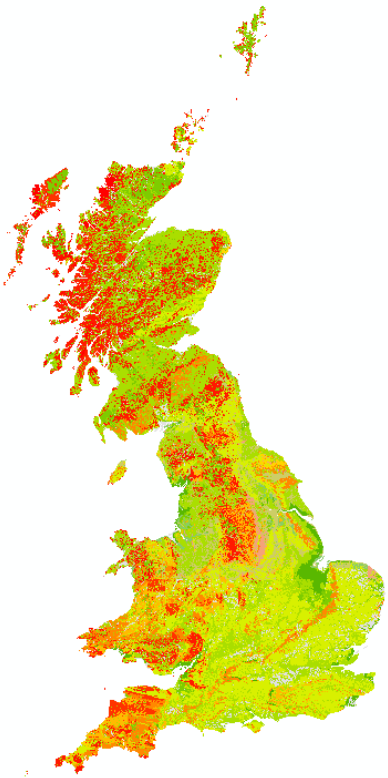
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

User Guide DiGMapPlus+ Engineering Properties: Strength dataset (version 1)

Information Products Programme

Open Report OR/12/43



BRITISH GEOLOGICAL SURVEY

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BRITISH GEOLOGICAL SURVEY

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The British Geological Survey is a component body of the Natural Environment Research Council.

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Foreword

This report presents a description and review of the methodology developed by the British Geological Survey (BGS) to produce a national scale assessment of Engineering Properties: Strength. Much of the methodology has been taken from an internal BGS document which outlines the development of the methodology which is summarised in this report. The purpose of this user guide is to enable those licensing this dataset to have a better appreciation of how the data set has been created and therefore better understand the potential applications and limitations that the dataset may have.

Acknowledgements

A number of individuals in the Information Products and Land Use and Development Programmes have contributed to the project and helped compile this report. This assistance has been received at all stages of the study. In addition to the collection and processing of data, many individuals have freely given their advice, and provided the local knowledge.

Contents

Summary

This report describes the national scale DiGMapPlus+ Engineering Properties: Strength dataset. The methods used to create the dataset have been critically assessed and its fitness for purpose determined by specialists in BGS.

This document outlines the background to why the dataset was created, its potential uses and gives a brief description of the content. Technical information regarding the GIS and how the data was created is described and advice is provided on using the dataset.

1 Introduction

This document provides information for users on the 'Engineering Properties: Strength' dataset.

The 'strength' of rocks and soils are an important factor in all engineering activities. The 'strength' of rock material depends on: composition; density; the strength of individual components within the rock; and how these components are bound together (by interlocking grain, cementation etc). However, the strength of the whole rock mass is affected by mechanical discontinuities, such as fissures, joints, shears and faults. The strength of both the rock material and rock mass can also be affected by alteration processes such as weathering; and by changes in water content and pore water pressures.

The dataset provides classification of strength of coarse soils and fine soils/rocks, as defined by British Standard 5930 1999 and modified 2003 and 2009.

Definitions of the engineering strength of **rocks (and fine soils)** are provided as minimum, maximum and typical strengths. This tri-fold classification allows for the wide range of variation encountered within some stratigraphic units. For example: the Mercia Mudstone Group where sandstones are included is classified as ***firm*** to ***strong*** because it has some mudstone beds that are firm due to weathering but also contains stronger sandstone and dolomitic beds. Because these locally weaker and stronger beds make up a small proportion of the deposit/formation, the most common 'strength' is determined as ***stiff***. Additionally, this 'typical' classification takes into account its weathered state, water content, and other variations.

Definitions of the engineering strength of **coarse soils** are provided as minimum, maximum and typical densities. Again, this tri-fold classification allows for the wide range of variation encountered within some stratigraphic units. For example; Kempton Park Gravel Formation is classified as ***loose*** to very ***dense*** because where it is at surface it tends to be in a loose state, whereas, at depth it may become very dense, however, it is most commonly dense. However, in the upper 2 m it is loose to dense and most commonly medium dense.

Units that may behave as coarse soils or as rocks, such as the Upper Greensand Formation and some formations of the Sherwood Sandstone Formation, have both density and strength ranges and, therefore, occur in both 'Density rating of coarse soil' and 'strength rating for fine soil and rocks.

