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User Guide for the British Geological Survey Corrosivity (Ferrous) dataset

Open Report OR/11/023

BRITISH GEOLOGICAL SURVEY

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Keywords

Parent Material, Ferrous, Soil, Corrosivity.

Bibliographical reference

TYE, A.M., ENTWISLE, D.E. & Newsham, R.. 2011. User Guide for the British Geological Survey Corrosivity (Ferrous) dataset. *British Geological Survey Open Report*, OR/11/023. 17pp.

Keyworth, Nottingham British Geological Survey 2011

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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 corrosivity. 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.

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Summary

This report presents a description and review of the methodology developed by the British Geological Survey (BGS) to produce a national scale assessment dataset of potential corrosivity of the ground beneath the topsoil.

This document outlines the background to why the dataset was created, its potential uses and gives a brief description of methodology used to create the dataset. The method has been critically assessed and its fitness for purpose determined by specialists in BGS.

Acknowledgements

Specialists in engineering geology, process geochemistry and geographic information systems have contributed to the project and aided in the compilation of the report and this user guide. 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 to assist the development and validation of the corrosivity dataset.

1 Introduction

Founded in 1835, the British Geological Survey (BGS) is the world's oldest national geological survey and the United Kingdom's premier centre for earth science information and expertise. The BGS provides expert services and impartial advice in all areas of geoscience and has a client base is drawn from the public and private sectors both in the UK and internationally.

The innovative digital data products aim to help describe the ground surface and subsurface across the whole of Great Britain. These digital products are based on the outputs of the BGS survey and research programmes and our substantial national data holdings. This data coupled with in-house geoscientific knowledge are combined to provide products relevant to a wide range of users in central and local government, insurance and housing, engineering and environmental business, and the public.

Examples of datasets available from BGS include:

- Six ground stability hazard datasets
- Superficial deposit thickness models
- Scans of onshore borehole logs for Great Britain
- Scans of geology and historic topography maps
- Ground permeability data
- Susceptibility to groundwater flooding data
- Geological indicators of past flooding data
- Environmental sensitivity data
- GIS data identifying potential radon hazard
- Non-coal mining hazards data
- National Soil Chemistry data
- Urban Soil Chemistry data

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2 About the Corrosivity (ferrous) dataset

2.1 BACKGROUND

The creation of a BGS Corrosivity (ferrous) dataset is in response to the growing awareness of the cost of maintenance of iron structures in the ground such as infrastructure pipelines, and building foundations. The cost of corrosion to the UK has been estimated at 4 % of GNP per year (Institute of Corrosion; http://www.icorr.org/). Some of this cost comes in the form of the corrosion of ferrous underground assets, particularly in what are termed ‘aggressive soils’. Thus the new dataset identifies where the ground beneath the topsoil has potentially ‘corrosive’ or ‘aggressive’ characteristics and places them within the recognised scoring framework developed by the Cast Iron Pipe Research Association (CIPRA) now the Ductile Iron Pipe Research Association (DIPRA).

2.2 WHO MIGHT REQUIRE THIS DATA?

Underground assets that are at risk from different types of corrosion include water pipelines, oil and gas pipelines, earthing rods, cabling, sewers and building foundations such steel piles. For this reason, the dataset is suitable for those who are responsible for the maintenance of these types of underground assets. In the near future greater amounts of infrastructure will need to be buried, possibly in areas where there is less information regarding soil properties. For example, the investment in new infrastructure for renewable energy resources including wind, solar and wave, which will often take place in coastal and upland areas. In addition, the corrosivity dataset can be used in project planning and desk study stages for new infrastructure to identify the appropriate construction materials and level of preventative action that may be required.

Currently, the dataset has the following potential users:

- Water companies
- Water regulators and coordinating bodies
- Petrochemical companies
- Regulatory and coordinating bodies
- Engineering and industrial insurers
- Energy providers
- Transport infrastructure providers including local authorities.

