Investigating recent 'surging' behaviour and hazard development, Belvedere Glacier, Italy

Dates in the field: 7th June – 6th July 2009

Preliminary report

Matthew Westoby, John Balfour and Alex Neen*

** contact: mjw08@aber.ac.uk*

1. Introduction

The team departed for Macugnaga in the Italian Alps on the 7th of June, arriving on the 9th. The original plan had been to camp or seek accommodation in a local hostel, however, for the same price we were provided with a flat located a short drive away from the chairlift at Pecetto which was to be used for daily access to the glacier.

Following a rest day, two days were spent doing general reconnaissance on and around Belvedere Glacier. On the third day the automatic weather station (AWS) was established on the smaller snout (location: N 45° 57.740, E 7° 55.094). For the next three weeks data collection was carried out on a daily basis (excluding rest days) before our departure. The team arrived back in the UK on the 6th July, earlier than originally anticipated due to financial constraints.

Outlined below are the main objectives of the individual projects, the methods employed in the field and plans for the processing and synthesis of results.

2. Project summaries

2.1 *Investigating past and present geomorphological processes occurring in moraine complexes in the context of the recent 'surge-type' event – John Balfour*

The main objective of the study was to investigate the past and present processes occurring in the lateral and terminal moraine complexes as a result of the surge-type movement in the early 1990s and 2001/2. As a result of this behaviour new moraine ridges have been formed within the existing moraines attributed to the Last Glacial Maximum (LGM).

Processes occurring in the new 'surge' moraine formations were investigated, in addition to those reactivated in the LGM moraines which may have been interpreted as slumps/mass movements in previous palaeoglaciological investigations. There are also potential implications for glacier hazards as the ability of the moraines to withstand snow/ice/rock avalanches may have been affected by the surge-type movement.

Clast macro-fabric analysis within 1 m x 0.5 m grids was carried out at 30 sites encompassing all lateral moraines. Sites were chosen using a random structured sampling regime in order to identify any contrasts in the processes occurring between sites. Additionally, sites were photographed from a distance of ~0.5 m and will be used for image analysis utilising the newly-developed 'Sedimetrix' software created by Loughborough University. The main aim is to calibrate this software with data collected in the field.

At present, analysis is still being undertaken on the data with the aim of having this completed within the next month. A full literature review will also be performed and included in the final report in order to relate the study to previous similar investigations.

2.2 *Sedimentological analysis of landforms associated with glacial advances and the 'surge' event – Alex Neen*

Fieldwork involved a mixture sedimentological analysis and geomorphological mapping in order to investigate the spatial extent of sedimentary landforms associated with glacial advances and in particular the surge-type advance of 2001.

Sediment and facies descriptions were carried out on the glacier, on glacigenic materials deposited by the glacier (largely in the form of moraine) and on material that has been reworked since deposition. This was in addition to clast analysis (roundness, surface character and a-b-c axis dimensions) which will help distinguish the mode of transport. The data will enable a spatial variation in transport type and modification by glacier transport to be established for the whole glacial and depositional system. It will also provide evidence of any basally derived debris entrained on to the glacier surface. This may be linked to thrusting mechanisms which are characteristic of a surge advances.

Detailed geomorphological mapping was carried out in the field, during which numerous individual moraine ridges and complexes were discovered which can be distinguished between Little Ice Age moraine and push moraine associated with recent surging advances. The latter follow the shape of the former but are smaller in size and evidently less stable with increased mass movement and no vegetation. The glacier itself was heavily crevassed in sections but there was little evidence of current activity.

The project is currently in the stage of advanced data analysis. A detailed literature review has been produced and the next stage of work will involve the construction of a detailed digitally produced geomorphological map using ArcMap (a cartographic computer software package). This will be done using mapping and observations derived from fieldwork in addition to satellite imagery, photographs and standard maps of the area.

2.3 *Investigating glacier surface albedo and energy balance components – Matt Westoby*

Due to a change in this project's main objectives (please refer to submitted 'notification of change of objectives') the focus was changed to the quantification of the spatial variability of glacier surface albedo. To this end, terrestrial photography using a Panasonic Lumix DMC-FZ7 digital camera was employed. The locations of sampling sites were determined using a handheld GPS in the field and designed to maximise spatial coverage of the glacier. At each site, calibration photographs using a Kodak grey card (surface of fixed reflectance – 18% of incident solar radiation in the visible spectrum) were taken, followed by a series of photographs taken at a fixed height looking directly downward (i.e. debris cover) and upward. The precise time of sampling was recorded, as well as observations of the illumination conditions (cloud cover, precipitation etc) to facilitate direct comparison with AWS data.

In total, 60 sites encompassing the entire lower half of the glacier (upper half inaccessible due to the persistence of snow cover) were sampled. In addition, four 'local-scale' experiments were carried out to quantify the spatial variation in albedo in a 100 m^2 area, the aim being to relate this to the variance in albedo represented by individual pixels in the ASTER image. As well as simply photographing the debris cover, sampling was carried out

over the complete range of surface types present on the glacier, namely bare glacier ice, patches of old snow and ice cliffs partially covered with clots of sediment. A variety of lithologies were also sampled.

Following the success of our application to NASA for the acquisition of an ASTER satellite image we were informed that the overpass and data capture would take place at 11.28 local time on the 27th of June.

Unfortunately, following an electrical storm the vast majority of the AWS data were rendered irretrievable as a result of a build up of static electricity in the atmosphere interfering with the datalogger. However, relative changes in albedo can still be calculated using the calibration photographs for each sampling site. The ASTER image has been obtained from NASA, but is extremely limited in its usefulness due to the abundance of thick cloud cover over the majority of the glacier.

The focus at present is on the processing of the spectral signatures of the photographs, which is being carried out using a combination of programs including Microsoft Excel, Image Pro 6 and OriginPro 8.

3. Final notes

The projects being carried out by Matt Westoby and Alex Neen will be written up in the form of Masters dissertations and will be completed by October 2009. Seminars are also to be given in early September within the Institute of Geography and Earth Sciences, Aberystwyth University. It is anticipated that the project being carried out by John Balfour will be completed by the end of 2009. A full final report will be submitted shortly after.