Short Communication

Geophysical investigation of the Blane Valley Pleistocene deposits

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Synopsis

Shallow geophysical surveys undertaken within the Blane Valley, floored by Loch Lomond Stadial proglacial lake deposits, show that the Pleistocene sequence is significantly thicker than previously suspected. Seismic refraction, resistivity and gravity data demonstrate that the depth to the Upper Old Red Sandstone bedrock varies from 30–100 m, suggesting significant relief on the submerged bedrock surface. The Pleistocene sequence extends to about 80 m below Ordnance Datumn.

Introduction

During the Loch Lomond Stadial (c.11 000–10 000 BP), one of the largest glaciers of the West Highland Glacier Complex occupied the Loch Lomond basin, damming lakes in a number of valleys, including those of Blane and Endick adjacent to its SE margin (Price 1983). This proglacial lake extended about 14 km along the Endrick Valley and about 10 km in the Blane Valley (Fig. 1).

Few details are available regarding the Pleistocene deposits of the Blane Valley. Rose (1981) suggests deposition occurred here in a Devensian proglacial lake, preceded by marine deposition as the sea drowned the

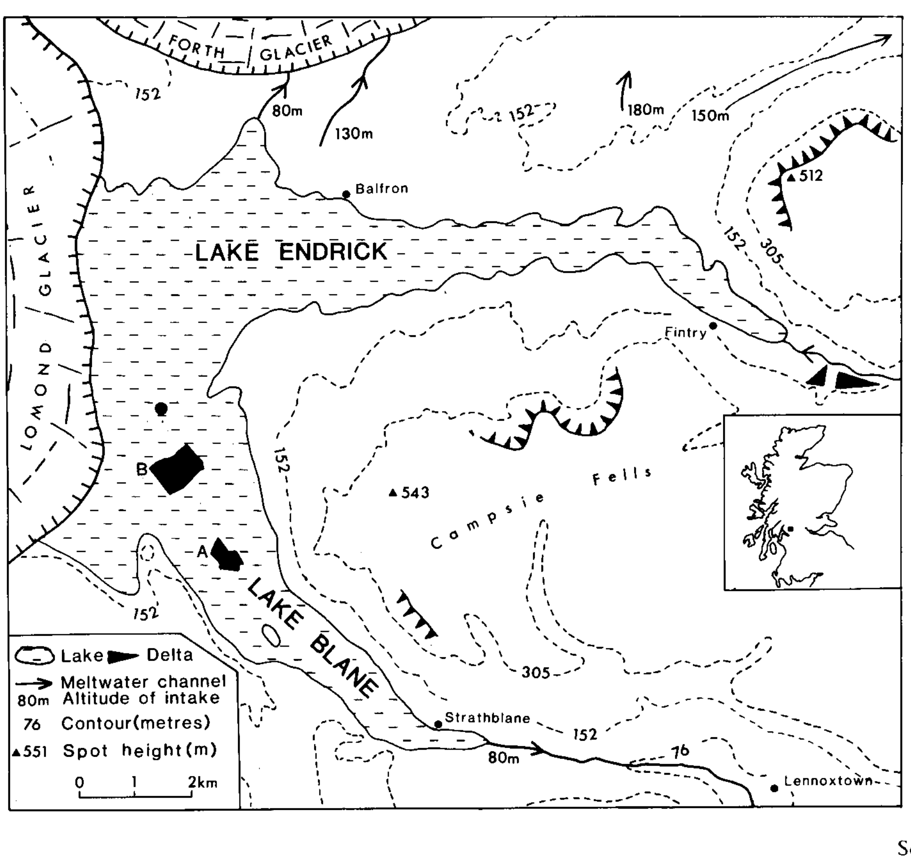

FIG. 1. Extent of the Loch Lomond Stadial proglacial lake that occupied the Blane and Endrick valleys. A and B are the sites of this study. Adapted from Price (1983). The location of the Killearn borehole is shown by a large dot.

