Using Discrete Debris Accumulations to Help Interpret Upland Glaciation of the Younger Dryas in the British Isles

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1. Introduction

With no glaciers in the British Isles in the last 10, 000 years or so, the acceptance of the 'Glacial theory' propounded by Agassiz and Charpentier in the Alps in the 1830-40s was late to be accepted in the British Isles (Chorley, et al., 1973). Scientists from the British Isles had travelled to areas with glaciers, yet even popular tourist areas such as the English Lake District area were not considered to have been affected by glaciers until the 1870s (Oldroyd, 2002). In Scotland however, the ideas of James Croll, giving a theoretical reason for changes in climate, were persuasive in an earlier acceptance of glacial interpretations (Oldroyd, 2002). Field mapping by the Geological Survey in Edinburgh helped to displace the 'floating iceberg' and 'diluvial' theories, especially in the explanation of erratics (Rudwic*k*, 2008). Once accepted, the basic tools of mapping the former extent of glaciers, for example by the recognition of moraines, became commonplace. More recently, aerial and satellite imagery have made drumlins and cross-cutting depositional modes important in elucidating the limits of the terrestrial Pleistocene glacial record (Clark et al., 2004). However, and perhaps inevitably, interpretations of the significance of some moraines and their corresponding glaciers has been in debate. Together with chronological methods, detailed mapping of glacial limits and altitudes allow comparisons with climatological models and general climatic interpretations such as the recent interpretations of the Younger Dryas in Scotland summarised by Golledge (2010).

In this paper I take an overview of the problems associated with a variety of features, other than moraines, associated with mapping the glacial limits (and associated climatic conditions) in the Younger Dryas Stadial in the British Isles. It does not aim to be comprehensive in treatment of these features in the British Isles but is concerned with the problems of mapping and interpreting a variety of features. Recognising the genesis is important as it may help to provide evidence for the magnitude-frequency of selected events as well as help to distinguish between a variety of events that may produce similar-looking landforms. Furthermore, as some features seen and mapped may be post-glacial slope failures rather than glacial deposits, their identification and correct interpretation may be useful for mapping slope failures in an area rather than glacial features. First however, it is necessary to identify some terms and meanings that will be used or have been used in mapping the Late Holocene in the uplands of the British Isles.

2. The Younger Dryas (YD) in the British Isles and the dating of events

In the British Isles, the cold period known as the Younger Dryas Stadial (12.8 – 11.5 ka BP) (Muscheler et al., 2008) but also, and more usually, considered to be 11 – 10 ka BP. It is also known as the Loch Lomond Stadial after the large inland loch to the north of Glasgow. The last stage of the Last Glacial Maximum in the British Isles is generally taken to be the Dimlington Stadial (Rose, 1985) 26 – 13 ka BP as part of the Late Devensian Glaciation. As such, the Younger Dryas saw a deterioration (increasingly cold and wet) period in which glaciers advanced (or grew) again. It followed a relatively warm period known in the British Isles as the Windermere Interstadial (= Allerød). The variability of the dating the YD may be related to when the cooling stage started and its severity. That the YD is generally agreed to be a world-wide phenomenon (Ivy Ochs et al., 1999) with glacier advances being seen e.g. in the Colorado Rockies of interior USA (Menounos and Reasoner, 1997) as well as more maritime areas such as the British Isles. It is also suggestive that the timing may not be exactly coeval everywhere but may indicate that responses to climate change may differ, e.g. in latitude, altitude as well as 'continentality' across the islands. These uncertainties need to be taken into consideration when viewing the landforms and processes in this paper. For example, the date of a recessional moraine of a glacier in the Alps may be known to a year but this is highly unusual in moraine sequences as far back as the YD. Even dated trees need to be put in context. Similarly the known maximum advances of glaciers in the Little Ice Age (again variously defined in terms of chronology but generally taken to be 1600 – 1850 CE). Examples from the Alps and Pyrenees as well as elsewhere provide some near present-day analogues that help interpretation in the British Isles.