2 About the Engineering Properties: Strength dataset

2.1 BACKGROUND

The product is a spatial model of strength information for use within a GIS. The model will allow **demonstration** of the spatial distribution of zones of rock strength and density defining a 'Strength' model for the uppermost 2m of all rocks and deposits distributed across Great Britain. Within this limited depth, weathering of material is to be expected and, therefore, the effects of weathering (to varying degrees) are considered.

This dataset forms part of a suite of GIS layers for different engineering parameters. It is based upon archive data of engineering soil strength coupled with the BGS DiGMapGB-Plus dataset and displayed via dictionaries of 'strength classes'.

The dictionaries, measurements and terminology used are in accordance with standard engineering vocabulary as recommended in EuroCode 7 and BS9530 standards (BSI, 1999; BSI, 1993).

More specific data of the top 2 m of geological materials are required for near surface infrastructure and excavations. The values supplied are the ***indicative*** minimum, maximum and typical values we would normally expect to encounter per geological unit but limited to the top 2 m. The main difference with other classifications is that these values will, in many cases, be in the weathered zone and may be of lower strength, consistency or density than the typical values or comprise of a mixture of coarse material or rock. The water content within the top metre or so will vary seasonally and annually depending on the weather/climate. This will affect the character of the fine-grained deposits. In wet weather firm or stiff clays 'wet up' and may become soft. In dry weather the top metre or more of deposits will become stiffer.

The upper metre or so of alluvium in some places and estuarine alluvium become desiccated and are firm or stiff whereas, at greater depth they are soft or very soft.

In response to this, The British Geological Survey initiated a development programme to produce datasets that identified and assessed a variety of engineering properties in Great Britain. These include strength, excavatability, fill and discontinuities.

Along with the engineering properties datasets, the programme also generates:

- Superficial Thickness Model
- GeoSure ground stability data
- Scans of onshore borehole logs for Great Britain
- Scans of geology and historic topography maps
- Ground permeability data
- Susceptibility to Groundwater Flooding
- Geological Indicators of Flooding
- Environmental sensitivity data
- Radon potential
- Non-coal mining hazards
- Potentially Harmful Elements

2.2 WHAT THE DATASET SHOWS

The data is a synthesis of national databases and technical engineering data held by BGS, based primarily on DiGMapGB-50 V6 and the National Geotechnical Properties Database, the initial layer being 0-2m depth.

The Strength GIS comprises a series of layers detailing spatial distribution of geological and engineering factors directly relevant to the strength of a material as well as 'other factors' of indirect relevance to excavating within the landscape; i.e. weathering.

The primary datasets for the Strength GIS are:

1. The DiGMapGB-Plus dataset
2. Geology-strength data derived from the National Geotechnical Properties Database and other site investigation information, primarily exploratory hole logs, from NGRC.
3. A 'look-up' dictionary that classifies the strength of material by its consistency, strength or density. The rock strength data is interpreted from BS5930:1999 (BSI, 1999).

The data provides national coverage for England, Scotland and Wales at a scale of 1:50,000.

The 'Strength' model provides data for the **uppermost 2 m** of all geological units distributed across Great Britain (including consideration of weathering). At present this layer includes limited rock mass discontinuity data. However, this data will be included in future versions.

2.3 WHO WOULD BENEFIT FROM THE DATASET?

It is envisaged that strength is of interest to a wide range of organisations concerned with the development including utility companies, local authorities, developers and engineering consultants and contractors.

Properties of rocks are important in all engineering projects and the classification of the strength of a rock formation is a priority objective. An estimate of this value in any desk study exercise would provide a valuable indication and allow for more effective planning and execution of any proceeding ground investigation.

3 Technical information

3.1 DATA EXAMPLES

Two examples have been provided with your licensed data. These are:

- Strength based on coarse soils (density values)
- Strength based on fine soils and rocks (strength values)

Users are recommended to take both values into account where available as this highlights the potential variability of weathering of the deposit and indicates the potential variation of strength that might be encountered. A weathered and disaggregated rock may be measured using density (i.e. as a coarse soil) but in an un-weathered state would be given a strength value. For example: the Nottingham Castle Sandstone Formation in an un-weathered state is a medium-strong rock,

where weathered, it is classified as weak. However, where weathered to a disaggregated material it is more correctly identified as a dense, coarse soil.

