



## **Classical Moraine, Non-classical Cause: The Waiho Loop, New Zealand**

James Shulmeister (1), Daniel Santamaria-Tovar (2), Natalya Reznichenko (2), and Tim Davies (2)

(1) School of Geography Planning and Environmental Management, University of Queensland, Brisbane, Australia, (2) Department of Geological Sciences, University of Canterbury, Christchurch, New Zealand (tim.davies@canterbury.ac.nz)

The Waiho Loop terminal moraine, Westland, New Zealand is one of the best examples of its type in the world, and has graced many textbooks and the cover of "Science". Its estimated early Holocene age made it for many years the best evidence that the Younger Dryas glaciation extended into the southern hemisphere, with corresponding implications for mechanisms of interhemispheric climate teleconnection. Recent dates from the Loop, however, suggested it was formed about 10500 BP; 2000 years too late for the Younger Dryas (Barrows et al 2007). However, a number of factors suggest that the Waiho Loop may not be the result of a climatic advance, but of a rock-avalanche induced advance. Large rock avalanches depositing onto ablation zones dramatically reduce ice-surface ablation (Reznichenko et al., 2010); the altered mass balance can cause an advance, followed by a retreat as the debris is replaced by clean ice from the accumulation zone. The rock avalanche debris can then form a terminal moraine (Hewitt, 1999; Deline, 2009; Orombelli and Porter, 1988).

The Waiho Loop shows a number of characteristics that suggest it may be a moraine of this type:

1. It does not coincide with known major advances of other glaciers in the region (or indeed worldwide)
2. It contains a high proportion of rock (sandstone) outcropping  $\sim 10$  km upvalley, suggesting a limited source area
3. Much of the debris is angular, suggesting dominantly supraglacial transport
4. The fine fraction of the debris shows agglomerations and coating typical of rock avalanche debris, and not seen in subglacially-derived sediments
5. Its morphology is unlike that of any other moraine in the area
6. Numerical modelling (Vacca et al, 2010) indicates a rock-avalanche-generated moraine in this location should have a high, steep triangular cross-section with ablation moraine to its rear; the Waiho Loop shows just these characteristics
7. The total volume of the Loop is  $\sim 1$  km<sup>3</sup>; other rock avalanches of this size are known in the region with sources close to the Alpine fault.

A non-climatic origin solves the problem of the age of the Waiho loop; however it also sounds a warning about palaeoclimatic interpretation of moraines. It is generally assumed that all moraines reflect climatic influence, but this is clearly not the case. The extent to which the palaeoclimate record is contaminated with non-climatic moraine dates is unknown, and there is an urgent need to study this. The fine-fraction signature of rock-avalanche sediments offers a reliable way of doing this.