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A provisional Quaternary and Neogene lithostratigraphical framework for Great Britain

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Abstract

This paper presents an overview of a provisional lithostratigraphical framework for the Quaternary and Neogene deposits of Great Britain (England, Scotland and Wales) (onshore). The objective is to provide a workable framework to aid future Quaternary mapping and research, and a stratigraphical scheme capable of use in a wide variety of applications. Using the full hierarchy, a supergroup, group and subgroup lithostratigraphy, based upon the primary mapping unit, the formation, is proposed. It is recommended that some classes of lithogenetically-defined deposits which, at present cannot be accorded formational status, should be assigned informally to one of the proposed groups or subgroups. The framework distinguishes one superficial deposits supergroup within which seven groups are defined: i) *Crag Group*, marine deposits (Late Pliocene to Early Pleistocene); ii), *Dunwich Group*, fluvial deposits (pre-Anglian/pre-Elsterian); iii) *Residual Deposits Group*; iv) *British Coastal Deposits Group*, coastal and marine deposits (Anglian to Holocene); v) *Britannia Catchments Group*, fluvial, organic and mass movement deposits (Anglian to Holocene) within broadly defined catchment areas related to Late Devensian to present-day physiography; vi) *Albion Glacigenic Group*, glacigenic deposits (pre-Devensian/pre-Weichselian), and vii) *Caledonia Glacigenic Group*, glacigenic deposits (Devensian/Weichselian). North of the Devensian (Weichselian) ice-sheet limit, a series of glacigenic subgroups are defined geographically for the two glacigenic groups on the basis of mappable formations of till. The subgroups include associated formations of glaciofluvial and glaciolacustrine deposits. Consequently some of the glacigenic water-lain units may extend beyond the Devensian limit. Catchment subgroups of the Britannia Catchments Group are proposed for formations and lithogenetic units defined within broad present-day physiographic regions by major river drainage systems that have developed since Middle Pleistocene time. Lithostratigraphical description and correlation of formations will aid the refinement of the proposed framework and enable the development of lithostratigraphical maps and three-dimensional models. As well as offering a unified framework for onshore Quaternary and Neogene deposits the proposed supergroup, group and subgroup structure may prove useful for a wide range of regional applications (e.g. hydrological, hydrogeological, engineering).

Keywords: Quaternary and Neogene lithostratigraphy, Glacigenic sediments, Catchments (drainage basins), Fluvial sediments, Coastal sediments, Great Britain

Introduction

Over several years, the Superficial Deposits Advisory Group (a Stratigraphical Framework Committee of the British Geological Survey, BGS) has been preparing a new lithostratigraphical framework for the Quaternary deposits of onshore Great Britain. A draft overview report was reviewed by the Stratigraphy Commission of the Geological Society (London) in 2004 and is currently being revised (McMillan et al., in prep. 2005). A detailed Quaternary stratigraphical framework report is also being prepared (McMillan & Hamblin, in prep.). These reports take into account conclusions from two workshops on Quaternary stratigraphical classification and nomenclature of British Quaternary deposits held at BGS, Keyworth, Nottingham, UK in February 1998 and February 2001. McMillan & Hamblin (2000) published initial ideas on the framework.

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Table 1. Summary of Quaternary and Late Neogene lithostratigraphical framework for Great Britain with relationship of groups to Quaternary stages and suggested correlation with marine isotope stages.

SERIES	SUBSERIES	BRITISH QUATERNARY STAGE (ONSHORE) (Gordon & Sutherland, 1993, Mitchell et al., 1973, West, 1961,1980, Zalasiewicz et al., 1991)		NW EUROPEAN QUATERNARY STAGE (Gibbard et al., 1991, Funnell, 1995, Lister, 1998, 2000, Zagwijn, 1992)	δ ^{18}O stage	SUPERGROUP	GROUPS: Glacigenic deposits	GROUPS: Non-glacigenic deposits		
HOLOCENE 11.5 ka					1 - 2	GREAT BRITAIN SUPERFICIAL DEPOSITS SUPERGROUP		RESIDUAL DEPOSITS GROUP	BRITANNIA CATCHMENTS GROUP	BRITISH COASTAL DEPOSITS GROUP
PLEISTOCENE	LATE	DEVENSIAN	Loch Lomond Stadial (Younger Dryas)	WEICHSELIAN			CALEDONIA GLACIGENIC GROUP			
			Windermere Interstadial (Bølling/Allerød)							
			Dimlington Stadial		3					
					4					
					5a - 5d					
	0.126 Ma	IPSWICHIAN		EEMIAN	5e					
	MIDDLE	'WOLSTONIAN'		SAALIAN	6 - 10		ALBION GLACIGENIC GROUP			
		HOXNIAN		HOLSTEINIAN	9 or 11					
		ANGLIAN		ELSTERIAN	12					
	0.78 Ma	CROMERIAN		CROMERIAN COMPLEX	13 - 21				DUNWICH GROUP	CRAG GROUP
	EARLY	BEESTONIAN		BAVELIAN	22 - 64					
				MENAPIAN						
				WAALIAN						
				EBURONIAN						
	1.806 Ma	PASTONIAN		TIGLIAN C5 - 6						
PLIOCENE	GELASIAN	PRE-PASTONIAN/ BAVENTIAN		TIGLIAN C4c	65 - 95					
		ANTIAN/ BRAMERTONIAN		TIGLIAN C1 - 4b						
		THURNIAN		TIGLIAN B						
		LUDHAMIAN		TIGLIAN A						
		Pre-LUDHAMIAN		PRAETIGLIAN	96-100					
	2.588 Ma			REUVERIAN C	103					

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Notes Table 1

- Climato-stratigraphical stages for Great Britain and NW Europe are based on inferences from biostratigraphical (pollen) and lithological evidence for 'temperate' and 'cold' events.
- Ages: base of series and subseries are taken from Global Timescale (Gradstein, Ogg et al., 2004). The Early/Middle Pleistocene boundary is correlated with the Bruhnes – Matuyama magnetic reversal, correlated with oxygen isotope stage 19. The base of Pleistocene is defined from top of sapropel layer 'e' of Vrica section, Calabria, Italy.
- Suggested correlation with oxygen isotope stages for Early to Middle Pleistocene is after Zagwijn (1992) and Funnell (1996), based on the stages of Shackleton et al. (1990).
- Abbreviations: ka = 1000 calibrated radiocarbon years; Ma = 10^6 years.
- The Crag Group is defined by marine formations.
- The Dunwich Group is defined by fluvial formations within pre-Anglian palaeo-catchments.
- The Residual Deposits Group includes Clay-with-Flints.
- The Great Britain Coastal Deposits Group is defined by coastal, estuarine and marine formations.
- The Britannia Catchments Group is divided into subgroups defined by fluvial formations within major drainage systems (includes peat, head, cover sand, loess and mass movement deposits).
- The Caledonia Glacigenic Group, lying mainly to the north of the Devensian limit, is divided into subgroups defined by till formations with associated glacigenic units. Some glaciofluvial units extend south of the Devensian limit.
- The Albion Glacigenic Group, preserved mainly to the south of the Devensian limit is divided into formations; to the north, the group is divided into subgroups defined by till formations with associated glacigenic units.

The BGS workshops addressed a number of questions fundamental to the establishment of a practical lithostratigraphical framework for the Quaternary deposits of Great Britain which takes as its premise its ability to be applied to geological mapping and three-dimensional modelling. Principal conclusions from the workshops and subsequent discussion included the following:

- The formation is the fundamental mapping unit (North American Commission on Stratigraphic Nomenclature – NACSN, 1983; Whittaker et al., 1991; Salvador, 1994; Bowen, 1999; Rawson et al., 2002).
- Members and beds should be mappable units at appropriate scales.
- Grouping of formations is desirable, particularly to aid regional mapping (Salvador, 1994) and interpretation by non-geologists.
- Groups and subgroups may or may not be composed entirely of named formations (NACSN, 1983) but the establishment of groups without constituent formations should be avoided (Salvador, 1994).
- Although lithostratigraphical units should be defined primarily on the basis of lithological character, lithogenetic descriptors are recommended for high-level units (super-groups, groups and subgroups) and for formations (if lithologically heterogeneous). This recommendation is considered necessary to demonstrate unifying features of Quaternary units but is contrary to the general guidance presented by Salvador (1994, p. 41)
- Lithological descriptors (e.g. sand, gravel) for formations and members are needed where they clearly convey a dominant lithological component of the unit.
- Morphological descriptors (e.g. moraine, terrace) for members could be valuable for deposits of variable or poorly known lithology or because they form a valuable criterion in defining a unit.
- In Britain and elsewhere, lithogenetic classification is a tried-and-tested practical mapping and descriptive tool, and will continue to be used as the primary method for describing Quaternary deposits. Lithogenetic units are locally mappable assemblages of rock strata, considered without regard to time (Schenck & Muller, 1941; Salvador, 1994) Some lithogenetic units are not readily amenable to lithostratigraphical classification at formation level because their stratigraphical relationships are poorly known (e.g. mass movement deposits).
- River terrace deposits should be considered as members of formations defined by a single catchment (i.e. a major river and its tributaries).