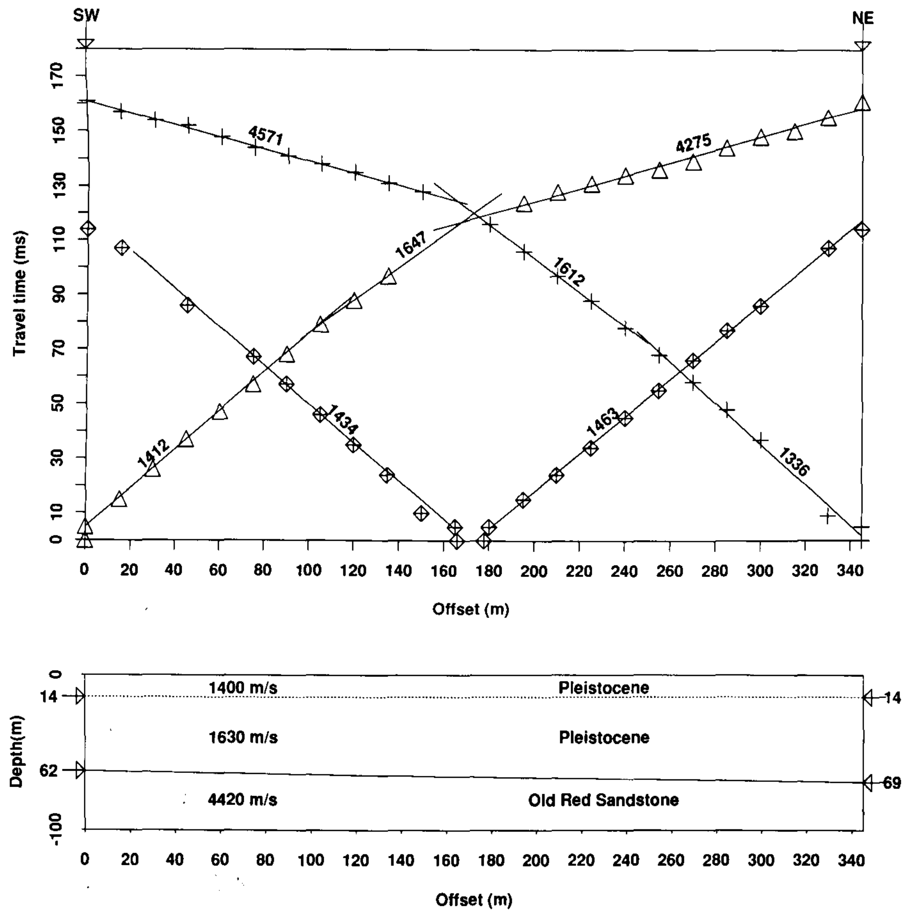

FIG. 2. Sample data (top) and model (bottom) from a seismic profile in Area B. The profile is orientated SW–NE and is located between Blaneswell and Moss; depth to the bedrock refractor increases from 62 m in the SW to 69 m in the NE.

valley during the Lateglacial Interstadial. This is supported by Browne and McMillan (1989, p.47) who report a borehole drilled near Killern House [GR 5100 8467], which penetrated 51 m of Pleistocene deposits before reaching bedrock. The top 15.61 m consisted of clays of the Blane Water Formation, underlain by 19.19 m of sands of the Killearn Formation. The lowest part comprised marine clays and silts of the Linwood and Paisley Formations.

The undergraduate course at Glasgow includes a week of geophysical fieldwork. This communication presents the results of these studies within the Blane Valley, which cast new light upon the deposits of the valley, revealing a substantial Pleistocene sequence of variable thickness. Several geophysical methods were employed to obtain an integrated model of depth to bedrock: seismic refraction, resistivity, magnetic and gravity. Seismic refraction and resistivity were of most value and form our main database, but we present also the results of a gravity profile.

Seismic profiles of 230–920 m length were established to detect arrivals refracted from the top of bedrock. Each profile comprised 24 receiver channels, with equally spaced geophones at intervals of 10–40 m. Small explosive charges were fired in boreholes, mostly at the ends of profiles. Standard interpretation methods were used (Kearey and Brooks 1991). Figure 2 shows a typical seismic dataset and model. Wenner arrays of up to 300 m length were established to carry out vertical electrical sounding profiles, oriented along the valley to ensure minimum variation in bedrock depth beneath. Computer modelling was undertaken, assuming a one-dimensional variation of ground electrical properties. A gravity profile was recorded perpendicular to the Blane Valley trend using a Worden Prospector gravity meter. This profile revealed an anomaly due to the density contrast of the Pleistocene sediments with the Upper Old Red Sandstone bedrock, permitting computer modelling of the valley fill.

