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PRONIVAL RAMPARTS: ORIGIN AND DEVELOPMENT OF TERMINOLOGY

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With 2 figures, 1 table and 1 photo
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Summary: Pronival ramparts are debris ridges formed at the downslope margins of perennial or semi-permanent snowbeds at the foot of bedrock cliffs. The close spatial proximity and morphological similarities of pronival ramparts to modified talus sheets and cones as well as protalus rock glaciers, moraines and landslides has led to difficulties in correctly identifying ramparts. Nevertheless, these landforms have been documented across the globe and, as a result, terms have been developed in different languages. However, the use and meaning of rampart terminology, particularly across several languages, are not consistent. This paper chronicles the origin of the term 'pronival rampart' and assesses its use in English language literature and exposes readers to terms from other languages and how their use may differ. Lastly, this paper highlights that, since the meaning of terms denoting pronival ramparts varies between languages, readers should be cognisant of the meaning of the term in a respective language as this may have implications for how pronival ramparts are identified in the context of talus-derived landforms. The paper also discusses whether ramparts are part of a non-developmental or developmental morphological continuum of talus-derived landforms.

Zusammenfassung: Bei pronival ramparts (Schneeschuttwällen) handelt es sich um Schuttwälle, die im Vorfeld perennierender oder semi-permanenter Schneebetten am Fuße von Felswänden gebildet wurden. Die enge räumliche Nachbarschaft und morphologische Ähnlichkeit zu überformten Schuttflächen und -halden sowie Blockgletschern, Moränen und Erdrutschen haben zu Schwierigkeiten bei der eindeutigen Identifizierung von pronival ramparts geführt. Gleichwohl wurden diese Formen vielerorts auf der Welt dokumentiert und infolgedessen haben sich in verschiedenen Sprachen unterschiedliche Fachbegriffe etabliert. Es bestehen jedoch Inkonsistenzen hinsichtlich Verwendung und Bedeutung der Begrifflichkeiten. In dem vorliegenden Beitrag wird der Ursprung des Begriffs „pronival rampart" chronologisch aufgearbeitet, seine Verwendung in der englischsprachigen Fachliteratur analysiert und entsprechende Termini in anderen Sprachen und ihre ggf. differierende Bedeutung und Verwendung aufgezeigt. Letztlich wird deutlich, dass begriffliche und sprachliche Unterschiede eine eindeutige Identifizierung der Form und ihrer Genese im Kontext des periglazialen Formenschatzes erschweren und daher eines kritischen Umgangs bei vergleichenden Betrachtungen bedürfen.

Keywords: Periglacial morphology, pronival rampart, protalus, moraine de névé, Schneeschuttwälle, nivomorena, derrubios de nivación

1 Introduction

Pronival ramparts are debris ridges formed at the downslope margins of perennial or semi-permanent snowbeds at the foot of bedrock cliffs (Photo 1). These landforms, also known as protalus ramparts, are typically located in periglacial environments and have long been considered to be 'simple, easily understood feature[s]' (Thorn 1988, 16). The apparent simplicity of rampart formation made these landforms far less interesting than other modified forms of talus in cold environments (Shakesby 1997). However, debate continues as to whether or not ramparts are part of a non-developmental or developmental morphological continuum of talus-derived landforms (see Shakesby 1997; Hedding 2014). In addition, the close spatial proximity and morphological similarities of pronival ramparts to modified talus sheets and cones as well as protalus rock glaciers, moraines and landslides has led to difficulties in correctly identifying ramparts (see Hedding and Sumner 2013). Collectively, this has resulted in confusion regarding the terms used to designate pronival ramparts. Hedding (2011) investigates the (in)appropriate use of terminology for pronival ramparts in English language literature and demonstrates that inappropriate terminology can have serious implications in terms of their use. Similarly, Whalley (1985, cited in Whalley 2015) indicated that a problem pervading glacial geomorphology was that of terminology. Swift et al. (2014) express the view that the variety of different processes and forms associated

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Photo 1: An actively-accumulating rampart on sub-Antarctic Marion Island

with nivation has bred considerable terminological difficulties and more rigorous definitions would aid this important aspect of periglacial geomorphology. Therefore, this paper chronicles the origin and use of terminology for pronival ramparts and expands this terminology to other languages with the aim to elucidate the context of current terms, in various languages. Advances in our understanding of pronival ramparts are presented to stimulate discussion on more appropriate translations between languages as well as place pronival ramparts in the context of talus-derived landforms.

