British Geological Survey

UK Mineral Waste Factsheets

Decarbonisation and Resource Management programme
Open report OR/24/040

BRITISH GEOLOGICAL SURVEY

DECARBONISATION AND RESOURCE MANAGEMENT PROGRAMME
OPEN REPORT OR/24/040

UK Mineral Waste Factsheets

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Front cover

Bantycock quarry, a gypsum mine near Newark, Nottinghamshire. Photo by Clive Mitchell © UKRI used with permission of Saint-Gobain Formula.

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Foreword

Transforming the Foundation Industries Research and Innovation Hub, referred hereinafter as TransFIRe, was a research consortium of academic institutions, industry partners, NGOs and government organisations that aimed to develop innovative technology to reduce energy and resource use within the foundation industries. These industries include cement, glass, ceramics, paper, metals and bulk chemicals sectors. This consortium was funded by UKRI under the Industrial Strategy Challenge Fund (ISCF) Transforming Foundation Industries (TFI) challenge. This report is published by the British Geological Survey addressing TransFIRe Workstream 2 'Where there's muck there's brass – creating new materials and process opportunities'. The report describes mineral waste produced in the United Kingdom, in terms of mineral waste locations, geological context, mineralogical, chemical and particle size data to encourage discussion on the utilisation and adoption of mineral wastes in the foundation industries.

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Without the support of the UK Minerals Industry, the samples forming the basis of this report and characterisation of UK mineral waste would not be possible. Therefore, the authors would like to thank the staff of the following companies and associations for their assistance in sharing mineral waste samples and operations knowledge:

- Breedon
- British Gypsum
- IMERYS Minerals Limited
- Lochaline Quartz Sands Limited
- McQuillen Quarries
- Mineral Products Association
- MI-SWACO
- Northstone Materials
- Fluorsid
- Hygrove Aggregates
- Omya UK Limited
- Saint-Gobain Formula
- Schlumberger Oilfield UK Limited
- Sibelco UK Limited
- Tarmac
- Tungsten West

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Summary

Minerals and the metals and materials derived from them are essential for our modern society. Critical minerals are required for the tools and technologies to enable the decarbonisation of the global economy. Industrial minerals are vital for supplying raw materials to industrial sectors. Construction aggregates are essential for supplying construction materials for infrastructure and housing projects. Despite commitments to increase resource and energy efficiency, reduce mineral waste and better manage mineral waste storage sites, mineral operations will inevitably produce mineral waste. Mineral waste is produced as either a product of removing topsoil, overburden or interburden to access the target economic mineral or as a by- or waste-product of mineral processing. Mineral waste is typically stored in containment areas (piles or tips) ready to infill an exhausted working, discarded and managed in tailings ponds or lagoons, or sold to the construction industry for use as a construction material with a wide variety of applications.

Significant quantities of mineral products produced by the UK minerals industry are consumed by the UK Foundation Industries (FI) (Mitchell et al., 2023). These FI consist of six main sectors: cement, glass, ceramics, papers, metals and bulk chemicals. UK FI collectively produce 75 % of all materials in the UK and generate an annual Gross Value Added (GVA) of approximately £52 billion to the UK economy (TransFIRe, 2024). However, these FIs also contribute approximately 10 % of the UK's CO_2 emissions (Hafez et al., 2024, TransFIRe, 2024). The UK FI face challenges including increasing the utilisation of waste materials thereby reducing waste production, minimising resource consumption, lowering energy usage and reducing emissions (TransFIRe, 2024). These challenges form the basis of the research produced by the TransFIRe hub (2021–2024), a research consortium of academia, industry partners, NGOs and government organisations that aim to develop innovative technology to reduce energy and resource use within the foundation industries.

As a part of the research project, the British Geological Survey aimed to characterise the composition and production of mineral waste, thereby providing data for Foundation Industries to consider the potential for mineral waste as a raw material in their production processes. The BGS has produced a method to estimate approximate mineral waste production in the UK based on waste-to-product ratios and UK mineral production statistics in the absence of available higher resolution data (Mitchell et al., 2023). This attainable methodology, providing mineral production and waste-to-product ratio data are available, could be used as a basis for estimating mineral waste production in any other nation and provides a dialogue for mineral waste utilisation in the global economy.

Sample characterisation data have been used to generate 24 factsheets covering mineral waste from operations extracting, or having recently extracted, the following commodities: ball clay, barytes, chalk, fluorspar, gritstone, high specification aggregate (HSA), kaolin, limestone, sand and gravel, silica sand and tungsten. Samples were characterised based on their mineralogical (XRD), chemical (XRF) and particle size distribution (wet-sieving and Sedigraph) properties. The data presented in this technical report provide preliminary data for the Foundation Industries, nationally and internationally, to evaluate mineral waste utilisation in industrial production as national and global economies transition to a circular economy.

1 Introduction

Minerals and the metals and materials derived from them are essential for our modern society. Critical minerals are required for the tools and technologies to enable the decarbonisation of the global economy. Industrial minerals are vital for supplying raw materials to industrial sectors. Construction aggregates are essential for supplying construction materials for infrastructure and housing projects. Despite commitments to increase resource and energy efficiency, reduce mineral waste and better manage mineral waste storage sites, mineral operations will inevitably produce mineral waste. Mineral waste has been a BGS focus since the 1990s, where the need for mineral waste research was driven by themes including the recognition that mineral resources are finite, environmental protection and the threat of global warming (Mitchell et al., 2023).

As part of the TransFIRe research project (2021–2024), the core research themes addressing mineral waste include resource efficiency, regulations to control the impact of mineral operations, industrial decarbonisation and security of supply of mineral resources vital for UK industries. As a result of the research carried out, the BGS has gained a better understanding of the composition and production of mineral waste in the UK, outlined in the subsequent sections of this report.

2 Background

2.1 FOUNDATION INDUSTRIES

The Foundation Industries (FI) are vital components of the UK industrial manufacturing sector. FI collectively produce 75 % of all materials in the UK, contributing around 10 % of the UK's carbon dioxide emissions and generate an annual Gross Value Added (GVA) of approximately £52 billion (Hafez et al., 2024, TransFIRe, 2024). UK FI consist of six main sectors: cement, glass, ceramics, paper, metals and bulk chemicals. These FI require significant quantities of mineral products, often with each sector consuming multiple products from the UK mineral industry (Mitchell et al., 2023). Despite utilising products from multiple sources in the UK mineral industry, UK FI face challenges including increasing the utilisation of waste materials thereby reducing waste production, minimising resource consumption, lowering energy usage and reducing emissions (TransFIRe, 2024).

2.2 MINERAL WASTE

2.2.1 Definition

The Environmental Permitting Guidance for the Mining Waste Directive by DEFRA (2010) states that Article 1(1)(a) of the Waste Frame Directive (European Parliment, 2006) defines 'waste' as "…any substance or object…which the holder discards or intends or is required to discard" (Department for Environment Food and Rural Affairs, 2010). This document further classifies types of extractive waste as inert, non-hazardous non-inert and hazardous (Department for Environment Food and Rural Affairs, 2010). This is echoed by further guidance from DEFRA (2012) in 'Guidance on the legal definition of waste and its application' withdrawn on 30th March 2023, within which item G3.1 states the same waste definition (Department for Environment Food and Rural Affairs, 2012).

For the context of the TransFIRe research project and this report, mineral waste is considered to be defined as all material that is extracted by a mineral operation and remains unsold (Mitchell et al., 2023). This includes material from the topsoil, overburden, interburden and discarded material from mineral processing.

2.2.2 Background

Despite commitments to increase resource and energy efficiency, reduce mineral waste production and better manage mineral operation and mineral waste storage sites, inevitably all operations will produce mineral waste. Waste is produced by multiple processes by the mineral extraction industry including:

- **Quarry blasting** produces fines that are typically retained for quarry site design and site rehabilitation. Quarry blasting is a fine balance between fragmenting enough reserve to generate large broken rock fragments, but not too little fragmentation to incur greater processing costs, or too much fragmentation to generate excess fines (Mitchell, 2009).
- **Material specification and mineral processing** ultimately drives the required processing route to produce products to a required specification by removing

mineral impurities and other undesirable materials and creating products of required particle size specification. For construction aggregates operations, this can involve size reduction (crushing) and separation into products (screening) at various particle sizes. Industrial minerals may be further processed including grinding, solid-liquid separation and flotation to further refine the specified product. Metalliferous mineral extraction fundamentally produces a mineral concentrate via crushing, grinding and beneficiating ore.

- **Site characteristics** including significant quantities of topsoil, overburden and interburden and gangue to be removed to access the target mineral or ore. At Bantycock gypsum mine operated by Saint-Gobian Formula, large volumes of overburden and interburden are removed to extract high purity seams of gypsum and anhydrite. Topsoil, overburden and interburden are stockpiled ready to back-cast into the exhausted cut. This gypsum working is an exception compared to other gypsum mines that produce far less mineral waste. The Bantycock mine is estimated to have a waste-to-product ratio up to 17:1 based on total excavation depth (50 m) and total thickness of worked gypsum seams (2.9 m) (Worley and Reeves, 2007).

UK mineral waste is stored in containment areas or piles (tips) and water-containing suspended materials may be discharged into tailings ponds or lagoons.

2.2.3 UK mineral waste production

Due to a lack of publicly available data on mineral waste production in the UK, one viable estimation method to calculate the amount of mineral waste produced in the UK is to apply waste to product ratios to UK mineral production statistics. For example, a waste to product ratio of 1:9 is used for sand and gravel operations (i.e. 10 % of the material extracted ends up as waste). The mineral waste ratios below are derived from UK mineral operator consultation, BGS research projects and the UK Minerals Forum. These ratios are published in Mitchell et al. (2023). UK mineral production data is from the UK Minerals Yearbook (Bide et al., 2024). As shown in the table below, in 2022 it was estimated that 43 million tonnes of mineral waste was produced in the UK based on a total UK mineral production of 203 million tonnes.

Table 1. Estimate of mineral waste production in the UK based on 2022 mineral production data and waste to product ratios. Waste to product ratios were determined by industry consultation and expert knowledge and are not calculated from mineral and mineral waste production statistics for 2022.

Mineral Product	Mineral production (Thousand tonnes)	Mineral waste (Thousand tonnes)	Waste:Product ratio
Ball clay	1 040	1 560	1.5:1
Barytes	30	1	1:21
Chalk, dolomite, igneous rock, limestone, sandstone and slate	126 474	14 053	1:9
Clay and shale	4 004	1 335	1:3
Coal deep mined	63	21	1:3
Coal open cast	651	9 765	15:1
Fireclay	0	0	0:1
Fluorspar	13	26	2:1
Gypsum	2 400	0	0:1
Kaolin	709	6 381	9:1
Polyhalite	953	2 383	2.5:1
Rock Salt	2 588	0	0:1
Sand and gravel	59 024	6 558	1:9
Silica sand	4 931	986	1:5
Talc	3	3	1:1
Total	**202 883**	**43 072**	

2.2.4 BGS Mineral Waste Research & TransFIRe

The BGS Minerals department has a long history of investigating the resource potential of mineral waste nationally and internationally with a wide range of publications on this topic (Colman et al., 2006, Harrison et al., 2002, Mitchell et al., 2023, Mitchell et al., 2001, Mitchell, 2009, Palumbo-Roe and Colman, 2010). However, since the 1990s, research focus on mineral waste in order to reduce consumption of finite resources, better protect the environment, and mitigate the impacts of global warming has morphed to address pertinent topics including:

- security of raw material supply
- resource efficiency and the circular economy
- impact reduction of mineral operations
- industrial decarbonisation (Mitchell et al., 2023).

However, information relating to the technical quality of mineral waste, as well as production of UK mineral waste, is either not readily available nor in the public domain. The BGS, as part of the TransFIRe research project (2021–2024), aimed to discover the hidden value of mineral waste by better understanding the composition and production of mineral waste (TransFIRe, 2024). Thereby assisting to determine potential applications for FI to investigate mineral waste adoption at larger volumes than typically consumed by the construction industry, such as construction filler (TransFIRe, 2024). If suitable for one or more of the FI, large volume consumption of mineral waste has the potential to:

- reduce reliance on foreign exports and therefore increase security of supply
- present economic opportunities to mineral operators and in turn reduce the volume of mineral waste to manage
- reduce the net carbon dioxide emissions of the FI by increasing resource efficiency and reducing the amount of finite resource extracted.

3 Conclusion

Results of the chemical, mineralogical and particle size analysis are presented as UK mineral waste factsheets in Appendix 1. The sample characterisation analytical methodology is described in Appendix 2. Twenty-four factsheets have been generated for mineral waste from operations extracting, or having recently extracted, the following commodities: ball clay, barytes, chalk, fluorspar, gritstone, high specification aggregate (HSA), kaolin, limestone, sand and gravel, silica sand and tungsten. Current mineral waste production in the UK is subject to commodity market dynamics, it is therefore noted that the Fluorsid operation at the Cavendish Mill and Milldam Mine has been placed under care and maintenance since October 2023 (Great Hucklow Parish Council, 2023) and the Hemerdon tungsten-tin mine, formerly known as Drakelands Mine, ceased operation in October 2018 (Tungsten West, 2025). Therefore, both these operations have ceased production of mineral waste.

These UK mineral waste factsheets, in addition to other mineral waste or equivalent inventories created (Jones, 2025, Jones and Gutiérrez, 2023) map mineral waste currently produced in the UK, and compliment previously reported fine-grained mineral waste characterisation as part of the REFILL project (Mitchell et al., 2001). Details of historic mineral waste characterisation are found below but are not exhaustive for the following sectors: iron and steel (Riley et al., 2020), slate (Oti et al., 2010), coal fly ash (Alberici et al., 2017, Jones et al., 2009), municipal waste (Gutiérrez-Gutiérrez et al., 2015). The mineral waste factsheets presented in this technical report provide the required characterisation data, in addition to the other sources mentioned, for FI to consider designing mineral waste into industrial production processes. Therefore, transitioning away from a linear economy model towards a circular economy.

Appendix 1 UK Mineral Waste Factsheets

A total of 24 sample factsheets have been prepared for mineral waste samples, summarising geological, mineralogical (XRD), chemical (XRF) and particle size data. All XRF results are calibrated except sample MPLY781, which due to analytical issues are not calibrated. The results for MPLY781 should be taken as indicative, rather than quantitative. Particle size data was collected through both wet-sieving and Sedigraph methods. Samples were collected from quarries and mines across the United Kingdom consisting of a variety of sample types, including aggregates, fines, rock samples, tailings, and waste materials. The UK mineral waste factsheets are grouped and classified by primary commodity production. The classification is further detailed in Table 2 below and locations of each sample are presented in Figure 1.

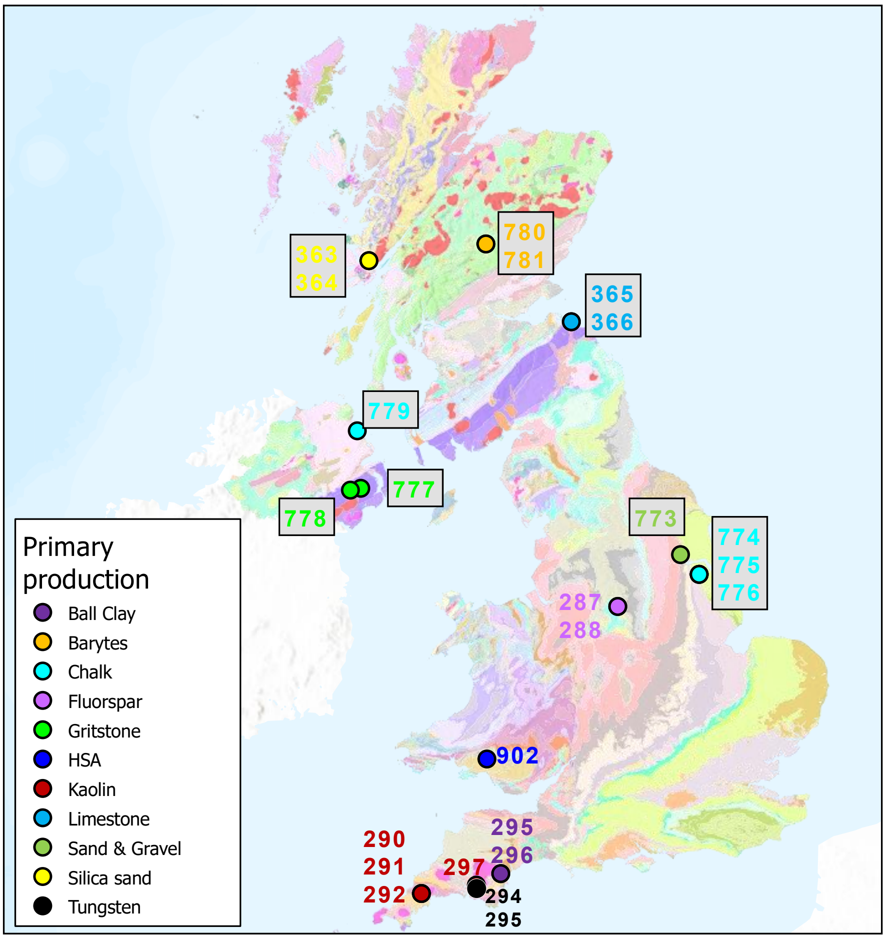


Figure 1. Locations of the UK mineral waste factsheets presented in this document, with coloured numbers relating to the sample number and coloured tab on each factsheet. Sample locations imposed on BGS Bedrock 625k Version 5 data (2008). Contains ESRI, TomTom, Garmin, FAO, NOAA, USGS data © OpenStreetMap Contributors, GIS User Community, ESRI, USGS 2025. Contains BGS Data © UKRI 2025.