Where only a density value is available, the geological deposit is un-lithified with very little or no fine-grained mineral content (a superficial sand and gravel deposit would be a typical example of this).

It is recommended that all values available should be taken into account when collating a desk study allowing for targeted site investigation and planning as the strength or density of material will affect different aspects.

*Users should note that this data should be used to provide **indicative** information only, and should **not** be used in place of site specific measurements.*

3.2 DEFINITIONS

The description and classification of engineering strength depends on the type of deposit. In engineering geology, earth materials are split into two groups, 1. soils and 2. rocks as given below:

- ***Soil*** is an aggregate of mineral grains or organic material that can be separated by such gentle means as agitation in water. Their behaviour is determined by the particulate nature, specifically the particle size, particle shape, particle mineralogy, water content and material density. The mass properties are largely influenced by its material characteristics. The principal soil types are clay, silt (fine soils) sand, gravel (coarse soils) cobble and boulder (very coarse soils). Whether the soil is classified principally as fine or coarse is dependent upon the behaviour of the material. Discontinuities affect the mass strength of some soils, primarily clay and silt.
- ***Rock*** is an aggregation of minerals connected by strong and permanent forces. The behaviour of the rock material depends on the material characteristics. The behaviour of the rock mass depends on a combination of the material characteristics and the discontinuities (including spacing, roughness, persistence, filling, orientation and the number of sets).

3.3 HOW THE DATASET WAS CREATED

Lithological type and variability are implicitly classified in the BGS Rock Classification Scheme for each LEX-RCS code, and so the minimum/maximum and typical strength parameters/values have been determined for all rocks and deposits using the LEX-RCS coding.
Codes and values for strength, consistency or density have been assessed using information in the BGS National Geotechnical Properties Database, technical reports, site investigation reports and by expert opinion. Categorisation is based on a formation level wherever possible.
The dataset includes the indicative minimum, maximum and typical values for the unit within 2m of the surface.

The Strength dataset provides information for the **uppermost 2 metres** of all geological units distributed across Great Britain. Within this limited depth, weathering of material is to be expected and, therefore, the effects of **weathering** (to varying degrees) are considered. Further information regarding details of geological units at greater depths can be provided on request (see contact information below).

3.3.1 Field descriptions

The data fields included in this dataset are described below. Full class descriptions as they appear in the dataset are shown in Appendices 1 and 2.

General lithology (GEN_LITH)

This is a simplified geological description of the parent material and is derived from the original DiGMapGB-50 LEX-RCS coding compared with the hierarchical classification of UK rocks from the BGS RCS system. In general the aim is to provide the user with as simplified a lithological description as possible.

Lexicon Rock Classification Scheme (LEX_RCS)

This field is the standard DiGMapGB-50 code that describes the geological units found in Great Britain. It provides the starting point for the parent material characterisation. It comprises a 'stratigraphic' code (LEX) and 'Lithology' code RCS).

Strength_Minimum (STR_MIN)

The minimum strength or consistency expected for this unit. Where there is more than one lithology present (heterolithic units) the strength of the weakest lithology is given. This does take into consideration weathering and alteration.

Strength_Maximum (STR_MAX)

The maximum strength or consistency expected for this unit. Where there is more than one lithology present (heterolithic unit) the strength of the strongest lithology is given. In general, this will be unweathered material and found at depth. However, in some situations the maximum strength may be where weak rocks or soils are altered and includes calcrete, silcrete and ferricrete.

Strength_Typical (STR_TYP)

The typical strength expected of the rock or soil. This is a simplification but provides guidance as to the typical strength and can be taken in relation with the Minimum and Maximum values. For example in a mixed lithology of strong to very strong sandstone with subsidiary weak mudstone, the rock may exhibit predominantly strong characteristics and, therefore its typical or dominant strength is strong.

Density_Minimum (DEN_MIN)

The minimum density expected for this unit, including rocks that are weathered or altered to coarse soil, generally near surface.