2 Early work and conceptualisation of the term 'protalus rampart'

The first descriptions of pronival ramparts appear to be those of Drew (1873) and Ward (1873) from the Upper Indus Basin and the Lake District, United Kingdom, respectively (Shakesby 1997). The traditionally assumed supranival mode of genesis was first proposed by Drew (1873, 445), who noted that '… a talus of snow forms first … and then upon the snow-heap rolls down the loosened stuff, which therefore finds rest only at the foot … of the snow talus; melting of this in summer leaves a heap of stones which may be of considerable height'. Ward (1873, 426) described 'mounds of scree material formed at the base of a slope, by sliding fragments over an incline of snow lying at the base of crags'. Subsequently, Kendall (1893, 69) added that rockfall fragments 'would find the base of the cliffs pre-occupied by a talus of snow, (and) would roll further out from the base and form a fringe of rock debris'. In the following year, Kinahan (1894, 237) erroneously referred to the some Irish examples of ramparts as 'terminal moraines' and to one specific example as 'a massive esker-like high accumulation of shingle'. Kinahan (1894, 236) referred to these landforms as 'snow stones' or '*cloghsnatty*' in Irish Gaelic, for which Warren (1979) provided *clogha snachta* as the correct spelling. Kinahan (1894, 238) also described their mode of formation by stating 'the slope in some years was covered by frozen snow, over which stones from the high ground slide'. Interestingly, Kinahan (1894, 236) stated that he first examined these rampart-like features, 'some forty years' prior to his publication and, thus, may well have been the first to recognise what we now call pronival ramparts. Later, Marr and Adie (1898) described 'snow slope detritus' which they differentiated from 'true moraine' in Snowdonia, Wales. Gatty (1906, 491) envisaged a similar mechanism of rampart formation to Ward (1873) when he observed that 'blocks of rock wedged off the cliffs above by the winter's frost roll or slide down and come to rest at the foot of the snow-shoot' at a site on Ben Nevis, Scotland. However, this landform was re-interpreted by Ballantyne (1989) as an avalanche rampart.

Cross and Howe (1905) identified landforms as 'snowbank accumulations', while Howe (1909) referred to 'snow-bank deposits' which presumably are all ramparts. These accounts, together with the description of Chamberlain and Salisbury (1906, 472–474) who noted that the 'disposition of talus appears to be due to snow banks at the bases of the mountains' whereby 'descending talus rolls out over snow, lodging at its outer edge', appear to be the first descriptions of pronival ramparts in North America. Calkin et al. (1998) indicated that in 1906, Moffit (1913) unknowingly photographed landforms in Alaska that were subsequently identified as pronival ramparts (Kaufman et al. 1989). Matthes (1900, 184) also associated landforms in the Bighorn Mountains, Wyoming, North America with nivation processes when describing 'morainal material, not in distinct heaps but rather spread out, lower down in the valley' which, due to a lack of striations, was not attributed to glacial motion. However, not enough evidence was presented to determine if these landforms are ramparts, which led Thorn (1988) to suggest that they are boulder pavements.

Daly (1912, 593, Plate 57) described 'wall-like piles' that were 'dependent on the formation of heavy snow-banks and a specially rapid frost-action before summer heat has melted the snow in large measure' as 'winter-talus ridges'. This term was later adopted by Lahee (1931) and permeates subsequent geology literature. Gregory (1917, 82) also provided an early description of 'ramparts' in North America when he noted 'miniature embankments ... ascribed to nivation, operating at a time when a perennial snowcap occupied the highland'. Subsequently, Gordon and Ballantyne (2006) have reinterpreted these landforms as being characteristic of rock glacier creep. Bowman (1916, 287) recognised that 'material ... rolls down a long incline of snow and comes to rest at the foot of it as a fringe of talus' and Behre (1933) indicated that Bowman (1916) incorrectly linked most of the waste material associated with the snowbanks to the erosive action of the snow. Nevertheless, Bowman (1916) appears to have been the first to note gravity-driven supranival debris transport and the formation of pronival ramparts in South America.

