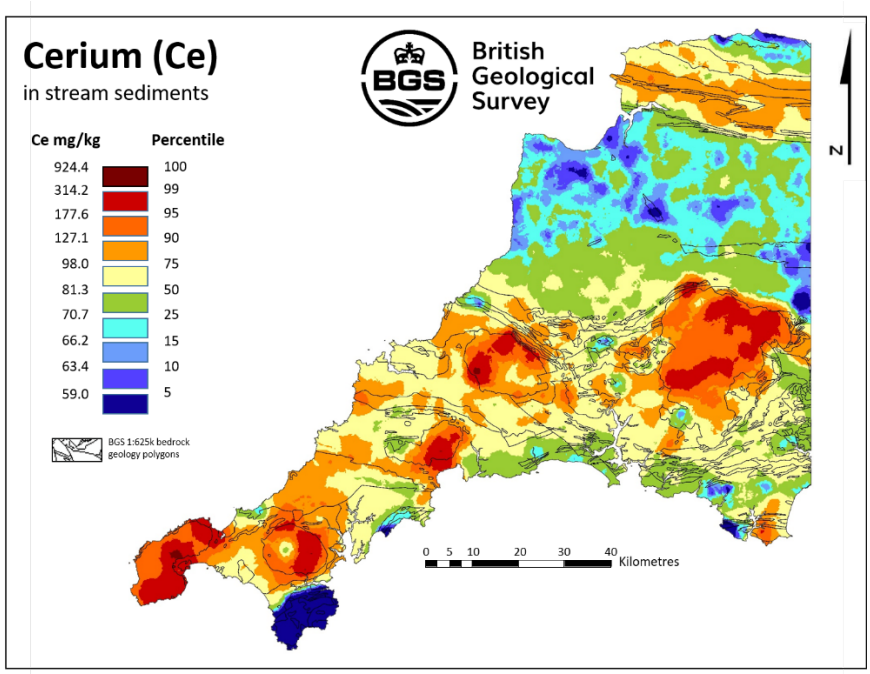
British Geological Survey

South-West England Rare Earth Elements (REE) Stream Sediment Dataset User Guide

Digital Geoscience

Open Report OR/19/050



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SW England Rare Earth Elements (REE) Stream Sediment Dataset User Guide

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Foreword

This report is a User Guide to accompany the British Geological Survey (BGS) South West (SW) England Rare Earth Elements (REE) Stream Sediment Dataset. Between 2002 - 2013, 3378 stream sediment samples were collected from parts of the counties of Somerset and Devon, and the entire county of Cornwall, in SW England as part of the BGS's Geochemical Baseline Survey of the Environment (G-BASE) project. Following collection, chemical analysis was funded by the BGS's TELLUS SW programme to determine the REE content in the samples. This report describes the methods used to publish the chemical data as a suite of ASCII grids. Colour enhanced interpolated geochemical maps showing the concentrations of REE in stream sediment across SW England have been generated from the dataset also, and may be downloaded via the BGS OpenGeoscience web page.

Acknowledgements

In addition to the BGS report authors, a large number of individuals have contributed to the G-BASE project. The endeavours of all the voluntary workers who collected samples, often in extremes of weather are greatly appreciated, as are those of BGS staff who spent time planning and managing the field teams.

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Summary

This report describes how 3378 stream sediment samples collected between 2002 and 2013 across SW England by the BGS G-BASE project were analysed to determine the total concentration of 16 rare earth elements (REE)by inductively-coupled mass spectrometry (ICP-MS) and x-ray fluorescence spectrometry (XRFS). It documents the methods used to process and display the resultant chemical data.

The analytical results were used to create a series of raster (ASCII format) grids and interpolated geochemical maps (PNG images) showing the distribution of REE across SW England.

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. Our client base is drawn from the public and private sectors both in the UK and internationally.

Our innovative digital data products aim to help describe the ground surface and what's beneath 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. These data, coupled with our in-house Geoscientific knowledge, are combined to provide products relevant to a wide range of users in central and local government, insurance and housing industry, engineering and environmental business, and the British public.

Between 2002 and 2013, systematic geochemical mapping was carried out in SW England by the BGS Geochemical Baseline Survey of the Environment (G-BASE) project. As part of this programme of work, stream sediments were collected and subsequently underwent chemical analysis. The results of these analyses, funded by the BGS TELLUS SW programme, form the source data for this product.

The G-BASE project aimed to conduct a national geochemical survey of Great Britain to improve understanding of our geology and the surface environment, providing quantitative evidence against which future environmental change can be gauged.