As underground assets get older, their potential to fail as a result of surface pitting and corrosion increases. According to the International Association of Engineering Insurers, underwriters must combine geological and geotechnical data in order to identify conditions that could cause problems. This includes soil chemistry, which is known to affect the rate of corrosion of pipe walls and equipment, and thus the likelihood of a leak. All companies that have underground pipes are required to engage inline inspection testing using Pipeline Inspection Gauges (PIGs) to assess the state of the pipeline. A risk based approach to these inspections that takes into account ground conditions would result in prioritised inspection plans and, therefore, potentially reducing unnecessary inspections. Pipeline coordinating bodies also have a role to play in agreeing policy and actions as well as preventing incidents which could cause injury and damage to the environment. Companies engaged in the distribution of electrical power (power, water or transport infrastructure) use earthing rods to ensure safety of the power supply. These earthing rods can be subject to corrosion under some types of ground conditions compromising safety.

The BGS Corrosivity dataset is based on the 1:50 000 bedrock and superficial geological digital data. It forms a GIS layer for underground asset management based on (i) properties contained within the database of the BGS Parent Material map (1:50 000) (Lawley (2009), (ii) data from various sources, iii) expert knowledge and (iv) modelled data that has been combined within a published framework of Corrosivity ratings provided by the Cast Iron Pipe Research Association (1964). Scores for 5 corrosive properties including (i) Moisture, (ii) Redox status, (iii) pH, (iv) Sulphates/Sulphides and (v) resistivity have been combined to give a final corrosivity score for each rock type. Each score gives an indication as to whether the ground conditions below the top soil are likely to cause corrosion of underground ductile iron assets.

3 Technical Information

3.1 SCALE

The BGS Corrosivity (Ferrous) dataset is produced for use at 1:50 000 scale providing 50 m ground resolution.

3.2 CREATION OF THE DATASET

The dataset was created by scoring 5 corrosive properties and assigning scores to the BGS Parent Material polygons according to an adapted Cast Iron Pipe Research Association dataset (CIPRA, 1964). The five parameters that are scored are:-

Soil pH

Soil-parent materials pH scores have been divided into three classes.

1. Soil pH values > 8.5
2. Soil pH values < 4.5
3. Soil pH values > 4.5 and < 8.5.

Moisture

Soil moisture was based on its texture as stated within the Parent Material database. Three classes were scored

1. Poor drainage, continuously wet
2. Fair drainage, generally moist
3. Good drainage, generally dry

Soil Redox status

Soil redox status was largely based on soil texture information contained within the Parent Material Database. Three classes were outlined for this soil property.

1. Well oxidised soils,
2. Soils prone to seasonal anaerobic conditions
3. Very wet or waterlogged soils such as peat or saltmarsh soils.

Resistivity

Information was obtained from a resistivity model developed by BGS. Resistivity modelling has been undertaken for all the LEX_RCS codes in the Midlands of England as part of an earlier study. This data was then used to inform other LEX_RCS codes outwith this area. Five factors have been identified from which resistivity values have been modelled. The factors are:

1. Clay mineral content
2. Porosity
3. Saturation
4. Pore water resistivity Ohm.m
5. Material factor based on the shape of the particles and pores.

Presence of Sulphides and Sulphates

This was based on data in the BGS LEX_RCS database, the National Geotechnical Properties Database and through extensive expert knowledge within the BGS and the literature (e.g. Czerewko & Cripps, 2006; Forster *et al*. 1995). The presence of primary sulphides in soils and parent materials are typically associated with mudstones, Cretaceous and Tertiary clays, coal seams as well as waterlogged soils such as peat and estuarine and river alluvium. Primary sulphates are found typically in the evaporite deposits of the Permo-Triassic and part of the Jurrasic periods. Secondary sulphates are found where sulphides have been oxidised leading to formation of sulphate ions. Further information on sulphide and sulphate relating to concrete is in the Building Research Establishment publication SD1 (BRE, 2001).

The scoring system in Table 1 has been used to assign values to the polygons represent the different parent materials held within the BGS Parent Material dataset.

Table 1. Scoring system applied to the Parent Material polygons.