Traditionally, and in common with many other geological surveys, the BGS has published maps and literature that employ a mixture of lithological, morphological and genetic terminology (Foster et al., 1999). The terminology has been developed by successive generations of survey geologists to map surface Quaternary deposits (usually the top metre or so of deposits) and to log sections and boreholes. Observation and recording of lithology, structure and morphology of deposits has led to the interpretation of their origin. Mapping practice has led to the refinement of the familiar specification of mapping symbols which feature on BGS maps ranging from the primary mapping scales of 1 : 10 000 and 1 : 25 000 to the most commonly published 1 : 50 000 scale (Ambrose, 2000). The specification corresponds to the hierarchical *Rock Classification Scheme for Natural and Artificial Superficial Deposits* (McMillan & Powell, 1999). The classification now forms the basis of and the dictionary for digital products such as the digitised and attributed 1 : 50 000 scale geological map coverage of Great Britain (DigMapGB-50) which requires the data to be structured for sensible retrieval of information (McMillan, 2002). Such objectives are common to many geological surveys and similar lithogenetic schemes have been established in many European countries (e.g. in France, Lebret et al., 1993).

Although there are good reasons for applying the principles of lithostratigraphy to the classification of Quaternary deposits,

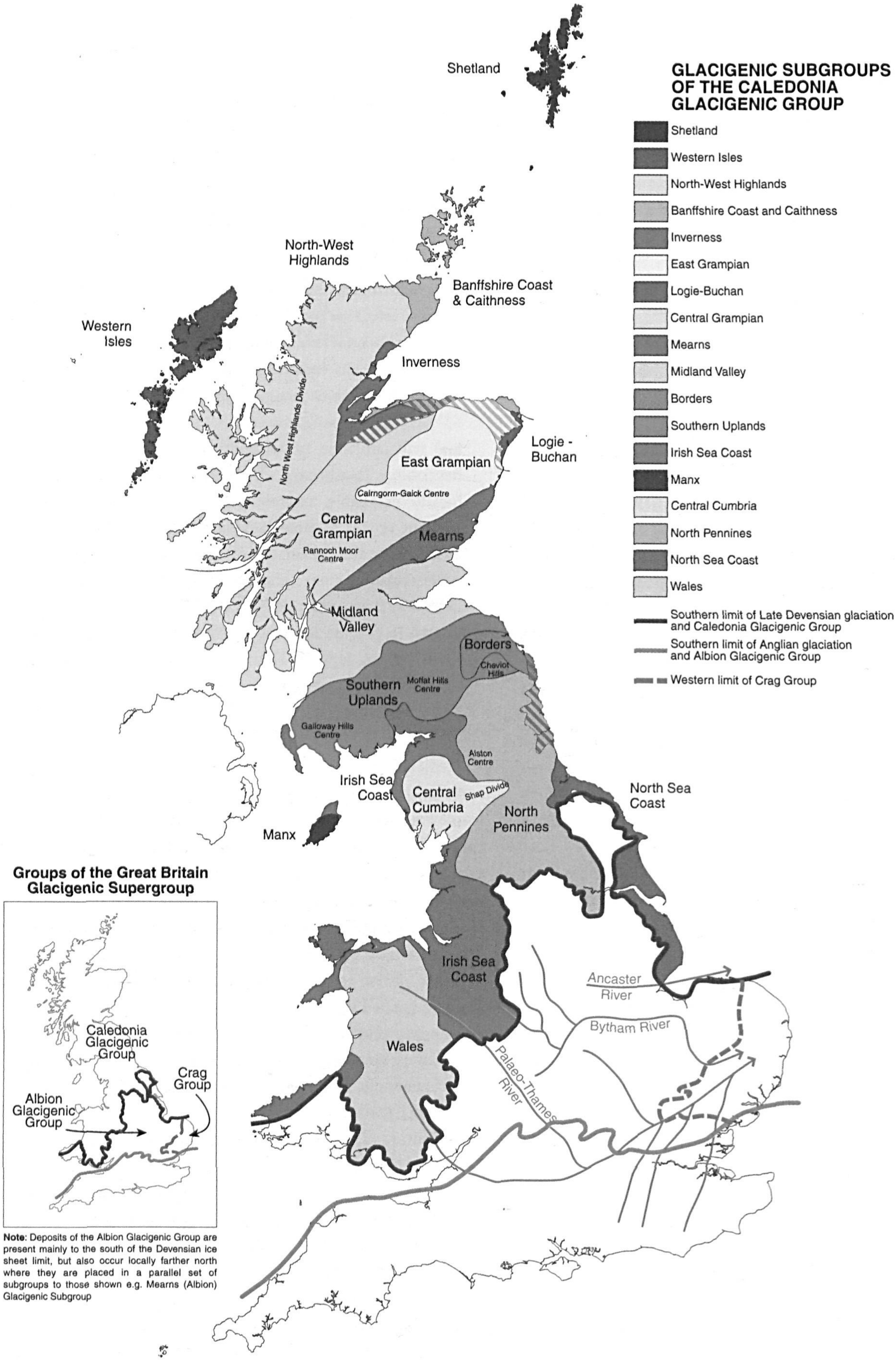

Fig. 1. Distribution of glacigenic groups and subgroups and marine deposits of the Crag Group (approximate courses of the pre-Anglian river systems also shown). Note that the geographical boundaries are approximate and will be refined as knowledge of the distribution of defining formations is improved.

it could be argued that most are in fact allostratigraphic units, that is they are mappable stratiform bodies of sediment defined and identified on the basis of their bounding discontinuities (NASCN, 1983). However, as Rawson et al. (2002) discuss, allostratigraphy has not been popularly accepted in Britain and elsewhere. Description and correlation of lithostratigraphical formations allow the development of an overarching classification, but it is recognised that many correlations will remain tentative. Numerous lithostratigraphical units have been described at type sections where their lateral and vertical lithological variation is indeterminate (Bowen, 1978). With this proviso, it is considered timely that a proposal for a framework utilising the full lithostratigraphical hierarchy is published. In Great Britain the requirement for a framework has assumed more urgency as the BGS recognises the need for modern Quaternary mapping and modelling (Walton & Lee, 2001; McMillan, 2002; Rose, 2002). No longer is it satisfactory to produce maps essentially of surface deposits in which, for example, tills of different lithologies and origins are depicted 'undivided' with minimal description. To address such issues in recent years BGS has applied lithostratigraphical classification to deposits in East Anglia, the Midlands of England, Cumbria, and West and Northeast Scotland. Generally, however, with respect to Quaternary stratigraphy, BGS maps lag behind those of many other European and North American surveys (cf. Willman & Frye, 1970).

Modern research and techniques, both onshore and offshore, offer great opportunity to define a framework which utilises the full lithostratigraphical hierarchy. The Geological Society Special Report No. 23 – *A revised correlation of Quaternary deposits in the British Isles* (Bowen, 1999), the successor publication to Mitchell et al. (1973), provides added impetus to establish the framework. Bowen (1999) describes lithostratigraphical units, at formation, member and bed level, and presents a revised set of proposals for correlations. The volume correlates with the marine isotope stratigraphic scale derived from ocean sediments ($\delta^{18}O$ stages) (Shackleton & Opdyke, 1973; Shackleton et al., 1990) and the aminostratigraphic record. Many of the units, particularly at bed level, referred to in Bowen (1999) have been defined at one or more well-exposed sections or from boreholes. Such units, as Bowen (1999) confirms, 'are not amenable to systematic and widespread mapping away from their stratotypes'. Nevertheless these units are important for correlation and inferences about climate.

The proposed framework outlined here recognises that the fundamental mapping unit is the formation and defines higher units (supergroup, group and subgroup) which have an important role for broader scale correlation and mapping (Salvador, 1994). The framework is built on the published literature (including BGS geological maps and Bowen, 1999). There is continuing debate about the application of a climate-driven chronostratigraphy and nomenclature (for discussion see Bowen, 1999) and, although the framework makes reference to the British and NW European climato-stratigraphical stages (Table 1), land-sea correlations are also *tentatively* proposed using the marine isotope stratigraphic scale derived from ocean sediments (Gordon & Sutherland, 1993; Bowen, 1999) (Tables 1 - 5). With the exception of the 'Wolstonian', the British stages are defined from type sections in East Anglia (Mitchell et al., 1973) (Table 1). It should be noted that there is, as yet, no formal proposal to replace the stage term 'Wolstonian' (Mitchell et al., 1973; Gibbard & Turner, 1988; Rose, 1988; Bowen, 1999), although the proposed framework adopts the lithostratigraphical Wolston Glacigenic Formation which may correlate with the Lowestoft Formation of East Anglia (Anglian/Elsterian) (see Sumbler, p. 37 in Bowen, 1999).

Is the Quaternary a special case?

As discussed above, lithostratigraphical principles can be applied to onshore Quaternary deposits but because vertical and lateral variation is commonly poorly known, correlation between units may be problematic. In attempting to define a broad framework based upon international and national stratigraphical guidance (NACSN, 1983; Whittaker et al., 1991; Salvador, 1994; Rawson et al., 2002) the BGS Superficial Deposits Advisory Group identified a combination of factors that, if not unique, are unusual in other parts of the stratigraphical column:

- Onshore Quaternary sequences may be thin and geographically extensive, although they can attain thicknesses of 200 m or more.
- Many Quaternary lithostratigraphical units, being surficial deposits, will have no upper boundary (or bounding surface). That surface and the associated landform may show characteristic features that can be used to define a unit.
- The distribution of some Quaternary deposits including mass movement and fluvial deposits is more or less related to the present-day physiography.
- Provenance is an important factor in defining many Quaternary deposits.
- Weathering characteristics and soil development play an important role in Quaternary stratigraphy.

