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Progress in marine geoconservation in Scotland's seas: assessment of key interests and their contribution to Marine Protected Area network planning

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ABSTRACT

Geoconservation in the marine environment has been largely overlooked, despite a wealth of accumulated information on marine geology and geomorphology and clear links between many terrestrial and marine features. As part of the wider characterisation of Scotland's seas, this study developed criteria and a methodology that follow the established principles of the terrestrial, Great Britain-wide geoconservation audit, the Geological Conservation Review, to assess geodiversity key areas on the seabed. Using an expert judgement approach, eight geodiversity feature categories were identified to represent the geological and geomorphological processes that have influenced the evolution and present-day morphology of the Scottish seabed: Quaternary of Scotland; Submarine Mass Movement; Marine Geomorphology of the Scottish Deep-Ocean Seabed; Seabed Fluid and Gas Seep; Cenozoic Structures of the Atlantic Margin; Marine Geomorphology of the Scottish Shelf Seabed; Coastal Geomorphology of Scotland; and Biogenic Structures of the Scottish Seabed. Within these categories, 35 key areas were prioritised for their scientific value. Specific interests range from large-scale landforms (e.g. submarine landslides, sea-mounts and trenches) to fine-scale dynamic features (e.g. sand waves). Although these geodiversity interests provided supporting evidence for the identification and selection of a suite of Nature Conservation Marine Protected Areas (MPAs) containing important marine natural features, they are only partially represented in these MPAs and existing protected areas. Nevertheless, a pragmatic approach is emerging to integrate as far as possible the conservation management of marine geodiversity with that of biodiversity and based on evidence of the sensitivity and vulnerability of geological and geomorphological features on the seabed.

1. Introduction

Until recently, in Scotland and elsewhere, marine geoconservation has received relatively little attention compared to the conservation of geoheritage in the terrestrial environment (Burek et al., 2013). However, this is now changing as a consequence of a growing body of information on marine geology and geomorphology, improved mapping of seabed features using new remote survey techniques, greater awareness of threats, better understanding of the links to biodiversity and new legislation. Although the coastline of Scotland is a striking boundary between the terrestrial and marine environments, there is a continuity of geological and geomorphological features across this boundary, from the highest mountains to the deep-ocean floor. Examples of this continuity include the igneous centres and flood basalts of the extensive Palaeogene Igneous Province (Bell and Williamson, 2002; Emeleus and Bell, 2005) and the Quaternary landforms and deposits produced by successive advances of the

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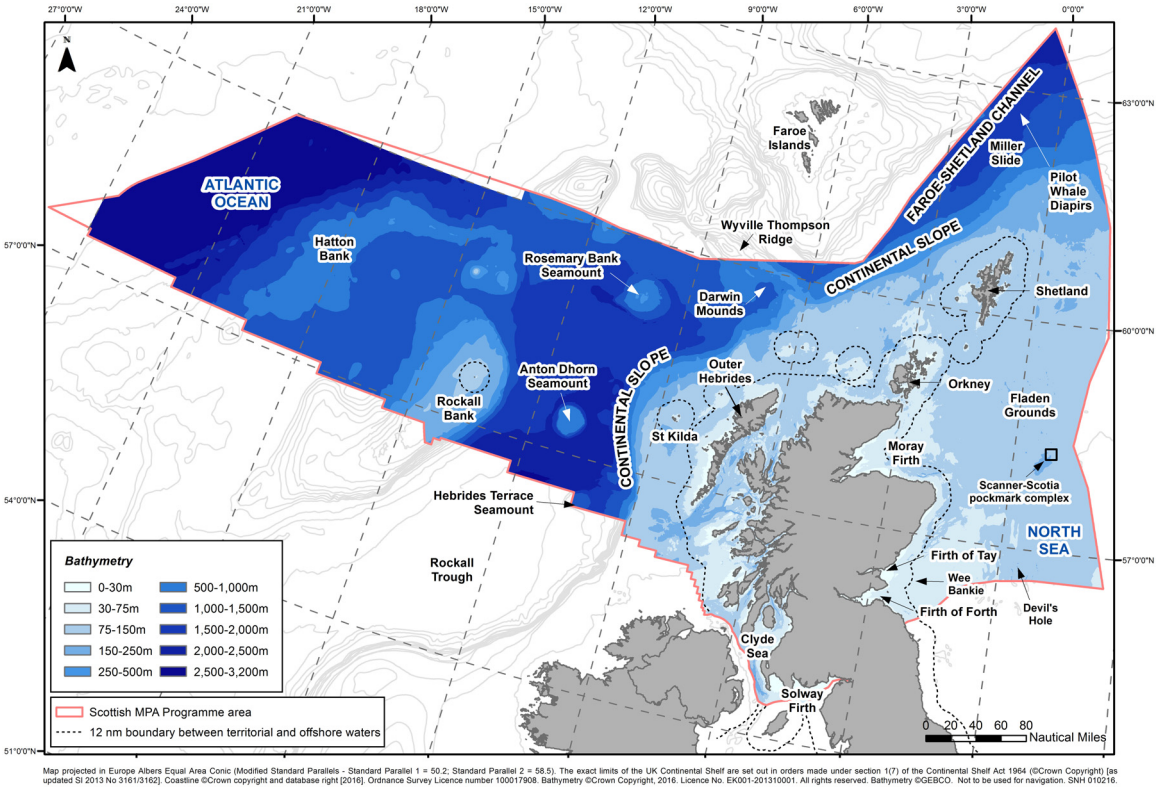
British–Irish Ice Sheet (Bradwell et al., 2008a). In the former case, the offshore geology complements the onshore evidence from islands such as Skye and Rum and is crucial to understanding the evolution of the wider North Atlantic Igneous Province (Ritchie and Hitchen, 1996). In the latter case, as global sea level fell periodically by as much as 120 m or more below its present level (Rohling et al., 2009), ice sheets extended offshore to the edge of the continental shelf to the west and north of Scotland and across the floor of the North Sea before retreating back on land as the climate ameliorated and sea level rose. Consequently, the greater part of the footprint of the last British–Irish Ice Sheet and its earlier counterparts lies offshore, as revealed in remarkable detail by the recent development of new underwater survey techniques, such as multibeam swath bathymetry (Bradwell and Stoker, 2015; Dove et al., 2015). More generally, understanding of the complex geological and geomorphological evolution of the NW European continental margin since the magmatism and rifting that led to the separation of Europe and North America in the early Eocene is fundamentally dependent on integrating onshore and offshore evidence (Hall and Bishop, 2002; Stoker et al., 2005, 2010a; Holford et al., 2009, 2010). A significant part of Scotland's geodiversity and geoheritage therefore lies offshore, as documented, for example, in British Geological Survey UK Offshore Regional Reports. To put this into context, the area covered by Scotland's seas is ~608,000 km^2 from MHWS out to the limit of the claimed UK Continental Shelf (Fig. 1). This is over 7.5 times the size of Scotland's land area (an estimated 80,060 km^2) (Baxter et al., 2011).