Density_Maximum (DEN_MAX)

The maximum density expected for this unit, including rocks that are weathered or altered to coarse soil, generally near surface.

Density_Typical (DEN_TYP)

The typical density expected of the soil. This is a simplification but provides guidance as to the typical density and can be taken in relation with the Minimum and Maximum values. For example in a soil of moderately dense to very dense sand and gravel with subsidiary loose sand, the soil may exhibit predominantly moderately dense characteristics and, therefore its typical or dominant density is moderately-dense.

Nominal Scale (Nom_Scale)

This field describes the notional x-y spatial scale of the data. Most geological map data in the dataset is captured and presented at a scale of 1:50,000. The field identifies a combination of scales used to create the map from the bedrock and superficial map sources. The available scales are show as follows:

Field Value	Meaning
50	No superficial data is present for this sheet and bedrock data is available at 1:50,000 scale
250	No superficial data is present for this sheet and bedrock data is available at 1:250,000 scale
625_50	Superficial data is present for this sheet at a scale of 1:625,000 and Bedrock data is available at a scale of 1:50,000
50_50	Superficial data is present for this sheet at a scale of 1:50,000 and Bedrock data is available at a scale of 1:50,000
35_50	Superficial data is present for this sheet at a scale of 1:35,000 and Bedrock data is available at a scale of 1:50,000
35_250	Superficial data is present for this sheet at a scale of 1:35,000 and Bedrock data is available at a scale of 1:250,000

3.4 DATA FORMAT

The ***Engineering Properties: Strength*** dataset is produced for use at 1:50000 scale providing 50 m ground resolution.

The data are released in ESRI shapefile formats. Other formats such as MapInfo TAB are available on request. The standard data supplied to customers has polygons or areas in a single layer or theme.

3.5 COVERAGE

Data is provided to indicate the strength of rocks and soils across Great Britain. The scale of map data available to create this dataset is shown in Appendix 4.

3.6 DATA HISTORY

Version 1 (released 2012): Derived from DiGMapGB-50 version 6.

3.7 LIMITATIONS

- The Engineering Properties datasets have been developed at 1:50 000 scale and must not be used at larger scales. All spatial searches against the data should be done with a minimum 50 m buffer.
- The spatial distribution of the data is limited by the distribution of the site investigation exploratory holes from which the geotechnical data have been extracted (shown in Appendix 3) and digital geological map data (DiGMapGB-50) (Appendix 4). Although the National Geotechnical Properties Database is the ‘first port of call’ for data it has limited coverage so other descriptive data from exploratory borehole logs or from Site Investigation Reports has been used.
- Strength data are created as vector polygons and are available in a range of GIS formats, including ArcGIS (.shp), ArcInfo Coverages and MapInfo (.tab). More specialised formats may be available but may incur additional processing costs.
- Strength dataset is concerned with the strength of a deposit related to NATURAL geological conditions only. It does NOT cover any man-made constructions, such as engineered fill.
- Strength is based on, and limited to, an interpretation of the records in the possession of The British Geological Survey at the time the dataset was created.

- Strength is a mechanical property rather than a physical property it is usually measured quantitatively in the laboratory or occasionally in the field and has several versions depending on application and test conditions. Thus a formation cannot have a unique value of strength, there is always some degree of variation. This is indicated in this dataset by providing the minimum, maximum and 'typical' strength values for each formation.
- An indication of the typical natural strength of a rock or soil does not necessarily mean that the rock properties are consistent throughout the outcrop. Such an assessment can only be made by inspection of the area by a qualified professional.

4 Licensing Information

The British Geological Survey does not sell its digital mapping data to external parties. Instead, BGS grants external parties a licence to use this data, subject to certain standard terms and conditions. In general, a licence fee will be payable based on the type of data, the number of users, and the duration (years) of a licence.