Table 2. UK mineral waste factsheets classification.

Primary Commodity	No. of factsheets	Page Numbers	Colour code
Ball Clay	2	9 – 12	
Barytes	2	13 – 16	
Chalk	4	17 – 24	
Fluorspar	2	25 – 28	
Gritstone	2	29 – 32	
High Specification Aggregate	1	33 – 34	
Kaolin	4	35 – 42	
Limestone	2	43 – 46	
Sand & Gravel	1	47 – 48	
Silica sand	2	49 – 52	
Tungsten	2	53 – 56	

Preston Manor Works

Sibelco UK Limited

Location: Preston Manor Works, Devon
Sample Description: Lignite-rich ball clay waste

Primary Production: Ball Clay
Sample Code: MPLY295
Date Sampled: 12/09/2022

GEOLOGICAL CONTEXT

The Bovey Formation is a deposit of sand, clay and lignite. It lies in a sedimentary basin termed the Bovey Basin, which extends from Bovey Tracey to Newton Abbot in South Devon, England. Gravity surveys of the area have recorded a maximum depth of the basin at more than 1 200 m. The deposit was formed from tropical weathering of Carboniferous and Devonian slates and the surrounding granitic uplands into the basin during the lower Tertiary period. Bedding dips generally at 15 degrees to the south-west. The individual beds of ball clay are selectively mined from the deposit as they vary considerably in quality with the main impurities being quartz sand and lignite.

View of black lignite-rich and grey ball clay bands at Southacre Pit, Preston Manor Works, Devon.

SUMMARY OF DATA

Sample MPLY295 from Preston Manor Works is representative of lignite-rich ball clay waste. Mineralogical analysis (X-ray diffraction) indicates that the sample is mainly composed of indistinguishable 'amorphous' material (67.8 wt. %), muscovite (18.0 wt. %) and kaolinite (12.7 wt. %), with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 78.5 wt. % volatiles, 9.7 wt. % SiO_2, 7.9 wt.% Al_2O_3 and a variety of other major oxides below 5 wt. %. The three most abundant trace elements in the sample include barium (134 ppm), zirconium (118 ppm) and vanadium (100 ppm). Most of the sample's mass comprises particles between 10 000 and 100 µm in diameter, although 21.8 % of the sample's mass is finer than 1 µm.

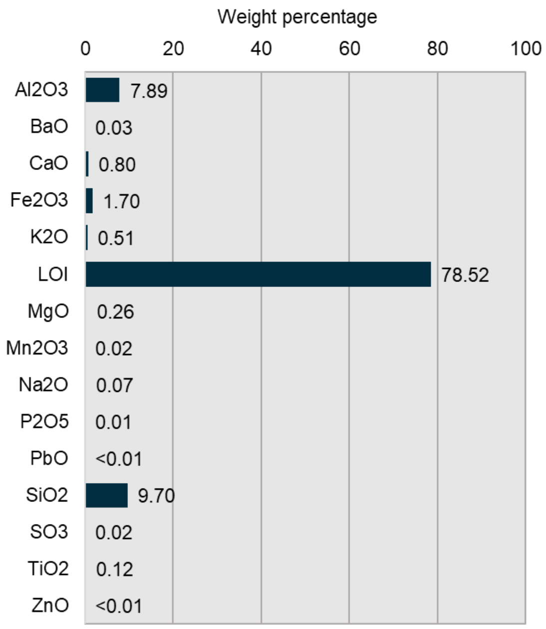
MINERALOGY

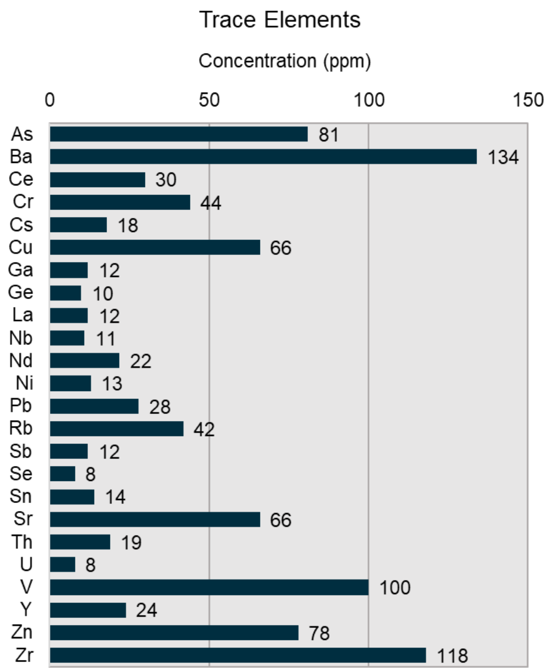
Mineral (wt. %)	MPLY295
Amorphous*	67.8
Calcite	<0.5
Kaolinite	12.7
Microcline	nd
Muscovite	18.0

Mineral (wt. %)	MPLY295
Orthoclase	nd
Pyrite	<0.5
Quartz	1.2
Tourmaline	nd

nd – not detected (concentration below the effective limit of detection).
*Amorphous material content, considering the high volatile content, is likely due to the presence of lignite.

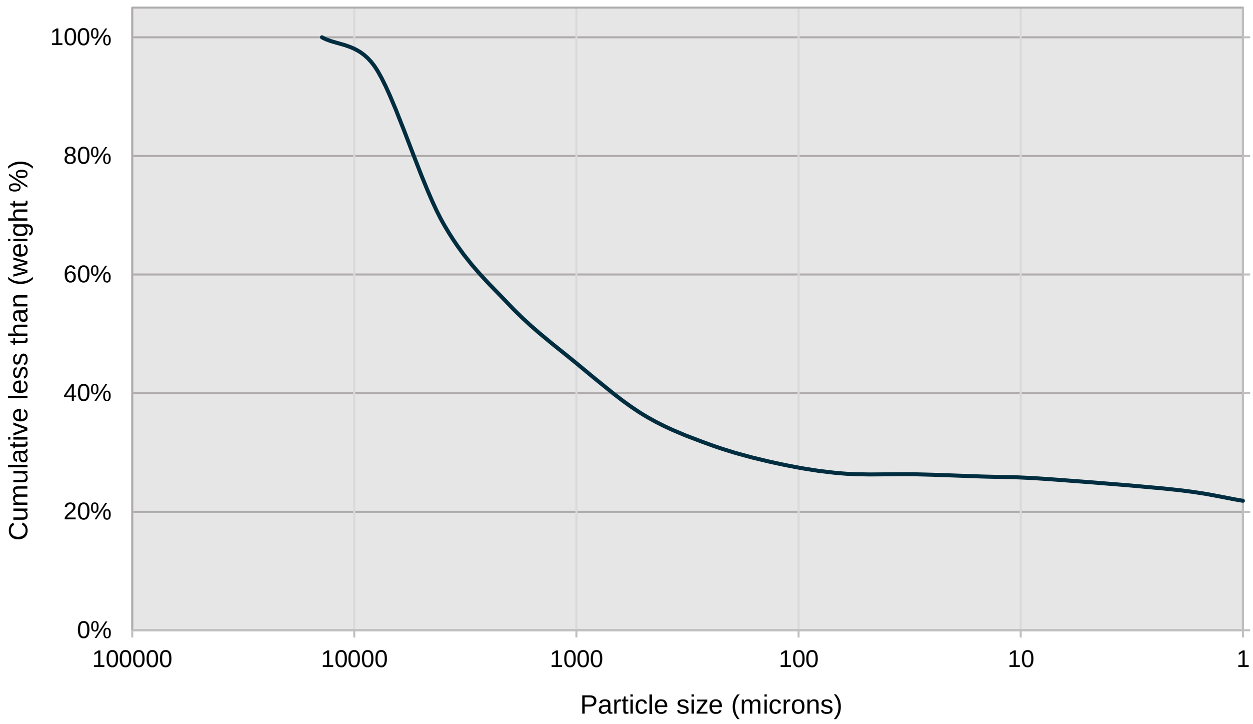
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Preston Manor Works | Sibelco UK Limited

Location: Preston Manor Works, Devon
Sample Description: Silica-rich ball clay waste

Primary Production: Ball Clay
Sample Code: MPLY296
Date Sampled: 12/09/2022

GEOLOGICAL CONTEXT

The Bovey Formation is a deposit of sand, clay and lignite. It lies in a sedimentary basin termed the Bovey Basin, which extends from Bovey Tracey to Newton Abbot in South Devon, England. Gravity surveys of the area have recorded a maximum depth of the basin at more than 1 200 m. The deposit was formed from tropical weathering of Carboniferous and Devonian slates and the surrounding granitic uplands into the basin during the lower Tertiary period. Bedding dips generally at 15 degrees to the south-west. The individual beds of ball clay are selectively mined from the deposit as they vary considerably in quality with the main impurities being quartz sand and lignite.

View of buff silica-rich and pale grey to cream ball clay bands at Southacre Pit, Preston Manor Works, Devon.

SUMMARY OF DATA

Sample MPLY296 from Preston Manor Works is representative of silica-rich ball clay waste. Mineralogical analysis (X-ray diffraction) indicates that the sample is mainly composed of quartz (91.0 wt. %) with a variety of minor minerals below 5 wt. %. This is reflected in the chemical analysis of the sample, which is composed of 83.5 wt. % SiO_2, 8.9 wt. % Al_2O_3 and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include zirconium (676 ppm), tin (101 ppm) and barium (94 ppm). Most of the sample's mass comprises particles between 1 000 and 5 µm in diameter.

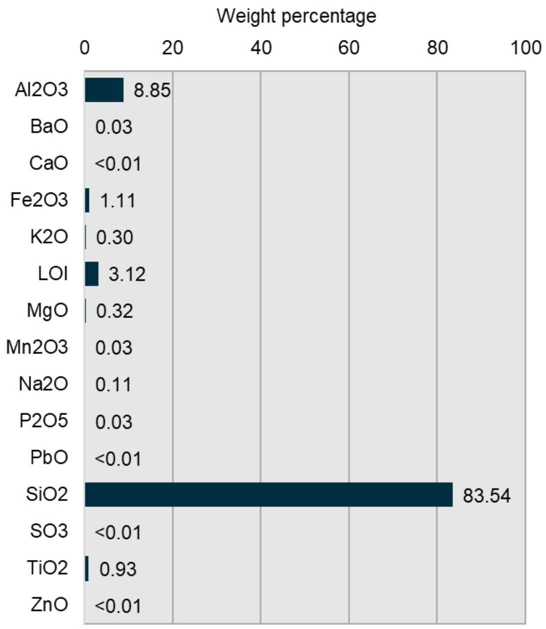
MINERALOGY

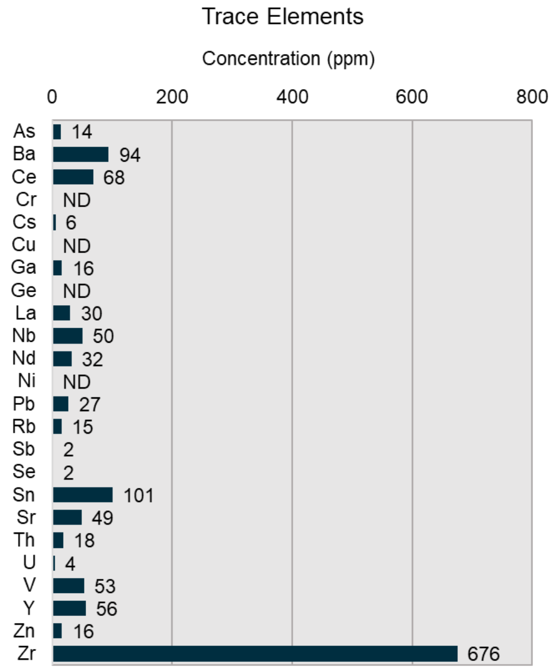
Mineral (wt %)	MPLY296
Amorphous	nd
Calcite	nd
Kaolinite	4.0
Microcline	<0.5
Muscovite	1.0

Mineral (wt %)	MPLY296
Orthoclase	nd
Pyrite	0.6
Quartz	91.0
Tourmaline	3.5

nd – not detected (concentration below the effective limit of detection).

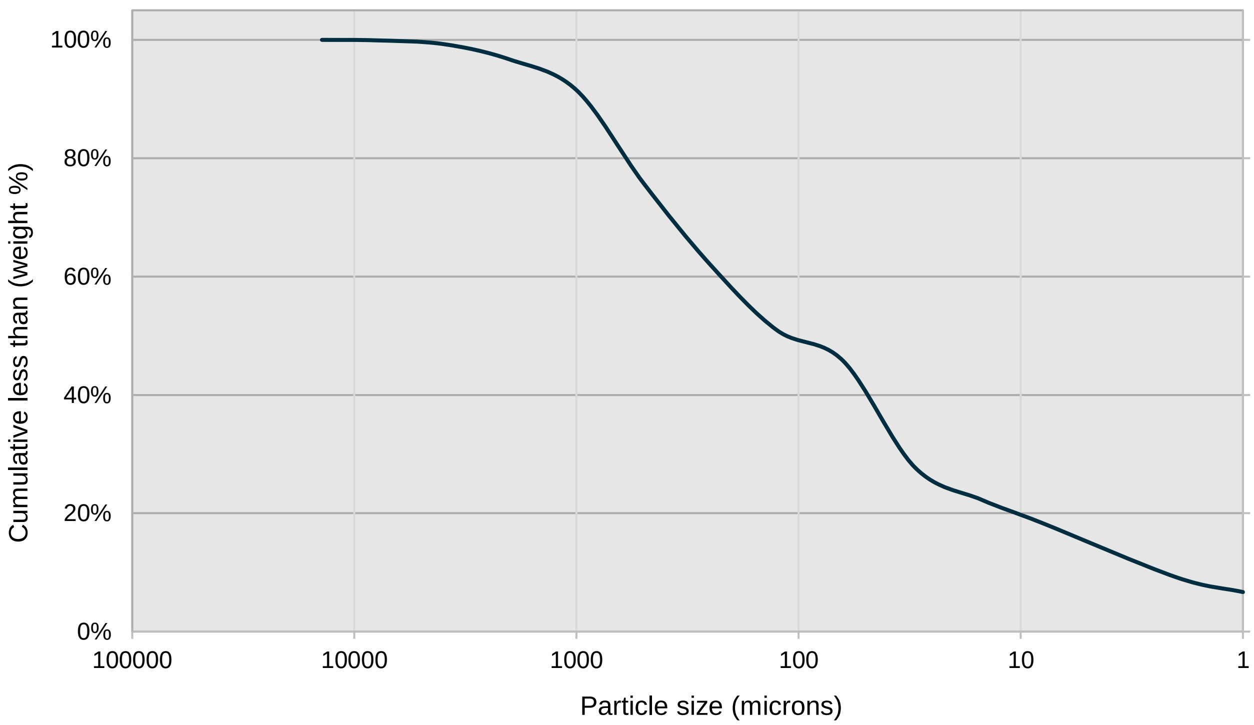
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Duntanlich Mine

Schlumberger Oilfield UK Limited / M-I SWACO

Location: Logierait, Perthshire
Sample Description: Mica-rich mineral waste

Primary Production: Barytes
Sample Code: MPLY780
Date Sampled: 18/04/2023

GEOLOGICAL CONTEXT

Duntanlich mine is located in the Ben Eagach-Duntanlich barytes deposit. The deposit is part of the Neoproterozoic Ben Eagach Schist Formation within the Dalradian Supergroup. It is 5 km along strike from the previously worked Foss mine in the Aberfeldy barytes deposit (which ceased operations in 2021). The deposit mainly comprises graphitic-quartz-muscovite schists. Barytes occurs as granoblastic stratiform beds up to several metres thick within siliciclastic and carbonate metasediments in association with chert, sulphides (mostly pyrite) and graphite. The barytes resource is estimated to be 7.5 million tonnes.

View of graphite-rich material at Duntanlich Mine.

SUMMARY OF DATA

Sample MPLY780 from Duntanlich Mine is representative of mica-rich mineral waste. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of muscovite (61.8 wt. %), quartz (19.3 wt. %) and clinochlore (17.1 wt. %), with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 52.5 wt. % SiO_2, 24.4 wt. % Al_2O_3, 7.1 wt. % K_2O, 5.7 wt. % volatiles and a variety of other major oxides below 5 wt. %. The three most abundant trace elements in the sample include barium (2 200 ppm), zinc (666 ppm) and zirconium (254 ppm).