Gripp (1929) provided an interesting early description of rampart formation from Spitsbergen. Van der Meer (2004, 108) explained that Gripp (1929) envisaged rampart formation whereby 'katabatic winds can deposit snow in front of an end moraine, where debris from the moraine can slide over the snow surface and accumulate as a block moraine overlying the sandur'. Such an accumulation of debris would mostly certainly be considered part of the moraine complex after deglaciation (Van der Meer 2004). This may represent one of only two descriptions of rampart genesis in front of moraines. The other comes from Marr and Adie (1898, 56) who, while describing concentric ridges of moraine, noted that on most of the moraine ridges 'rest sub-angular perched blocks, whilst the innermost crescent of the drift dam consists of angular blocks as though some at least of this material was rather of the nature of snow-slope detritus than true moraine'.

Following from the work of Daly (1912), Behre (1933) correctly identified the traditionally envisaged supranival gravity-driven mechanism of debris transport. Behre (1933, 630) observed that 'talus blocks, breaking from rock ledges, roll down over the snow and continue bounding toward its lower edge'. This observation appears to be similar to the explanations of debris transport provided by Howe (1909) and Crawford (1913). Shortly thereafter, Russell (1933, 935) noted that 'as boulders and spalls roll down a snow surface with greater ease than down similarly inclined talus, they accumulate below the lower margins of permanent or semi-permanent snow drifts, where they form conspicuous benches'. Howe (1909) observed that with larger or smaller snow banks, ridges would form at different distances from the cliff which, according to Gutiérrez (2013), led Sharpe (1960) to infer that ridges which are parallel to each other are indicative of parallel slope retreat. Boch (1946) discussed debris transportation associated with snowpatches from the northern part of the Urals and represents one of the earliest known references to supranival debris transport in modern-day Russia.

Behre (1933) introduced the term 'nivation ridge' which was subsequently adopted by Lewis (1966), Unwin (1975) and Butzer (1976). Recently, Luckman (2013, 571) has stated that 'at some talus sites, a perennial firn (snow) patch may develop at the base of the slope. Rockfall or avalanche debris landing on this icy surface slides to the base, accumulating as a ridge which has been termed a protalus rampart or nivation ridge'. Other similar terms, such as nivation moraine (Imamura 1937, 1940; Derbyshire et al. 1979) and nival moraine (Karczewski et al. 1981; Dzierżek and Nitychoruk 1987) were also proposed. Shakesby (1997) pointed out that other, less popular, terms for these landforms can also be found in the English language literature. Examples include pseudo-moraines (Peev 1966; Watson 1966) and 'firn pseudo-moraines' (Bizubová and Škvarček 1999), miniature moraines (Manley 1949), talus terraces (Liestøl 1962) and protalus ridges (Gardner et al. 1983). Derbyshire et al. (1979) preferred the term 'nivation moraine' to protalus rampart for fines-rich in contrast to boulder-rich examples, although Shakesby (1997, 396) highlighted that 'it is not always clear whether the landforms referred to (above) formed in the manner envisaged for ramparts'. Many of these terms are no longer used but Neuendorf et al. (2005, 724) have since defined 'winter protalus ridge' as 'a wall-like protalus rampart formed of blocks and boulders derived from cliffs above a snowbank-occupied cirque before the summer heat melts the snow across which the blocks roll'. This illustrates that the adoption of terminology can be slow across different disciplines.

Bryan (1934) was the first to propose the term 'protalus rampart' when reviewing the article by Behre (1933), since nivation was perceived to be associated with erosion and not deposition around snowbank margins. Later, Knoll (1977, 14) defined a protalus rampart as 'a linear to arcuate ridge, composed of unsorted blocky rubble, formed by the downslope gliding of rock fragments across a snow or firn bank to their site of deposition'. Knoll (1977) developed an elaborate scheme that sub-divides protalus ramparts according to form and suggested that 'each term implies a mode of formation of the rampart that is different from the rest' but, unfortunately, this is not the case as will be discussed later. The work of Knoll (1977) was cited by Butler (1986a) but not elsewhere and, thus, the terms used to sub-divide protalus ramparts have remained largely ignored by the geomorphology community. In the mid-1980s, Butler (1986b) advocated reintroducing the term 'winter-talus ridge' in place of 'protalus rampart', which was commonly used at the time (e.g. Washburn 1979; Butler 1986a; Ono and Watanabe 1986; Harris 1986). Butler (1986b, 543) argued that the latter term 'was not necessary, nor has it been since 1912' but its reintroduction received little support mainly because, as Porter (1987, 248) pointed out, the term was misleading due to the fact that 'the release of rock debris from mountain slopes reaches a maximum frequency during mid- to late spring' and not in winter but also partly due to fact that the term 'protalus rampart' had, by then, become entrenched in the literature (Ballantyne 1987).