Corrosion Property	Value	Score
pH	< 4.5	3
	4.5-8.5	0
	>8.5	3
Moisture conditions	Sand	0
	Sand > loam	0
	Sand > loam >clay	1
	Loam	1
	Loam > sand	1
	All	1
	Loam > clay	1
	Clay + loam	1
	Clay > loam	1
	Clay	2
	Peat	2
Resistivity, Ohm.m	<7	10
	7 – 10	8
	10 – 12	5
	12 – 15	2
	15 – 20	1
	>20	0
Redox Status	Well oxidised soils e.g. course and highly permeable soils	0
	Soils prone to seasonal waterlogging e.g. clay soils	4
	Very wet or waterlogged soils e.g. peat and salt marsh soils	5
Sulphides / Sulphates	Primary	3.5
	Secondary	3.5
	Not present or unlikely	0

The final score for each polygon within the dataset are created by summing all the individual scores for all five corrosive properties (as shown in the table above).

The original CIPRA scoring scheme suggested that any soils with a combined score exceeding 10 were likely to be corrosive. Soils were thus given one of two scores, <10 or >10. However, a third category has been included for those values around the score of '10' as parent materials that may require additional examination. Table 2 describes the colour coding and subsequent recommendations; whilst in Figure 1 shows the final dataset.

Table 2 Scoring system used in the final corrosivity dataset.

For ease of interpretation the final published dataset does not contain the values for the individual corrosion properties, it uses the following classification scheme:

Yellow signifies *'Ground conditions beneath topsoil are unlikely to cause corrosion of iron' (Score 0-8.5)*

Green signifies *'Ground conditions beneath topsoil may cause corrosion to iron'(score 9-11)'*

Blue signifies *'Ground conditions beneath topsoil are likely to cause corrosion to iron (score 11.5 -23.5)'.*

It also includes a recommendation and a backfill field, more details of this can be found in the table below.

Underline text is the field heading used in the GIS dataset, colour coding refers to the colours setup in the accompanying layer file. "Typical Material Description" is in this table for reference and it not in the final GIS dataset.

CLASS	SCORE	Ground Conditions	Recommendation	Backfill	Colour coding	Typical Material Description
CLASS	**SCORE**	**LEGEND**	**RECOMMENDA**	**BACKFILL**		
1	**<9**	**Ground conditions beneath topsoil are unlikely to cause corrosion to iron**	**Special protection probably not required, unless the ground is clay or peat or likely to contain saline water (estuarine or marine) if so see class 3.**	**Do not use peat or salty materials for backfill. Only use clay materials if they do not contain sulphide or sulphate crystals or are of low pH**	**Yellow**	**Most rocks e.g. sandstone, limestone, chalk, igneous and metamorphic rocks, boulders, cobbles, gravel, sand and silt**
2	**9 - 11**	**Ground conditions beneath topsoil may cause corrosion to iron**	**Special protection probably required if materials at site are clay, peat or likely to contain saline water (estuarine or marine). If so see class 3** **Do not use peat or salty materials for backfill. Only use clay materials if they do not contain sulphide or sulphate crystals or are of low pH**	**Do not use peat or salty materials for backfill. Only use clay materials if they do not contain sulphide or sulphate crystals or are of low pH**	**Green**	**Mostly 'clays' and mudstones with relatively low clay size content and do not contain iron sulphide or calcium sulphate.**
3	**>11**	**Ground conditions beneath**	**Special protection**	**Do not use peat or salty**	**Blue**	**A variety of material types depending on the**

		topsoil are likely to cause corrosion to iron	**probably required if materials at site are clay, mudstone, peat or likely to contain saline water (estuarine or marine). If so, further ground investigation is required to assess whether the hazard exists.** **Do not use peat or salty materials for backfill. Only use clay materials if they do not contain sulphide or sulphate crystals or are of low pH**	**materials for backfill. Only use clay materials if they do not contain sulphide or sulphate crystals or are of low pH**		**lithostratigraphical classification** **The following indicate corrosivity hazard:** **i) Grey to black clay, brown near surface. May be mudstone at depth. May contain white or translucent 'soft' crystals (gypsum) at a few metres depth.** **ii) Red clay or mudstone, may contain white or translucent 'soft' crystals (gypsum) at a few metres depth** **iii) Peat.** **iv) Contains saline water**

3.3 DATASET HISTORY

This is the first version of the BGS Corrosivity (Ferrous) dataset. BGS is continually surveying and resurveying, extending, improving and updating the geological maps and databases.

