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Quaternary Provinces and Domains – a quantitative and qualitative description of British landscape types

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ABSTRACT

This paper presents an outcome of a British Geological Survey digital mapping programme of the geology of the British Isles. This programme had created a methodology that provides a quantitative description of the geology of an area, which can be interrogated according to the particular objective(s) of a study. Here we seek to describe the landscape and geology in terms of the critical processes responsible for their formation, in order to provide information suitable for science and a range of end-users. The approach adopted is at a regional scale, but can be used as a model for other objectives or a steer for future, finer-scale studies. The landmass of Great Britain is divided into provinces and domains. Three provinces are identified, based on the processes responsible for the landscape evolution during the Quaternary and the nature and distribution of superficial deposits across the country. The non-glaciated Province lies beyond the known limit of glaciations in England, with the Glaciated Province within this limit. The Glaciated Province is divided into two sub-provinces: those areas that were glaciated during the Last Glaciation (MIS 2/Devensian/< c.30 ka), and those with deposits and landforms relating to earlier Quaternary glaciations (pre-MIS 2/> c.30 ka). The Coastal, Estuarine and Fluvial Province is independent of glaciation and is associated primarily with Holocene processes including effects of human activity. Nine domains have been differentiated, partly based on recurring assemblages of landforms and superficial deposits. The provinces and domains are described qualitatively in terms of characteristic relief, processes and stratigraphic arrangement, and quantitatively in terms of the percentages bedrock outcrop and superficial deposit cover, and the proportions of particular process-defined lithological types. The findings are discussed in terms of their significance for quantitative landscape description, processes of geological mapping, and a range of practical applications.

1. Introduction

1.1. Geological and societal context

The need to understand and manage the landscape has increased exponentially with the increasing requirements demanded by activities such as housing, industry, infrastructure, utilities, agriculture and recreation. A large number of procedures and methodologies exist at the site investigation level, appropriate to the task at hand, such as ground engineering requirements for a route development or new housing, industry or recreation (Fookes, 1997). However there is, as yet, little quantitative information about landscape types and there are few schemes that use quantitative information to define larger areas or regions in terms of physical characteristics which can provide preliminary information necessary to steer the more detailed work. In the past, typical approaches have made reference to basic geological, geomorphological, hydrological and soil surveys, but assimilation of the information provided by these surveys has taken an ad hoc approach without reference to the necessary process controls that determine the physical characteristics of the region concerned, and hence do not provide the background needed to predict the likely ground conditions at a site.

One of the tasks of the British Geological Survey (BGS), since its foundation in 1835, has been to complete the systematic mapping and description of onshore deposits in the United Kingdom, including superficial (Quaternary) sediments. From then to the present-day, the focus of the BGS's activities has evolved in response to ever-changing priorities such as those identified

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above. In particular the BGS has taken into consideration customer need and environmental and political factors. '*Geology for our diverse economy*' (Walton and Lee, 2001) identified the fact that most users of geological information are interested in the near-surface (i.e. within 10 m below the surface), and approximately 90% of the near-surface geology of the British Isles comprises superficial deposits almost all of which are of Quaternary age. Despite the fact that this publication appeared fourteen years ago, the importance of understanding superficial deposits remains, and indeed is perhaps more relevant with current pressures caused by development for major infrastructure projects, new housing developments and the use of brown-field sites and agricultural demands. Thus, an accurate and detailed knowledge of the spatial distribution and variability of these deposits including anthropogenic materials, their physical properties and the processes that led to their formation, is critical for the management of human activities within a region. Consequently it has become apparent that any conceptual scheme should be based on, or take into consideration, the Quaternary processes that have shaped a region. Thus, as a result of the survey carried out by Walton and Lee, the BGS's 2005–2010 programme focussed on the three dimensional (3D) characterisation and modelling of the UK landmass (Litho-Frame UK – http://www.bgs.ac.uk/services/3Dgeology/lithoframe.html), with a particular emphasis on the mapping of those surface and shallow sub-surface layers (including engineering soils and agricultural soils) classified as Quaternary. In addition the decision was made to make available that information locked-up in BGS digital map data and other such archives for both scientists and the user-community. An outcome of these developments and decisions is that the BGS now hosts an array of data concerning superficial deposits that are represented in 2D map form, as 3D models and in a quantitative form.