3 Origin and use of the term 'pronival rampart'

Until the mid-1990s, 'protalus rampart' was used as the standard term because as Porter (1987) highlighted it was used 'as a descriptive, non-genetic designation'. Shakesby et al. (1995) then proposed that this term be replaced with 'pronival rampart'. They noted that 'protalus' was an inappropriate descriptor for ramparts in Romsdalsalpane, Norway, which lay at the foot of snowbeds occupying valley-side niches at the top, rather than the foot, of talus as indicated by the term 'protalus'. The descriptor 'pronival' (snow-front), therefore, provided a universally appropriate term that described these firn-foot debris accumulations, regardless of their position on the slope (Fig. 1). The descriptor 'pronival' largely gained acceptance in the literature (e.g. Shakesby et al. 1999; Harris et al. 2004; Paasche et al. 2006; Colucci 2016) when research started to focus on actively-accumulating features (e.g. Hedding et al. 2007; Hedding et al. 2010; Margold et al. 2011). Studies on actively-accumulating pronival ramparts have shown that these features are not simple, easily understood landforms and that their genesis (origin and maintenance) often result from various modes of formation. This observation makes it clear that the origins suggested for many relict examples are often unfeasible.

Some studies use both 'pronival' and 'protalus' as descriptors (e.g. Shakesby et al. 2006; Bartsch et al. 2008; Hedding et al. 2010; Brook and Williams 2013; Jarman et al. 2013) but many texts (e.g. Fukui 2003; Serrano and González-Trueba 2005; Whalley 2009; Carrera-Gómez and Valcárcel-Díaz 2010) continue to only use the descriptor 'protalus'. Protalus ramparts, as envisioned by Haeberli (1985), were terrace-like landforms at the foot of perennially frozen talus and Scapozza et al. (2011) have recently proposed that the disused term 'protalus rampart' be used to define small permafrost creep phenomena (embryonic rock glaciers). This may lead to further uncertainty in the literature because the differentiation of protalus ramparts (embryonic rock glaciers) from pronival ramparts may prove difficult, particularly in relict landforms (see Hedding 2011). Thus, a clear nomenclature is crucial to facilitate the correct identification in the context of talus-derived landforms (see Hedding and Sumner 2013), usage and meaning of terms for the use of pronival ramparts in palaeo-environmental reconstructions that can form the basis for translations to other languages (Tab. 1).

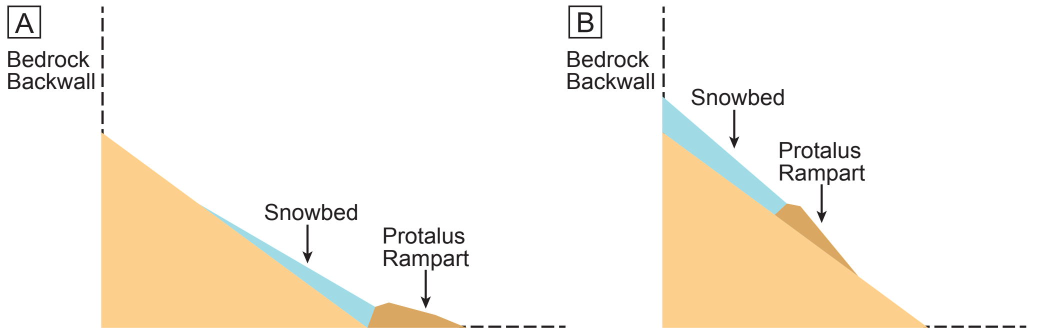

Fig. 1: Simplified position of (A) a 'protalus' rampart at the foot of talus slope and (B) position of pronival ramparts at the foot of snowbeds occupying the top of valley-side niches. The descriptor 'pronival' (snow-front), therefore, provides a universally appropriate term that described these firn-foot debris accumulations, regardless of their position on the slope

4 Pronival ramparts as part of a continuum of talus-derived landforms

Identification of pronival ramparts in the field is difficult because these landforms resemble glacial moraines, rock-slope failures and other discrete talus-derived landforms (i.e., protalus rock glaciers, solifluction deposits, avalanche deposits and landslides) as well as morphologically similar geological structures (Shakesby 1997; Hedding 2014). The close proximity of pronival ramparts to modified talus sheets and cones as well as protalus rock glaciers and moraines has led to speculation on the linkages between ramparts, protalus rock glaciers and moraines (Shakesby 1997) for over a century. As an example, Howe (1909) initially suggested that ramparts were a transition stage between talus and rock streams (rock glaciers) but later expressed the view that ramparts were not genetically related to rock glaciers (Sharpe 1960). Recently, Bickerdike et al. (2016) suggest that debate continues about the glacial versus periglacial origin of pronival ramparts in some areas (see Carr et al. 2007; Shakesby 2007). However, Hedding et al. (2007) have demonstrated that a glacial origin is not necessary for rampart genesis.