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- reproduce extracts from the data up to A3 for use in external analogue (paper/hard copy) or non-queryable electronic (e.g. secured .pdf) format: to meet a public task duty; fulfil a statutory requirement; and/or as part of academic or other non-commercial research

But **will not** be permitted to:

- provide a bureau service for others or incorporate the data in the generation of products or services for commercial purposes
- sell, assign, sublicense, rent, lend or otherwise transfer (any part of) the dataset(s) or the licence
- place (any part of) the dataset(s) on the Internet

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When the BGS digital datasets are revised any upgrades will be automatically supplied to the licensee, at no additional cost. Geological map datasets are revised on a periodic rather than on an annual basis, licensees will therefore not automatically receive a new dataset each year unless changes have been made to the data.

These are general comments for guidance only. A licensee of BGS's digital data is provided with full details of the basis on which individual BGS datasets licensed to them are supplied.

If you have any doubts about whether your proposed use of the BGS data will be covered by a BGS digital licence, the BGS Intellectual Property Rights (IPR) section will be happy to discuss this with you and can be contacted through the following email address: iprdigital@bgs.ac.uk. BGS IPR will usually be able to provide reassurance that the licence will cover individual user requirements and/or to include additional 'special conditions' in the licence documentation, addressing specific requirements within BGS's permitted usage.

4.1 CONTACT INFORMATION

For all data and licensing enquiries please contact:

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Appendix 1 DiGMap-Plus Strength (DMS) Engineering Properties - Strength Legend

Field name	Field description	Description
GEN_LITH	Generalised lithology description	This is a simplified geological description of the parent material and is derived from the original DiGMapGB-50 LEX-RCS coding compared with the hierarchical classification of UK rocks from the BGS RCS system. In general the aim is to provide the user with as simplified a lithological description as possible.
LEX_RCS	BGS Lexicon-rock classification code	This field is the standard DiGMapGB-50 code that describes the geological units found in Great Britain. It provides the starting point for the parent material characterisation. It comprises a 'stratigraphic' code (LEX) and 'Lithology' code RCS).
DEN_MIN	***Density_Minimum*** Minimum density for coarse soils (if present)	The minimum density expected for this unit, including rocks that are weathered or altered to coarse soil, generally near surface.
DEN_MAX	***Density_Maximum*** Maximum density for coarse soils (if present)	The maximum density expected for this unit, including rocks that are weathered or altered to coarse soil, generally near surface.
DEN_TYP	***Density_Typical*** Typical density for coarse soils (if present)	The typical density expected of the soil. This is a simplification but provides guidance as to the typical density and can be taken in relation with the Minimum and Maximum values. For example in a soil of moderately dense to very dense sand and gravel with subsidiary loose sand, the soil may exhibit predominantly moderately dense characteristics and, therefore its typical or dominant density is moderately-dense.
DEN_TYP_BL	Typical density blows	Blows required to drive a 50mm square peg 300mm
DEN_TYP_DE	Typical density description	Description as defined in BS5930 (1999,2009)
STR_MIN	Minimum strength for fine soil/rocks	The minimum strength or consistency expected for this unit. Where there is more than one lithology present (heterolithic units) the strength of the weakest lithology is given. This does take into consideration weathering and alteration.
STR_MAX	***Strength_Maximum*** Maximum strength for fine soil/rocks	The maximum strength or consistency expected for this unit. Where there is more than one lithology present (heterolithic unit) the strength of the strongest lithology is given. In general, this will unweathered material and found at depth. However, in some situations the maximum strength may be where weak rocks or soils are altered and includes calcrete, silcrete and ferricrete.
STR_TYP	***Strength_Typical*** Typical strength for fine soil/rocks	The typical strength expected of the rock or soil. This is a simplification but provides guidance as to the typical strength and can be taken in relation with the Minimum and Maximum values. For example in a mixed lithology of strong to very strong sandstone with subsidiary weak mudstone, the rock may exhibit predominantly strong characteristics and, therefore its typical or dominant strength is strong.
STR_TYP_MP	Typical strength value	Values expressed as mega-pascals (MPa)