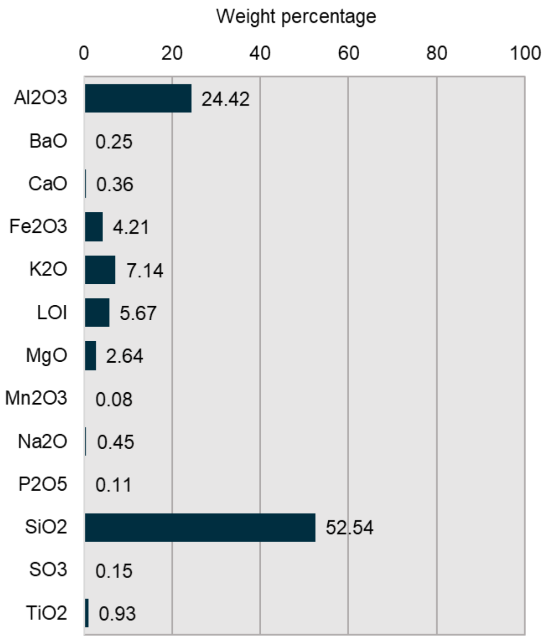
MINERALOGY

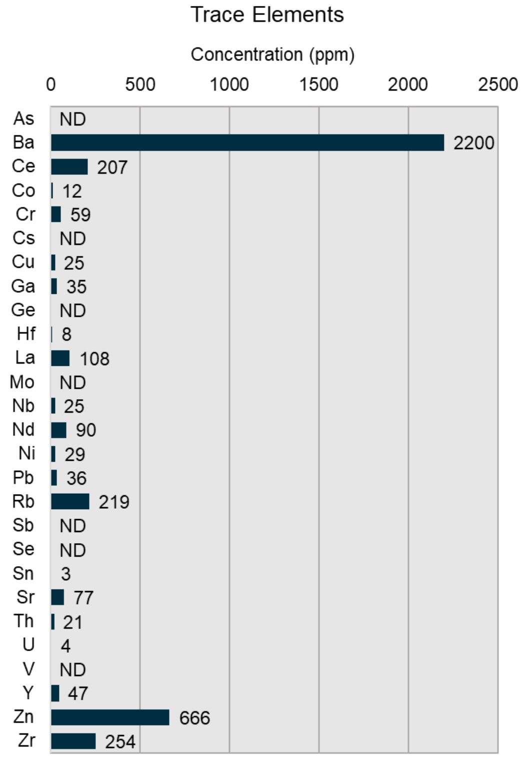
Mineral (wt %)	MPLY780
Albite	<0.5
Baryte	nd
Clinochlore	17.1
Dolomite	0.6
Graphite	<0.5
Kaolinite	<0.5

Mineral (wt %)	MPLY780
Lepidolite?	0.9
Muscovite	61.8
Pyrite	<0.5
Quartz	19.3
Sphalerite	nd

nd – not detected (concentration below the effective limit of detection).

CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION

No particle size distribution data was collected for this material.

Duntanlich Mine

Schlumberger Oilfield UK Limited / M-I SWACO

Location: Logierait, Perthshire
Sample Description: Sulphide-rich mineral waste

Primary Production: Barytes
Sample Code: MPLY781
Date Sampled: 18/04/2023

GEOLOGICAL CONTEXT

Duntanlich mine is located in the Ben Eagach-Duntanlich barytes deposit. The deposit is part of the Neoproterozoic Ben Eagach Schist Formation within the Dalradian Supergroup. It is 5 km along strike from the previously worked Foss mine in the Aberfeldy barytes deposit (which ceased operations in 2021). The deposit mainly comprises graphitic-quartz-muscovite schists. Barytes occurs as granoblastic stratiform beds up to several metres thick within siliciclastic and carbonate metasediments in association with chert, sulphides (mostly pyrite) and graphite. The barytes resource is estimated to be 7.5 million tonnes.

View of sulphide-rich material, below the red marker, at Duntanlich Mine.

SUMMARY OF DATA

Sample MPLY781 from Duntanlich Mine is representative of sulphide-rich mineral waste. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of pyrite (99.2 wt. %), with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 44.8 wt. % SO_3, 18.4 wt. % Fe_2O_3 and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include barium (3 090 ppm), neodymium (431 ppm) and cobalt (378 ppm). Most of the sample's mass comprises particles between 1 000 and 100 µm.

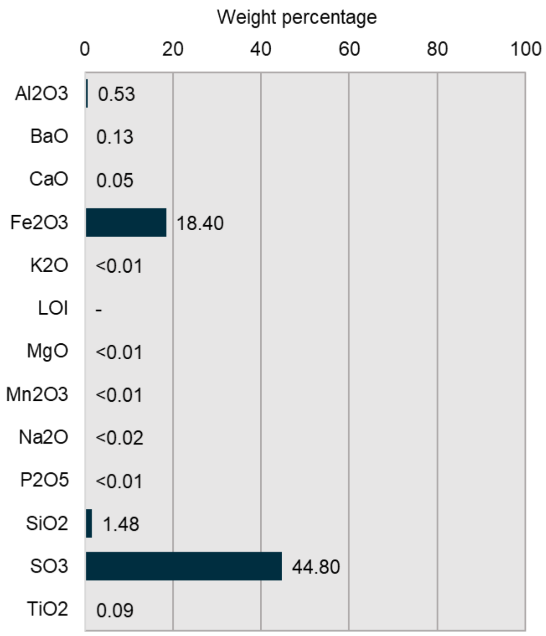
MINERALOGY

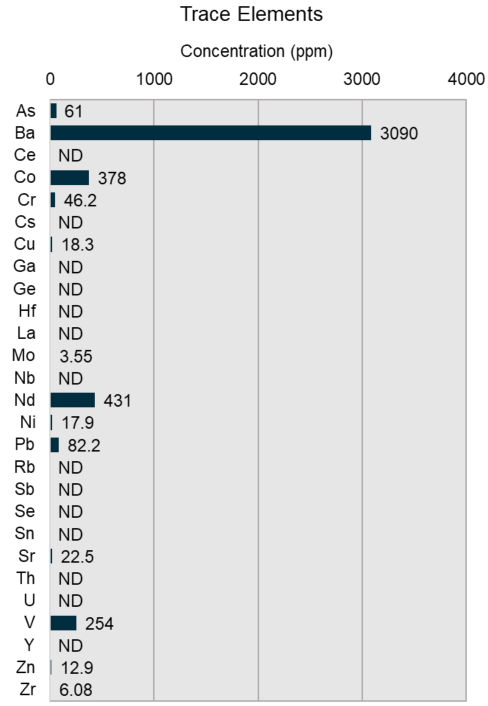
Mineral (wt %)	MPLY781
Albite	nd
Baryte	<0.5
Clinochlore	<0.5
Dolomite	nd
Graphite	nd
Kaolinite	nd

Mineral (wt %)	MPLY781
Lepidolite?	nd
Muscovite	<0.5
Pyrite	99.2
Quartz	<0.5
Sphalerite	<0.5

nd – not detected (concentration below the effective limit of detection).

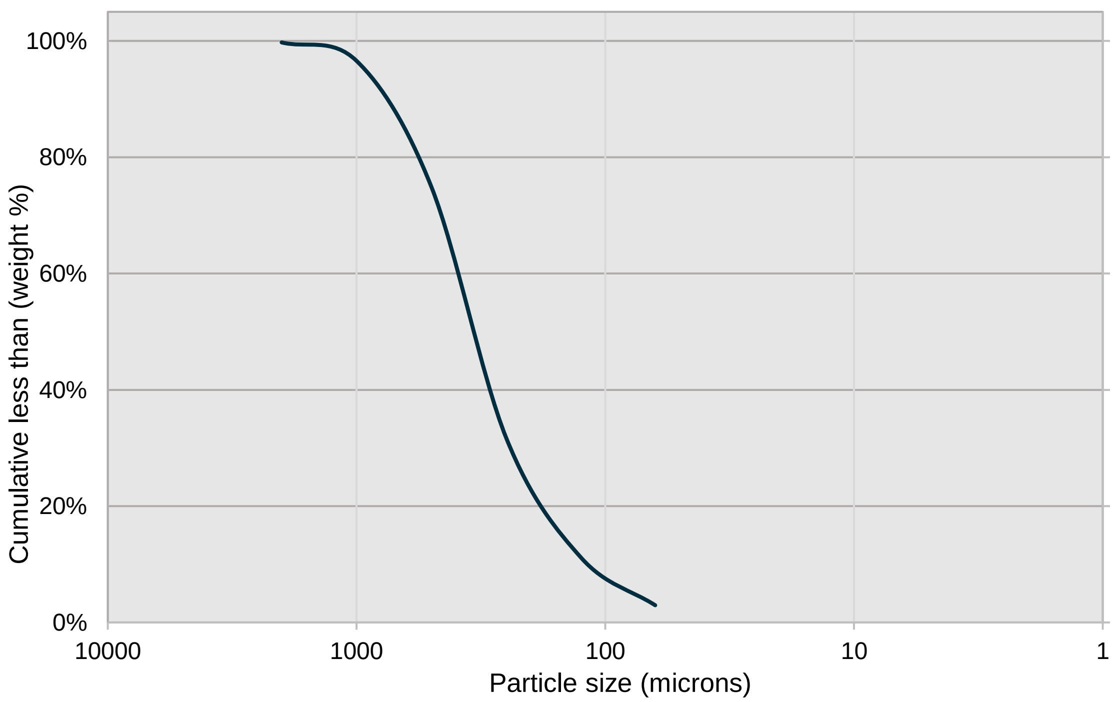
CHEMISTRY





ND – not detected (concentration below the effective limit of detection). The XRF analysis for this sample, due to analytical problems, is non-calibrated, and as such should be considered as indicative, rather than quantitative.

PARTICLE SIZE DISTRIBUTION



Melton Chalk Works

Omya UK Limited

Location: North Ferriby, East Riding of Yorkshire
Sample Description: Flint reject

Primary Production: Chalk
Sample Code: MPLY774
Date Sampled: 14/06/2023

GEOLOGICAL CONTEXT

The Cretaceous Welton Chalk Formation consists of white, thickly bedded chalk with flint nodules and is approximately 50 m thick at Melton Chalk Works. High purity calcium carbonate (chalk) is extracted from Melton Quarry and processed to produce a range of fillers, powders and extenders which are used in a variety of industrial, pharmaceutical, chemical and food applications.

View of Melton Chalk Works, North Ferriby.

SUMMARY OF DATA

Sample MPLY774 from Melton Chalk Works is representative of flint reject material. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of quartz (99.6 wt. %) and a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 96.3 wt. % SiO_2 and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include chromium (94 ppm), copper (42 ppm) and zirconium (29 ppm).

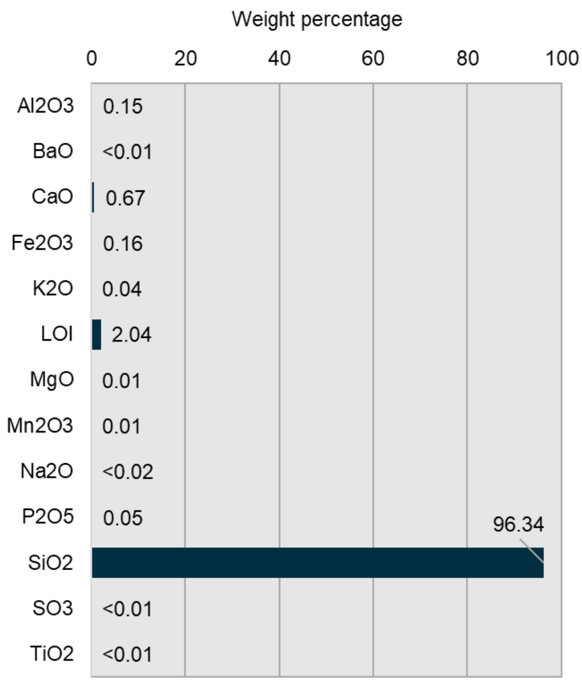
MINERALOGY

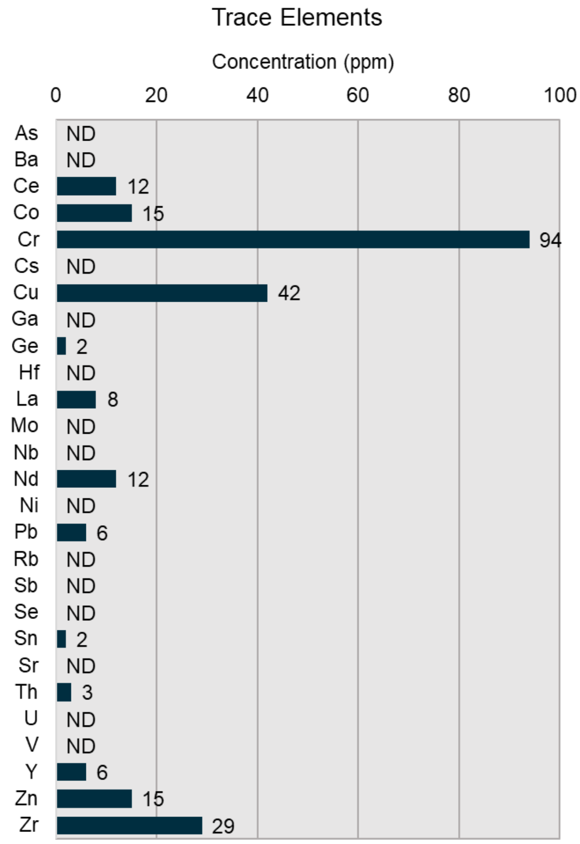
Mineral (wt %)	MPLY774
Albite	nd
Anorthite	nd
Augite	nd
Calcite	<0.5
Clinochlore	<0.5
Forsterite	nd

Mineral (wt %)	MPLY774
Kaolinite	nd
Muscovite	<0.5
Pyrite	nd
Quartz	99.6

nd – not detected (concentration below the effective limit of detection).

CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION

No particle size distribution data was collected for this material.

Melton Chalk Works

Omya UK Limited

Location: North Ferriby, East Riding of Yorkshire
Sample Description: Coarse X-ray sorted reject material

Primary Production: Chalk
Sample Code: MPLY775
Date Sampled: 14/06/2023

GEOLOGICAL CONTEXT

The Cretaceous Welton Chalk Formation consists of white, thickly bedded chalk with flint nodules and is approximately 50 m thick at Melton Chalk Works. High purity calcium carbonate (chalk) is extracted from Melton Quarry and processed to produce a range of fillers, powders and extenders which are used in a variety of industrial, pharmaceutical, chemical and food applications.

View of Melton Chalk Works, North Ferriby.

SUMMARY OF DATA

Sample MPLY775 from Melton Chalk Works is representative of coarse reject material from the X-ray sorter. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of quartz (61.6 wt. %) and calcite (38.4 wt. %), with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 59.2 wt. % SiO_2, 22.3 wt. % CaO, 17.4 wt. % volatiles and a variety of other major oxides below 5 wt. %. The three most abundant trace elements in the sample include strontium (262 ppm), zirconium (43 ppm) and copper (41 ppm). Most of the sample's mass comprises particles between 4 000 and 30 µm in diameter.

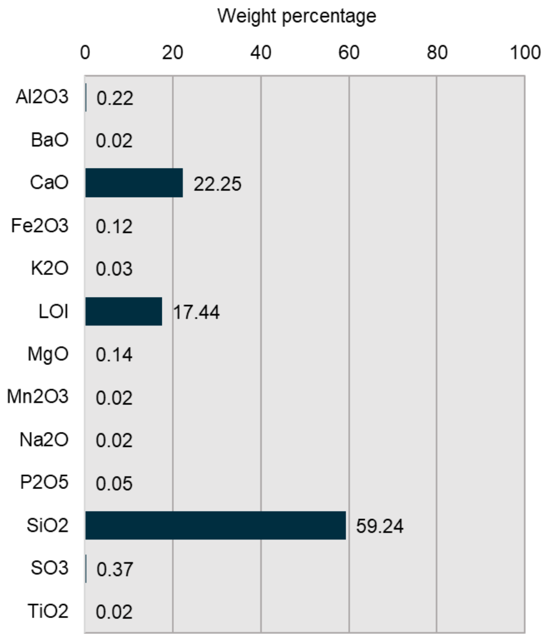
MINERALOGY

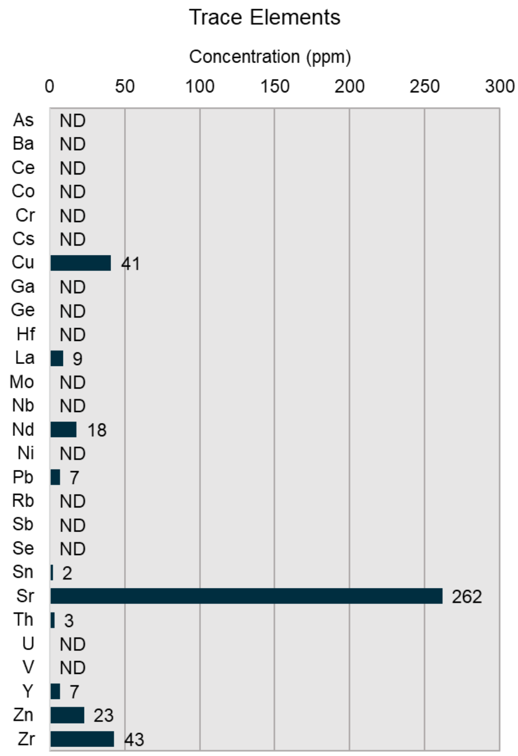
Mineral (wt %)	MPLY775
Albite	nd
Anorthite	nd
Augite	nd
Calcite	38.4
Clinochlore	<0.5
Forsterite	nd

Mineral (wt %)	MPLY775
Kaolinite	nd
Muscovite	<0.5
Pyrite	nd
Quartz	61.6

nd – not detected (concentration below the effective limit of detection).