There are two contrasting views of pronival ramparts and the continuum of talus-derived landforms. One holds that pronival ramparts represent a morphological continuum of talus-derived landforms (e.g. Haeberli 1985; Ballantyne and Kirkbride 1986). Ballantyne (2002) highlights that some authors view pronival ramparts as progenitors of protalus rock glaciers (e.g. Barsch 1996) whereas Palacios and Sánchez-Colomer (1997) and Van Tatenhove and Dikau (1990) appear to link the development of ramparts with that of moraines. Conversely, pronival ramparts, protalus lobes, protalus rock glaciers and moraines are seen as separate, independently produced forms of modified talus occurring in a non-developmental morphological continuum (e.g. Shakesby et al. 1987). The latter view appears to be favoured by most authors (see Shakesby 1997) and stems from the observation of Johnson (1983, 28) that the 'morphological continuum is not necessarily a process continuum'. Kirkbride (1989) argued that the term continuum should only be used where there is an underlying continuum of process linking various forms but Shakesby et al. (1989) highlighted that talus-derived landforms can result from one or a combination of formative processes, depending on the flux of debris and ice (Fig. 2). Therefore, it is plausible that pronival ramparts can, under certain climatic conditions, transform into protalus rock glaciers (e.g. Corte 1976; Ballantyne and Kirkbride 1986) and even moraines (Van Tatenhove and Dikau 1990) but this is not a ubiquitous occurrence. For instance, Ballantyne and Benn (1994) indicated the potential existence of pronival moraines (a hybrid) with morphologies influenced by moving ice, but which also receive a gravity-fed debris supply across the topographic surface of the ice body. Moreover, Hedding et al. (2007) showed that pronival ramparts can also develop under fluctuating, possibly declining, snowfalls while climatic amelioration can also lead the incorporation of the ridges within scree deposits. This transformation may occur as the snowbed disappears and rockfall debris fills the proximal trough to create a continuous apron of debris from the foot of the rockwall. Colucci (2016) note that the occurrence of heavy rainfall and debris flows, primarily in late summer and autumn, can be important processes in the destructive evolution of pronival ramparts. Thus, the view expressed by Shakesby et al. (1987), Shakesby et al. (1989) and

Tab. 1: Terms for pronival rampart in several languages

Language	Terms	Reference
French	*bourrelet de conger; bourrelet de névé; les bourrelets; moraine de névé; rempart de éboulement*	Lengellé (1970); André (1985); Pancza (1998); Boyé (1952); Nicod (1968); Faugeres (1969); Orengo (1973); Francou (1977a, b); Serrano and González-Trueba (2005); Kotlyakov and Komarova (2006)
German	*Schneeschuttwälle; Hangblockwulst; Schneehaldenmoränen; Haldenfußwall; Firnhaldenmoränen; Geröllwall*	Krebs (1925); Morawetz (1933); Grötzbach (1965); Barsch (1993); Höllermann (1983); Völk (2001); Kotlyakov and Komarova (2006)
Spanish	*derrubios de nivación; morenna de nevero; caballón de derrumbamiento; morennas de nevé*	Carrera-Gómez and Valcárcel Díaz (2010); Kotlyakov and Komarova (2006)
Irish Gaelic	*clogha snachta*	Warren (1979)
Italian	*nivomorena*	*
Russian	осыпной вал (osypnoy val)	Kotlyakov and Komarova (2006)
Polish	*wały niwalne; snehový/firnový; sutinový val*	Sedláková and Bugár (2012); Kotarba (2007) and Raczkowska (2007)
Romanian	*potcoave nivale*	Marcu (2011)
Japanese (Katakana script)	プロテーラスランパート	** (term for protalus rampart)

* Information from personal communication with Dr Francesco Brardinoni, Dipartimento di Scienze Geologiche e Geotecnologie, Università degli Studi Milano-Bicocca, Piazza della Scienza 4, 20126 Milano, Italy, January 2013

** Information from personal communication with Dr Kotaro Fukui, Tateyama Caldera Sabo Museum, 68 Bunazaka-Ashikuraji Tateyama-machi Nakaniikawagun, Toyama, Japan, October 2013

Shakesby (1997) that ramparts are part of a non-developmental morphological continuum is supported here (see Fig. 2).