It is evident that, as for other rock units, the distribution of Quaternary formations can be linked not only to the processes by which they formed or were modified, but also to geographical setting. For example, the extent and behaviour of ice sheets during the Quaternary directly influenced the distribution of a range of glacigenic deposits including tills and glaciofluvial deposits. Thus, in Great Britain, the limit of the most extensive (Anglian/Elsterian) ice sheet and the latest (Devensian/Weichselian) ice sheet (Fig. 1) play an important part in defining distribution. Early glacigenic deposits of the Anglian ice sheet are present mainly to the south of the Devensian ice sheet limit and north of a line drawn approxi-

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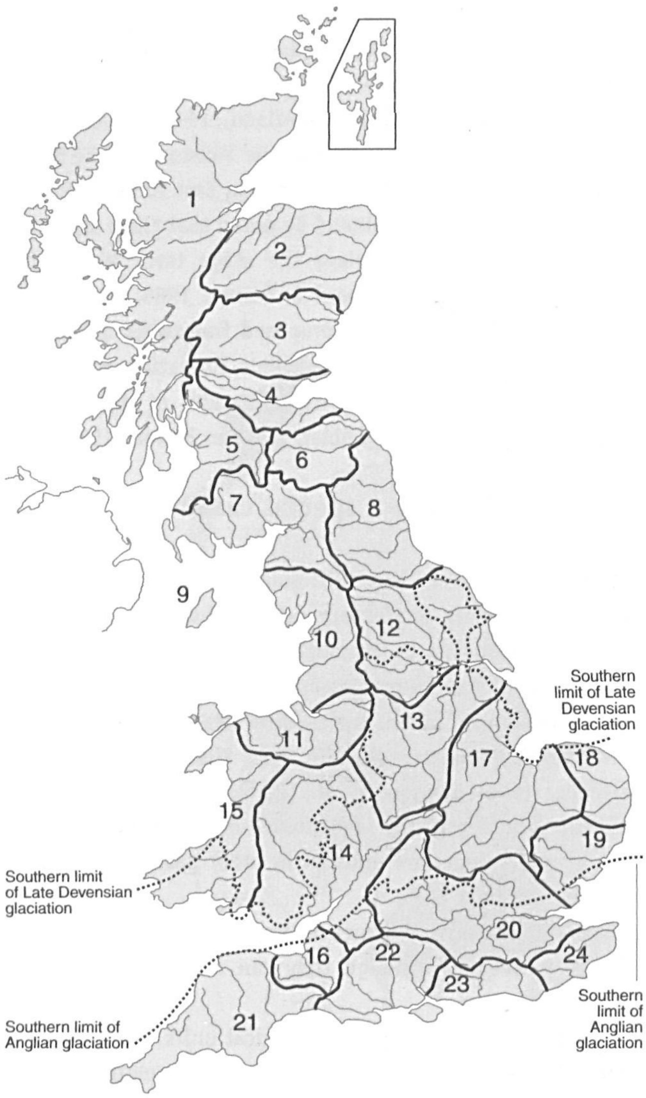

Fig. 2. Distribution of catchments subgroups of the Britannia Catchments Group. Numbers refer to the Catchments Subgroups listed in Table 3. Note that the geographical boundaries are approximate and will be refined as knowledge of the distribution of defining formations is improved.

mately east-west from the River Thames to the River Severn (Fig. 1). These deposits also occur, locally, farther north and may be present in the sub-surface below deposits of the Devensian ice-sheet. Devensian deposits are present to the north of the Devensian ice sheet limit and to a limited extent, for example in the form of outwash deposits, to the south. Pre-Devensian deposits may exhibit complex weathering profiles (indicative of a range of climatic conditions) that may aid stratigraphical correlation.

Deposits of catchments (fluviatile, lacustrine, residual and mass movement) and coastal areas present other lithostratigraphical problems and correlation between formations of different river catchments needs to be applied with caution. Allowing for glacio-isostatic and relative sea level changes, in practice, Late Devensian to Holocene river deposits of northern Britain can normally be related to the present day physiography. Close to and south of the Devensian ice sheet limit the distribution and elevation of river terrace deposits is more complicated. River terrace deposits such as those of the River Thames and its precursors (Gibbard, pp. 45-58 in Bowen, 1999), extend back to pre-Anglian time and have been subject to variations in base level over time (reflecting relative sea level and isostatic changes). Early rivers changed course during and between former glaciations.

Proposed lithostratigraphical framework

McMillan & Hamblin (2000) published initial ideas on the proposed framework, placing deposits within a series of lithogenetically and provenance-defined groups. Further discussion has led to the new framework which is proposed in this paper. The framework distinguishes seven broad categories at group level (Table 1):

- marine deposits (Upper Pliocene to Lower Pleistocene)
- fluvial deposits (pre-Anglian/pre-Elsterian)
- residual deposits including the Clay-with-Flints
- coastal and marine deposits (Anglian/Elsterian to Holocene)
- fluvial, organic and mass movement deposits (Anglian/Elsterian to Holocene) within broadly defined catchment areas related to the Late Devensian to present-day physiography
- glacigenic deposits (pre-Devensian/pre-Weichselian)
- glacigenic deposits (Devensian/Weichselian).

A single supergroup named the Great Britain Superficial Deposits Supergroup, is proposed for Quaternary and Neogene superficial deposits. It is recognised that in some regions where formations have not been defined, the supergroup will contain lithogenetic units that are informally related to groups and subgroups.

Non-glacigenic deposits

Five groups are established for Quaternary and Neogene deposits of onshore Great Britain not directly associated with glacigenic processes.

Crag Group

The Crag Group (Tables 1, 2) is established for mainly marine deposits which formed in pre-Anglian time during the Late Pliocene to Early Pleistocene. The group straddles the current internationally defined age for base for the Quaternary (1.806 Ma, Gradstein, Ogg et al., 2004). These deposits lie to the south of the Devensian ice sheet limit and their distribution is unrelated to the present-day physiography. The distribution of Crag Group deposits is shown in Fig. 1. The term 'Crag' originates from the descriptions in the 18th and 19th centuries with formations being established in the 20th century (for a

Table 2. *Examples of formations of the Crag Group and the Dunwich Group*

GROUP	Examples of defining formations	δ ^{18}O stage	Status of units (stratoypes indicated where known)	Reference in Bowen, 1999
DUNWICH GROUP	Letchworth Gravel Formation	13 - ?	Defined by Smith & Rose (1997)	
	Cromer Forest-bed Formation	17 - ?	Freshwater members of the Cromer Forest-bed Formation of Lewis in Bowen (1999)	Lewis, p. 15
	Pedogenic units (Valley Farm Soil) above Kesgrave Formation and Bytham Valley Formation		Lewis in Bowen (1999)	Lewis, p. 22
	Bytham Formation	13 - ?	Proposed formation. Members include: Timworth Gravel, Knettishall Gravel, Ingham Farm Gravel, Seven Hills Gravel, High Lodge Gravel, Lakenheath Gravel, Fodderstone Gravel and Shouldham Thorpe Gravel members. Bytham Sands and Gravels defined by Rose (1994) and Bateman & Rose (1994). Includes the Ingham Sand and Gravel (Clarke & Auton, 1982, Lewis, 1993, Lewis in Bowen, 1999). Also includes the Shouldham Formation of Lewis in Bowen (1999)	Lewis, p. 19
	Kesgrave Formation	? 61 - 13	Proposed formation. Includes Lower St Osyth, Wivenhoe, Ardleigh and Waldringfield members, Colchester Formation (Kesgrave Group) of Whiteman & Rose (1992). Westmill Gravel* Gerrards Cross*, Beaconsfield*, Satwell*, Westland Green*, Waterman's Lodge† and Stoke Row* members of the Sudbury Formation (Kesgrave Group) of Whiteman & Rose (1992)	Lewis, p. 22; Allen, p. 24 Gibbard, p. 57 (*Middle Thames Formation) Gibbard, p. 47-49 (*Middle Thames Formation. †Northern Drift Formation)
	Nettlebed Formation	? 68 - ?	Nettlebed Member of Pebble Gravel Formation of Gibbard in Bowen, 1999)	Gibbard, p. 48
CRAG GROUP	Wroxham Crag Formation	? 17 - ? 67	Established by Rose et al. (2001) and Moorlock et al. (2002). The Sidestrand Member of the Norwich Crag Formation (Lewis in Bowen, 1999), and the marine Paston and Mundesley members of the Cromer Forest-bed Formation (Lewis in Bowen, 1999) are included.	Lewis, p. 15
	Norwich Crag Formation	? 68 - ? 81	Established by Funnell & West (1977). Four members (Mathers & Zalasiewicz, 1988, Lewis in Bowen, 1999): the Chillesford Clay, Chillesford Sand, College Farm Clay and Creeting Sand	Lewis, p. 22
	Red Crag Formation	? 82 - ? 103	Established by Funnell & West (1977). Zalasiewicz et al. (1988) defined two members in Suffolk: Sizewell and Thorpeness members. The Ludham Member of Norfolk (Lewis in Bowen, 1999) and the Netley Heath Member of the Blackwater – Loddon valleys (Gibbard in Bowen, 1999) also defined.	Lewis, p. 22 Gibbard, p. 53
	Coralline Crag Formation		Defined by Balson et al. (1993) with three members: Aldeburgh, Sudbourne and Ramsholt members	

review of the literature see Reid, 1890; Funnell & West, 1977; & Bowen, 1999). The group is defined with reference to stratotypes in Suffolk of the four principal constituent formations (Table 2), namely the Coralline Crag Formation (Balson et al., 1993), the Red Crag Formation (term first used by Funnell & West, 1977; with members defined from the Aldeburgh – Sizewell transect borehole, Suffolk, Zalasiewicz et al., 1988), a redefined Norwich Crag Formation (Chillesford Church Pit, Suffolk; Funnell & West, 1977; Mathers & Zalasiewicz, 1988) and a newly proposed Wroxham Crag Formation (Rose et al., 2001; Moorlock et al., 2002; to include the marine members of the Cromer Forest Bed series of Funnell & West, 1977). Hamblin et al. (1997), have correlated the onshore deposits of the Red Crag Formation with the Westkapelle Ground Formation of the southern North Sea which contains pollen spectra of Thurnian type (Cameron et al., 1992). Onshore deposits of the redefined Norwich Crag Formation (Antian/Bramertonian to Baventian age) are correlated with the Smith's Knoll Formation (Hamblin et al., 1997).