Geophysical results

Two areas within the Blane Valley were investigated (Fig. 1): Area A west of the Glengoyne Distillery [GR 528 826], and area B near Moss Bridge [GR 516 839].A (Fig. 1): Area A west of the Glengoyne Distillery [GR 528 826], and Area B near Moss Bridge [GR 516 839].A reason, we discuss the results of Area B in detail; those of Area A are very similiar. Bedrock depths obtained from seismic and resistivity profiles within Area B are displayed in Figure 3. The valley floor is located at 20 m above Ordnance Datum (OD). Thus, posted depths show the Pleistocene deposits to extend to about –80 m OD.

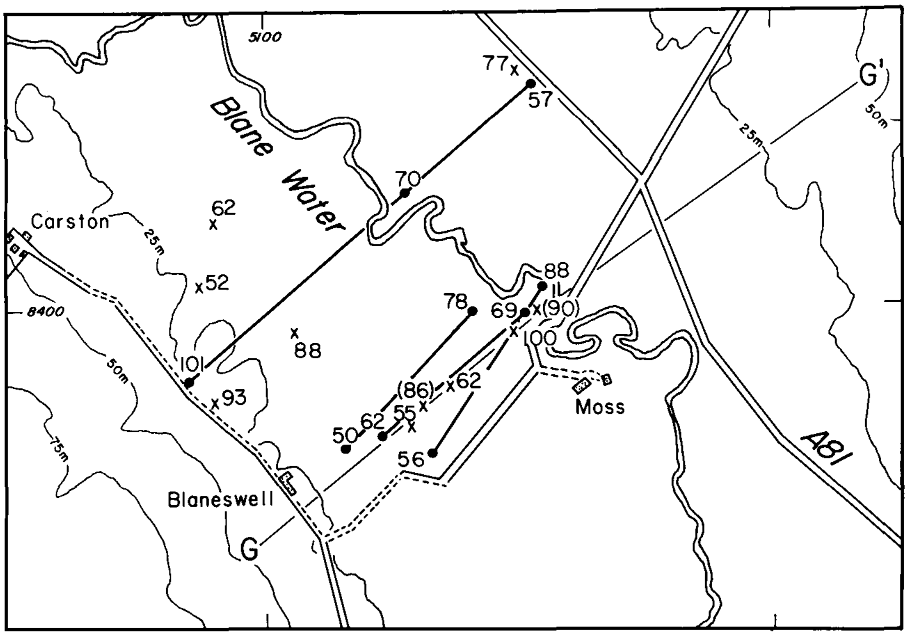

FIG. 3. Depths (in metres) to bedrock in Area B: seismic lines are shown by solid lines with dots for shotpoints where depths have been determined; a cross is the centre of a resistivity sounding from which the posted value is derived, bracketed values are minima; GC′ is the gravity profile of Figure 4; 1 km grid lines indicated by ticks.

Seismic. Top layer seismic velocities of 1490–2200 ms^{-1} were observed, underlain by a refractor of 3130–4420 ms^{-1}. These are interpreted as Pleistocene and Upper Old Red Sandstone sediments respectively. Some data show that the top 5–15 m of the Pleistocene sequence has a slightly lower velocity of 1200–1400 ms^{-1}. This may be the Blane Water Formation seen in the Killearn borehole.

Depths to bedrock posted at shotpoints in Figure 3 were obtained by assuming a planar refractor (rockhead) between shotpoints. This assumption holds in broad terms only given the depth variation observed, but the data do not justify a more sophisticated analysis. Bedrock depths of about 50–100 m were obtained beneath Area B, corresponding to –30 and –80 m OD respectively.

Three seismic profiles SW of Moss show the bedrock surface to deepen north-eastwards from the valley edge toward its centre. A fourth profile, located further north in Area B, suggests shallowing of the bedrock surface across the entire valley from the SW. Thus, we see evidence of significant, but not well defined, relief on the bedrock surface.

Resistivity. The resistivity of the Pleistocene sequence varies greatly, but is usually less than 100 ohm-m; the deepest unit observed has resistivities of several hundred ohm-m. Depths to this unit, assumed to be bedrock, are shown in Figure 3. All suggest bedrock to be at, or in excess of, depths obtained for the bedrock from seismic data. The most reliable depths (55, 62 and 100 m) indicate progressive deepening of the rockhead toward the valley centre.