1.2. Quaternary provinces and domains

Following from the above, this paper presents the results of an initiative undertaken to characterise the UK landmass on the basis of known landscape history over the last c. 2.6 Ma. The purpose of this initiative was to provide an insight into the landforms, sediments and processes that created them. Importantly, it provides essential contextual information for both scientific and applied research on topics such as Quaternary geology, geomorphology, soil science, hydrogeology and water resources, mineral resources planning and the insurance industry risk assessment. It does not provide detail of a particular site, but a context for the likely processes that determine the earth science properties of that site. As a consequence of the study, we have created a series of maps of Britain which define geologically/geomorphologically distinctive regions. These regions are known as Quaternary Domains. For instance, southern Britain is known as the Lowland Periglacial Domain, characterised by slopes and surface sediments which were, in the main, formed in a periglacial climatic regime overridden by an anthropogenic imprint, whereas areas like the Lake District of England and the main part of the western Highlands of Scotland is known as Mountain and Valley Domain characterised by steep relief and highly variable thicknesses of superficial deposits.

In order to do this we have adopted a hierarchical approach. At first order, the landmass of Britain has been divided into provinces, based on the main processes determining landscape evolution during the Quaternary: the bedrock geology, the geomorphology and the nature and distribution of superficial deposits across the landscape (Fig. 1). These provinces are the Non-glaciated Province (N-gP), lying beyond of the known limit of glaciations in England, the Glaciated Province (GP) and the Coastal, Estuarine and Fluvial Province (CE&FP) which is largely independent of glaciation, formed predominantly during the Holocene and includes a significant anthropogenic dimension. The Glaciated Province is subdivided into two: the area glaciated between about 30,000 and 11,700 years ago (GP $<$ c.30 ka) (LGM) (the area represented by the Caledonia Glaciogenic Group of McMillan et al., 2011), and the areas that were glaciated between c. 450,000 and c. 30,000 years BP (GP $>$ c.30 ka) (the area represented by the Albion Glaciogenic Group of McMillan et al., 2011) (Rose, 2009, 2010; Bradwell et al., 2008; McMillan et al., 2011; Clark et al., 2012; McMillan and Merritt, 2012). The limit of glaciation is taken as that represented in Bowen et al. (1986) in the central and eastern part of England, and modified in the region of the southern Welsh Borderland as a result of BGS mapping and the revised distribution of glacial deposits. An ice limit from the upper Bristol Channel to the region of the Isles of Scilly is omitted as a consequence of more recent work within the region and the recognition that the glacial deposits on the Scilly Isles are of Last Glaciation age (Scourse and Furze, 2001; McCarroll et al., 2010). The limit of the Last Glaciation is taken from Clark et al. (2012). Thus we have three provinces, one of which is sub-divided into two sub-provinces, at this first order of designation.

At the second order of designation, and the main concern of this paper, Britain has been sub-divided into nine domains (Table 1; Fig. 2). In order to complete this exercise we needed to draw boundaries on a map that have defined the domains and these boundaries are used in this paper. It is important to state here that these boundaries were drawn in 2002–2004 based on existing BGS 1:50,000 scale geological map information and knowledge of the regional Quaternary history. This is before ready access existed to digital topographical datasets such as NEXTMap (see for instance: Smith et al., 2006; Bradwell et al., 2008; Finlayson et al., 2014) and the latest version of DigMapGB50 (the digital version of BGS's 1:50,000 scale maps). For the purposes of this paper we believe that the boundaries used here are adequate to define the regions we wish to determine and illustrate the concepts we wish to develop. The domains identified for this exercise are defined to achieve the objectives of this study, but with different objectives different boundaries and domains could have been proposed. We do not see this as a problem. The scheme we propose takes the primary elements of the Quaternary landscape and geology, and the exercise described here outlines the methodology of deriving these domains and uses them as an example to demonstrate their utility to science and society. Should others so wish, they could tune the definition of areas of terrain (domains) to an issue of concern, such as for instance, rock control of topography, flooding, or landslipping, and apply the principles adopted here.

The domains approach presented here has been developed in conjunction with other studies at the BGS such as the hydrogeological assessment of Quaternary Deposits as part of the report to the Water Framework Directive (SNIFFER, 2006), the 1:1,000,000 scale Engineering Geology Map of the UK (Dearman et al., 2011a,b; Dobbs et al., 2012) and the BGS Peat Characterisation project (http://www.bgs.ac.uk/research/climatechange/peat/home.html). The report for the Water Framework Directive (McConvey, 2006a,b), explores the concept of domains in further detail, and presents many of the findings outlined here, although specifically with reference to the hydrogeological potential of Quaternary deposits. The findings of this report are considered in further detail in Section 5.

Rose (2010) has adopted similar concepts to identify and propose the climatic, human and geological processes (forcing factors) that have determined the Quaternary geology of the British Isles. This was undertaken at the same time and in conjunction with the BGS Quaternary initiatives from which this paper and McMillan (2005), McMillan et al. (2011) and McMillan and Merritt (2012) have emerged. Finally, the domains and the information they contain have been uploaded onto the BGS web site with