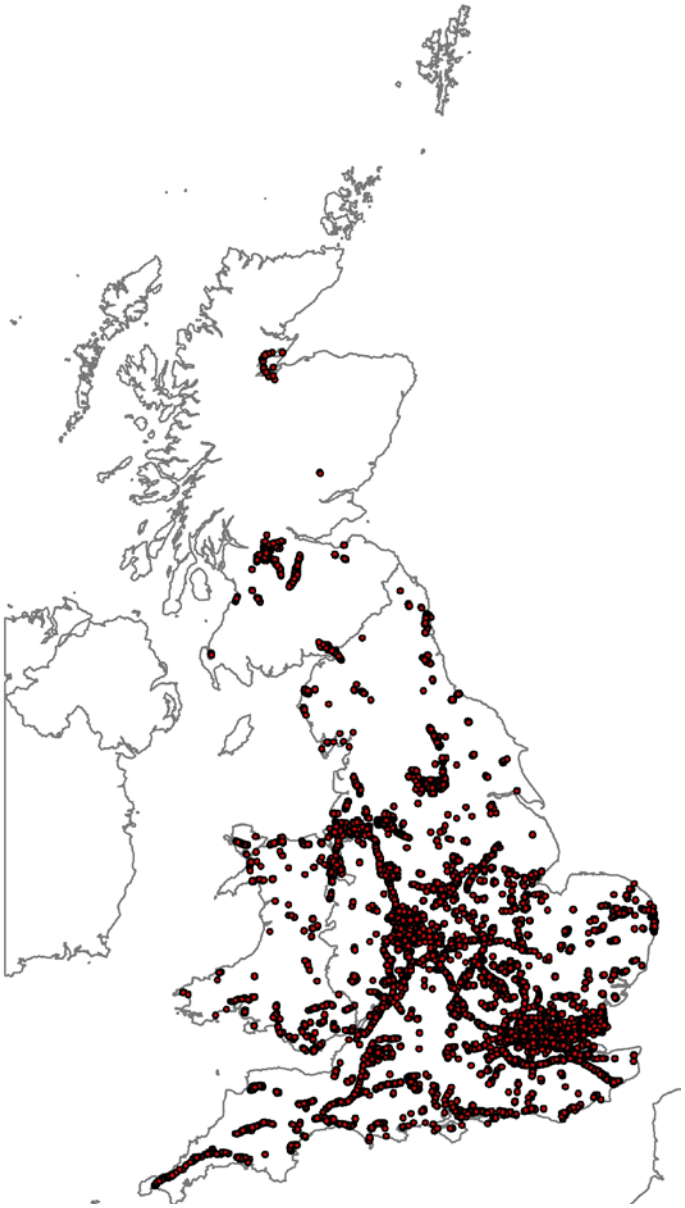
STR_TYP_DE	Typical strength description	Description as defined in BS5930 (1999,2009)
NOM_SCALE	***Nominal Scale*** Nominal use scale	This field describes the notional x-y spatial scale of the data. Most geological map data in the dataset is captured and presented at a scale of 1:50,000. The field identifies a combination of scales used to create the map from the bedrock and superficial map sources.
UID	Unique identifier	Map metadata
VERSION	Version of the dataset	Map metadata