Throughout the lifetime of the G-BASE project, strict quality control procedures have been in place at all stages from sample collection to analytical data reporting. Analytical data have been closely monitored to ensure continuity across field campaigns and between different analytical methods. All data have been conditioned with respect to primary reference materials to provide both accurate and precise element concentrations with a high degree of confidence.

This product presents maps showing the total concentrations of 16 rare earth elements (REE) determined in the SW England stream sediment dataset.

REE are naturally occurring chemical elements that are found in a wide range of geological environments. They are a group of chemically similar metallic elements that are of increasing interest because they have a variety of applications in a diverse range of consumer electronics (including mobile phones), environmental technologies (including batteries and wind turbines) and industrial applications.

2 About the SW England REE dataset

This dataset comprises the publication of raster maps in ASCII grid format showing the predicted concentrations of 16 rare earth elements (REE) measured in stream sediment samples collected across SW England.

The dataset supplements the previously released “G-BASE for SW England” (http://www.bgs.ac.uk/gbase/gbaseSW.html#dataDownload) dataset and geochemical maps, by providing data for an extended range of chemical elements.

The stream sediment samples were collected from first and second order streams i.e. small tributaries that flow into and ‘feed’ larger streams, but do not often have smaller streams flowing into them. Samples were collected at an average sample density of 1 sample per 2.2km^2. Chemical analysis was carried out on the <150µm fraction of the collected sample.

Details of the sampling methodology can be found in the GBASE Field Procedures Manual. 2005 G-BASE field procedures manual - NERC Open Research Archive ([1]Johnson, C. 2005).

Raster grids for the REE La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu and Y have been prepared using data generated by lithium borate fusion followed by inductively coupled plasma-mass spectrometry (ICP-MS) analysis of 3378 stream sediment samples. For Sc, the data were generated by X-ray fluorescence spectrometry (XRFS). Table 1 shows the lower limits of detection (LLD) reported during the analysis. Whilst not part of the lanthanides (La – Lu), Sc and Y are considered to be REE as they often occur in association with the lanthanides and exhibit similar chemical properties.

This product represents the first release of analytical results for the REE from the G-BASE stream sediment dataset for Great Britain. The raster (ASCII) grids can be downloaded from http://www.bgs.ac.uk/opengeoscience/downloads.html

Table 1 Summary of elements presented in the SW England REE dataset

Element		Method	Lower Limit of Detection
Symbol	Name	Analytical method	mg/kg
La	Lanthanum	ICP-MS	0.10
Ce	Cerium	ICP-MS	0.10
Pr	Praseodymium	ICP-MS	0.02
Nd	Neodymium	ICP-MS	0.30
Sm	Samarium	ICP-MS	0.05
Eu	Europium	ICP-MS	0.02
Gd	Gadolinium	ICP-MS	0.05
Tb	Terbium	ICP-MS	0.01
Dy	Dysprosium	ICP-MS	0.05
Ho	Holmium	ICP-MS	0.02
Er	Erbium	ICP-MS	0.03
Tm	Thulium	ICP-MS	0.01
Yb	Ytterbium	ICP-MS	0.05
Lu	Lutetium	ICP-MS	0.01
Sc	Scandium	XRFS	3.00
Y	Yttrium	ICP-MS	0.10

The data were subject to stringent quality assurance procedures prior to creation of the ASCII grids. ArcGIS 10.3.1. was used to construct and populate the grids.

3 Technical Information

3.1 DEFINITIONS

The following definitions apply to the SW England REE stream sediment dataset:

ORDINARY KRIGING: The interpolation method used was ordinary kriging. This geostatistical method attempts to provide optimal unbiased predictions according to the spatial autocorrelation of the input data. The input data are the point-sampled element concentrations.

SPATIAL AUTOCORRELATION: The degree to which a variable e.g. element concentration correlates with itself through space. In nature, as stated in Tobler's first law of geography – "everything is related to everything else, but near things are more related than distant things" ([2]Tobler, W R. 1970). Ordinary kriging constructs a model of how this autocorrelation varies with distance, it uses the results to calculate optimal predictions. The spatial correlation is quantified by calculating a variogram for each element presented.

CONCENTRATION: The proportion of a material, by weight, a particular element occupies. Reported here in mg/kg (equivalent to parts per million (ppm)).

STANDARD DEVIATION: A measure of the variation or dispersion of a set of data values. These provide an indication of the uncertainty associated with the predicted concentration value for each grid cell.