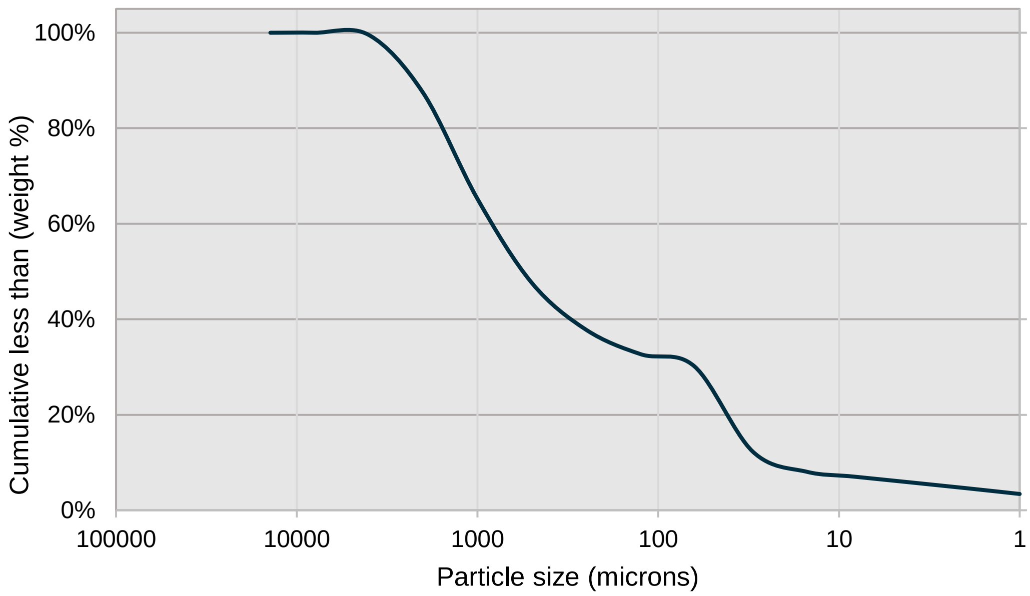
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Melton Chalk Works

Omya UK Limited

Location: North Ferriby, East Riding of Yorkshire
Sample Description: Fine X-ray sorted reject material

Primary Production: Chalk
Sample Code: MPLY776
Date Sampled: 14/06/2023

GEOLOGICAL CONTEXT

The Cretaceous Welton Chalk Formation consists of white, thickly bedded chalk with flint nodules and is approximately 50 m thick at Melton Chalk Works. High purity calcium carbonate (chalk) is extracted from Melton Quarry and processed to produce a range of fillers, powders and extenders which are used in a variety of industrial, pharmaceutical, chemical and food applications.

View of Melton Chalk Works, North Ferriby.

SUMMARY OF DATA

Sample MPLY776 from Melton Chalk Works is representative of fine reject material from the X-ray sorter. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of calcite (97.7 wt. %) and quartz (2.3 wt. %), with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 51.8 wt. % CaO, 40.9 wt. % volatiles and a variety of other major oxides below 5 wt. %. The three most abundant trace elements in the sample include strontium (617 ppm), zirconium (62 ppm) and zinc (53 ppm). Most of the sample's mass comprises particles between 500 and 1 µm in diameter.

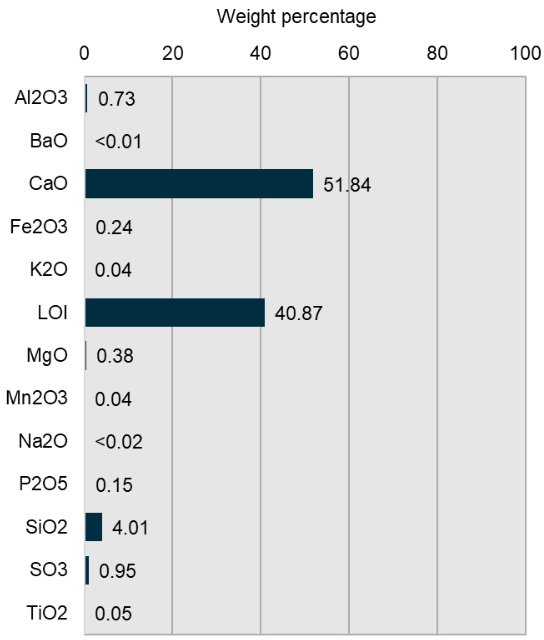
MINERALOGY

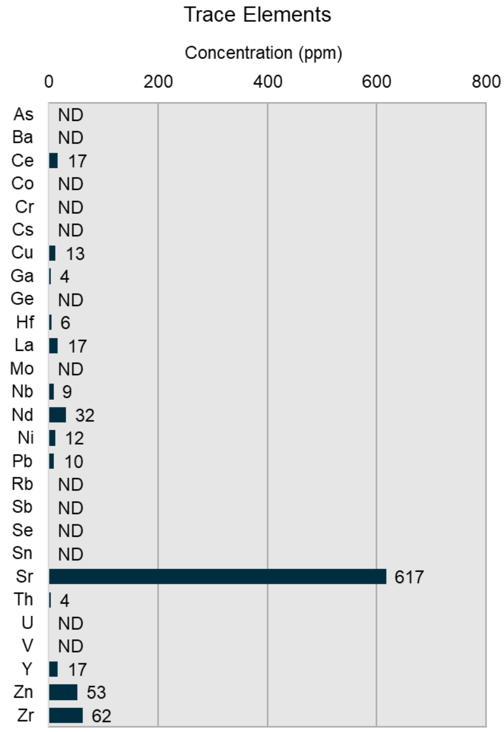
Mineral (wt %)	MPLY776
Albite	nd
Anorthite	nd
Augite	nd
Calcite	97.7
Clinochlore	<0.5
Forsterite	nd

Mineral (wt %)	MPLY776
Kaolinite	nd
Muscovite	<0.5
Pyrite	nd
Quartz	2.3

nd – not detected (concentration below the effective limit of detection).

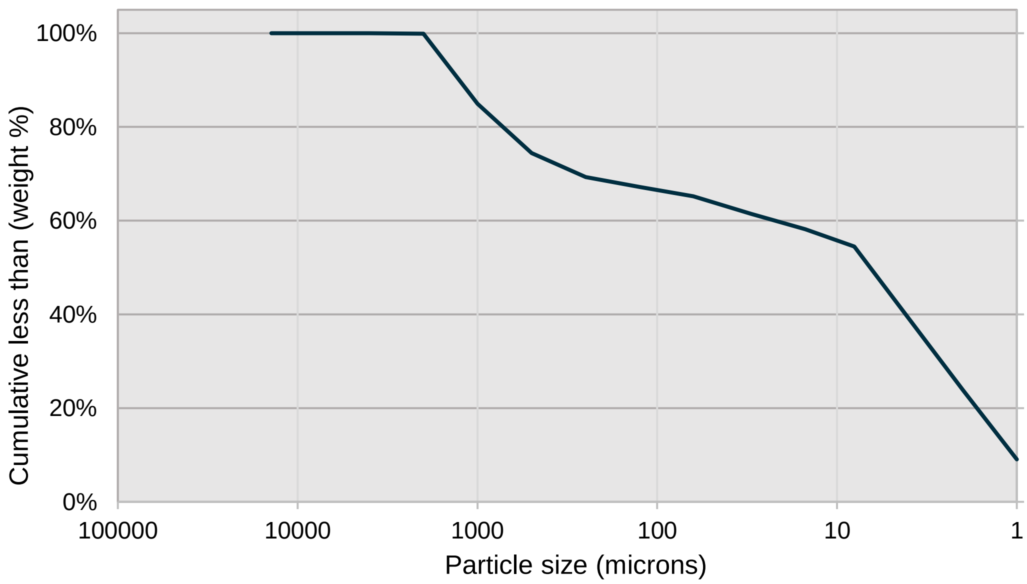
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Demesne White Limestone Quarry

Omya UK Limited

Location: Glenarm, County Antrim, Northern Ireland
Sample Description: Basalt overburden

Primary Production: Chalk
Sample Code: MPLY779
Date Sampled: 03/10/2023

GEOLOGICAL CONTEXT

The Antrim Lava Group largely consists of basalt and covers most of County Antrim in Northern Ireland in an area known as the Antrim Plateau. The basaltic lava was erupted during the Palaeogene 62 million years ago. Basalt at Demesne quarry is known as the Lower Basalt Formation and overlies Ulster White Limestone Formation chalk (the focus of the quarrying operation). Basalt, which can be up to 10 m thick, is currently removed as overburden to access chalk and is stockpiled on site with small amounts being sold as aggregate. Thin paleosols of weathered basalts and red volcanic dust mark the tops of individual lava flows.

View of the basalt overburden at Demesne Quarry, Northern Ireland.

SUMMARY OF DATA

Sample MPLY779 from Demesne Quarry is representative of basalt overburden. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of albite (34.6 wt. %), anorthite (13.4 wt. %), augite (20.3 wt. %), clinochlore (11.2 wt. %), forsterite (11.2) and muscovite (9.1 wt. %), with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 45.1 wt. % SiO_2, 13.7 wt. % Al_2O_3, 12.8 wt. % MgO, 12.4 wt. % Fe_2O_3, 9.0 wt. % CaO and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include chromium (879 ppm), nickel (423 ppm) and strontium (269 ppm).

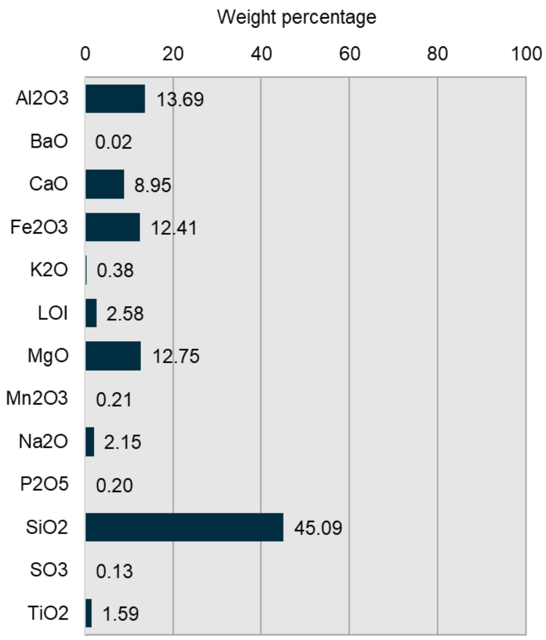
MINERALOGY

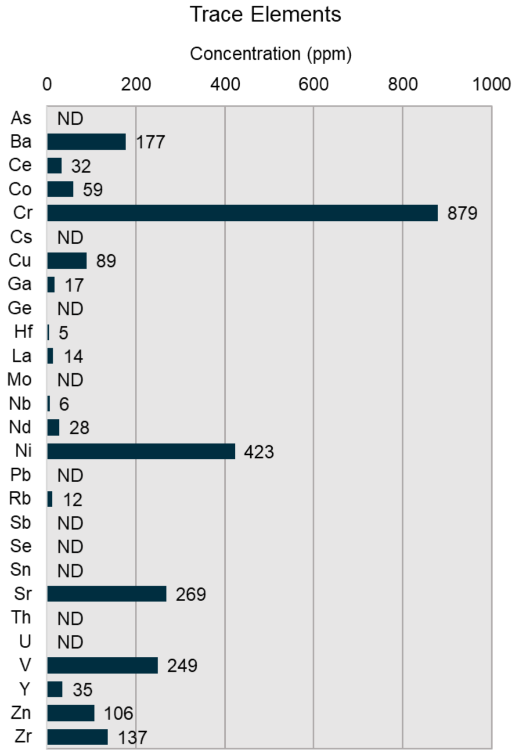
Mineral (wt %)	MPLY779
Albite	34.6
Anorthite	13.4
Augite	20.3
Calcite	nd
Clinochlore	11.2
Forsterite	11.2

nd – not detected (concentration below the effective limit of detection).

Mineral (wt %)	MPLY779
Kaolinite	<0.5
Muscovite	9.1
Pyrite	<0.5
Quartz	<0.5

CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION

No particle size distribution data was collected for this material.

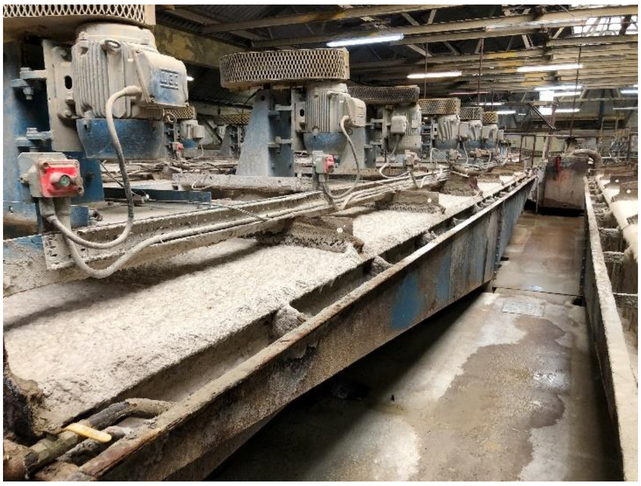
Cavendish Mill | Fluorsid

Location: Cavendish Mill, Derbyshire
Sample Description: Coarse tailings

Primary Production: Fluorspar
Sample Code: MPLY287
Date Sampled: 26/08/2022

GEOLOGICAL CONTEXT

Fluorspar (CaF_2, otherwise known as Fluorite) occurs as mineralised veins in Carboniferous limestone near Stoney Middleton, Derbyshire. The near vertical veins, formed by hot, mineral rich fluids flowing through fractures in the host limestones, have an east-west trending orientation and range from 2 to over 15 m in width. The veins contain 15 to 40 % fluorspar with a small amount of other ore minerals, primarily barytes ($BaSO_4$) and galena (PbS).



View of the froth flotation processing machinery at Cavendish Mill, Derbyshire.

SUMMARY OF DATA

Sample MPLY287 from Cavendish Mill is representative of coarse tailings. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of calcite (81.1 wt. %) and quartz (13.8 wt. %), fluorspar (3.5 wt. %) and dolomite (1.6 wt. %). This is reflected in the chemical analysis of the sample, which is composed of 49.7 wt. % CaO, 37.8 wt. % volatiles, 7.8 wt. % SiO_2 and a variety of other major oxides below 5 wt. %. The three most abundant trace elements in the sample include barium (1 480 ppm), lead (1 110 ppm) and zinc (668 ppm). Most of the sample's mass comprises particles between 250 and 100 µm in diameter.

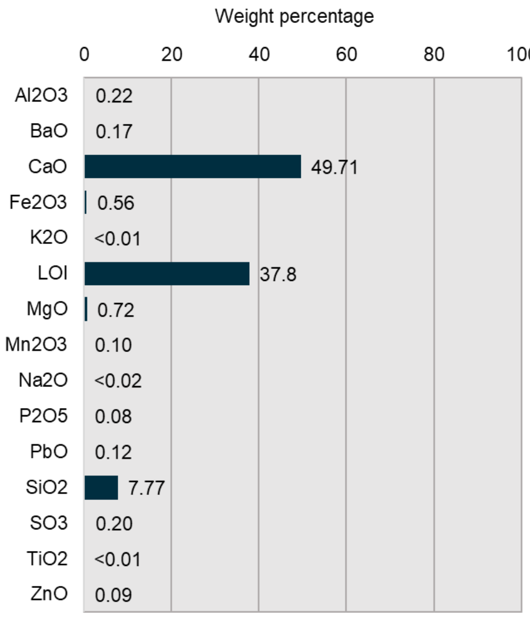
MINERALOGY

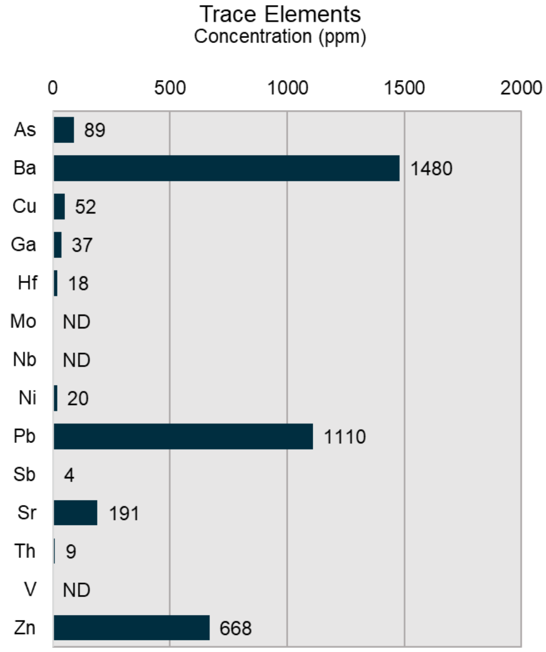
Mineral (wt %)	MPLY287
Baryte	nd
Calcite	81.1
Celestite	nd
Clinochlore	nd
Dolomite	1.6
Fluorspar	3.5

Mineral (wt %)	MPLY287
Quartz	13.8

nd – not detected (concentration below the effective limit of detection).