Appendix 2 Descriptions of 'Strength' used in the GIS

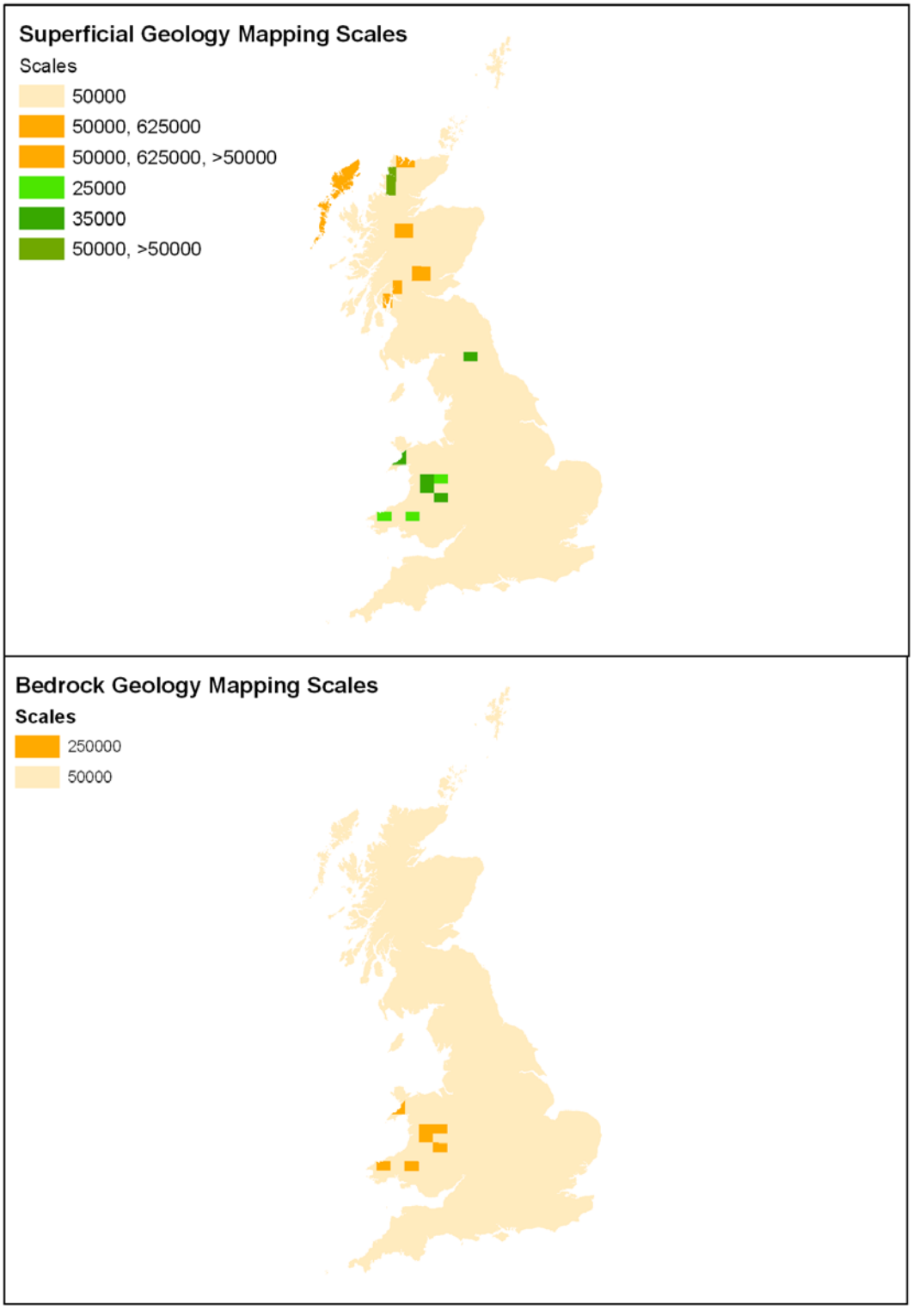
BS5930_term	Unconfined compressive strength or SPT N-values	BS5930_field_assessment
Extremely Strong	250+ MPa	May be chipped or not with geological hammer, rock may ring when hit, may be broken or not by sledge hammer
Very Strong	100 - 250 MPa	Requires many blows with a geological hammer to fracture
Strong	50 - 100 MPa	Requires more than one blow of a geological hammer to fracture
Medium Strong	25 - 50 MPa	Cannot be scraped or peeled with pocket knife, specimen can be fractured with one blow of a geological hammer.
Weak - Strong	5 - 100 MPa	Ranges from: Can be peeled with pocket knife with difficulty and shows shallow indentations with firm blows with point of geological hammer, to: requires more than one blow of a geological hammer to fracture.
Weak - Medium Strong	5 - 50 MPa	Ranges from: Can be peeled with pocket knife with difficulty and shows shallow indentations with firm blows with point of geological hammer. to : Cannot be scraped with pocket knife.
Weak	5 - 25 MPa	Can be peeled with pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer, Gravel sized lumps broken in half with heavy hand pressure.
Very Weak - Very Strong	1 - 250 MPa	Ranges from: Can be peeled by a pocket knife or crumbles under firm blows with point of geological hammer, to: requires many blows of a geological hammer to fracture.
Very Weak - Strong	1 - 100 MPa	Ranges from: Can be peeled by a pocket knife or crumbles under firm blows with point of geological hammer, to: requires more than one blow of a geological hammer to fracture.
Very Weak	1 - 5 MPa	Can be peeled by pocket knife. Crumbles under firm blows with geological hammer. Gravel-size lumps can be crushed between finger and thumb
Extremely Weak	0.6 - 1.25 MPa	Can be idented by thumbnail. Gravel sized lumps crush between finger and thumb.
Hard	*0.6 - 1.25 MPa*	Can be scratched by thumbnail. Should only be used for transported materials such as tills, otherwise classed as extremely weak rock.
Very Stiff	*0.3 - 0.6 MPa*	Thumb nail will indent. CCrumbles in rolling a 3mm thick thread and cannot be remoulded into a lump
Stiff to Very Strong	*0.15 - 250 MPa*	Ranges from: Thumb nail will indent. Crumbles in rolling a 3mm thick thread, but can be remoulded into a lump, to: requires many blows with a geological hammer to fracture.
Stiff - Weak	*0.15 - 25 MPa*	Ranges from: Thumb nail will indent, to: can be peeled with pocket knife with difficulty and shows shallow indentations with firm blow with point of geological hammer.
Stiff - Very Weak	*0.15 - 5 MPa*	Ranges from: Can be indented by thumb nail, to: can be peeled by pocket knife and crumbles under firm blows with geological hammer.
Stiff	*0.15 - 0.3 MPa*	Thumb nail will indent. Crumbles in rolling a 3mm thick thread, but can be remoulded into a lump
Firm - Stiff	*0.08 - 0.3 MPa*	Ranges from: Thumb easily makes an impression and cannot be moulded by fingers and rolls in the hand a 3 mm thick thread without breaking or crumbling, to: can be slightly indented and crumbles when rolled to a 3 mm thick thread but can be remoulded into a lump.
Firm	*0.08 - 0.15 MPa*	Thumb makes impression (easily). Cannot be moulded by fingers, rolls in the hand to a 3 mm thick thread without breaking or crumbling.
Soft - Firm	*0.04 - 0.15 MPa*	Ranges from: Finger pushed in by 10mm and moulds with light finger pressure, to: thumb easily makes impression and rolls in the hand to a 3 mm thick thread without breaking or crumbling.
Soft	*0.04 - 0.08 MPa*	Finger pushed in by 10mm. Moulds by light finger pressure.
Very Soft - Soft	*<0.08 MPa*	Ranges from: Finger pushed in by 25mm and exudes between the fingers, **to:** finger pushed in by 10mm and moulds by light finger pressure
Very Soft	*<0.04 MPa*	Finger pushed in by 25mm and exudes between the fingers
Very Dense - Weak	50+ Blows to 25 MPa	Ranges from: Requires pick for excavation. 50 mm wooden peg hard to drive, to: can be peeled with pocket knife with difficulty and shallow indentations with firm blow with point of geological hammer.