3.2 SCALE

The SW England REE stream sediment dataset provides geochemical predictions on a regular 200 x 200m grid: each cell represents 0.04km^2.

3.3 FILE DESCRIPTIONS

The SW England REE stream sediment dataset contains two sets of ASCII grids (concentrations and uncertainty) and a CSV colour table for each element. Table 2 contains details of the contents of each file type.

Table 2 File Descriptions

File Name	File Type	Description
*Element_symbol*_concentration.asc	ASCII raster grid containing floating point	Predicted median concentration of the element in stream sediments within the grid cell. Units are mg/kg.
*Element_symbol*_uncertainty.asc	ASCII raster grid containing floating point	Predicted standard error of the element's concentration in stream sediments within the grid cell. An indication of the uncertainty associated with the prediction
*Element_symbol*_concentration_ colour_table.csv	CSV table	Table showing the concentration ranges and colours required to apply the standard BGS 'GBASE' colour scheme. The scheme uses percentiles based on the input point samples values, **not** the interpolated grid. As a result, the min and max values for each class may not occur in the interpolated grid. Colours are provided as both HEX and RGB

4 Grid Creation

To convert the point source data to continuous surface geochemical maps, grids were created in ArcGIS using the Geostatistical Wizard within Geostatistical Analyst, using ordinary kriging. As the data were not normally distributed, it was necessary to apply a log-transformation as part of the grid generation process. Prior to output, the data were back-transformed to the original data

units then exported as a raster grid. An exponential semivariogram model was generated for each element.

Ordinary kriging makes use of a variogram – a model of the spatial autocorrelation within the data – in order to optimise the weights given to surrounding sample points when interpolating concentrations to new locations (in this case the cell centres of the output grid).

During ordinary kriging, all default parameters were accepted with the exception of number of nearest neighbours included. This was set as 7 for all elements in order to retain short-scale geochemical variation evident in the raw data. For more technical detail on grid creation, the user may refer to the following document; http://www.bgs.ac.uk/downloads/start.cfm?id=3125 ([3]Kirkwood et al. 2016).

5 Spatial Coverage

The dataset covers parts of the counties of Somerset and Devon, and the entire county of Cornwall, in SW England (Figure 1).

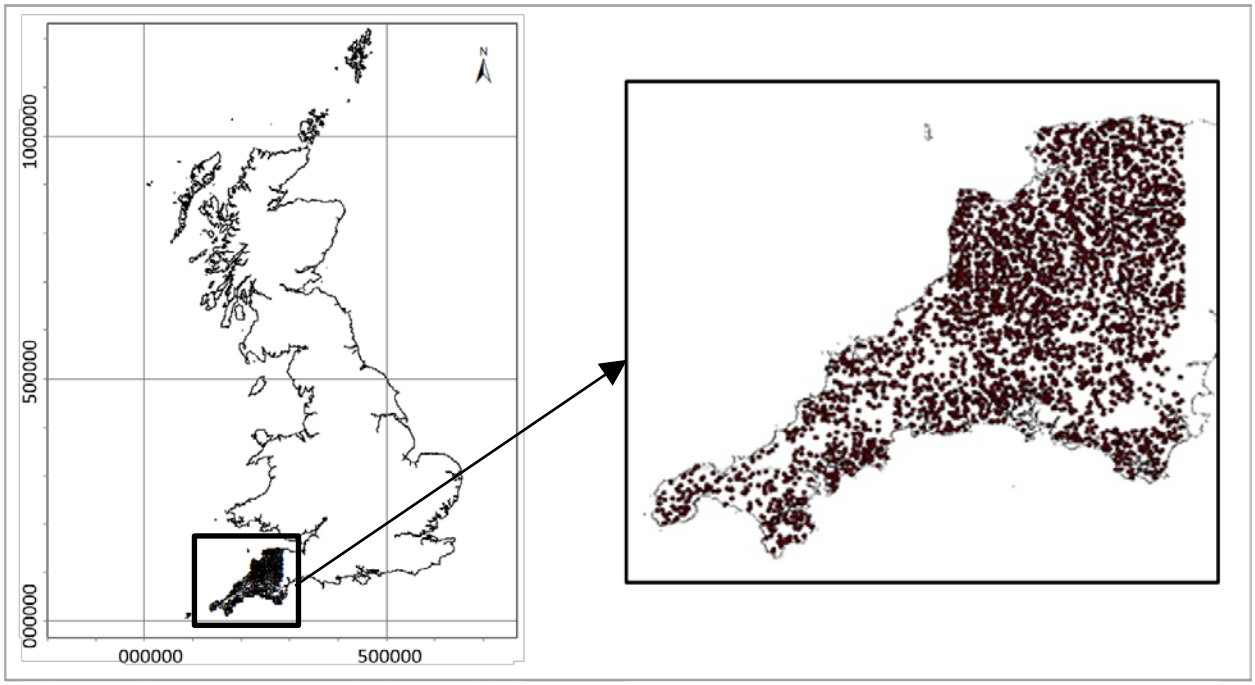

Figure 1 Spatial distribution of samples included in the SW England REE dataset.