In upland areas, where the Younger Dryas glaciers may have been small and reacting to subtle variations in a rapidly changing climate, the analysis may require careful mapping and interpretation for specific areas. This is shown by Benn and Lucas in their landsystems approach in NW Scotland (Benn & Lukas, 2006). They use present-day analogues to help their interpretation much in the same way that Hauber et al. (2011) have used Svalbard to provide periglacial analogues for Martian landforms. The use of analogues is used generally for the interpretation of surface features in planetary geology (Farr, 2004). This use is appropriate as periglacial and possibly permafrost features are associated with upland regions of the British Isles in the Younger Dryas. Compilations of processes, mechanisms and chronologies can be found in Ballantyne and Harris (1994) and Gordon and Sutherland (1993) and other overviews have been provided in several other volumes (Boardman, 1987; Gillen, 2003; Gordon, 2006; Gordon & Sutherland, 1993; McKirdy et al., 2007; Wilson, 2010).

A distinction should be made be made between periglacial, that is, around a glacier and permafrost, a thermal condition where the mean annual air temperature is assumed to be <-2°C. So a snowbank is generally assumed to be a periglacial feature but is not glacial, ie with the dynamics of a glacier-ice body. Neither condition is extant in the British isles at the present day and we shall see that may produce interpretational difficulties. The term paraglacial has been used to indicate features that are postglacial and are involved with sediment movement (Ballantyne, 2002; 2007). It was instituted into the literature by Church and Ryder (1972) as, materials that were produced by 'non-glacial processes that are conditioned by glaciation'. Ballantyne (2007) defines it as 'the study of the ways in which glaciated landscapes adjust to nonglacial conditions during and after deglaciation'. However, in many cases this does not help with the interpretation as it may not be at all clear what was glacier or snow or permafrost-related. Further discussion can be found in Slaymaker (2009).

If there are problems in interpreting the significance of moraines this is also true of landscape features where the ice-debris mix is of less certain origin and formative process unclear. For example, the ice-cored moraines investigated by Østrem in Scandinavia (Østrem, 1964) were interpreted by Barsch (1971) as being 'rock glaciers'. This dispute (Østrem, 1971) is still not resolved. There are several reasons for this uncertainty; problems of observation as well as nomenclature and understanding of the geological processes and mechanisms involved and their rates of operation. This is despite advances of glacial theory, sedimentology and dating techniques. Additionally, researchers coming from diverse backgrounds have tended to have different, often divergent, views about the processes operating and therefore the interpretations. Further discussion on this will follow below.

3. Discrete Debris Accumulations and terminology

The term Discrete Debris Accumulations (DDA) has been used to encompass a range of features that can be mapped in the field or from aerial photographs (Whalley, 2009). It is used here as a non-genetic and descriptive term, such that focus can be given to whatever is under study without any preconceived notion of origin or significance. The actual interpretation of these features is, in the British Isles, very much related to the use of analogues. This is especially significant when the presence of ice (of some origin) is considered and so the recognition of ice-debris features and their mechanisms is considered. Although DDAs *may* be paraglacial it could be that some are fossil glacial features and not at all modified by post YD activity. Hence, there needs to be some care in distinguishing between periglacial, proglacial, paraglacial and permafrost in these studies.

This paper is specifically concerned with recognising the process and mechanisms of debris accumulations rather than dating *per se*. In particular, the association of specific features can be associated with climatic conditions. For example, moraines are associated with glaciers and the size (mass balance) of the glaciers. In the British Isles there is an assumed west-east gradient in glacier net balance, such has been found in Scandinavia (Chorlton & Lister, 1971). There are also possibilities of changes in prevailing winter storm tracks that may influence the size of glaciers (Whalley, 2004) that have not yet been investigated for the palaeo-conditions for the British Isles compared with suggestions for northern Scandinavia (Bakke et al., 2005; 2008).

The traditional view of the relationship between glacier extent, mass balance and glacial record is the linear set of boxes in Figure 1. The 'geological record' is usually taken as being manifest in the simplest (or least complicated) debris accumulation associated with glaciers; a moraine. Although the basic idea may hold, interpretation is more complicated for periglacial features such as snowbanks and their rock debris remnants such as 'protalus lobes'. Is such a feature classed as periglacial, proglacial or indeed paraglacial (Slaymaker, 2007; 2009)? This problem will be considered in more detail below.