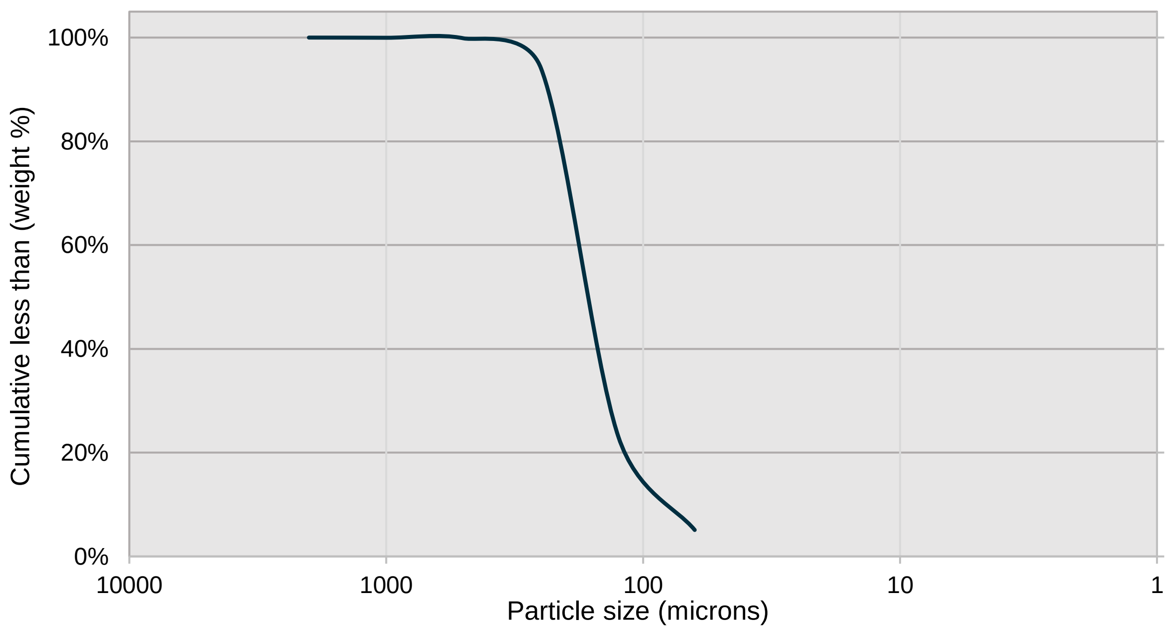
CHEMISTRY





ND – not detected (concentration below the effective limit of detection). Cerium, cobalt, chromium, caesium, germanium, lanthanum, neodymium, rubidium, selenium, tin, uranium, yttrium and zirconium all contain ‘not detected’ values for sample MPLY287.

PARTICLE SIZE DISTRIBUTION



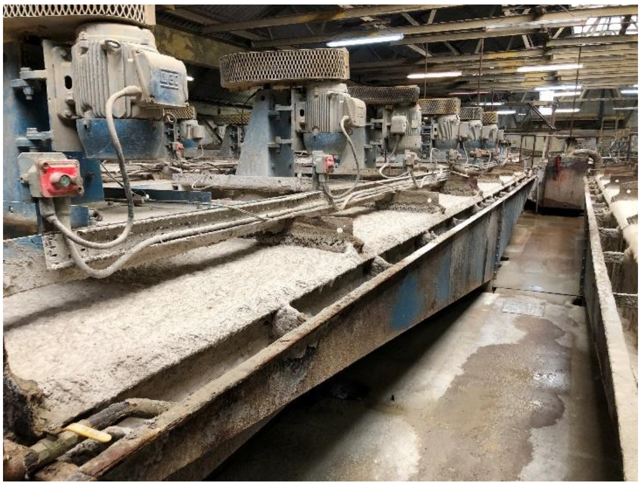
Cavendish Mill — Fluorsid

Location: Cavendish Mill, Derbyshire
Sample Description: Fine tailings

Primary Production: Fluorspar
Sample Code: MPLY288
Date Sampled: 26/08/2022

GEOLOGICAL CONTEXT

Fluorspar (CaF_2, otherwise known as Fluorite) occurs as mineralised veins in Carboniferous limestone near Stoney Middleton, Derbyshire. The near vertical veins, formed by hot, mineral rich fluids flowing through fractures in the host limestones, have an east-west trending orientation and range from 2 to over 15 m in width. The veins contain 15 to 40 % fluorspar with a small amount of other ore minerals, primarily barytes ($BaSO_4$) and galena (PbS).



View of the froth flotation processing machinery at Cavendish Mill, Derbyshire.

SUMMARY OF DATA

Sample MPLY288 from Cavendish Mill is representative of fine tailings. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of calcite (61.3 wt. %) and quartz (27.3 wt. %), fluorspar (8.0 wt. %) with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 37.7 wt. % CaO, 26.1 wt. % volatiles, 20.7 wt. % SiO_2 and a variety of other major oxides below 5 wt. %. The three most abundant trace elements in the sample include barium (37 600 ppm), lead (8 000 ppm) and zinc (3 580 ppm). Most of the sample's mass comprises particles between 250 and 1 µm in diameter.

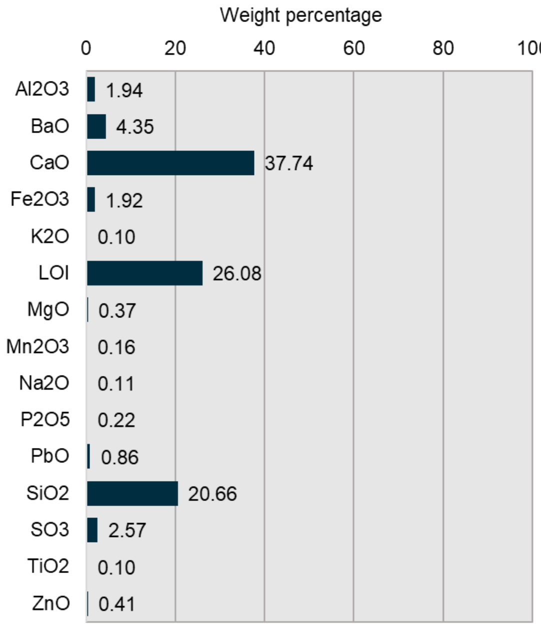
MINERALOGY

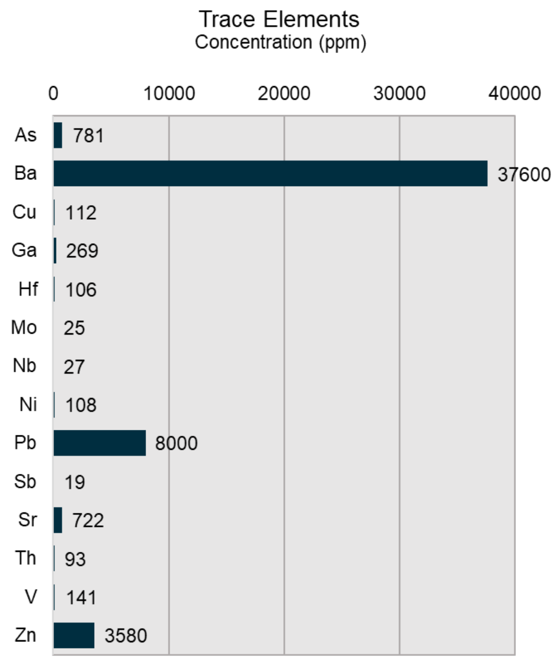
Mineral (wt %)	MPLY288
Baryte	2.9
Calcite	61.3
Celestite	<0.5
Clinochlore	<0.5
Dolomite	<0.5
Fluorspar	8.0

Mineral (wt %)	MPLY288
Quartz	27.3

nd – not detected (concentration below the effective limit of detection).

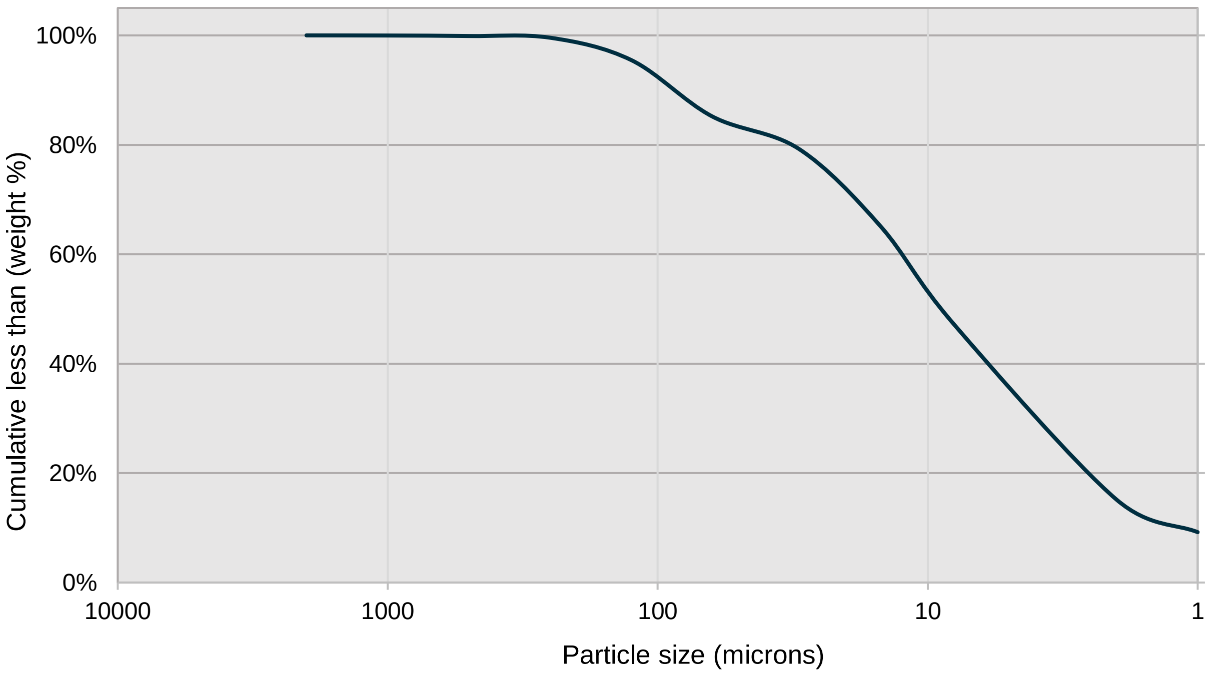
CHEMISTRY





ND – not detected (concentration below the effective limit of detection). Cerium, cobalt, chromium, caesium, germanium, lanthanum, neodymium, rubidium, selenium, tin, uranium, yttrium and zirconium all contain 'not detected' values for sample MPLY288.

PARTICLE SIZE DISTRIBUTION



Ballynahinch Quarry Northstone Materials

Location: Ballynahinch, County Down, Northern Ireland
Sample Description: Quarry fines

Primary Production: Gritstone
Sample Code: MPLY777
Date Sampled: 03/10/2023

GEOLOGICAL CONTEXT

Ballynahinch Quarry extracts metamorphosed sandstones, referred to as 'gritstones' from the Gala Group. This is a Silurian aged unit of interbedded sandstones and mudstones that have been formed by periodic flows of sediment into a deep marine basin, known as turbidites. These have been subsequently metamorphosed, folded, faulted and disrupted by igneous intrusions. The sandstones are known for their high Polished Stone Value (PSV) which makes them valued for road surfacing applications. These are preferentially quarried and finer grained rocks are stockpiled and typically used for restoration.

View of Ballynahinch Quarry, Northern Ireland.

SUMMARY OF DATA

Sample MPLY777 from Ballynahinch Quarry is representative of quarry fines. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of albite (40.3 wt. %), quartz (24.7 wt. %), clinochlore (14.4 wt. %), and microcline (12.3 wt. %) and muscovite (5.9 wt. %) with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 61.2 wt. % SiO_2, 15.5 wt. % Al_2O_3, 5.0 wt. % Fe_2O_3 and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include barium (1 650 ppm), strontium (374 ppm) and zirconium (327 ppm). Most of the sample's mass comprises particles between 4 000 and 100 µm in diameter.

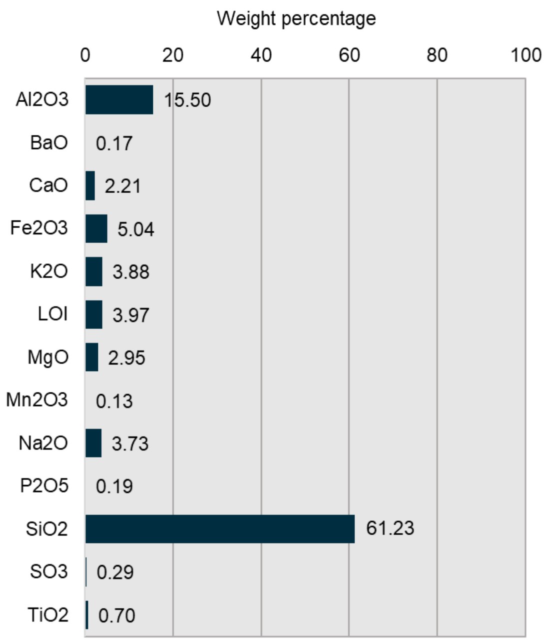
MINERALOGY

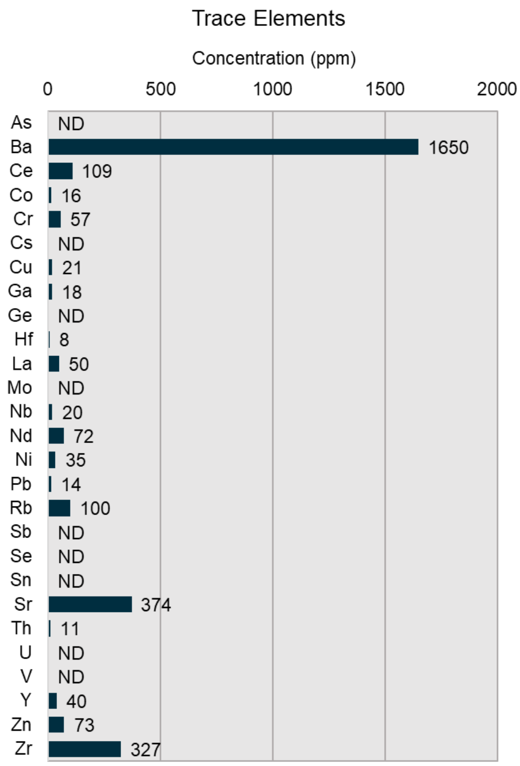
Mineral (wt %)	MPLY777
Albite	40.3
Calcite	0.7
Clinochlore	14.4
Dolomite	1.8
Hematite	<0.5
Microcline	12.3

Mineral (wt %)	MPLY777
Muscovite	5.9
Quartz	24.7

nd – not detected (concentration below the effective limit of detection).