Gravity. Gravity was measured along line GC′ (Fig. 3). Values were reduced to Bouguer anomalies, referred to a local datum (Fig. 4). For the Bouguer reduction and subsequent modelling, a near-surface density of 1.99 g cm^{-3}, appropriate for wet alluvium or clays was used (e.g. Kearey and Brooks 1991). After removal of a linear regional trend there remains a negative anomaly of about 1.3 mGal, due to the contrast between the low-density Pleistocene deposits and Old Red Sandstone bedrock. A density of 2.36 g cm^{-3} was assumed the latter (McLean and Qureshi 1966).

The valley fill was modelled as a 2-dimensional prism using 'Gravmag', an interactive modelling program. A simple model of one prism accounts for the anomaly (Fig.4). Note how the sides of the Blane Valley continue to depth under the Pleistocene fill at about the same gradient. Further, the basin thickness on the SW side matches well with the depth to rockhead independently inferred from a coincident seismic line (Fig. 3). The basin reaches a depth of about –85 m OD. Errors in the model, due to the assumed regional trend removed and density contrast, could be up to about 20%, implying a similar error in the fill dimensions.

Geological implications and discussion

The study was conducted deep within the Blane Valley, about 6 km NW of Strathblane. Bedrock has been shown to be at substantial depth below a Pleistocene valley fill of up to approximately 100 m in thickness, extending to some –80 m OD. Fill thickness is generally much greater than observed in the Killearn borehole (51 m). The nature of the deeper Pleistocene material cannot be determined by this survey. Areas A and B show similar results, suggesting that much of the Blane Valley is underlain by substantial Pleistocene deposits.

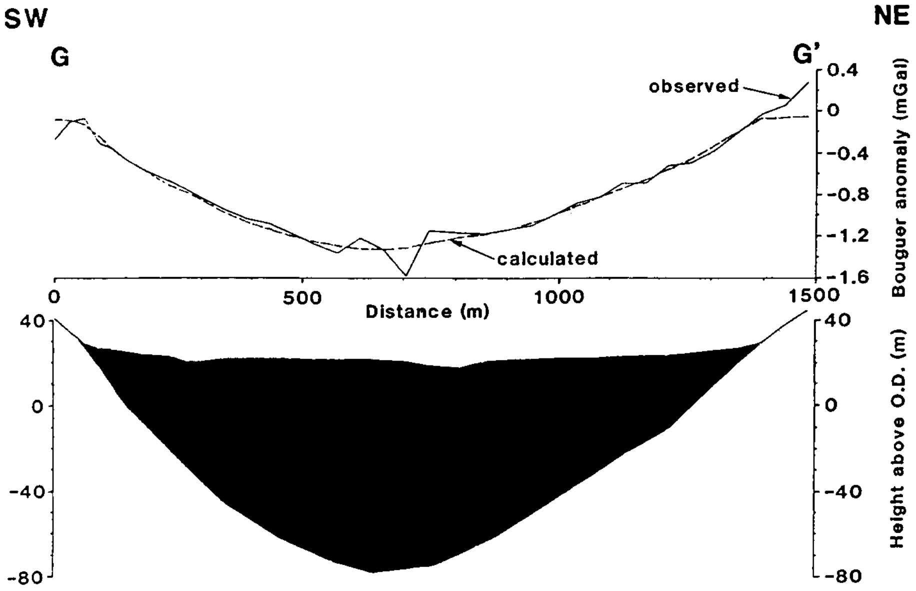

Fig. 4. Bouguer anomaly data and computer model for gravity profile GG′ in Area B. See Figure 3 for the location of the profile.

Variation in fill thickness is observed along and across the valley, indicating deposition on an irregular bedrock surface.

Internal layering of the Pleistocene sequence is indicated. Lower seismic velocities within the top 5–15 m may be due to the Blane Valley Formation observed in the Killearn borehole. If so, this work confirms that these Devensian lake deposits form only a small (topmost) part of the valley fill.

In conclusion, this geophysical survey has revealed substantial Pleistocene deposits within the Blane Valley. The Pleistocene thickness varies greatly due to deposition on an irregular bedrock surface, generally exceeding that observed in the Killearn borehole (51 m). Whilst this survey establishes the wider significance of the borehole information, it is clear that the borehole penetrated a thinner part of the Pleistocene deposits.

Acknowledgements

These surveys were carried out with the efforts of our third year students in 1988–90. It was their task to acquire, process and provide an initial interpretation of the data. We are grateful to Mr. and Mrs. J. Parker, Mr. J. Bilsland, Miss Skelton and Sir Archibald Edmonston for permission to carry out these surveys across their land. Our colleagues Chris Burton and Graham Jardine are thanked for useful discussions.

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