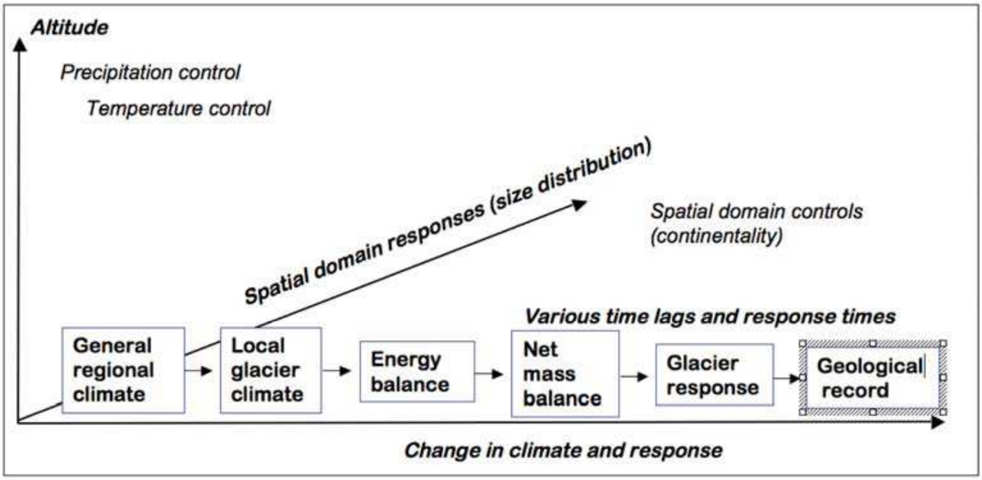

Fig. 1. The basic controls on glaciers and their responses in the geological record; from Whalley (2009) after Andrews (1975) and Meier (1965). The boxed sequence is embedded within domains that ultimately affect the geological record.

4. Mapping Discrete Debris Accumulations

Despite remote sensing techniques, direct field observation is still important when process recognition remains a problem. In this paper it is suggested that care must be used when interpreting landforms, especially when related to their past climatic history. This is especially important where rates of process are assumed and where similar landforms might be produced by different processes ('equifinality' or 'form-convergence').

Weathered rock debris accumulations, whether directly deposited from a glacier or by some creep or flow mechanism, frequently have distinct forms, to which names are given – although the origins may be disputed. Such discrete debris accumulations can be mapped. To interpret these forms, especially to make inferences about environmental conditions, observations have to be placed within the context of imperfect knowledge of behaviour and response to past environmental conditions or events. This paper suggests that caution and more precise glacio-geomorphological investigations are required. Selected examples illustrate such problems from present day analogues and from ice-free areas.

The geological literature has many examples of differing or changed opinions about features – in the widest sense. For example, in the present context, Wilson (2004) now views certain rock glaciers in Donegal (Ireland) as (paraglacial) rock slope failures. This changes the paleo-environmental interpretation from being related to permafrost to one where permafrost (nor glacier) were involved.

A change in climate leading to glacier mass balance change and a glacier leaving an interpretable and dated trace (such as a moraine) is useful in a regional as well as temporal manner. Shakesby and co-authors (Shakesby, 1997; Shakesby & Matthews, 1993; Shakesby et al., 1987) have discussed problem related to protalus ramparts. There are different responses according to glacier size as well as the mode of precipitation input (winter storms, summer monsoon) and the effects of continentality as suggested above. For example, Harrison et al. (1998) suggested that a small glacier existed in the lee of the Exmoor plateau. This was based on their interpretation of a small moraine or protalus rampart at the foot of a small valley head (combe/corrie/cirque). Indeed, the use of the term 'moraine' or 'protalus lobe' may well indicate differences of interpretation. Some of these, perhaps indistinct, features, tend to be problems of interpretation rather than mapping. Certain debris accumulations in the English Lake District (Sissons, 1980) present problems of climatic interpretation, especially when it is not clear what the features represent in terms of debris and ice input. Similarly, Harrison et al. (2008) have discussed features that have generally been called 'rock glaciers' and their environmental significance. More precise matching of formation processes and mechanisms to environmental conditions will help to improve modelling of ice mass extents and volumes and associated climatic environments (Gollege & Hubbard, 2005; Hubbard, 1999).