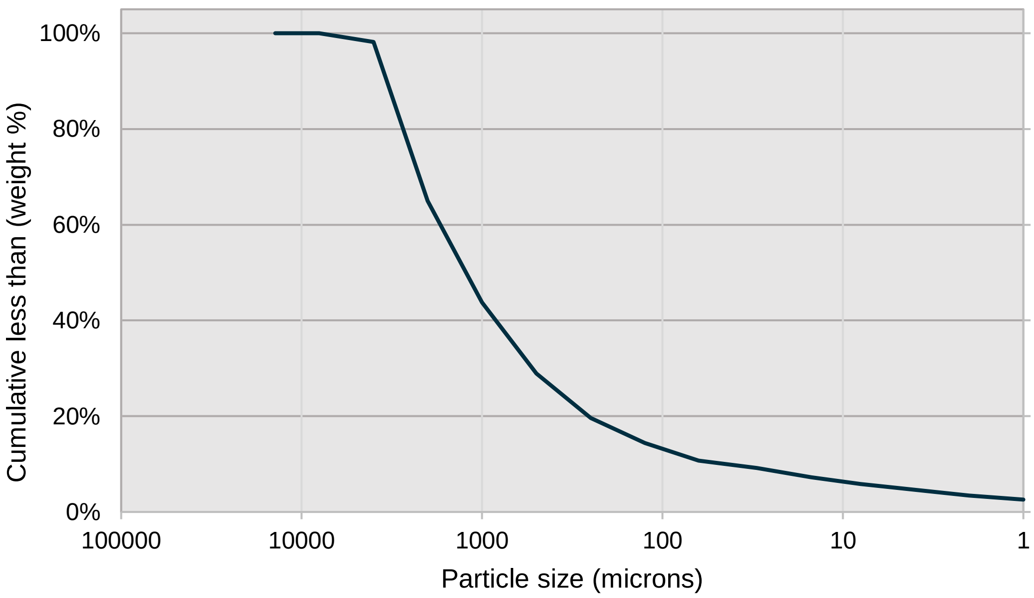
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Edentrillick Gritstone Quarry — McQuillen Quarries

Location: Dromore, County Down, Northern Ireland
Sample Description: Quarry fines

Primary Production: Gritstone
Sample Code: MPLY778
Date Sampled: 04/10/2023

GEOLOGICAL CONTEXT

Edentrillick Quarry extracts metamorphosed sandstones, referred to as 'gritstones' from the Gala Group. This is a Silurian aged unit of interbedded sandstones and mudstones that have been formed by periodic flows of sediment into a deep marine basin, known as turbidites. These have been subsequently metamorphosed, folded, faulted and disrupted by igneous intrusions. The sandstones are known for their high Polished Stone Value (PSV) which makes them valued for road surfacing applications. These are preferentially quarried and finer grained rocks are stockpiled and typically used for restoration.

View of the quarry fines at Edentrillick Quarry, Northern Ireland.

SUMMARY OF DATA

Sample MPLY778 from Edentrillick Quarry is representative of quarry fines. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of albite (34.8 wt. %), quartz (34.2 wt. %), clinochlore (15.1 wt. %), muscovite (8.4 wt. %), microcline (6.9 wt. %) with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 66.7 wt. % SiO_2, 13.0 wt. % Al_2O_3, 5.5 wt. % Fe_2O_3 and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include barium (703 ppm), zirconium (385 ppm) and strontium (201 ppm). Most of the sample's mass comprises particles between 4 000 and 100 µm in diameter.

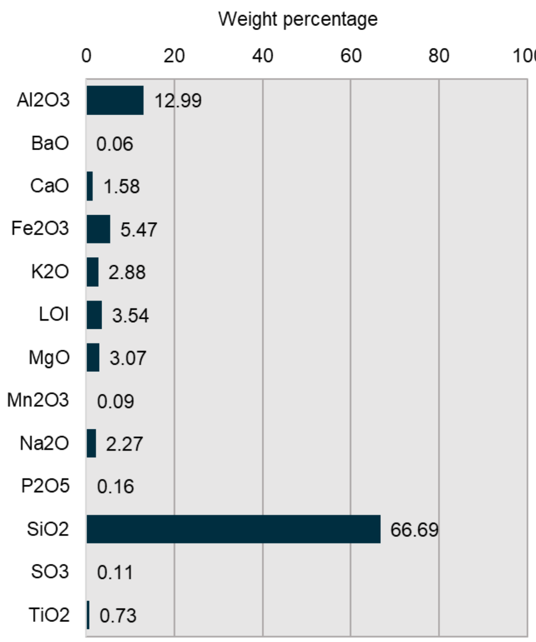
MINERALOGY

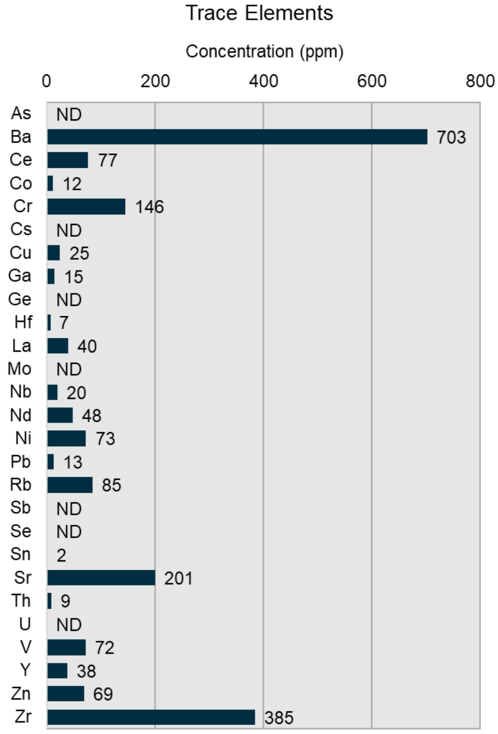
Mineral (wt %)	MPLY778
Albite	34.8
Calcite	0.7
Clinochlore	15.1
Dolomite	nd
Hematite	<0.5
Microcline	6.9

Mineral (wt %)	MPLY778
Muscovite	8.4
Quartz	34.2

nd – not detected (concentration below the effective limit of detection).

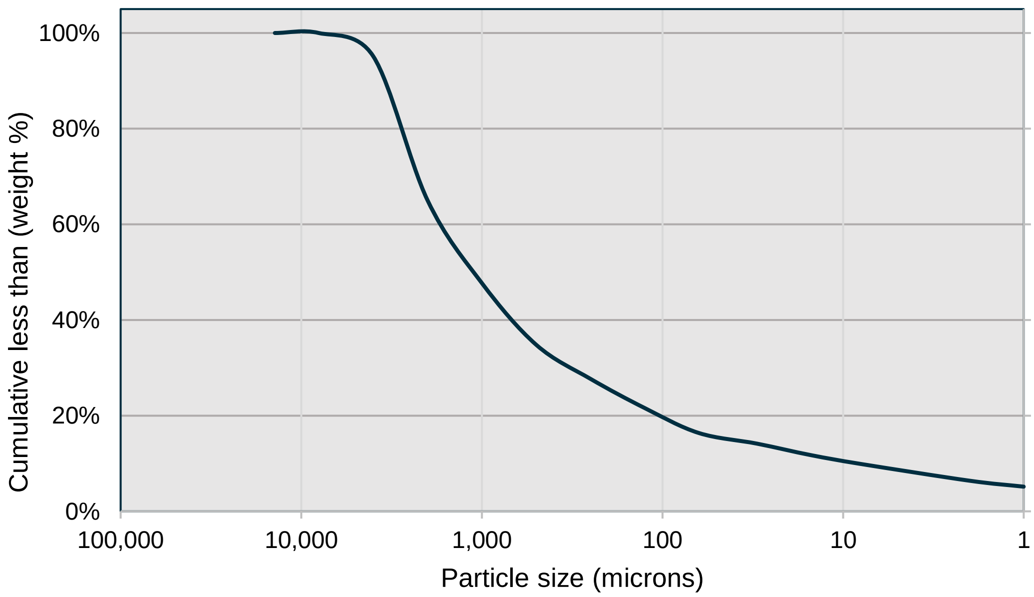
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Cwm Nant Lleici Quarry

Hygrove Aggregates

Location: Gellifowy Road, Ynysmeudwy, Pontadawe, Neath Port Talbot
Sample Description: Quarry fines

Primary Production: High specification aggregate
Sample Code: MPLY902
Date Sampled: 22/05/2024

GEOLOGICAL CONTEXT

Cwm Nant Lleici Quarry extracts metamorphosed sandstones, referred to as 'gritstones' from the Pennant Sandstone Formation. This is a Carboniferous aged unit of interbedded sandstones and mudstones, formed in wide river channels and associated floodplains. The sandstones are known for their high Polished Stone Value (PSV) which makes them valued for road surfacing applications. These are preferentially quarried and finer grained rocks are stockpiled and typically used for restoration.

View of Cwm Nant Lleici Quarry, Neath Port Talbot

SUMMARY OF DATA

Sample MPLY902 from Cwm Nant Lleici Quarry is representative of quarry fines. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of quartz (74.7 wt. %), muscovite (15.1 wt. %), with a variety of minor minerals below 5 wt. %. Most of the sample's mass comprises particles between 10 000 and 100 µm in diameter.

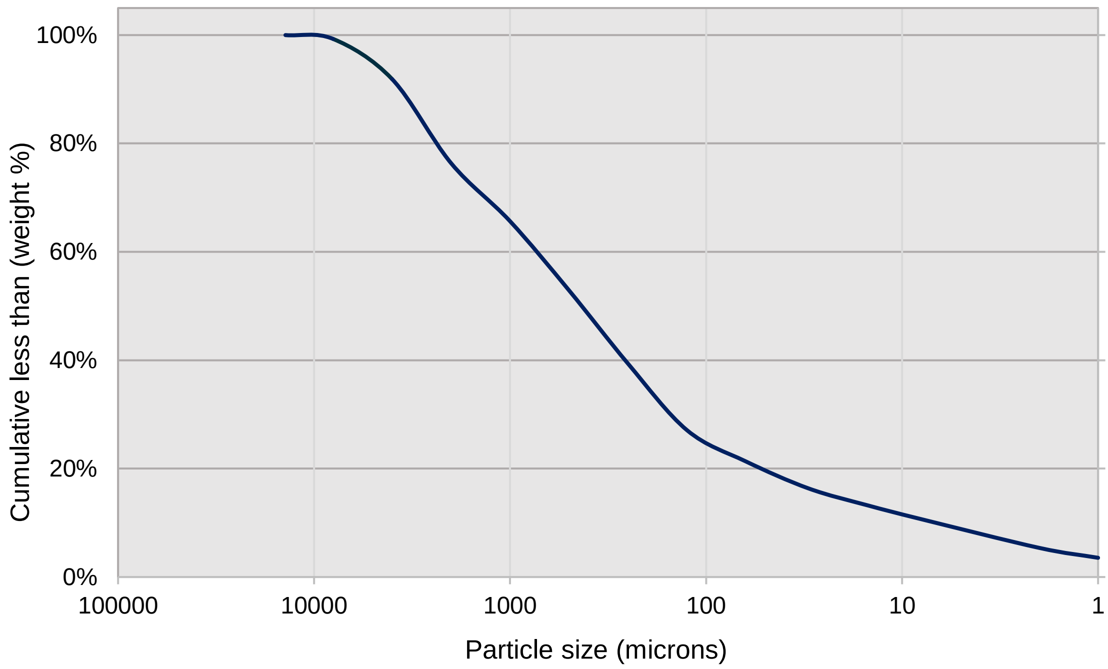
MINERALOGY

Mineral (wt %)	MPLY902
Albite	3.8
Clinochlore	4.7
Microcline	<0.5
Muscovite	15.1
Pyrite	<0.5
Quartz	74.7

Mineral (wt %)	MPLY902
Siderite	1.7

nd – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Melbur China Clay Works   IMERYS Minerals Limited

Location: Melbur China Clay Works, St Stephen, Cornwall
Sample Description: Waste sand

Primary Production: Kaolin
Sample Code: MPLY290
Date Sampled: 13/09/2022

GEOLOGICAL CONTEXT

China Clay, or kaolin, from the Melbur China Clay Works has been formed by in situ alteration of plagioclase feldspars from the St Austell Granite, which covers an area of 93 km^2. The kaolinisation processes involved the decomposition of feldspar by hydrothermal fluids and surface weathering to form kaolinite and mica leaving residual quartz and unaltered feldspar. Kaolinised zones are related to fluid flow through fractures and vein systems altering the host rock. These form vertical funnel like structures. Alteration may extend to depths over 250 m although 100 m is more typical.

View of the Melbur China Clay Works in St Stephen, Cornwall.

SUMMARY OF DATA

Sample MPLY290 from Melbur China Clay Works is representative of a waste sand. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of quartz (86.0 wt. %) and tourmaline (8.7 wt. %), with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 84.9 wt. % SiO_2, 7.9 wt. % Al_2O_3 and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include rubidium (154 ppm), zirconium (73 ppm) and tin (69 ppm). Most of the sample's mass comprises particles between 10 000 and 100 µm in diameter.

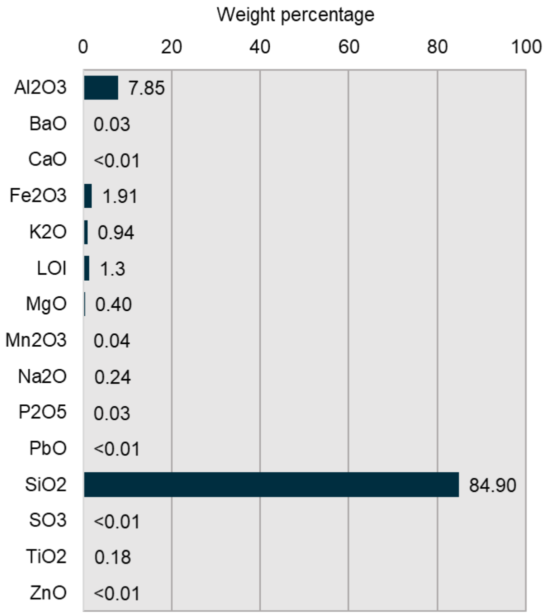
MINERALOGY

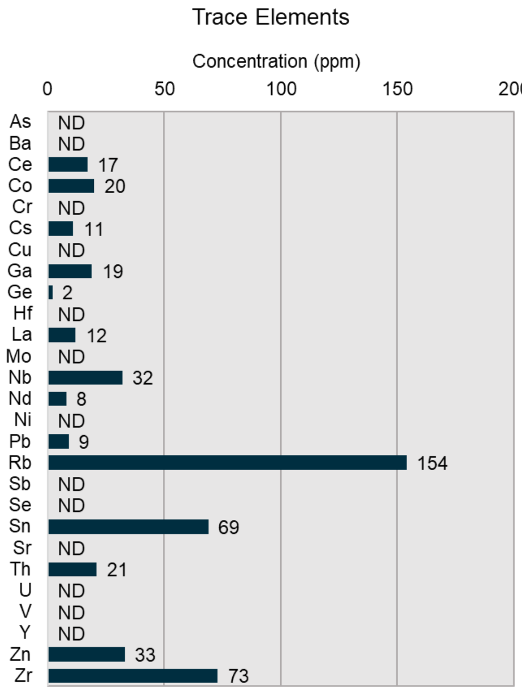
Mineral (wt %)	MPLY290
Albite	<0.5
Apatite	<0.5
Calcite	0.8
Kaolinite	<0.5
Microcline	<0.5
Muscovite	2.8

Mineral (wt %)	MPLY290
Orthoclase	<0.5
Pyrite	<0.5
Quartz	86.0
Siderite	<0.5
Tourmaline	8.7

nd – not detected (concentration below the effective limit of detection).

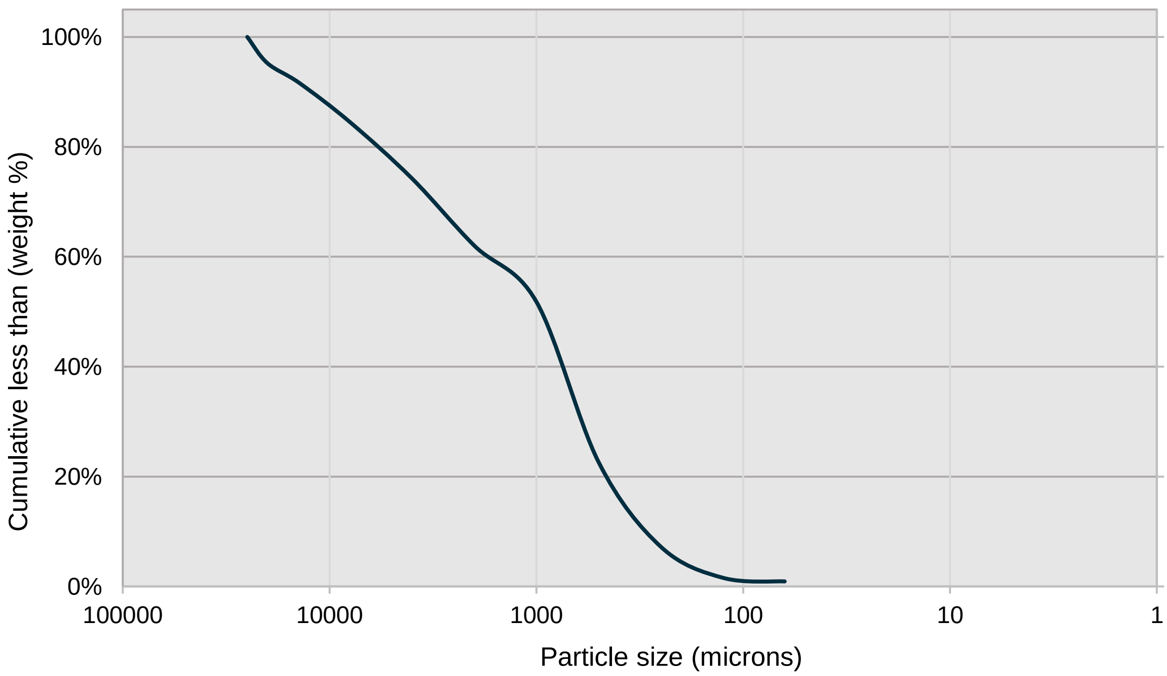
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Melbur China Clay Works

IMERYS Minerals Limited

Location: Melbur China Clay Works, St Stephen, Cornwall
Sample Description: Fine sand-silt waste

Primary Production: Kaolin
Sample Code: MPLY291
Date Sampled: 13/09/2022

GEOLOGICAL CONTEXT

China Clay, or kaolin, from the Melbur China Clay Works has been formed by in situ alteration of plagioclase feldspars from the St Austell Granite, which covers an area of 93 km^2. The kaolinisation processes involved the decomposition of feldspar by hydrothermal fluids and surface weathering to form kaolinite and mica leaving residual quartz and unaltered feldspar. Kaolinised zones are related to fluid flow through fractures and vein systems altering the host rock. These form vertical funnel like structures. Alteration may extend to depths over 250 m although 100 m is more typical.