Version 1 (released 2012): Derived from BGS Parent Material Map version 1. More details on this product can be found at this website http://www.bgs.ac.uk/products/onshore/soilPMM.html.

3.4 COVERAGE

The map covers all of the Great Britain at 1:50 000 scale including the Isle of Man

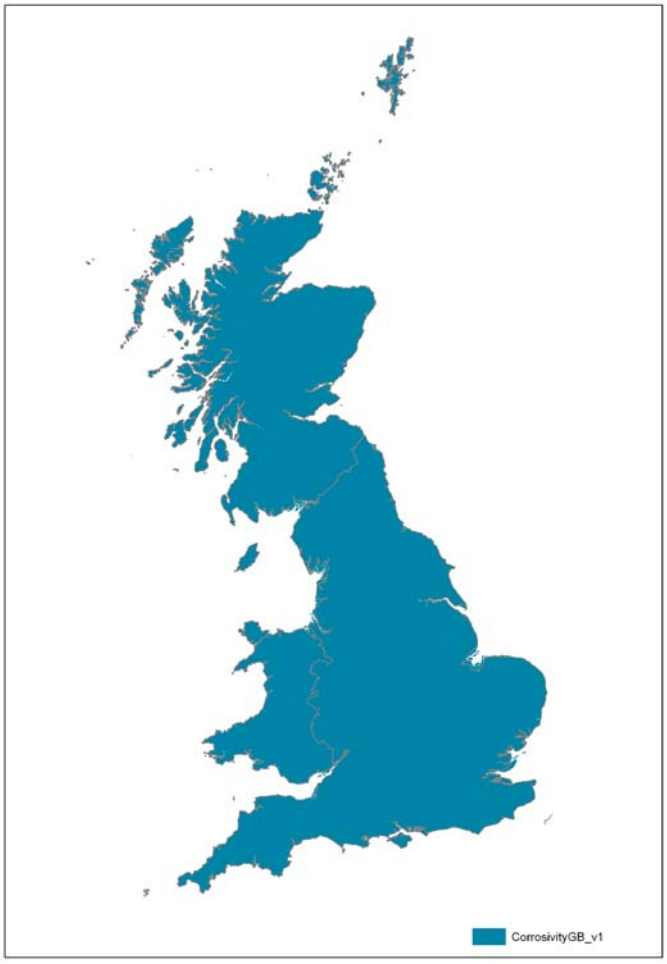

Figure 1. Corrosivity dataset showing extent of coverage

3.5 DATA FORMAT

The Corrosivity dataset has been created as vector polygons and are available in a range of GIS formats, including ArcGIS (.shp) and MapInfo (.tab). More specialised formats could be made available but may incur additional processing costs.

3.6 LIMITATIONS

- The Corrosivity dataset has been developed at 1:50 000 scale and must not be used at larger scales. All spatial searches against the data should be conducted using a minimum 50 m buffer.
- The Corrosivity dataset is based on, and limited to, an interpretation of British Geological Survey records at the time the data set was created.
- The 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 could be made available but may incur additional processing costs.
- The Corrosivity dataset is based on the general corrosive properties likely to be associated with different soil-parent materials. It does not take into account local conditions such as the depth and change of water table or the effects of topography on the variables. Soil moisture content, for example, would be expected to be higher in valleys. It is therefore recommended that users consider local conditions.
- The Corrosivity dataset is concerned with 'aggressive soils' related to *natural* geological conditions only. It does NOT cover any man-made hazards, such as contaminated land or mining.

- The Corrosivity dataset score is based on the properties of the geological formation that is likely to be found at the surface at any particular location and does not consider geology at depth.

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