5. Debris input to glacial systems

To the basic glacial parameters of Figure 1 weathered rock debris needs to be added to the system for there to be traces in the geological record. This complication is rarely considered; not just a morainic marker but to consider where, when and from where the debris addition was made. It may well have a considerable effect on the system as a whole. The total amount may be important. Dead ice preserved at the snout of a glacier long after the debris-free glacier has melted may give hummocky moraine or even a rock glacier form. Further, the debris flux may have an effect upon the ice extent. For example, a glacier in equilibrium that receives a debris input near the snout (as from a large rockfall) could produce a glacier advance as the ablation area is reduced. The timing of debris input (at the start or end of a glacier advance phase for example) may be significant. Some work has been done on this in the British Isles, eg. (Ballantyne & Kirkbride, 1987). Although dating such events via cosmogenic ratio methods is now becoming easier (Ballantyne & Stone, 2004; Ballantyne et al., 1998) care must be taken in the temporal interpretation.

Figure 2 indicates the potential complexity here, again related to altitude, continentality and temporal input variations. Rock debris can be added to a glacial, permafrost or periglacial system. Unknowns include the relative and absolute amounts of ice/water and debris but also the flux changes in time (Nakawo et al., 2000; Whalley et al., 1996). Even 'simple' glacial systems may show this. For example a large rockslide on or near the snout of a glacier may allow the snout to advance but if away from the snout the glacier may be hardly affected. In the relatively small glacier in the British Isles however, substantial, but largely unknown, effects may be produced.

Figure 3 illustrates possible scenarios produced by the relative additions of weathered debris quantities to snow/ice bodies. This should not be taken to show that certain features *will* form but that they are possible given the relative components at any time. For example, the time element is not considered as part of the formative process. Some features might be form 'rapidly', others take some time. For the most part process studies do not give a good indication of the time needed to produce a feature. If the debris is lacking then there may be no feature formed at all. However, the diagram does suggest that there is a continuum of features and it does help guide interpretation of what is seen or mapped.

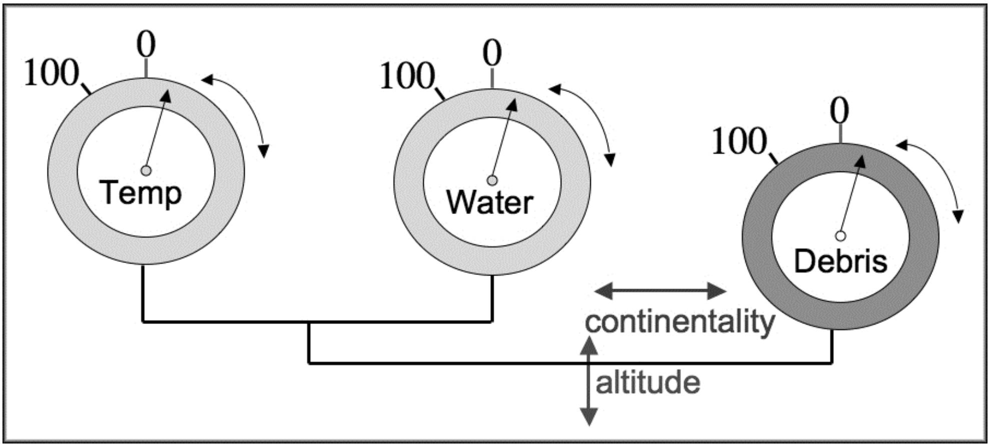

Fig. 2. An illustration of the weathered rock debris constituent needs to be taken into account when considering 'glacial, proglacial, perglacial or permafrost conditions. Not only may the debris addition be sudden (rock avalanche) or slow and continuous (scree formation); after Whalley (2009).

A further formational aspect not shown in Figure 3 are the possible altitude-temperature/precipitation-continentality controls (Figures 1 and 2). Thus, it is by no means clear where the 'best' analogues for the YD in the British Isles should be taken. For example, it was once thought that rock glaciers were only found in 'continental' mountains until examples from Iceland were found. The answer lay in the relative amounts of debris supplied to small glacier systems. Furthermore, Icelandic rock glaciers are found where there is no (or only sporadic) permafrost. Hence, the inverse interpretation; relict rock glacier = former permafrost, needs to be used carefully. This applies in fact to most of the features here classed as DDAs

6. Rock debris production in upland British Isles

As the ideas shown in Figures 2 and 3 depend upon debris input some consideration will now be given to the production of rock debris. At the present day, however, there is very little active rock fall production. There are some active scree slopes (talus), as shown by the lack of vegetation, but these are relatively uncommon.