View of the Melbur China Clay Works in St Stephen, Cornwall.

SUMMARY OF DATA

Sample MPLY291 from Melbur China Clay Works is representative of a waste sand. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of quartz (61.4 wt. %), muscovite (22.6 wt. %), tourmaline (9.4 wt. %) and microcline (5.4 wt. %) with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 67.4 wt. % SiO_2, 17.9 wt. % Al_2O_3 and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include rubidium (749 ppm), zirconium (137 ppm) and tin (114 ppm). Most of the sample's mass comprises particles between 500 and 63 µm in diameter.

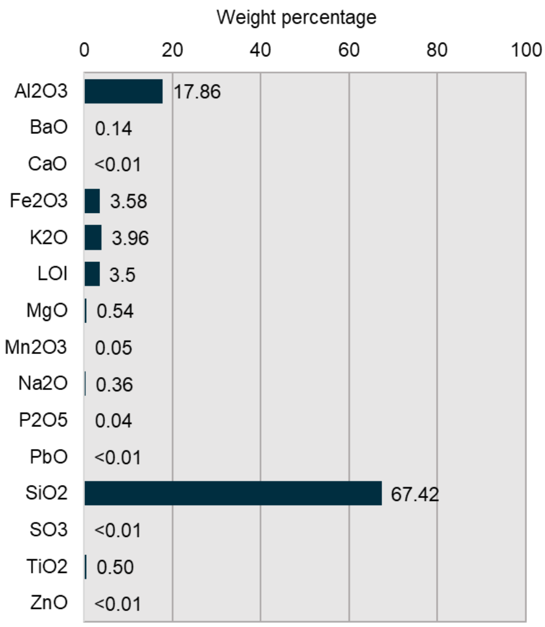
MINERALOGY

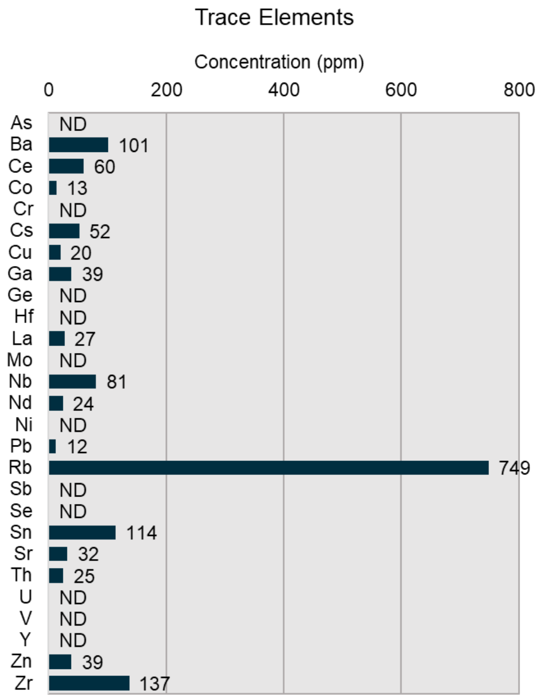
Mineral (wt %)	MPLY291
Albite	nd
Apatite	nd
Calcite	nd
Kaolinite	0.9
Microcline	5.4
Muscovite	22.6

Mineral (wt %)	MPLY291
Orthoclase	nd
Pyrite	<0.5
Quartz	61.4
Siderite	nd
Tourmaline	9.4

nd – not detected (concentration below the effective limit of detection).

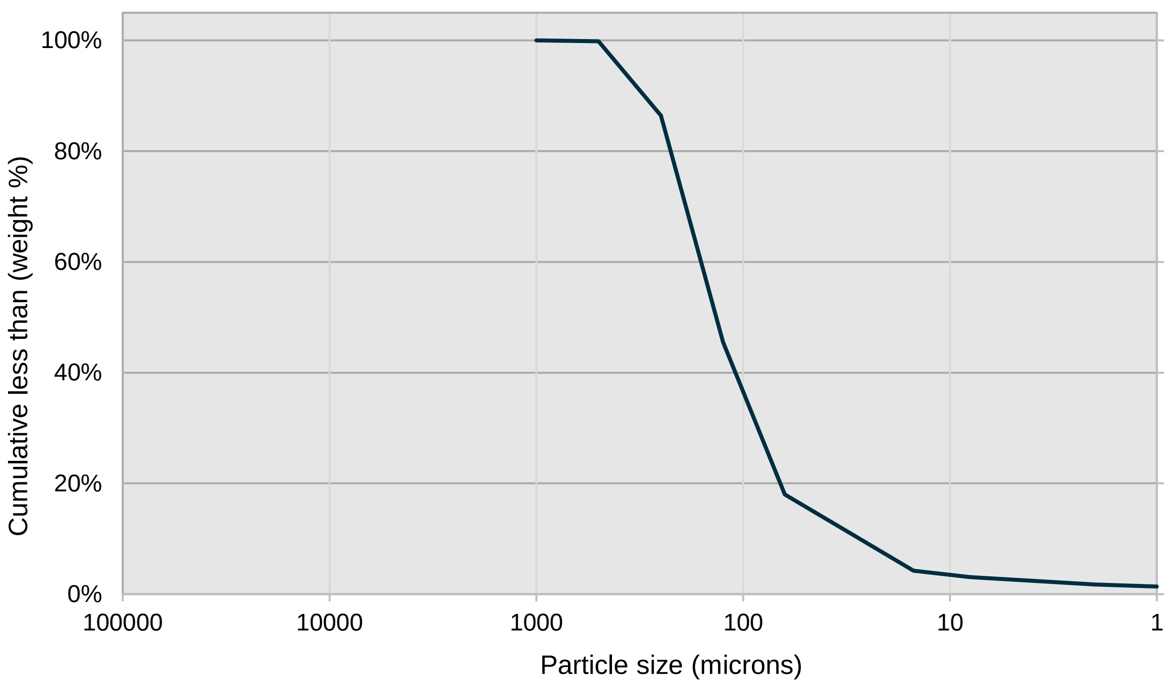
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Melbur China Clay Works

IMERYS Minerals Limited

Location: Melbur China Clay Works, St Stephen, Cornwall
Sample Description: Waste sand

Primary Production: Kaolin
Sample Code: MPLY292
Date Sampled: 13/09/2022

GEOLOGICAL CONTEXT

China Clay, or kaolin, from the Melbur China Clay Works has been formed by in situ alteration of plagioclase feldspars from the St Austell Granite, which covers an area of 93 km^2. The kaolinisation processes involved the decomposition of feldspar by hydrothermal fluids and surface weathering to form kaolinite and mica leaving residual quartz and unaltered feldspar. Kaolinised zones are related to fluid flow through fractures and vein systems altering the host rock. These form vertical funnel like structures. Alteration may extend to depths over 250 m although 100 m is more typical.

View of the Melbur China Clay Works in St Stephen, Cornwall.

SUMMARY OF DATA

Sample MPLY292 from Melbur China Clay Works is representative of a waste sand. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of quartz (89.3 wt. %) and tourmaline (5.9 wt. %) with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 85.5 wt. % SiO_2, 7.7 wt. % Al_2O_3 and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include rubidium (201 ppm), zirconium (91 ppm) and niobium (49 ppm). Most of the sample's mass comprises particles between 4 000 and 250 µm in diameter.

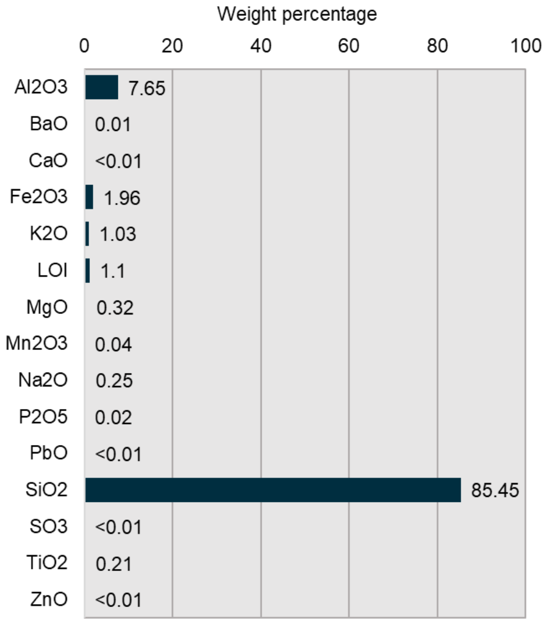
MINERALOGY

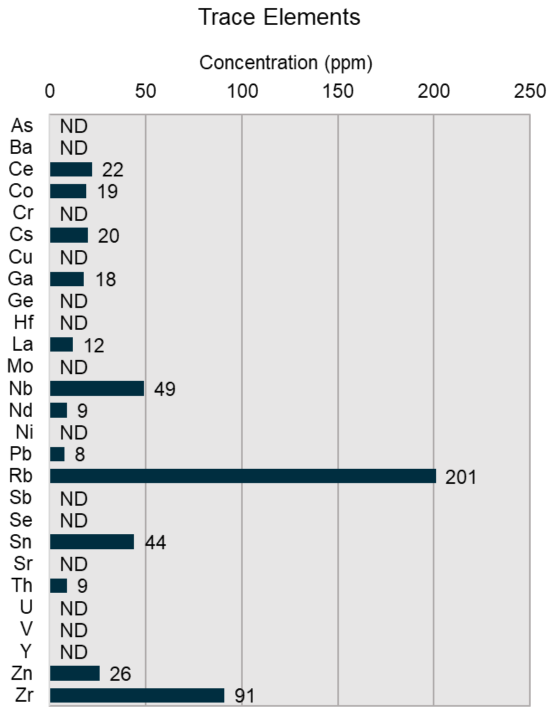
Mineral (wt %)	MPLY292
Albite	nd
Apatite	nd
Calcite	nd
Kaolinite	<0.5
Microcline	<0.5
Muscovite	4.2

Mineral (wt %)	MPLY292
Orthoclase	nd
Pyrite	0.6
Quartz	89.3
Siderite	nd
Tourmaline	5.9

nd – not detected (concentration below the effective limit of detection).

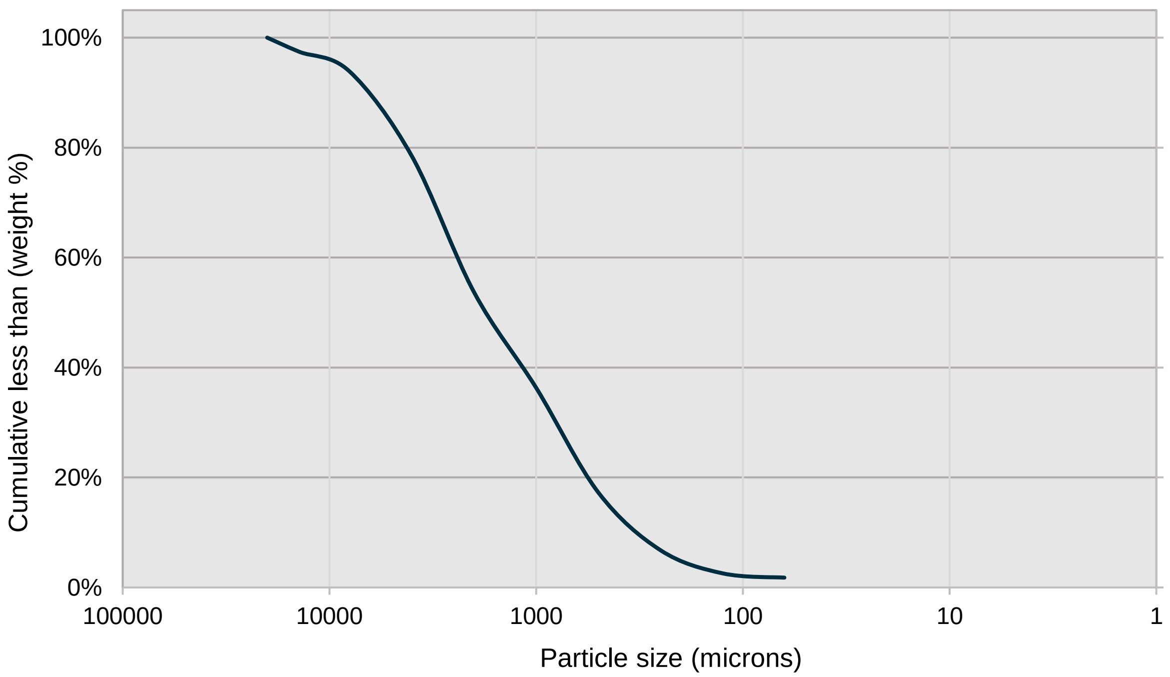
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Lee Moor — Sibelco UK Limited

Location: Lee Moor, Devon
Sample Description: Mica-rich tailings

Primary Production: Kaolin
Sample Code: MPLY297
Date Sampled: 06/07/2022

GEOLOGICAL CONTEXT

China Clay, or kaolin, from the Lee Moor has been formed by in situ alteration of plagioclase feldspars from the Dartmoor Granite. The kaolinisation processes involved the decomposition of feldspar by hydrothermal fluids and surface weathering to form kaolinite and mica leaving residual quartz and unaltered feldspar. Kaolinised zones are related to fluid flow through fractures and vein systems altering the host rock. These form vertical funnel like structures. Alteration may extend to depths over 250 m although 100 m is more typical.

View of the Lee Moor pit in Devon.

SUMMARY OF DATA

Sample MPLY297 from Lee Moor is representative of mica-rich tailings. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of muscovite (39.8 wt. %), quartz (21.2 wt. %), kaolinite (19.5 wt. %) and microcline (17.3 wt. %) with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 57.9 wt. % SiO_2, 24.5 wt. % Al_2O_3, 5.5 wt. % K_2O, 6.5 wt. % volatiles and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include rubidium (662 ppm), zirconium (310 ppm) and barium (385 ppm). Most of the sample's mass comprises particles between 250 and 2 µm in diameter.

MINERALOGY

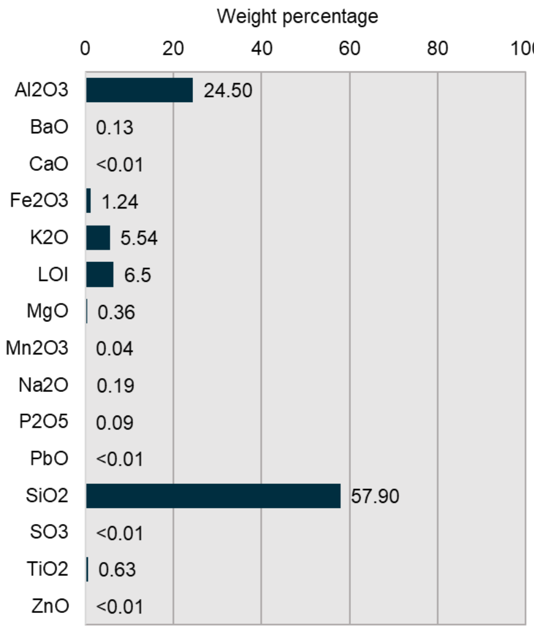
Mineral (wt %)	MPLY297
Albite	0.7
Apatite	nd
Calcite	nd
Kaolinite	19.5
Microcline	17.3
Muscovite	39.8

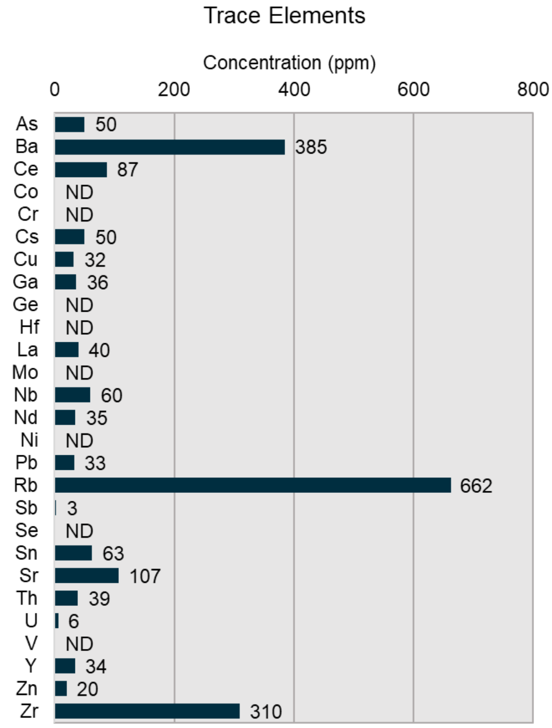
Mineral (wt %)	MPLY297
Orthoclase	nd
Pyrite	<0.5
Quartz	21.2
Siderite	nd
Tourmaline	1.7

nd – not detected (concentration below the effective limit of detection).