6 Data Format

6.1 ASCII GRIDS

The SW England REE stream sediment dataset has been created as a series of ASCII raster grids. Figure 2 shows examples of the format of the grids, which default to greyscale when loading.

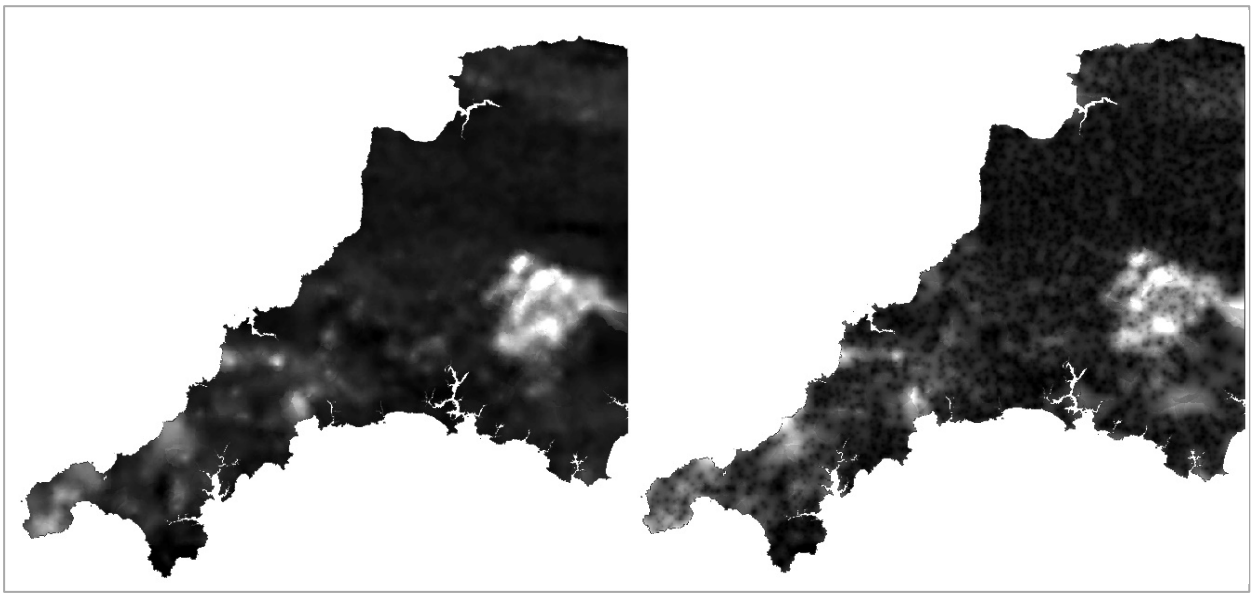

Figure 2 ASCII raster grid of
(a) Element concentrations (b) Element uncertainty

More specialised digital formats may be provided to the end-user on request, however, these may incur additional processing costs.

6.2 PORTABLE NETWORK GRAPHIC (PNG) IMAGES

A series of high-resolution PNG images have also been created for download via the BGS OpenGeoscience web page. http://www.bgs.ac.uk/opengeoscience/downloads.html

Each image illustrates the interpolated data for a single element, showing the distribution of that element in stream sediment across SW England. The maps are coloured using a colour percentile-class bin scale, an example is shown in Figure 3.