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Marine strata that succeed Baventian regression form the newly proposed Wroxham Crag Formation (Rose et al., 2001), the oldest part of which (including the Sidestrand Member, formerly of the Norwich Crag Formation) may correlate with the Winterton Shoal Formation offshore (Hamblin et al., 1997).

Other onshore deposits of Neogene age including the Buchan Gravels Formation of Aberdeenshire (Merritt et al., 2003) and the St Erth Beds of Cornwall (Edmonds et al., 1975) may be considered within the framework in due course.

Dunwich Group

A new palaeo-catchment Dunwich Group (Tables 1, 2) is established for mainly fluvial sands and gravels of rivers which formed in pre-Anglian time and were over-ridden by ice of the Anglian glaciation (Fig. 1). These deposits lie to the south of the Devensian ice sheet limit and their distribution is unrelated to the present day catchment physiography. The group is defined with reference to stratotypes of five principal constituent formations described in Bowen (1999), namely the Nettlebed Formation (Rose et al., 2001), the Kesgrave *Formation and associated pedogenic units of Suffolk* (Hey, 1965; Rose & Allen, 1977; Whiteman & Rose, 1992), the Bytham Valley Formation (to include the Ingham and Shouldham formations of Lewis, 1993), the Letchworth Gravel Formation of Hertfordshire (Smith & Rose, 1997) and the Cromer Forest-bed Formation (Funnell & West, 1977), redefined to include only the non-marine members exposed on the Weybourne to Kessingland coast of Suffolk and Norfolk.

Residual Deposits Group

The Residual Deposits Group is established for residual deposits that have undergone modification over lengthy periods during the Neogene and Quaternary. Included within this group are the Clay-with-Flints, a residual deposit or alterite which overlies Cretaceous and Neogene strata of Southern Britain (Pepper, 1973) and may be compared with *les biefs à silex* of the Paris Basin (Quesnel, 2003). These deposits may have resulted primarily from pedogenesis and clay illuviation during interglacials and cryoturbation under periglacial conditions.

Britannia Catchments Group

The Britannia Catchments Group (Tables 1, 3; Fig. 2) includes all post-Cromerian deposits of a non-glacigenic origin. They comprise predominantly gravels, sands and silts of fluvial, lacustrine and aeolian (cover sands and loess) origin. Organic (peat) and mass movement (head) deposits are also included within the group. The term 'Britannia' was referred to by Pliny as an alternative name for 'Albion', i.e. Scotland, England, Wales. The earliest, possibly pre-Anglian, terrace deposits of the southern England catchments are also included in the group. The group and constituent subgroups (see below) are defined with reference to stratotypes of several principal river valley formations described in Bowen (1999), most notably in southern Britain by the Thames Valley Formation (modified from Gibbard, pp. 45 - 58 in Bowen, 1999), the Trent Valley Formation (Brandon, p. 41 in Bowen, 1999) and the Severn Valley Formation (Sumbler & Maddy, pp. 34 - 36 in Bowen, 1999); and in northern Britain to proposed river valley formations including the Clyde Valley Formation (modified from Sutherland, pp. 109-110 in Bowen, 1999, with members originally defined as formations by Browne & McMillan, 1989).

Catchments subgroups

The linking of broad catchment geology to the present-day drainage systems may have advantages for a wide range of environmental users. A series of catchment subgroups are proposed for formations and lithogenetic units defined, within broad present-day physiographic regions (Tables 3a - e, Fig.2), by major river drainage systems developed since Cromerian time. The subgroups are generally related either to river systems draining to a major estuary (e.g. Forth Catchments Subgroup, Severn and Avon Catchments Subgroup) or to an area with several smaller rivers draining regional catchments (e.g. Cumbria - Lancashire Catchments Subgroup, Sussex Catchments Group).

Of the 24 subgroups of the Britannia Catchments Group that are currently proposed (Tables 3a - e, Fig. 2), 11 lie fully to the north of the Late Devensian ice sheet limit (Tables 3a - b), 4 straddle the limit (Table 3c), and 9 lie to the south (Tables 3d - e). North of the Devensian limit the deposits of each catchment subgroup comprise formations and lithogenetic units of generally Late Devensian to Holocene age. In the proximity of, and to the south of Devensian ice sheet limit, catchment subgroups comprise deposits which range from Anglian to Holocene age. It is proposed that each catchment subgroup will contain river valley formations, named after the principal rivers of the subgroup area.

British Coastal Deposits Group

The British Coastal Deposits Group (Tables 1, 4a - b) includes all post-Cromerian non-glacigenic gravels, sands and silts of estuarine, marine and beach origin (including beach dune deposits). Thin, interbedded fluvial sediments may also be included within dominantly marine and estuarine sequences. The defining formations occur at or near the present day coast and within estuaries and also as raised marine and beach units. Examples of component formations are shown in Tables 4a - b. The group is defined with reference to established stratotypes of constituent formations including the St Fergus Silt Formation and Spynie Clay Formation of NE Scotland (Merritt et al., 2003), the Clyde Clay Formation and Bridgeton Sand Formation of west central Scotland (modified from

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Browne & McMillan, 1989) and the Errol Clay Formation (after Paterson et al., 1981). In southern Britain, established formations with constituent members include the Fenland Formation (Ventris, 1985), the Breydon Formation (Arthurton et al., 1994), the Romney Marsh Formation (Gibbard & Preece, p. 61 in Bowen, 1999) and the West Sussex Coast Formation (Gibbard & Preece, pp. 61 - 62 in Bowen, 1999).

Glacigenic deposits

For glacigenic deposits the Great Britain Superficial Deposits Supergroup embraces two groups (defined below). The groups comprise all glacigenic deposits (glacial, glaciofluvial, glaciolacustrine and proximal glaciomarine deposits) and associated periglacial, organic and paraglacial units occurring at surface or concealed in onshore Great Britain.

Albion Glacigenic Group

The Albion Glacigenic Group comprises all formations and lithogenetic units of pre-Ipswichian age (Table 1). The name is derived from the Old English (via Latin) from the Celtic name for Great Britain. These deposits commonly form the surface deposits of southern Britain mainly, *but not exclusively*, confined to land between the Anglian and main Devensian ice sheet limits. Deposits of this group are present both at the surface and as concealed sequences, locally, in Britain to the north of the main Devensian ice sheet limit. In southern Britain, the surface, having been subjected to denudation and weathering over varying lengths of time and under a range of extreme climatic regimes, exhibits a generally subdued morphology. The group may be considered the equivalent of the 'Older Drift' of previous classifications (Wright, 1937). The

Table 3a. Subgroups and examples of formations of the Britannia Catchments Group (see also Fig. 2).

SUBGROUP	Examples of defining formations	δ ^{18}O stage	Status of units (stratoypes indicated where known)	Reference in Bowen, 1999
1. Northern Highland and Argyll Catchments Subgroup	Helmsdale Formation, Halladale River Formation	1	Proposed formations. Stratotypes to be defined.	
	Argyll Formation	1	To include fluvial and organic members of the Argyle Formation of Sutherland in Bowen (1999)	Sutherland, p. 111
2. Cromarty Catchments Subgroup	Strath Spey Formation	1	Proposed formation. Stratotypes to be defined.	
3. Tay Catchments Subgroup	Strathtay Formation, South Esk Formation, North Esk Formation, Strathearn Formation	1	Proposed formations. Stratotypes to be defined.	
4. Forth Catchments Subgroup	Lothian Tyne Valley Formation, Carron Valley Formation, Almond Valley Formation, Forth Valley Formation	1	Proposed formations. Stratotypes to be defined.	
5. Clyde Catchments Subgroup	Clyde Valley Formation	1	Proposed formation will include fluvial members of the Clyde Valley Formation of Sutherland in Bowen (1999). Established members (Browne & McMillan, 1989) include: Law Sand and Gravel (Law Borehole), Lochwinnoch Clay (Lochwinnoch Borehole) and Clippens Peat* members (Linwood Borehole)	Sutherland, p. 110
	Strathendrick Formation	1	Proposed formation will include fluvial members of the Clyde Valley Formation of Sutherland in Bowen (1999). Established members (Browne & McMillan, 1989) include: Endrick Sand and Kilmaronock Silt members (Mains of Kilmaronock Borehole)	Sutherland, p. 111 - 112
	Strathkelvin Formation, Leven Valley Formation, Ayr Valley Formation, Irvine Valley Formation	1	Proposed formations. Stratotypes to be defined.	

