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Classification of sorted patterned ground areas based on their environmental characteristics (Skagafjörður, Northern Iceland)

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ABSTRACT

A multivariate statistical method (factor analysis of mixed data and hierarchical classification) was used to classify the environmental settings where sorted patterned ground develops in a wet oceanic periglacial area (Skagafjörður, Northern Iceland). A total of 750 periglacial features, distributed over 75 sites, were studied. Nine explanatory variables were assessed by fieldwork and using a digital elevation model, the variables were subdivided into three groups (latitude, topography and soil characteristics) and then integrated into a geographical information system. Furthermore, a correlation between the environmental variables and an intrinsic variable (patterned ground mesh diameter) was determined by a bivariate test. The results show that sorted patterned ground are spread over three homogenous areas, mostly differentiated by altitude, insolation, grain size characteristics and type of drift. In addition, feature diameters differ significantly from one group to another. Finally, it appears that patterned ground diameters are positively correlated with (i) the proportion of clay to medium silt content ($r=0.35$), (ii) altitude ($r=0.51$), and especially with (iii) clast length ($r=0.97$). This strong relationship with clast length is observed in each homogenous patterned ground area at both site and feature scales.

1. Introduction

Sorted patterned ground is geometric features, including circles, nets and polygons, which develop in polar, subpolar and high alpine environments by repeated thawing and freezing cycles (Washburn, 1979). These widespread forms have various dimensions, from miniature patterns (in which mesh diameter does not exceed 20 cm according to the classification of Wilson and Clark, 1991) to large forms (several metres). Sorted patterned ground is composed of a stone area and a raised fine centre, or cell. According to Washburn (1956), a common explanation for these phenomena involves two mechanisms: upfreezing of boulders and raising and expansion of cell soil due to frost heave. The distribution and morphometry of these features depend on (i) various variables that lead to sorting and (ii) frost susceptibility (microtopography, texture of regolith, water content, hydrostatic pressure, and thermal conductivity). Recently, Kessler and Werner (2003) suggested that patterned ground self-organises following a numerical model. They stated that the compression of a confined stone area by adjacent soil redistributes boulders along the axis of the elongated stone area. According to these authors, polygons form when confinement of the stone area dominates, whereas circles and labyrinths form when sorting dominates.

Most patterned ground studies have focused on their mechanism of genesis (e.g. Washburn, 1956; Chambers, 1967; Ballantyne and Matthews, 1983; Jahn, 1985; Hallet et al., 1988; Krantz, 1990; Van Vliet-Lanoë, 1991; Kling, 1997, 1998; Kessler et al., 2001; Kessler and Werner, 2003; Matsuoka et al., 2003; Peterson and Krantz, 2008), as well as on the environmental conditions associated with their occurrence (e.g. Matthews et al., 1998; Etzelmüller et al., 2001; Luoto and Hjort, 2004, 2005, 2006; Hjort et al., 2007; Feuillet, 2011). These authors show, for instance, the importance of soil moisture (Matthews et al., 1998; Luoto and Hjort, 2004), till presence (Luoto and Hjort, 2005; Feuillet, 2011) and concave topography/wetness index (Luoto and Hjort, 2006) as prerequisite environmental parameters for both patterned ground presence and activity. However, less attention has been paid to the statistical classification of these prone environmental conditions at large scale (Raynolds et al., 2008; Hjort and Luoto, 2009; Treml et al., 2010). Is it possible to classify patterned ground areas into homogeneous groups, as a function of their environmental characteristics such as topography, soil and altitude? Which environmental variables mostly characterise these

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areas? Do intrinsic characteristics of features (dimension) vary significantly according to each homogeneous group? Such issues have never been addressed in depth for Icelandic patterned ground, in spite of their commonality. Previous works (Thoroddsen, 1913; Thorarinsson, 1951, 1953; Bout, 1953; Thorarinsson, 1964; Priesnitz and Schunke, 1983; Krüger, 1994; Dąbski, 2005) have focused on either patterned ground features taken individually, or a non-quantitative description of their distribution. Therefore, the first aim of this study was to describe and attempt to classify different types of environment where sorted patterned ground (active or inactive) develops along a large fjord (more than 100 km from south to north) located in Northern Iceland. This analysis was mainly based on GIS (geographic information systems) and DEM (digital elevation model) tools, which enabled a set of environmental variables to be associated with each patterned ground site. After collecting the dataset, we selected a particular analysis (factor analysis of mixed data, FAMD) to classify the types of favourable patterned ground setting. FAMD was suitable for this task as it takes into account both qualitative and quantitative variables. Then, groups of environmental settings were defined using a hierarchical classification. Following this