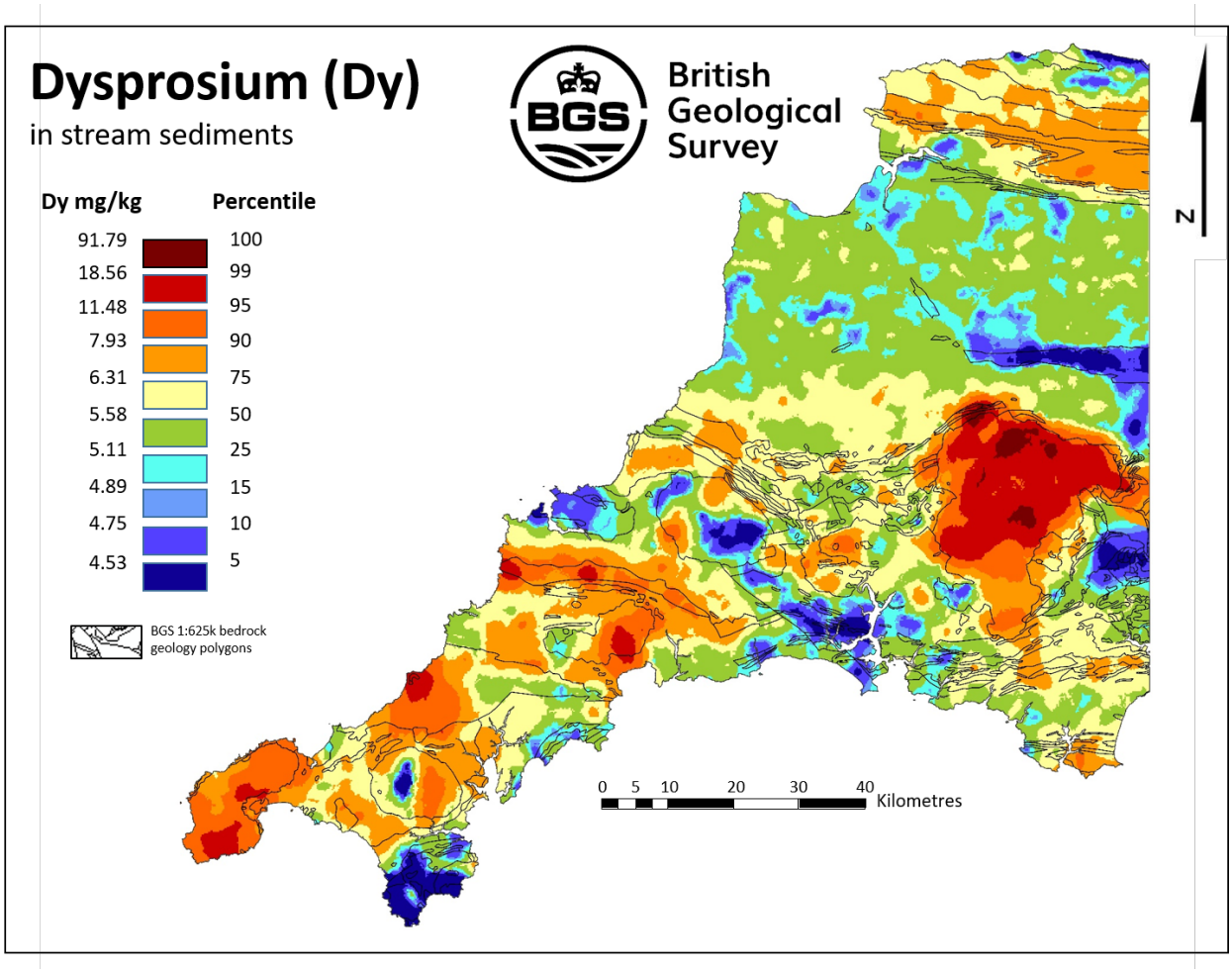

Figure 3 Example of interpolated geochemical stream sediment map (Dysprosium) for SW England (PNG image)

7 Licensing Information

To encourage the use and re-use of this dataset we have made it available under the Open Government Licence (www.nationalarchives.gov.uk/doc/open-government-licence/version/3/), subject to the following acknowledgement accompanying the reproduced BGS materials: "Contains British Geological Survey materials ©UKRI [2020]".

The Open Government Licence is a simple and straightforward licence that allows anyone - businesses, individuals, charities and community groups - to re-use public sector information without having to pay or get permission.

8 Limitations

Limitations to consider when using the SW England REE stream sediment dataset:

- Each grid or map consists only of predictions generated by a geostatistical model (based on a sample density of 1 to 2.2km^2) and does not display absolute measurements.
- Data should **not** be used at a resolution higher than the original 200 x 200m grid.

- Data are based on, and limited to, an interpretation of the G-BASE records in the possession of British Geological Survey at the time the interpretation was carried out.
- This dataset utilises only analytical data derived from the analysis of stream sediment material.

References

The 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: https://envirolib.apps.nerc.ac.uk/olibcgi.

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