Notes

1. The catchment subgroups are defined principally by formations of fluvial deposits.
2. The catchment subgroups also embrace lithogenetic units including mass movement deposits (e.g. head, talus), organic deposits (e.g. peat), mountain regolith and cover sand. Where appropriate some of these units have been raised to formation status: examples are denoted thus *.

group is defined with reference to stratotypes of several formations. These include the Lowestoft Formation of East Anglia (Lewis, p. 11 in Bowen, 1999), and, in the English Midlands the Wolston (after Sumbler, p. 37 in Bowen, 1999), Seisdon (after Worsley, p. 32 in Bowen, 1999), Nurseries (after Maddy, p. 34 in Bowen, 1999), Oakwood (after Worsley, pp. 32 - 34 in Bowen, 1999) and Ridgacre formations (after Maddy & Sumbler, p. 34 in Bowen, 1999). Examples of formations from Northern England and the Isle of Man are shown in Table 5a.

Caledonia Glacigenic Group

The Caledonia Glacigenic Group comprises all formations and lithogenetic units of Devensian age (Table 1). The name is derived from the Latin for the Highlands of Scotland where the principal British ice sheets originated. These deposits commonly form the surface deposits of northern Britain and are confined to land lying mainly to the north of the main Devensian ice sheet limit. Being the products of the latest

Table 3b. Subgroups and examples of formations of the Britannia Catchments Group (see also Fig. 2).

SUBGROUP	Examples of defining formations	δ ^{18}O stage	Status of units (stratoypes indicated where known)	Reference in Bowen, 1999
6. Tweed Catchments Subgroup	Tweed Valley Formation	1	Proposed formation. Stratotypes to be defined.	
7. Solway Catchments Subgroup	Cree Valley Formation, Fleet Valley Formation, Kirkcudbright Dee Valley Formation, Nithsdale Formation, Annandale Formation	1	Proposed formations. Stratotypes to be defined.	
	Solway Esk Valley Formation	1	Proposed formation will include Bigholm Burn Member (Bowen, 1999)	Sutherland, p. 107
	Eden Valley Formation, Wampool Valley Formation, Waver Valley Formation, Ellen Valley Formation, Solway Derwent Valley Formation	1	Proposed formations. Stratotypes to be defined.	
8. Northumbria Catchments Subgroup	Coquet Valley Formation, Tyne Valley Formation, Wear Valley Formation, Tees Valley Formation, Esk Valley Formation, Teeside Formation	1	Proposed formations. Stratotypes to be defined.	
9. Isle of Man Catchments Subgroup	Sulby Glen Formation, Curragh Formation*, Ballaugh Formation*, Glen Balleira Formation*	1	Formations established by Thomas in Bowen (1999) and revised by Chadwick et al. (2001)	Thomas, p. 94
10. Cumbria-Lancashire Catchments Subgroup	Ehen Alluvial Formation	1	Formation established by Merritt & Auton (2000)	
	Esk Alluvial Formation	1	Proposed formation. Stratotypes to be defined.	
	Blelham Peat Formation*	1	Blelham Formation of Thomas in Bowen (1999) and adopted by Merritt & Auton (2000)	Thomas, p. 96
	Lune Valley Formation, Ribble Valley Formation	1	The Ribble Valley and Lune Valley formations are proposed in place of the Swettenham Formation of Thomas in Bowen (1999)	Thomas, p. 95
11. Cheshire - North Wales Catchments Subgroup	Mersey Valley Formation, Weaver Valley Formation, Dee Valley Formation, Clwyd Valley Formation, Conway Valley Formation	1	Proposed formations. Stratotypes to be defined.	

Notes

1. The catchment subgroups are defined principally by formations of fluvial deposits.
2. The catchment subgroups also embrace lithogenetic units including mass movement deposits (e.g. head, talus), organic deposits (e.g. peat), mountain regolith and cover sand. Where appropriate some of these units have been raised to formation status: examples are denoted thus *.

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Table 3c. Subgroups and examples of formations of the Britannia Catchments Group (see also Fig. 2).

SUBGROUP	Examples of defining formations	δ 18O stage	Status of units (stratoypes indicated where known)	Reference in Bowen, 1999
12. Yorkshire Catchments Subgroup	Swale Valley Formation, Ure Valley Formation, Nidd Valley Formation, Aire Valley Formation, Hull Valley Formation, Humber Formation, Yorkshire Ouse Valley Formation, Derwent Valley Formation, Wharfe Valley Formation	1	Proposed formations. Stratotypes to be defined.	
	Ringingslow Formation	1	Thomas in Bowen (1999)	Thomas, p. 97 - 98
	Sutton Blown Sand Formation*	1 (LLS)		
13. Trent Catchments Subgroup	Trent Valley Formation	1 - 8	Members after Brandon in Bowen (1999)	Brandon, p. 41
	Proto-Trent Valley Formation		Members after Brandon in Bowen (1999)	Brandon, p. 42
	Devon Valley Formation		Members after Brandon & Sumbler in Bowen (1999)	Brandon & Sumbler, p. 42
	Bain Valley Formation		Members after Brandon & Sumbler in Bowen (1999)	Brandon & Sumbler, p. 14-15
	Trent Derwent Valley Formation		Members after Derwent Valley Formation of Brandon in Bowen (1999)	Brandon, p. 39
	Soar Valley Formation		Members after Maddy in Bowen (1999)	Maddy, p. 39
14. Severn and Avon Catchments Subgroup	Severn Valley Formation	1 - 11	Members after Maddy & Sumbler in Bowen (1999)	Maddy & Sumbler, p. 34 - 36
	Avon Valley Formation		Members after Maddy in Bowen (1999)	Maddy, p. 37 - 38
	Bristol Avon Valley Formation		Members defined within the Avon Valley Formation of Maddy, Keen & Sumbler in Bowen (1999)	Maddy, Keen & Sumbler, p. 37-38
15. West Wales Catchments Subgroup	Dovey Formation, Afon Formation, Teifi Formation, Tywi Formation, Neath Formation, Tregaron Formation, Ystog Formation		Possible formations for consideration (Tywi after Bowen, 1999 but restricted to deposits of the Tywi valley). Tregaron and Ystog formations after Bowen (1999)	Bowen, p. 79 - 90 (Wales)

Notes

1. The catchment subgroups are defined principally by formations of fluvial deposits.
2. The catchment subgroups also embrace lithogenetic units including mass movement deposits (e.g. head, talus), organic deposits (e.g. peat), mountain regolith and cover sand. Where appropriate some of these units have been raised to formation status: examples are denoted thus *.

glaciations, the deposits commonly have distinct morphological expression and this morphology is commonly an important part of the definition of component formations and their subdivisions. In terms of age, distribution and morphology, the group comprises deposits of the 'Newer Drift' of earlier workers (e.g. Wright, 1937). The group and constituent subgroups (see below) are defined with reference to stratotypes of regionally significant till formations and associated formations of glaciofluvial, glaciolacustrine and glaciomarine origin. Defining formations are described from Lincolnshire and from the Cheshire and the Severn Valley in the English Midlands. In Lincolnshire, the Holderness Formation (North Sea Coast Glacigenic Subgroup) is a succession of diamict, gravel, sand, silt and clay with three till members, the Bridlington (Basement Till of Catt & Penny, 1966; Catt, 1991), Skipsea Till and the Withernsea Till members, all interpreted to be of Devensian age (McCabe & Bowen, p. 13 in Bowen, 1999; Bowen et al., 2002). In Norfolk, two members are recognised, the Holkam Till and the Ringstead Sand and Gravel members (after Lewis, pp. 18 - 19 in Bowen, 1999). In the English Midlands, Worsley (1991) has demonstrated that the Four Ashes Formation (partly Ipswichian and partly Early and Middle Devensian, $\delta^{18}O$ stages 5d - 3) is overlain by Stockport Glacigenic Formation (Irish Sea Coast Glacigenic Subgroup). Examples defining formations from northwest England, the Isle of Man and southern Scotland are shown in Table 5b. Further north,

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stratotypes of the Midland Valley Glacigenic Subgroup are established for the Baillieston Till (pre-Late Devensian), the Wilderness Till (Dimlington Stadial, Late Devensian) and Gartocharn Till formations (Loch Lomond Stadial) (Rose et al., 1988; Browne & McMillan, 1989). In northeast Scotland, Merritt et al. (2003) have defined the Whitehills Glacigenic

Table 3d. Subgroups and examples of formations of the Britannia Catchments Group (see also Fig. 2).