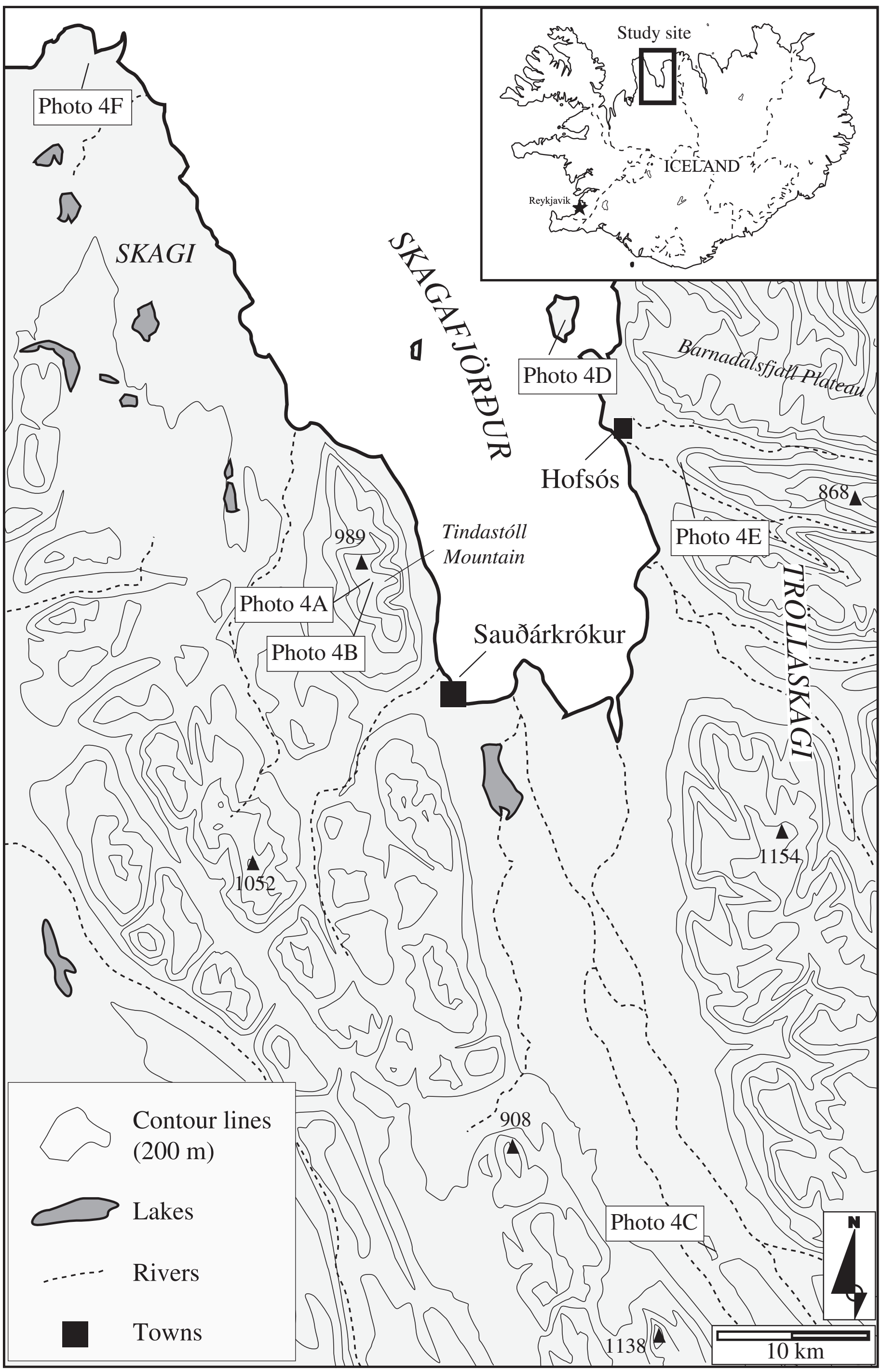

Fig. 1. Location map of the study area.