	Laboratory no.	^{14}C age	Intercept cal. yr BP/BC	1/2 sigma cal. yr BP	1/2 sigma cal. yr BC
Salix sp.	Beta-155582	5220 ± 80	5940/3990	6010-5910/6190-5870 and 5820-5760	4060-3960/4240-3920 and 3870-3810

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