Rockfalls (of indeterminate size) may be associated with periods of cliff instability related to a number of possible factors. These include glacial unloading and seismic, neotectonic, tremors associated with isostatic readjustment (e.g. Jarman, 2006) large-scale weakening of rock buttresses caused by intense periglacial weathering; permafrost melting or a combination of these factors. Some characteristics of these rock glaciers includes: location within mapped Younger Dryas glacier limits, high and steeply-angled cliffs upslope of the landform and largely unvegetated surfaces. A review of large 'felssturz' (rockfall events) in extra-glacial areas of Austria by (Meissl, 1998) shows how significant such events may be even today. There is compelling evidence (Whalley, 1984; Whalley et al., 1983) that near-glacial conditions were, and are, important in the development of rockfalls and slides.

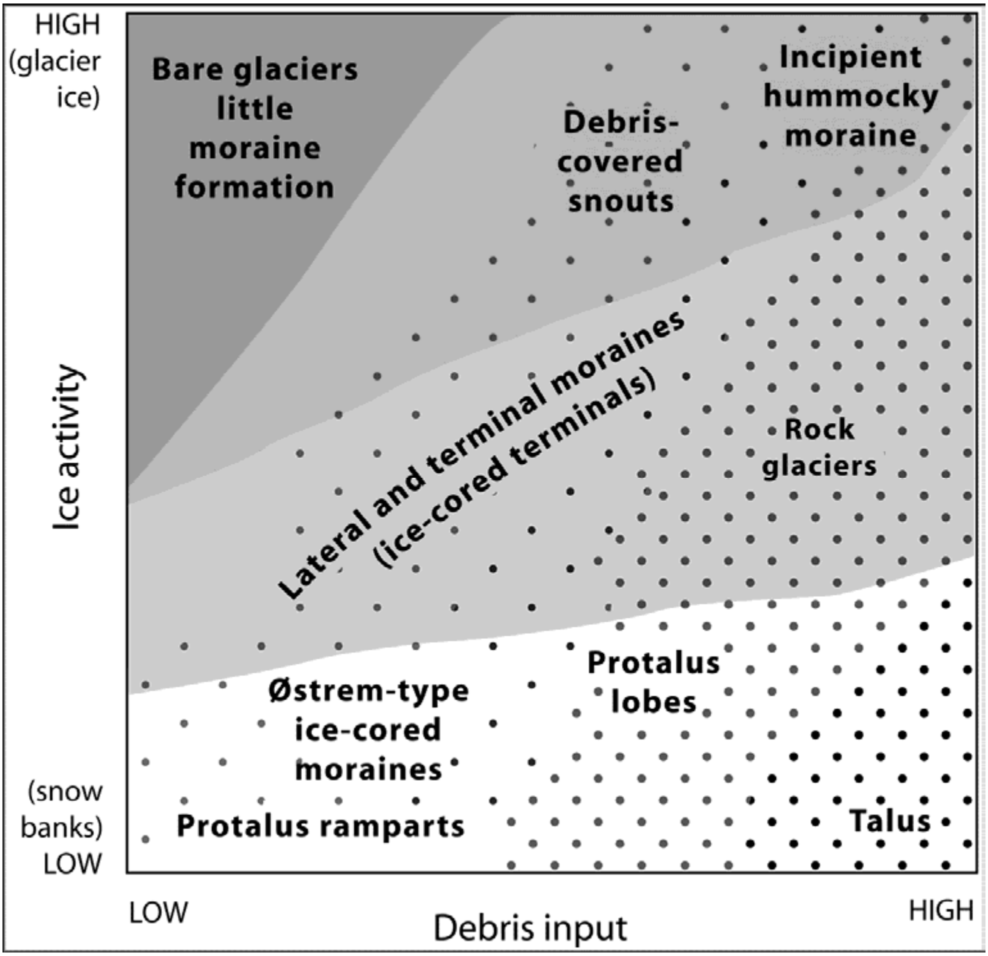

Fig. 3. A schema illustrating the relative proportions (and perhaps fluxes) of snow/ice and rock weathering debris in a 'glacial' geomorphic system. From Whalley (2009).