Very Dense	50+ Blows	Requires pick for excavation. 50 mm wooden peg hard to drive in.
Dense	30 - 50 Blows	Requires pick for excavation. 50 mm wooden peg hard to drive in.
Medium Dense - Dense	10 - 50 Blows	Requires pick for excavation. 50 mm wooden peg hard to drive in.
Medium Dense	10 - 30 Blows	Requires pick for excavation. 50 mm wooden peg hard to drive in.
Loose - Medium Dense	4 - 30 Blows	Ranges from: Can be excavated with spade and 50 mm wooden peg easily driven in, to: requires pick for excavation and 50 mm wooden peg hard to drive in.
Loose	4 - 10 Blows	Can be excavated with spade. 50 mm wooden peg easily driven.
Very Loose	< 4 Blows	Can be excavated with spade. 50 mm wooden peg easily driven.
Variable		Highly variable currently cannot be predicted
Not Applicable		Value is not applicable as the deposit is of wrong type (eg classifications for coarse soil sare not applicable for material sthat are fine soils or engineering rock.

Appendix 3 Distribution of data points held in the National Geotechnical Properties Database.



Appendix 4 Mapping Scales



References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

BSI. 1999a. BS5930:1999. Code of practice for site investigation incorporating Amendment No.1 (and Amendment 2 when available summer 2010. British Standards Institution, London.

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