SUBGROUP	Examples of defining formations	δ ¹⁸O stage	Status of units (stratoypes indicated where known)	Reference in Bowen, 1999
16. Somerset Catchments Subgroup	Parrett Formation		Defined with several members by Campbell et al. in Bowen (1999)	Campbell et al., p. 78
17. Ouse-Nene Catchments Subgroup	Nar Valley Formation	1 - ?9	Marham, Pentney, Wormegay and Nar members after Ventris (1985) and Lewis in Bowen (1999)	Lewis, p. 18
	Lark Valley Formation	1- ?	Lackford, Cavenham, Kentford, Fornham, Eriswell and Sicklesmere members after Lewis in Bowen (1999)	Lewis, p. 21
	Cam Valley Formation		Barnwell Station, Sidgwick Avenue, Barnwell Abbey, Barrington Village, Histon Road, Huntingdon Road, Little Wilbraham, Bordeaux Pit and North Hall members after Lewis in Bowen (1999)	Lewis, p. 21 - 22
	Bure Valley Formation	1 - ?6	Proposed formations. Stratotypes to be defined.	
	Nene Valley Formation			
	Ouse Valley Formation			
	Slea Valley Formation			
	Welland Valley Formation			
	Witham Valley Formation			
18. Yare Catchments Subgroup	Waveney Valley Formation	1 - 11	Shotford, Wortwell and Broome members after Lewis in Bowen (1999). Hoxne Formation (Wymer in Bowen, 1999) assigned member status	Wymer, p. 24, Lewis, p. 25
	Yare Valley Formation		Proposed formations. Stratotypes to be defined.	
19. Suffolk Catchments Subgroup	Currently lithogenetic units			
20. Thames Catchments Subgroup	Thames Valley Formation	1 - 12	Proposed formation. Members after Maidenhead Formation (Gibbard in Bowen, 1999)	Gibbard, p. 49 - 50
	Kennet Valley Formation	1 - 8	Members after Kennett (sic) Valley Formation (Collins in Bowen, 1999)	Collins, p. 51 - 52
	Blackwater – Lodden Valley Formation	1 - 8	Possible members after Blackwater – Lodden Valley Formation (Gibbard in Bowen, 1999)	Gibbard, p. 53
	Colne Valley Formation		Possible members after Colne Formation (Gibbard in Bowen, 1999)	Gibbard, p. 53
	Mole – Wey Valley Formation	1 - 9	Possible members after Mole – Wey Formation (Gibbard in Bowen, 1999)	Gibbard, p. 54
	Wandle Valley Formation	1 - 8	Possible members after Wandle Formation (Gibbard in Bowen, 1999)	Gibbard, p. 54
	Lea Valley Formation	1 - 11	Possible members after Lea Formation (Gibbard in Bowen, 1999)	Gibbard, p. 54 - 56
	Darent – Cray Valley Formation	1 - 11	Possible members after Darent Formation (Gibbard in Bowen, 1999)	Gibbard, p. 56
	Medway Valley Formation	1 - 9	Possible members after Medway Valley Formation (Bridgland in Bowen, 1999)	Bridgland, p. 56 - 57

Notes

1. The catchment subgroups are defined principally by formations of fluvial deposits.
2. The catchment subgroups also embrace lithogenetic units including mass movement deposits (e.g. head, talus), organic deposits (e.g. peat), mountain regolith and cover sand. Where appropriate some of these units have been raised to formation status: examples are denoted thus *.

Formation (here assigned to Banffshire Coast and Caithness Glacigenic Subgroup), the Banchory Till Formation (here assigned to the East Grampian Glacigenic Subgroup) and the Hatton Till Formation (here assigned to the Logie-Buchan Glacigenic Subgroup). The distribution and general relation of these to other component formations is shown in Fig. 3.

Glacigenic Subgroups

In northern Britain, north of the Devensian limit, the provenance of glacigenic deposits, as demonstrated by lithology, is strongly influenced by the build-up and decay of regionally distinct ice sheets (e.g. Central Grampians – Rannoch Moor) or ice domes (e.g. Central Cumbria – Lake District). In these areas it is possible and potentially useful to demonstrate lithological similarities of Quaternary sediments of varying age. It is proposed to divide the Caledonia Glacigenic Group into a series of subgroups that are defined primarily on the basis of mappable formations of till (see above for examples of the defining formations). The till formations are related geographically to the principal areas of ice accumulation and dispersal that determine their provenance and gross lithological characteristics (e.g. Cumbria Glacigenic Subgroup, Irish Sea Coast Glacigenic Subgroup, Table 5a, b) (Fig. 1). Each subgroup will embrace associated formations of glaciofluvial, glaciolacustrine and glaciomarine deposits. All deposits will be placed in the

Table 3e. Subgroups and examples of formations of the Britannia Catchments Group (see also Fig. 2).

SUBGROUP	Examples of defining formations	δ ¹⁸O stage	Status of units (stratoypes indicated where known)	Reference in Bowen, 1999
21. Cornubian Catchments Subgroup	Currently lithogenetic units			
22. Solent Catchments Subgroup	Meon Formation	1 - pre 13	Proposed formation. Seven aggradations above Alluvium	
	Hamble Formation		Proposed formation. Three aggradations above Alluvium	
	Itchen Formation		Proposed formation. Up to seven aggradations above Alluvium	
	Test Formation		Proposed formation. Up to eleven aggradations above Alluvium	Gibbard & Preece, p. 63
	Hampshire Avon Formation		Proposed formation. Up to eleven aggradations above Alluvium. Includes the Ringwood Formation (formerly 'Older River Gravel Formation') and some members of the New Forest Formation of Gibbard & Preece in Bowen (1999)	
	Dorset Stour Formation		Defined by Allen and Gibbard (1994). See Sway Member of New Forest Formation of Gibbard & Preece in Bowen (1999)	Gibbard & Preece, p. 63
	Frome-Piddle Formation		Defined by Allen & Gibbard (1994). Members described by Gibbard & Preece in Bowen (1999)	Gibbard & Preece, p. 64
23. Sussex Catchments Subgroup	Cuckmere Formation	1	Proposed formation. Two aggradations above Alluvium. Cuckmere Member of the Sussex Valleys Formation of Gibbard & Preece in Bowen (1999)	Gibbard & Preece, p. 62
	Sussex Ouse Formation		Proposed formation. Four aggradations above Alluvium. Lower Ouse Member of the Sussex Valleys Formation of Gibbard & Preece in Bowen (1999)	
	Arun Formation		Proposed formation. Seven aggradations above Alluvium. Arun Member of the Sussex Valleys Formation of Gibbard & Preece in Bowen (1999)	
	Adur Formation		Proposed formation. Three aggradations above Alluvium	
	Sussex Rother Formation		Proposed formation, Five aggradations above Alluvium	
24. South Kent Catchments Subgroup	Kentish Rother Formation	1	Proposed formation. Stratotypes to be defined.	
	Pegwell Formation	2 - 3	Formation established by Gibbard & Preece in Bowen (1999)	Gibbard & Preece, p. 61
	Kentish Stour Formation	3 - 10	Possible members after Gibbard & Preece in Bowen (1999)	Gibbard & Preece, p. 59

Notes

1. The catchment subgroups are defined principally by formations of fluvial deposits.
2. The catchment subgroups also embrace lithogenetic units including mass movement deposits (e.g. head, talus), organic deposits (e.g. peat), mountain regolith and cover sand. Where appropriate some of these units have been raised to formation status: examples are denoted thus *.

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Table 4a. Examples of formations of the British Coastal Deposits Group.

GROUP	Examples of defining formations	$\delta^{18}O$ stage	Status of units (stratoypes indicated where known)	Reference in Bowen, 1999
BRITISH COASTAL DEPOSITS GROUP	Beauly Silt Formation, Moniack Peat Formation, Foulis Silt Formation, Lemlair Sand Formation, Ardullie Silt Formation	1	Proposed formations – Beauly Firth, NE Scotland. Formerly members of the Cromarty and Clava formations (Sutherland in Bowen, 1999)	Sutherland, p. 103 - 106
	Balmeanach Silt Formation, Barnyards Silt Formation, Longman Gravel Formation	1 (LLS)		
	Culbokie Silt Formation, Kessock Bridge Silt Formation	1 - 2 (WIS)		
	Spynie Clay Formation, St Fergus Silt Formation	2	NE Scotland formations established by Merritt et al. (2003)	
	Ardyne Formation	1 - 2 (LLS - WIS)	Killellan, Toward, and Ardyne Point members defined as units by Peacock et al. (1978)	Sutherland, p. 110
	Buchannan Formation	1	Formations established by Browne & McMillan (1989)	Sutherland, p. 110
	Inverleven Gravel Formation, Balloch Clay Formation	1 (LLS)		
	Clyde Clay Formation	1 - 2 (WIS - LLS)	Formation proposed. Linwood and Paisley members (Linwood Borehole) Browne & McMillan, (1989)	
	Bridgeton Sand Formation	2 (WIS)	Formation established by Browne & McMillan (1989)	
	Grangemouth Formation	1	Saltgreens, Skinflats and Grangemouth Docks members after Barras & Paul (1999)	Sutherland, p. 113 - 114
	Claret Silt and Clay Formation		After Claret Formation of Barras & Paul (1999)	
	Letham Silt Formation	1 - 2 (WIS)	Units established by Browne et al. (1984), assigned as members of the Forth – Teith Formation by Sutherland in Bowen (1999) and now proposed as formations	
	Bothkennar Gravel Formation, Abbotsgrange Silt Formation, Kinneil Kerse Silt Formation, Loanhead Clay Formation	2		
	Kingston Sand Formation, Post-Carse Estuarine Formation, Carse of Gowrie Clay Formation	1	Proposed formations. Units defined by Paterson et al. (1981). Mainly assigned as members of the Forth –Teith Formation by Sutherland in Bowen (1999)	Sutherland, p. 114
	Carey Sand and Silt Formation	1 (LLS to Holocene)		
	Culfargie Sand Formation, Powgavie Clay Formation	1 - 2 (WIS)		
	Errol Clay Formation	2	Proposed formation. Errol Beds of Paterson et al. (1981), Errol Member of Tay Formation (Sutherland in Bowen, 1999). Correlated with St Abbs Formation (offshore) Stoker et al. (1985)	Sutherland, p. 114, Holmes, p. 130
	Girvan Formation	1	Established by Sutherland in Bowen (1999)	Sutherland, p. 109
	Redkirk Formation	1	Established by Sutherland in Bowen (1999). Component units defined by Bishop and Coope (1977). Bigholm Burn Member now assigned to the Solway Esk Valley Formation	Sutherland, p. 107
	Point of Ayre Formation	1	Established by Thomas in Bowen (1999), revised by Chadwick et al. (2001)	Thomas, p. 94

Notes

1. The above formations comprise mainly coastal and marine deposits. Locally interbedded fluvial and organic deposits may also be present.
2. LLS Loch Lomond Stadial (Younger Dryas); WIS Windermere Interstadial (Bølling/Allerød).