Permafrost warming post Younger Dryas may also have had a significant part to play as has been suggested for present-day rockfall production and (Davies et al., 2003; Whalley et al., 1996) have shown that large debris accumulations are often associated with Little Ice Age events. It is not yet clear how substantial and variable was the production of debris in the Younger Dryas, although some attempts have been made (Ballantyne & Kirkbride, 1987). More recently, Jarman (2009) and Wilson (2009) have examined rockfalls and slope failures associated with Younger Dryas slope activity and the production of discrete debris accumulations. What does seem to be the case is that fossil rock glaciers and protalus lobes are relatively rare in the British Isles and Ireland compared with many mountainous regions. This may well be a consequence of the lack of weathering or rockfalls from the Caledonide rocks that comprise much of upland Britain (Harrison et al., 2008). It is perhaps not surprising that Norway, similar in a geology of hard old rocks, also seems deficient in rock glaciers and protalus lobes. Unsurprisingly however, present-day scree formation in Norway does seem more active than in Britain because of more severe weathering conditions.

7. Mechanical properties of ice and ice-rock mixtures

Having thus indicated the importance, yet variability of ice/water/debris fluxes within mountain systems in the British Isles in Younger Dryas times we now need to consider what the effects might be upon the mechanical properties of the materials produced. This has been considered in several papers (Whalley, 2009; Whalley & Martin, 1992; Whalley & Azizi, 1994; 2003) and will not be elaborated upon here. Figure 4 illustrates graphically another continuum, of strength or flow of ice according to the content or dispersion of rigid rock particles.

We have to use present-day analogues and known rheological behaviour to interpret past deposits. Unfortunately, even the present day features may be in dispute. This makes interpretation of Younger Dryas DDAs even more problematic, hence even more to interpret past climate from such features.

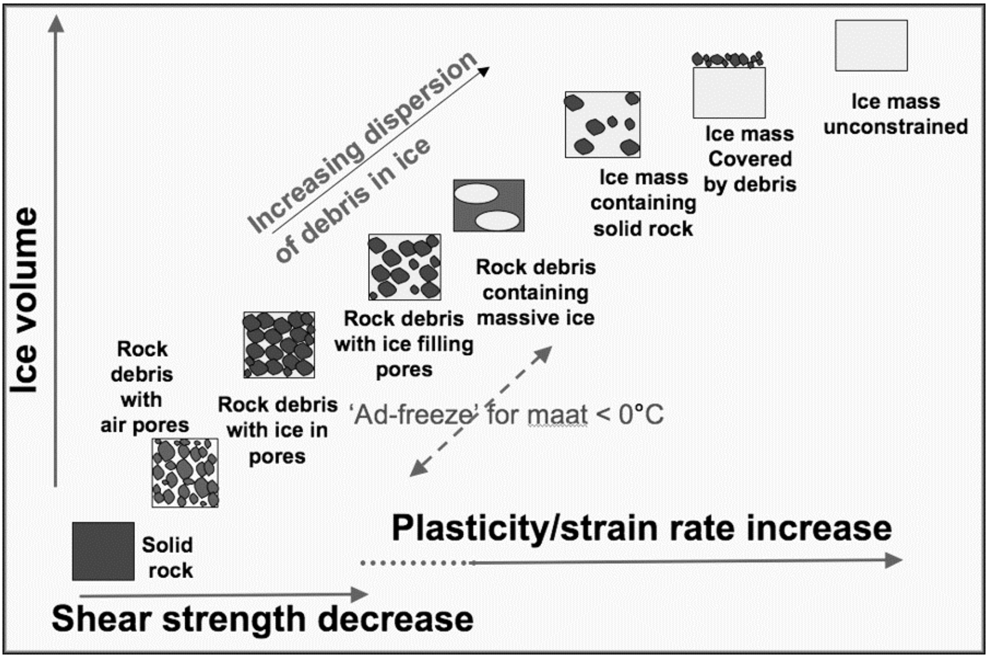

Fig. 4. This indicates both the possible mixture models likely to have been associated with the formation of most discrete debris associations and their mechanical properties. Thus, from the bottom left, rock slopes may fail and provide rigid blocks, perhaps amassed as scree with air spaces. If water/ice is mixed with the particles the mass is still rigid until there is enough ice in the mixture to allow ice deformation (Azizi and Whalley, 1995; Whalley and Azizi, 1994).

