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# The varve-related ice-dammed lake events in Glen Roy and vicinity: a new interpretation

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ABSTRACT

This paper presents a new interpretation of the sequence of events in Glen Roy and vicinity during the Loch Lomond Stadial that can be inferred from a detailed varve record constructed by Palmer et al. (2010). 300 years of Younger Dryas glacier advance in the Scottish Highlands are recorded by very thin varves formed in an ice-dammed lake up to 35 km long. At a varve site now occupied by Loch Laggan the lake stood permanently at 260 m, but in Glen Roy varves were also laid down in a lake at 325 m and, later, 350 m caused by glacier advance. Initial ice retreat recorded by a gradual increase in varve thickness was soon followed by much thicker varves. The varve sequences are interrupted by a sand bed caused by sudden drainage of the 350 m lake. The major varves of the Glen Roy sequence show that storminess was still increasing in intensity at least 160 years after glacier retreat had begun. At the Loch Laggan site 15 cm of deformed sediments register an earthquake that produced 3 m faulted uplift of all three Glen Roy shorelines, a response to the abrupt removal of 5 $km^3$ of water when the 260 m lake was catastrophically drained by jökulhlaup. The deformed sediments are immediately followed by varves deposited in a local lake, ice-dammed lake sedimentation now having ceased, having lasted more than 460 years.



## 1. Introduction

The Glen Roy ice-dammed lakes were first identified by Agassiz (1840) and later explained by Jamieson (1863, 1892). It was not until recently that annually laminated lake deposits (varves) that are exposed in Glen Roy and preserved beneath Holocene sediments in nearby Loch Laggan (Fig. 1) were studied in great detail by Palmer et al. (2010). Their varve chronology, based on the micromorphological examination of, and correlations between, the Glen Roy and Laggan varved deposits, suggested that the ice-dammed lakes existed for a total of 515 years. Furthermore, they proposed a sequence of changes in the positions of glacier ice margins and of concomitant lake levels based on variations in the thickness and structure of the varves. The purpose of the present paper is to give a new interpretation of the sequence of events that can be inferred from the varve properties. The varve record itself remains exactly as stated in 2010.

The ice-dammed lakes of Lochaber (Glen Roy and vicinity) existed during the Younger Dryas (Loch Lomond) Stadial. A lake was produced when ice derived mainly from west of the Great Glen blocked the drainage of Glen Spean. As the ice advanced eastwards, it merged with ice from the south that occupied upper Glen Spean and the westernmost part of Loch Laggan. At its greatest extent the lake was 35 km long, overflowing east of Loch Laggan (Fig. 1). In the Loch Laggan area the lake stood at 260 m. In Glen Roy, however, glacier advance (to line A, Fig. 1) caused lake level to rise to a col at 325 m, through which it drained to the Loch Laggan area. Further advance (to line B) raised lake level to 350 m, overflowing at the head of Glen Roy. When the ice retreated the 325 m lake formed again and then the 260 m lake.

The position of the ice dam (C, Fig. 1) when the 260 m lake was initially drained is approximately indicated by the western termination of the shoreline on each side of Glen Spean. This limit is generally accepted as also applying when the lake first formed since no other evidence is known.

In Glen Roy the limit of the glacier advance (D) is defined by the northern limit of a massive drift accumulation. In the Turret valley the limit (E: discussed in Sissons (2015), in this issue) is marked by morainic mounds and by the western margin of a large outwash fan. At the western end of Loch Laggan the limit (F) is a conspicuous end moraine. Only these three limits are shown in Fig. 1 since no others are directly relevant to the varve sequence.

In Glen Roy the most important sites for varve studies were several exposures on the surface of the Turret fan. At the eastern end of Loch Laggan cores were obtained from varved sediments