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Caledonia Glacigenic Group unless they are known to be older (e.g. as has been demonstrated in NE Scotland, Merritt et al., 2003). To maintain a strict hierarchy, known pre-Devensian units will be assigned to a set of glacigenic subgroups that mirror those of the Caledonia Glacigenic Group and are identified by the addition of the word 'Albion', e.g. Irish Sea Coast (Albion) Glacigenic Subgroup. Examples of component formations of these older subgroups are shown in Table 5a. It is not presently intended to propose subgroups of the Albion Glacigenic Group south of the Devensian ice sheet limit because the origin and lithological variation is less clear. However, lithological and palynomorph analysis of Middle Pleistocene tills in East Anglia, reported by Lee et al. (2002), may offer the potential to extend the subgroup concept into this area.

As indicated above, glacigenic subgroups will be defined on the basis of lithological characteristics and properties common to two or more till formations. Subgroups will assume parental status for formations in areas where they are adopted. There are examples where it is possible to demonstrate interdigitation of formations belonging to different subgroups which are the product of different ice streams during several glaciations (e.g. in northeast Scotland, Fig. 3, Merritt et al., 2003). The complexity of glacigenic sequences may depend on preservation potential associated with the location of a site with respect to the ice-dispersal centre (Andrews, 1979; Lowe & Walker, 1997). The thickest and most complex sequences may be preserved at sites that were glaciated for the shortest time.

Table 4b. Examples of formations of the British Coastal Deposits Group.

GROUP	Examples of defining formations	$\delta^{18}O$ stage	Status of units (stratoypes indicated where known)	Reference in Bowen, 1999
BRITISH COASTAL DEPOSITS GROUP	Lytham Formation	1	After formation established by Thomas in Bowen (1999)	Thomas, p. 95
	Drigg Point Sand Formation		Formation established by Merritt & Auton (2000)	
	Hall Carleton Formation	1 - 2 (WIS)	Nethertown Gravel, Rabbit Cat Silt, Netherholme Sand and Fern Bank Silt members established by Merritt & Auton (2000)	
	Grange Formation	1 - 2	Formations established by Thomas in Bowen (1999)	Thomas, p. 95 - 96
	Seacombe Sand Formation	?2		
	Shirdley Hill Sand Formation	1 - ?2		
	Kenfig Formation	1	Defined by Bowen (1999)	Bowen, p. 83
	Ynslas Formation		Proposed formations in Wales. Stratotypes to be defined.	
	Wentloog Formation			
	Gower Forrmation	5e		
	Breydon Formation, North Denes Formation	1	Formations defined by Arthurton et al. (1994) for NE Norfolk	
	Fenland Formation	1	Ventris (1985), McCabe in Bowen (1999), Lewis in Bowen (1999)	McCabe, p. 14, Lewis, p. 16
	Blakeney Formation	1 - ?6	Formerly Morston Member of Hunstanton Formation (Lewis in Bowen, 1999)	Lewis, p. 18
	Romney Marsh Formation	1	Formation established by Gibbard & Preece in Bowen (1999)	Gibbard & Preece, p. 61
	West Sussex Coast Formation	2 - 13	Component units described by Hodgson (1964)	Gibbard & Preece, p. 61 - 62
	Poole Harbour Formation	1	Proposed Formation. To include Poole Harbour Member (Gibbard & Preece in Bowen, 1999)	Gibbard & Preece, p. 64
	Gwent Levels Formation, Oldbury and Avonmouth Levels Formation	1	Proposed formations. Stratotypes to be defined.	
	Somerset Levels Formation	1	Defined by Campbell et al. in Bowen (1999)	Campbell et al., p. 78
	Burtle and Kenn Gravel Formation	?5b	Defined as Burtle Formation with several members by Campbell et al. in Bowen (1999)	Campbell et al., p. 77 - 78

Notes

1. The above formations comprise mainly coastal and marine deposits. Locally interbedded fluvial and organic deposits may also be present.
2. LLS Loch Lomond Stadial (Younger Dryas); WIS Windermere Interstadial (Bølling/Allerød).

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Formations and sub-divisions

Salvador (1994) describes the formation as 'the primary formal unit of lithostratigraphic classification used to map, describe and interpret the geology of a region'. The formation is a geographically mappable unit that may consist of one or more lithologies defined by type section, or more commonly by type area. Rawson et al. (2002) recognise that 'the basic unit is the formation which is generally defined as the smallest mappable unit. However 'mappability' is a loose criterion, for it depends on the scale of mapping'. Formations should be mappable using recognised techniques of surveying, logging of natural and temporary sections and boreholes. A formation should be readily represented on a 1 : 50 000 scale map, and its subdivisions (members and beds) should be mappable either at this scale or at larger scales.

Where possible, top and base should be defined by type sections in natural and excavated exposures or in boreholes. It is recognised that the nature of these boundaries and the bounding deposits may vary laterally, and that, commonly, bounding surfaces for Quaternary deposits are discontinuities (unconformities or faults). Although Rawson et al. (2002) acknowledge that formations may stand separately or form part of a group, the proposed framework recommends that all Quaternary formations should be referred to a lithostratigraphical unit of higher status. Where appropriate, it is recommended that Quaternary formation names should include a geographical qualifier together with a lithological descriptor (e.g. Kilblane Sand and Gravel Formation, Table 5b) or, for heterolithic units, a lithogenetic descriptor (e.g. Gretna Till Formation, Seascale Glacigenic Formation, Table 5a). Rarely, morphological descriptors (e.g. moraine) have been applied to some formations. If a landform description is regarded as important attribute, a link may be made between the deposit and the associated landform by referring to the lithogenetic classification and mapping schemes (see below).

It is recommended that river terrace deposits, including alluvium, be assigned as members of a river valley formation (cf. Gibbard in Bowen, 1999). The formation may also contain non-fluvial deposits such as organic (peat) and lacustrine deposits. Separate formations may be set up, within the Britannia Catchments Group or the British Coastal Deposits Group, for non-fluvial deposits that do not form part of a river valley formation.

Lithogenetic units

A lithogenetic unit (cf. Schenck & Muller, 1941; Salvador, 1994), regionally mappable or otherwise, is defined, initally without regard to time, by its lithology, morphology and mode of origin (genesis). For BGS maps and databases lithogenetic units are classified according to the current scheme (McMillan

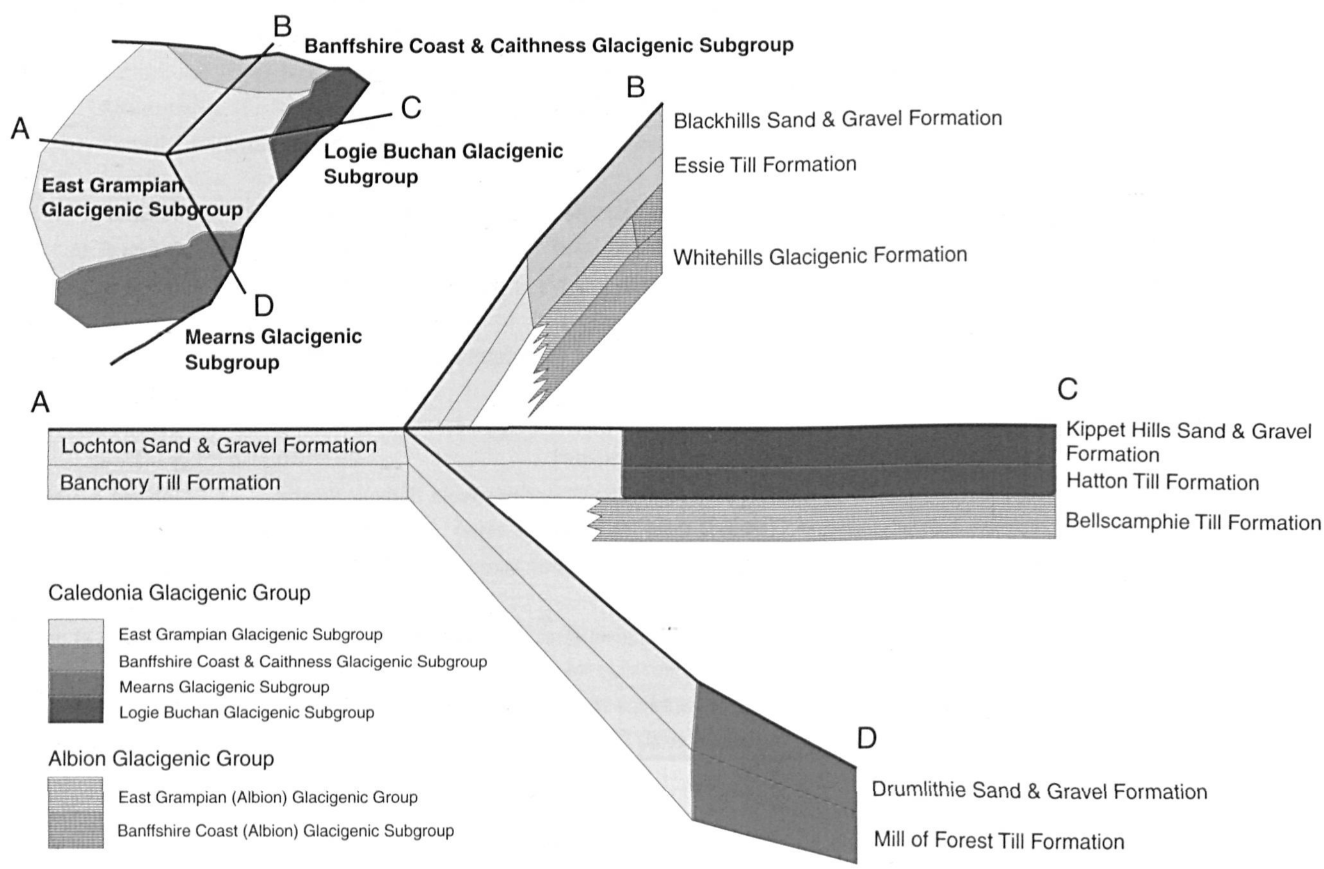

Figure 3. Examples of formations, subgroups and groups of the Great Britain Superficial Deposits Supergroup in NE Scotland.