8. Interpreting Discrete Debris Accumulations

Table 1 (after Whalley, 2009) lists the main features likely to be seen as Younger Dryas Discrete Debris Accumulations in the uplands of the British Isles. This must, at present, be taken as a rather rough typology. It has not proved possible to provide a key system to help identify features. There are three reasons for this. First, the features themselves are somewhat variable in form and location on a hillside. Secondly, the debris input location and type needs to be taken into account (following from Figure 3). Thirdly, the interpretation itself may change. Thus, some of the following photographs show variations in form. The diverse papers about the origin of the Beinn Alligin ‘rockslide’ exemplifies both the second and third reasons starting with the original description (Sissons, 1975; Whalley, 1976) and with further detailed interpretations (Ballantyne, 1987; Ballantyne & Stone, 2004; Gordon, 1993). A clear example of a change in opinion is that by Wilson, already mentioned, in revising his formation model of some rock glaciers in northern Ireland to be massive rockslides. This view then casts doubt on the interpretation of the rock glacier (in the same geology) on Islay (Dawson, 1977). This also illustrates a further difficulty, that of terminology, a problem that has long bedevilled this area of research, especially that of rock glaciers (Hamilton & Whalley, 1995; Martin & Whalley, 1987).

Feature name	**Comments on formation etc**	**Environmental interpretation use or caution**
Blockfield *	If autochthonous (*in situ*): i Was it deformed by over-riding ice sheets? ii How old is it?	If undeformed or not removed how is this interpreted? Possible cosmogenic ratio exposure data. Use of tors related to blockfield might be helpful.
Hummocky moraine*	Passive formation (ablation) In some cases might be related to push moraines	Various interpretations, related to moraines, debris transport location, ice deformation; possible link to Østrem-type moraine
Landslide	Any YD or post-glacial event	Ice probably not involved but the resultant landform may look like one or other of the features listed here.
Østrem-type moraine	Originally, frontal debris deposition over 'old' snowbank; Possible confusion with: i Push moraine ii Rock glacier (glacier ice or permafrost) iii Protalus lobe iv Hummocky moraine	Relict feature difficult to interpret due to lack of ice and (as far as known) a significant relict feature. May look like a rock glacier - which then provides possible interpretation problems. To date, these have not been attributed to any feature in the British Isles.
Protalus lobe	i Involvement with glacier/snowbank ice + debris	Glacial, nival or permafrost maintenance, length of time of

Feature name	Comments on formation etc	Environmental interpretation use or caution
	input flux ii Involvement with permafrost-derived + ice debris input flux	preservation; dating problems possible
Protalus rampart	i Debris passively over snowbank ii Construction by small glacier iii Might develop into rock glacier (permafrost or glacier related?)	Size may indicate origin of ice; assumption that snow-derived relates to regional snowline rather than possible glacierisation altitude
Push moraine *	Topographic forms may have various origins and perhaps associated glacier dynamics	Interpretation as glacier margin movement or permafrost-related dynamics?
Rock glacier	i Glacier origin ii Permafrost origin iii Rockslide relict iv Composite origin v Breach of lateral moraine wall (not known in the British Isles)	Permafrost formative conditions or glacier; use in constructing regional trends for glacier ice (below regional limit) or assumption that all rock glaciers are of permafrost origin; Difficult to trace if rockfall-related
Rockslide	Large, one-off event, YD or post-glacial	Ice probably not involved but the resultant landform may look like one or other of the features listed here (see also 'landslide'). Bergsturz also used in the literature
Talus (scree slope)	Usually unambiguous; Length of time of formation may be considerable.	Paraglacial reactivation of old feature possible; may grade into other features down-slope (protalus lobe, protalus rampart, rock glacier)

Table 1. This table (derived from Whalley 2009), provides a summary of the main discrete debris accumulations likely to be found in the British Isles and Ireland, other than moraines. The features are listed alphabetically but those marked * are not referred to in this paper. Protalus lobe is equivalent to 'lobate rock glacier' or 'valley wall rock glacier' of some workers. A protalus ramparts is also known as 'winter nival ridge', 'pronival ridge' or 'snow-bed feature'.

9. Some examples of Discrete Debris Accumulations in the British Isles and possible analogues

The following illustrations illustrate some of the features in Table 1 as well as highlight interpretational problems associated with them. Where appropriate the UK National Grid co-ordinate system is used.

Fig. 6. Terminal area of a small glacier descending from Y Glydder, Snowdonia (SH 625727). This may have been a debris covered section of the lower glacier or even an incipient rock glacier.

Fig. 7. Corrie in Tröllaskagi, Northern Iceland where there has been a small glacier but very little debris to protect the ice from melting (Whalley, 2009). The debris cover is left as an indistinct trace after the ice has melted. A neighbouring corrie has a distinct rock glacier feature (Whalley et al., 1995) produced by high ice fluxes but with corresponding debris input to protect the ice.

