Glacial geology in Scotland

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Introduction

Firstly, I'd like to sincerely thank the QRA for awarding me the Lewis Penny Medal. It is an honour to have my research recognised in this way, and to join the list of existing recipients. The catalyst for my interest in Quaternary studies was Colin Ballantyne's enthusiastic lectures on the Quaternary geomorphology of Scotland, while I was an undergraduate at St Andrews. Upon graduating in 2001, I based myself in the amazing landscape of the Canadian Rockies where I became convinced that a geomorphology-related career was the path for me. In 2004 I completed the excellent MSc in Quaternary Science at Royal Holloway, led at the time by John Lowe, and made thoroughly enjoyable by a positive peer group. I was employed by BGS the following year, where I was fortunate to join a growing Quaternary team in the Edinburgh Office. My work at BGS led me onto investigating landforms and stratigraphic sequences in the Scottish glacial record. In 2009 Tom Bradwell suggested that I talk with David Sugden about starting a part-time PhD at Edinburgh University, and the project took off immediately. Tom and David's advice, enthusiasm and confidence made it an extremely rewarding experience, and I submitted the PhD at the end of last year.

My main research interests since joining BGS fall under three broad themes.

Palaeoglaciological reconstructions

There is a strong history of palaeoglaciological research in Britain and Ireland (e.g. Charlesworth, 1955; Penny, 1964; Ballantyne 1989, 2007; Evans et al. 2005). Perhaps one of the most significant contributions in recent years was the compilation of the BRITICE database (Clark et al., 2004), which triggered a renewed focus on British-Irish Ice Sheet (BIIS) research. By presenting an up-to-date synthesis of existing geomorphological evidence at an ice-sheet-wide scale, the BRITICE work provided an initial template from which larger-scale ice sheet reconstructions, similar to those of the former Laurentide and Fennoscandinavian Ice Sheets, could be based. The synthesis also highlighted sectors of the BIIS where little evidence had been described, and therefore could be used to direct new work that could subsequently contribute to a detailed, whole ice-sheet reconstruction.

My work initially took me to the Creag Meagaidh range in the western Grampian Highlands, where I became interested in ice field configuration during the Loch Lomond Readvance, and the signature of ice sheet retreat prior to the readvance (Finlayson, 2006). This work extended to the Beinn Dearg range in NW Scotland where collaboration with Tom, Nick Golledge and Derek Fabel allowed the comparison of a numerically simulated and empirically reconstructed former ice cap (Finlayson et al. 2011). The key outcomes were: that areas of glacier inception and ice retreat were not necessarily the same; that wind redistribution of snow played an important role in ice cap configuration, which we attempted to quantify; and that soft-sediment landforms from an earlier deglacial stage had survived under ice cap outlet glaciers.

I also became interested in ice-sheet scale problems, and through collaborative work, presented an interpretation of the last ice sheet cycle in western Scotland (Finlayson et al. 2010, 2014). Having

spent almost every childhood summer holiday on the Island of Arran, field work in this part of the world was an enjoyable experience and a nice opportunity to revisit some of my favourite places under the pretence of 'work'! The research in western Scotland highlighted the important influence of subglacial topography on dynamic and stable zones of the former ice sheet, and provided evidence for significant changes in ice sheet flow that were brought about by the growth and collapse of a marine-terminating sector. Our work also recognised that many features in the landscape relate to an early restricted mountain ice sheet configuration – thought to have been the dominant glacial mode in the early and middle Quaternary (Lee et al. 2012).

Three-dimensional geological modelling

I was introduced to three-dimensional geological modelling through working on urban geology projects. My original involvement in this work related to the development of shallow subsurface geology models that could be interrogated to inform urban planning and sustainable urban regeneration projects in Glasgow. However, I quickly realised that the models also have significant potential to inform us about the volumes of sediment that were deposited by glacial and post-glacial processes. Incorporating thousands of borehole records, I developed a catchment-scale three-dimensional Quaternary geology model for the Clyde basin, and linked with an ice sheet reconstruction to elucidate patterns and quantify volumes of sediment moved during the last glacial cycle (Finlayson, 2012a). The results suggested that, in the Clyde basin, ice marginal and sub-marginal processes were key agents of sediment movement, while sediment transfer under the ice sheet was far more restricted. The models also allowed layers, or packages, of sediment to be 'peeled off' the land surface to reveal buried landscapes. One application of this was to test how quantitative palaeoglaciological studies, based on modern topographic data, can be affected by a 'mask' of postglacial sediments in lowland, depositional environments (Finlayson, 2013a).

I believe there is a lot of potential for new three-dimensional geological modelling or mapping techniques in Quaternary studies, and recent software developments have made it a relatively user-friendly and accessible tool. As an example, in Iceland I have been applying the technique to model the internal structures of a modern glacier, based on structural glaciological measurements, radar data and terrestrial LiDAR scans (Phillips et al. 2013). This has been part of a larger field project led by Jez Everest, and has involved particularly enjoyable work with Emrys Phillips – a self-confessed bedrock geology convert who has now turned to the 'dark side' of Quaternary studies!

Applied Quaternary Geology in Scotland

My job has always involved elements of applied Quaternary geology, which I find very rewarding. In the UK ongoing development places increasing demands on the underlying landscape (e.g. energy supply, waste storage, transport networks, aggregate resources). To inform planning decisions, a good understanding of the likely surface and subsurface ground conditions is required. In formerly glaciated terrain, a landsystems approach (Eyles, 1983; Evans, 2005) can play an important role in planning ground investigations and interpreting the results. The costs of putting geologists on the ground are very small compared to overall site investigation costs, yet the benefits can be significant. By working with colleagues such as Clive Auton and Jon Merritt, I have been able to see how Quaternary geologists can add real value to large-scale infrastructure projects.

Since joining BGS, I have been involved in providing Quaternary geological input to projects at

Hunterston, Dounreay and Drigg, relating to radioactive waste storage and site restoration (Golledge et al., 2009; Finlayson, 2010; Smith et al. 2010). I have contributed to geological site assessments for buried power cable routes (Finlayson et al., 2012) and wind farm sites (Barron et al. 2011; Finlayson, 2013b), and have included Quaternary geological information in approximately 50 desk-based site assessments for private and public sector clients. Around the River Clyde in west central Scotland, I am involved in work, led by Diarmad Campbell, generating three-dimensional Quaternary and bedrock geology models which are helping planners to anticipate ground conditions and identify contaminant pathways for a variety of brown-field regeneration projects (Campbell et al., 2007; Finlayson, 2012b). A particular early highlight for me at BGS was contributing to work by Alan MacDonald, Clive Auton and others, characterising the Quaternary sediments and groundwater flow in a flood prone part of north-east Scotland (MacDonald et al. 2007; MacDonald et al. 2012). The results informed design of a flood alleviation scheme, resulting in huge savings through prevented groundwater flooding damage.

These types of projects continuously remind me that the work of Quaternary scientists, in understanding the processes that have shaped our land surface over the last 2.6 million years, is important; and it is necessary for continued sustainable development on our landscape.

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