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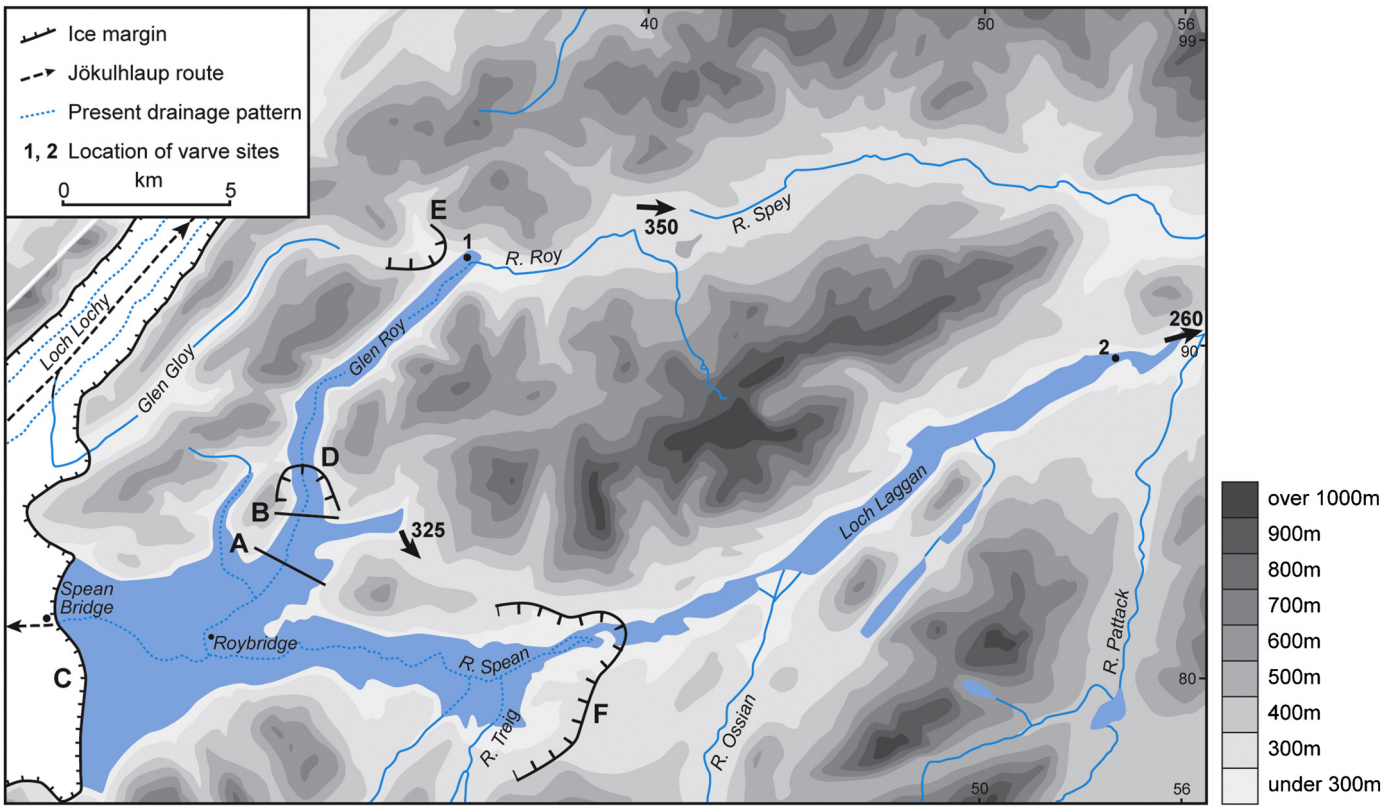


**Fig. 1.** The 260 m lake at its greatest extent, showing the limit of the Loch Lomond advance where it is relevant to the varve sequence, lake overflow routes, and the locations of the varve sites at the Turret fan (1) and east Loch Laggan (2). (A)–(F) are explained in the text.

beneath about 10 m of Holocene deposits (Fig. 1). The results from the two areas were combined in the *Lochaber Master Varve Chronology*, reproduced as Fig. 2.

## 2. Interpretation of the varve records

### 2.1. Advance of glaciers

It was shown by Palmer et al. (2010) that the earliest known varves were deposited at the Loch Laggan East (LLE) site. It was also shown that in Glen Roy, at the Turret fan sites, the first varve corresponds with varve 191 of the LLE sequence. Although the Turret sites are below the 260 m lake level, it is inferred that outwash being deposited on the fan ahead of the advancing ice prevented the deposition of varves. The varve record in Glen Roy therefore begins with lake level rise towards 325 m. The rise to 350 m is not identified in the varve sequence.

### 2.2. Glacial retreat, sand bed, 325 m lake replaces 350 m

At both the LLE and Turret sites the varves are interrupted by a sand bed that ranges in thickness from 6 mm to 30 cm. The presence of the sand bed in both these areas is explained by the drop in lake level from 350 to 325 m. This drop would have been very rapid since there was no impediment to water flow, the overflow route having already been used during the rising lake sequence. Possibly no more than a day was involved. The torrential flow explains the sand bed at LLE. In Glen Roy the sudden exposure to erosion of valley floors and steep valley sides explains the sand layer, which probably took more than one year to form.

Draining of the 350 m lake means ice retreat had begun. In accord with this climatic amelioration varves begin to increase in thickness before the sand bed is laid down. This occurs at both Glen Roy and LLE. The increase begins about varve 300. Lake level drop to 325 m occurred between varves 316 and 317.

The pronounced increase in varve thickness after the sand layer at the Turret site (Fig. 2) represents continued climatic amelioration. The contrast with the 300 far thinner varves associated with ice advance is extreme. However, an additional factor was the greatly increased area in and around Glen Roy supplying water and sediment, caused by the abandonment of the 350 m overflow.

### 2.3. 260 m lake replaces 325 m

When the drop in lake level from 325 to 260 m occurred the escaping water, had it flowed over land, must have produced obvious evidence, but none exists. It is therefore concluded that this lowering of lake level took place over and/or through the ice that then occupied lower Glen Roy and a large area of Glen Spean. It is suggested that the fall in lake level to 260 m is recorded by the considerable increase in average varve thickness at about varve 165 in Fig. 3. It is inferred that the increased thickness results from the availability of unconsolidated material on newly exposed ground. Varves were now able to form in the 260 m lake at the Turret fan because glacier retreat was well established.

### 2.4. Turret varves and summer storms

A feature of the Turret varves that followed the deposition of the sand bed is the presence of thick members that register stormy summers, a consequence of exposure of this area to winds from between south and west that were funnelled up the glen. This influence is also seen in the width of the nearby lake shorelines. In Glen Roy as a whole the 325 and 350 m shorelines average 10 m in width, but behind the fan, values of 15–35 m are normal (Sissons, 1978).