Fig. 8. Protalus rampart, Herdus Scaw (NY 111161) one of several in the English Lake District described by Ballantyne and Kirkbride (1986). This is typical of those found in the uplands of the British Isles and is associated with snowpatch or snowbed. It is not known how long it took to build such a feature but a few hundred years seems a reasonable possibility.

Fig. 9. This protalus rampart (Oxford, 1985) is considerably larger than that shown in Figure 8 and has also been called a moraine (Sissons, 1980).

Fig. 10. The feature (arrowed) shown in Figure 9 in context of the north-facing cliffs of Robinson (NY 197176) English Lake District. Viewed like this it becomes easier to visualise a small glacier building the moraine/protalus rampart and why is it perhaps difficult to distinguish between the terms if they relate to the size of the snowbank/glacier. A similar example can be found below Fan Hir, Mynydd Du, South Wales (Shakesby & Matthews, 1993; Whalley & Azizi, 2003).

Fig. 11. Protalus rampart being formed by debris falling from the cliff and sliding/avalanching to the rampart feature. The rock is gabbro and would be equivalent to the low weathering rates from cliffs in Upland Britain during the Younger Dryas. Goverdalen, Lyngen Alps, Troms, Norway.

Fig. 12. Feature below Dead Crags, English Lake District (NY 267318) desribed as protalus rampart (Ballantyne & Kirkbride, 1986) and Oxford (1985). In contrast to the features shown in Figures 8 and 9 the deposit here is very subdued and tends more towards a lobe.

Fig. 13. Rock glacier or protalus lobe below the cliffs of Craig y Bera, Nantlle , Gwynedd, North Wales (SH 541538). This is an unusual feature in that it faces south although the cliffs here appear to weather more easily than other locations in the area. It may be a 'landslide' rather than rock glacier although may be similar to landslide features described by (Watson, 1962) some 20km south at Tal y Llyn.

Fig. 14. Feature (between arrow heads) interpreted as a (talus) rock glacier in the northern Lairig Ghru, Cairngorms, Scotland (NH961037) (Ballantyne et al., 2009; Sandeman & Ballantyne, 1996) and is similar to features found in Strath Nethy (see also Wilson 2009). The valley of the Lairig Ghru has many 'avalanche landforms' (Ballantyne & Harris 1994) which may be related, although these are much more down-slope, linear features.

Fig. 15. Although this has some similarities to protalus lobes this feature, on the edge of the Kinder Scout Millstone grit escarpment, Derbyshire (SK089895) is probably a slump/landslide. As it faces south-west snow/ice is unlikely to have lasted long here. However, ridges interpreted as moraines have been found at Seal Edge some 4km to the west where the escarpment is north facing (Johnson et al., 1990).

10. Conclusions

There are many features that may have been formed during the Younger Dryas (Loch Lomond Stadial) event in the British Isles. The examples shown here suggest that there are often different, and changing, opinions as to how they were formed and thus their environmental and climatic significance. The size of a ridge on a protalus rampart may be large enough to have been produced by a small glacier as opposed to a snowpatch. Mixing and matching the snow/ice/debris quantities and fluxes may produce a continuum of landforms and interpreting these forms presents problems. These mixtures may also have a significant effect on the mechanical properties, especially where ice is mixed with rock fragments. Landslides may well produce forms that look similar to forms such as protalus lobes and ridges. Although many of these forms have been mapped over thirty years or more, further work is needed to provide unequivocal interpretation of their formative mechanism and thus environmental significance. This is particularly important when the diversity of possible interpretations is viewed. Thus, slope failures (such as Fig. 15) may be indicative of the susceptibility of local geology to slope failure (which may be re-activated by localised human intervention) rather than of past climatic conditions. Conversely, in areas such as the British Isles where there is a strong west-east climatic gradient (Fig. 1), identification of features such as debris accumulations may assist in the evaluation of past climates and the extent of ice or perennial snow.

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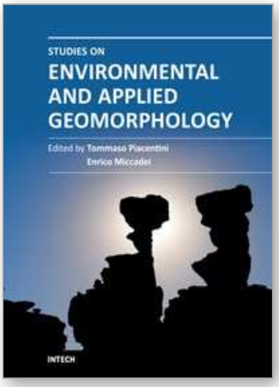

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