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& Powell, 1999) that corresponds to the BGS map specifications (Ambrose, 2000). The specifications enable lithostratigraphical and age codes to be attached to conventional mapping symbols for lithogenetic units that can be assigned lithostratigraphical status following the identification and description of stratotypes or type areas. It recognised that types of slope (mass movement) deposits (Dines et al., 1940) have been inconsistently mapped and are lithologically poorly known. Unless such deposits can be correlated it is recommended that initially they be assigned only a lithogenetic classification and informally related to a subgroup or group (e.g. Britannia Catchments Group).

The objective of this approach is that, at group level, the proposed lithostratigraphical framework embraces *all* formations and lithogenetically-defined units. This should enable a coded lithostratigraphical superscript to be applied to every Quaternary map symbol defined in Ambrose (2000). The framework also offers a unique designation for use in digital databases and for digital map production where a strict hierarchy of units is necessary.

Comparison between the proposed framework for Great Britain (onshore) and schemes for other NW European countries

A common rationale between the proposed framework for Great Britain and those proposed or in operation for other parts of Europe is that they can be successfully applied to address a range of scientific and applied questions. Within the scope of this paper two examples of other approaches are compared. The ability to provide an overarching framework, which is the main aim of the proposed scheme for Britain, offers the potential for broad scale correlation both with adjoining land masses and with the offshore sequences especially in the North Sea. The newly proposed facies association scheme of the integrated land and sea stratigraphical model of the Netherlands and the Dutch sector of the North Sea (Laban et al., 2003) has similarities with the British onshore scheme. In the Netherlands formations are assigned to broad facies associations, for example glacigenic, marine and fluviatile. Similarly, in Britain formations are defined primarily by their lithofacies and genesis. The glacigenic subgroups of the Caledonia Glacigenic Group are geographically defined by till formations with broad lithological similarities. The catchment subgroups of the Britannia Catchments Group embrace fluvial formations. Marine formations are assigned to the Great Britain Coastal Deposits Group. The difference between the schemes appears to be in the definition of subgroups and groups. Thus the four Netherlands stratigraphical subgroups (Laban et al., 2003), defined on the basis of North Sea Basin-wide unconformities, embrace formations of both glacigenic and non-glacigenic origin. In contrast, the British groups retain distinctions between glacigenic and non-glacigenic (mainly fluviatile and marine) categories. However, all Quaternary deposits are included within an overarching supergroup (Great Britain Superficial Deposits Supergroup) that is equivalent to the Upper North Sea Group of Laban et al. (2003). In the UK sector of the central North Sea, ten major seismostratigraphic formations have been defined that can be correlated with the Quaternary stages of NW Europe (Stoker et al., 1985). However, their defining criteria (and survey techniques) are different from those applied onshore and, as yet, no attempt has been

Table 5a. Examples of formations, subgroups and groups of the Caledonia Glacigenic Group and the Albion Glacigenic Group in southern Scotland, north-west England and the Isle of Man.

SUBGROUP	Examples of defining formations	δ ¹⁸O stage	Status of units (stratoypes indicated where known)	Reference in Bowen, 1999
Southern Uplands (Albion) Glacigenic Subgroup	No formations currently identified			
Irish Sea Coast (Albion) Glacigenic Subgroup	Drigg Till Formation	6	Glacigenic formation in West Cumbria established by Merritt & Auton (2000)	
	Kiondroughad Formation		Formations revised by Chadwick et al. (2001).	Thomas, p. 91 - 94
	Ayre Formation	9 - 12	Ayre Lighthouse Formation formerly the Isle of Man	
	Ayre Lighthouse Formation		Formation of Thomas in Bowen (1999)	
	Seisdon Glacigenic Formation	10 or 12	Worsley in Bowen (1999)	Worsley, p. 32
Central Cumbria (Albion) Glacigenic Subgroup	Thornsgill Till Formation	pre-5e	After Thomas in Bowen (1999)	Thomas, p. 95

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Table 5b. Examples of formations, subgroups and groups of the Caledonia Glacigenic Group and the Albion Glacigenic Group in southern Scotland, north-west England, the Isle of Man and northern Wales.

SUBGROUP	Examples of defining formations	δ ^{18}O stage	Status of units (stratoypes indicated where known)	Reference in Bowen, 1999
Southern Uplands Glacigenic Subgroup	Langholm Till Formation Kirkbean Sand and Gravel Formation Dalswinton Moraine Formation Mouldy Hills Gravel Formation	2	Proposed formations for Dumfries & Galloway (McMillan et al., in prep. 2005)	
Irish Sea Coast Glacigenic Subgroup	Gretna Till Formation Kilblane Sand and Gravel Formation Cullivait Silt Formation Kerr Moraine Formation Plumpe Sand and Gravel Formation	2	Proposed formations for Dumfries & Galloway (McMillan et al., in prep. 2005)	
	Morecambe Bay Formation Carlisle Glacigenic Formation Penrith Glacgenic Formation Irthing Glacigenic Formation Selker Formation	2	Glacigenic formations in Cumbria. After Thomas in Bowen (1999)	Thomas, p. 95 - 96
	Gosforth Glacigenic Formation Aikbank Farm Glacigenic Formation	2	Glacigenic formations in West Cumbria established by Merritt & Auton (2000)	
	Seascale Glacigenic Formation	2 early		
	Glannoventia Till Formation	?3		
	Carleton Silt Formation	?4		
	Jurby Formation Orrisdale Formation Shellag Formation	2	Isle of Man glacigenic formations. Thomas in Bowen (1999) and Chadwick et al. (2001)	Thomas, p. 94
	Kirkham Formation	2	Glacigenic formation in Lancashire correlated with the Stockport Glacigenic Formation (Thomas in Bowen, 1999)	Thomas, p. 95
	Lleyn Till Formation	2	Proposed till formation (NW Wales). Other till and glaciofluvial formations to be considered (e.g. members of the St Asaph Formation of Bowen, 1999 after McKenny-Hughes, 1887)	Bowen, p. 84 and 89
	Stockport Glacigenic Formation	2	Defined by Worsley (1991). Maddy in Bowen (1999)	Maddy, p. 34
	Four Ashes Sand and Gravel Formation	3 - 5e		
Central Cumbria Glacigenic Subgroup	Wolf Crags Formation	1	Thomas in Bowen (1999)	Thomas, p. 96
	Windermere Formation	1 - 2		
	Blengdale Glacigenic Formation	2	Glacigenic formation in West Cumbria established by Merritt & Auton (2000)	
	Threlkeld Till Formation	2	After Thomas in Bowen (1999)	Thomas, p.96
	Maudsyke Till Formation	?4	Glacigenic formation in West Cumbria established by Merritt & Auton (2000)	

made to group these units. In the southern North Sea the formations of the Neogene to Quaternary Crag and Dunwich groups have been the subject of extensive research and can be broadly correlated with the NW European climato-stratigraphic stages (Funnell, 1995, 1996).

Early Scandinavian approaches to lithostratigraphy of glacial deposits placed much emphasis on provenance studies to enable the modelling of the pattern of regional ice streams. For Southern Sweden a revised lithostratigraphic scheme of formations (Lagerlund, 1983) has departed from the traditional 'ice stream stratigraphy' (of several workers during the 20th century). Groups and subgroups have not been assigned. The original units were strictly related to provenance. New biostratigraphical and chronostratigraphical data have resulted in parts of the original provenance-defined units being separated in time and correlated with separate formations. Comparison with the British scheme suggests that the Swedish formations could sit within a group equivalent to the

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Caledonia Glacigenic Group, which embraces deposits of the Devensian (Weichselian) glaciation. Arguably, if a group was introduced in this way, subgroups defined by tills of similar broad scale lithological characteristics could then be established, thus offering a 'value-added' interpretation.

Conclusion

The proposed lithostratigraphical framework is, to the author's knowledge, a rare departure from conventional application of lithostratigraphy to Neogene and Quaternary deposits. In establishing supergroups, groups and subgroups the approach takes forward some of the ideas and proposals outlined in Bowen (1999, Chapter 1). Many geologists appear to have been constrained by a belief that Quaternary sequences are so thin and short-lived when compared with the rest of the geological column that it is inappropriate to define units of a status higher than that of formation. The proposed scheme departs from this doctrine, mainly formulated by 'bedrock' geologists, thus accommodating the diversity of depositional environments, lithological variation and geographical distribution of Quaternary deposits. The framework also potentially provides geoscientists with a usable scheme, and the user of geological data with a lithostratigraphy of direct relevance, not simply for broad scale correlation, but also for a range of applications including engineering and hydrogeological modelling purposes.

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