Hamilton and Whalley (1995) and later Johnson et al. (2007) proposed that protalus lobes (a progenitor to rock glaciers) should be distinguished from pronival ramparts on the basis that ramparts are process specific and involve rocks transported by gravity over seasonal snow fields (Degenhardt 2009). However, it is pertinent to highlight that supranival (e.g. rockfall, snow avalanche) and subnival (e.g. snow push, solifluction) processes are responsible for the development of pronival ramparts. Also Hedding et al. (2007) question the inclusion of pronival ramparts as a transitional landform in the morphological continuum of talus-derived landforms since all actively-accumulating ramparts do not necessarily develop below snowbeds which are progressively increasing in extent and thickness and, therefore, do not always 'grow' into protalus rock glaciers or moraines. Moreover, the origin and dynamics of the snowbed associated with the landform are critical (see Serrano et al. 2011). These observations emphasise the sentiment of Whalley (2009) who, referring to the observation of Johnson (1983), noted that caution should be used when interpreting landforms, and especially for the reconstruction of past climates since morphologically similar landforms may be produced by different processes resulting in so-called 'equifinality' or form-convergence.

5 Conclusion

Swift et al. (2014) indicate that more rigorous definitions are needed for pronival ramparts. By chronicling the development of terminology for pronival ramparts, the origin and use of current terms, in various languages, is elucidated. The advances in our understanding of pronival ramparts in the context of talus-derived landforms were made when studies focussed on actively-accumulating features and the consolidation of the current terminology for pronival ramparts, presented here, may enable

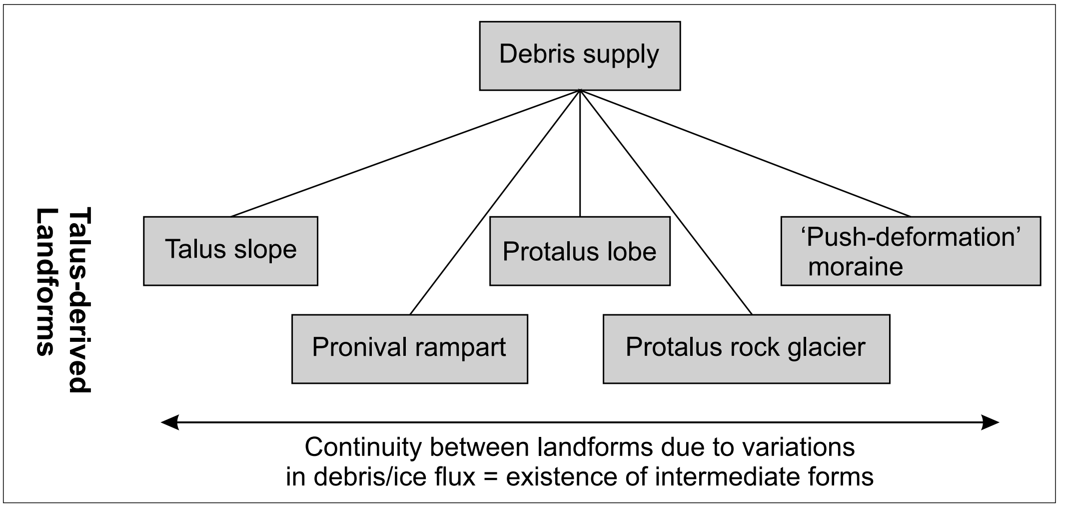

Fig. 2: A conceptual model of the non-linear morphological and developmental continuum of talus-derived landforms. Talus-derived landforms can transform into other landforms and intermediate (hybrid) talus-derived landforms may exist, depending on the dominant formative process(es) and flux of debris and ice (adapted from Shakesby et al. 1987; Kirkbride 1989)

more appropriate translations between languages. Pronival ramparts should be viewed as part of a non-developmental morphological continuum and this paper is intended as a catalyst for discussion on the identification of pronival ramparts in the context of talus-derived landforms, potentially resulting in new and important understandings.

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