Much of the focus on nature conservation policy and management in the UK, and elsewhere, has centred on protected areas in the terrestrial environment, including the coast (Evans, 1997; Marren, 2002). However, the EU Birds Directive (1979), the Habitats Directive (1992), the OSPAR Convention (1992) and the EU Marine Strategy Framework Directive (2008) have directed attention towards the marine environment. In turn, these international measures have been transposed into UK domestic legislation through the Conservation (Natural Habitats, &c.) Regulations 1994, the UK Marine and Coastal Access Act 2009, the Marine (Scotland) Act 2010 and the Marine Act (Northern Ireland) 2013. Although primarily addressing the requirements of biodiversity, these acts include provisions for marine geoconservation (Marine Scotland, 2011a; Burek et al., 2013). Also, deriving from the Convention on Biological Diversity (CBD) (1992), the ecosystem approach has become an important conservation policy driver both in the terrestrial and marine environments and is reflected in the Millennium Ecosystem Assessment (MA) (2005), the UK National Ecosystem Assessment (UK NEA) (2011), the EU Biodiversity Strategy (European Commission, 2011), A Strategy for Marine Nature Conservation in Scotland's Seas (Marine Scotland, 2011a), the 2020 Challenge for Scottish Biodiversity (Scottish Government, 2013) and Scotland's National Marine Plan (Scottish Government, 2015). It requires a holistic approach that values both geodiversity and biodiversity and the interactions between them (Gray et al., 2013).

At the same time, there has been growing interest globally in the geomorphology of the seafloor (Chiocci and Chivas, 2014; Harris et al., 2014; Dowdeswell et al., 2016). From a conservation viewpoint, this includes benthic marine environment mapping and seabed characterisation to inform a spatial approach to marine conservation through Marine Protected Areas, based on biophysical indicators of benthic habitats and ecosystems as abiotic surrogates for biological communities and species diversity (Roff et al., 2003). Examples include the international GeoHab (Marine Geological and Biological Habitat Mapping) initiative (Todd and Greene, 2007; Heap and Harris, 2011; Harris and Baker, 2012), the MAREANO (Marine AREal Database for NOrwegian Waters) mapping programme in Norway (Dolan et al., 2009; Thorsnes et al., 2009; Buhl-Mortensen et al., 2015a,b) and MAREMAP in the UK (Diesing et al., 2014; Howe et al., 2015a). Amid growing



Map projected in Europe Albers Equal Area Conic (Modified Standard Parallels - Standard Parallel 1 = 50.2; Standard Parallel 2 = 58.5). The exact limits of the UK Continental Shelf are set out in orders made under section 1(7) of the Continental Shelf Act 1964 (©Crown Copyright) [as updated SI 2013 No 3161/3162]. Coastline ©Crown copyright and database right [2016]. Ordnance Survey Licence number 100017908. Bathymetry ©Crown Copyright, 2016. Licence No. EK001-201310001. All rights reserved. Bathymetry ©GEBCO. Not to be used for navigation. SNH 010216.

Fig. 1. Extent of Scotland's seas, showing bathymetry and locations of major physiographic features.