Lee Moor Sibelco UK Limited

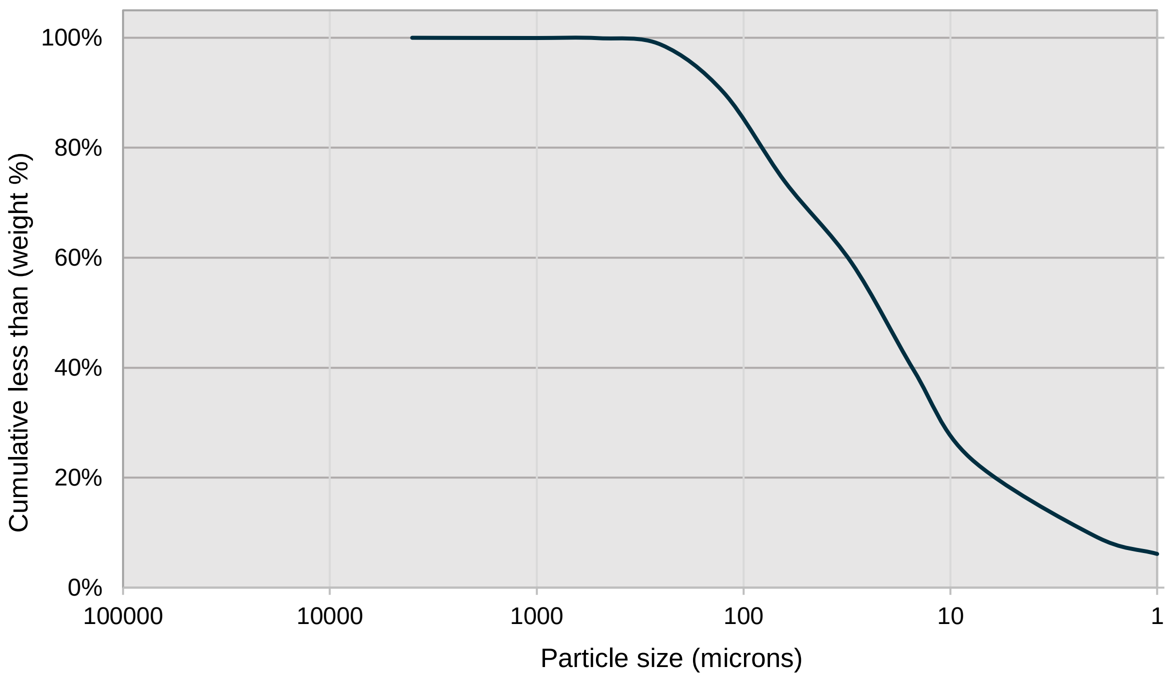
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Dunbar Cement Works | Tarmac

Location: Dunbar, East Lothian, Scotland
Sample Description: Shale from Borehole 3.

Primary Production: Limestone
Sample Code: MPLY365
Date Sampled: 05/10/2022

GEOLOGICAL CONTEXT

Dunbar Quarry works the Carboniferous Lower Limestone Formation which consists of a sequence of interbedded limestone, sandstone and shale. This was formed by periods of sea level fluctuating causing sandstones and thin coals to be deposited at time of low sea level, fossiliferous limestone under shallow marine conditions transitioning to shales in deeper waters. Three units, an upper limestone, a shale and a lower limestone are selectively extracted for cement manufacture. Shales, which occur up to 23 m thick above the upper limestone as well as beds within the limestone and sandstones, are selectively removed and used for post extraction landscaping and restoration to access limestone.

View of the limestone quarry at the Dunbar Cement Works, East Lothian.

SUMMARY OF DATA

Sample MPLY365 from Dunbar Cement Works is a representative shale. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of quartz (41.9 wt. %), muscovite (24.0 wt. %), calcite (15.4 wt. %) and kaolinite (10.5 wt. %) with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 43.5 wt. % SiO_2, 18.0 wt. % volatiles, 17.4 wt. % Al_2O_3, 8.0 wt. % CaO and a variety of other major oxides below 5 wt. %. The three most abundant trace elements in the sample include barium (291 ppm), strontium (270 ppm) and chromium (120 ppm).

MINERALOGY

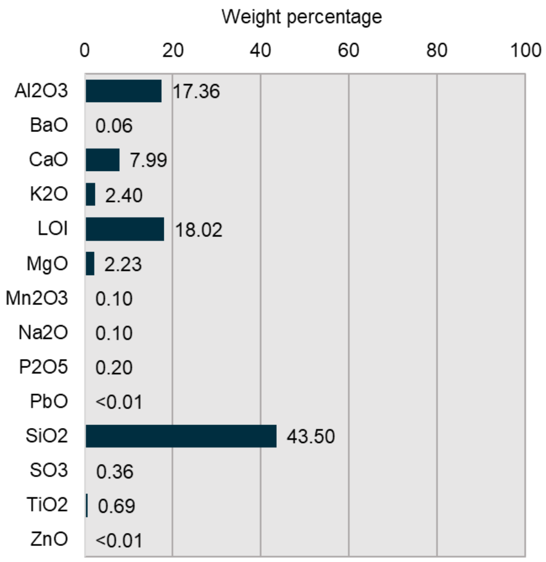
Mineral (wt %)	MPLY365
Albite	<0.5
Ankerite	nd
Calcite	15.4
Clinochlore	1.7
Dolomite	0.6
Kaolinite	10.5

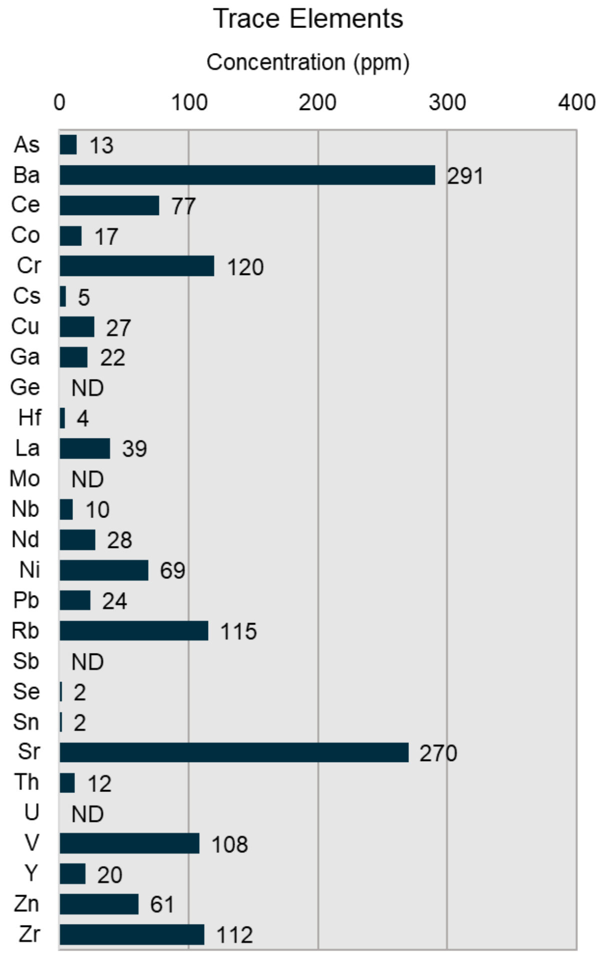
Mineral (wt %)	MPLY365
Microcline	<0.5
Muscovite	24.0
Pyrite	3.5
Quartz	41.9
Siderite	2.3

nd – not detected (concentration below the effective limit of detection).

Dunbar Cement Works Tarmac

CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION

No particle size distribution data was collected for this material.

Dunbar Cement Works Tarmac

Location: Dunbar, East Lothian, Scotland
Sample Description: Sandstone from Borehole 3.

Primary Production: Limestone
Sample Code: MPLY366
Date Sampled: 05/10/2022

GEOLOGICAL CONTEXT

Dunbar Quarry works the Carboniferous Lower Limestone Formation which consists of a sequence of interbedded limestone, sandstone and shale. This was formed by periods of sea level fluctuating causing sandstones and thin coals to be deposited at time of low sea level, fossiliferous limestone under shallow marine conditions transitioning to shales in deeper waters. Three units, an upper limestone, a shale and a lower limestone are selectively extracted for cement manufacture. Shales, which occur up to 23 m thick above the upper limestone as well as beds within the limestone and sandstones, are selectively removed and used for post extraction landscaping and restoration to access limestone.

View of the limestone quarry at the Dunbar Cement Works, East Lothian.

SUMMARY OF DATA

Sample MPLY366 from Dunbar Cement Works is a representative sandstone. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of quartz (44.0 wt. %), calcite (19.3 wt. %) and kaolinite (13.1 wt. %), muscovite (11.0 wt. %) with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 46.7 wt. % SiO_2, 17.2 wt. % volatiles, 14.5 wt. % Al_2O_3, 10.9 wt. % CaO and a variety of other major oxides below 5 wt. %. The three most abundant trace elements in the sample include strontium (591 ppm), zirconium (256 ppm) and barium (291 ppm).

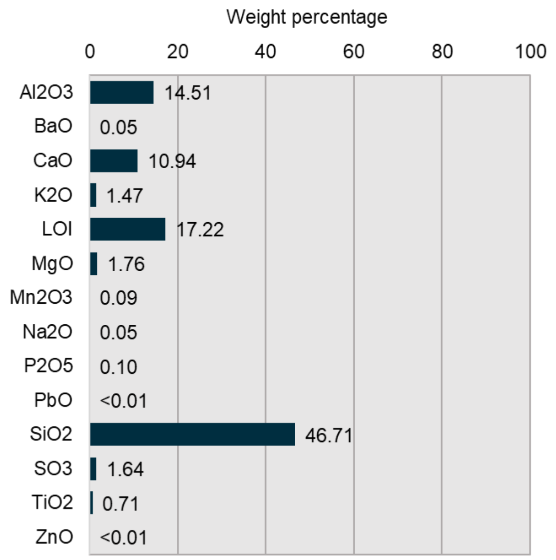
MINERALOGY

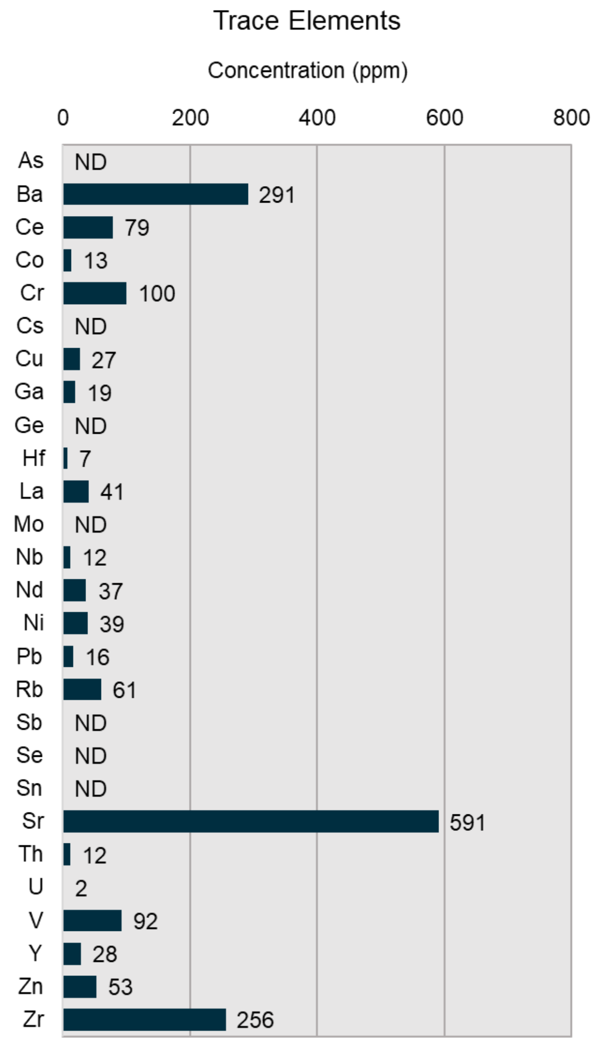
Mineral (wt %)	MPLY366
Albite	<0.5
Ankerite	4.7
Calcite	19.3
Clinochlore	nd
Dolomite	nd
Kaolinite	13.1

Mineral (wt %)	MPLY366
Microcline	4.1
Muscovite	11.0
Pyrite	<0.5
Quartz	44.0
Siderite	3.5

nd – not detected (concentration below the effective limit of detection).

CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION

No particle size distribution data was collected for this material.

North Cave Quarry — Breedon

Location: North Cave Quarry, Brough, East Riding of Yorkshire
Sample Description: Tailings

Primary Production: Sand and gravel
Sample Code: MPLY773
Date Sampled: 20/04/2023

GEOLOGICAL CONTEXT

North Cave Quarry extracts sand and gravel which have been deposited from river systems flowing from melting glaciers during the Devensian ice age. The movement of glacial ice resulted in a significant amount of erosion and transport of material. This was subsequently sorted by fluvial processes into beds of sand and gravel as glaciers retreated north across the Vale of York. These deposits are often associated with lacustrine clays and windblown sands.

View of the open pit at North Cave Quarry in East Riding of Yorkshire.

SUMMARY OF DATA

Sample MPLY773 from North Cave Quarry is representative of tailings from sand and gravel production. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of quartz (95.6 wt. %), with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 87.5 wt. % SiO_2 and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include zirconium (747 ppm), barium (259 ppm) and strontium (74 ppm). Most of the sample's mass comprises particles between 500 and 30 µm.

MINERALOGY

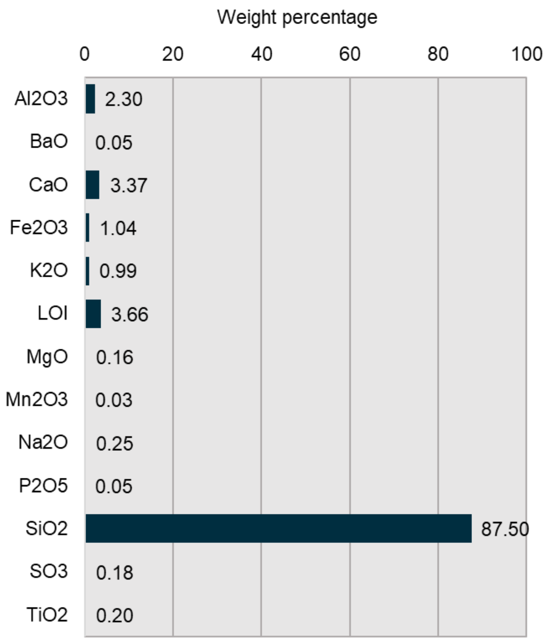
Mineral (wt %)	MPLY773
Albite	0.9
Anorthite	nd
Calcite	2.6
Clinochlore	<0.5
Microcline	1.0
Muscovite	<0.5

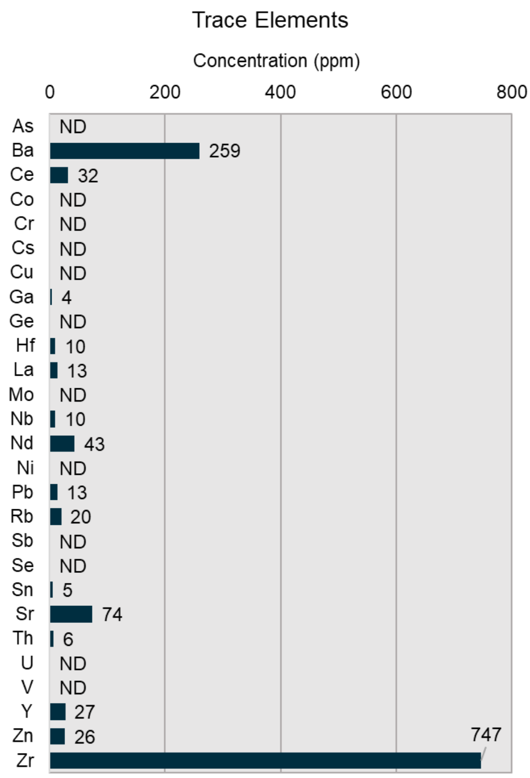
Mineral (wt %)	MPLY773
Pyrite	<0.5
Quartz	95.6

nd – not detected (concentration below the effective limit of detection).

North Cave Quarry Breedon

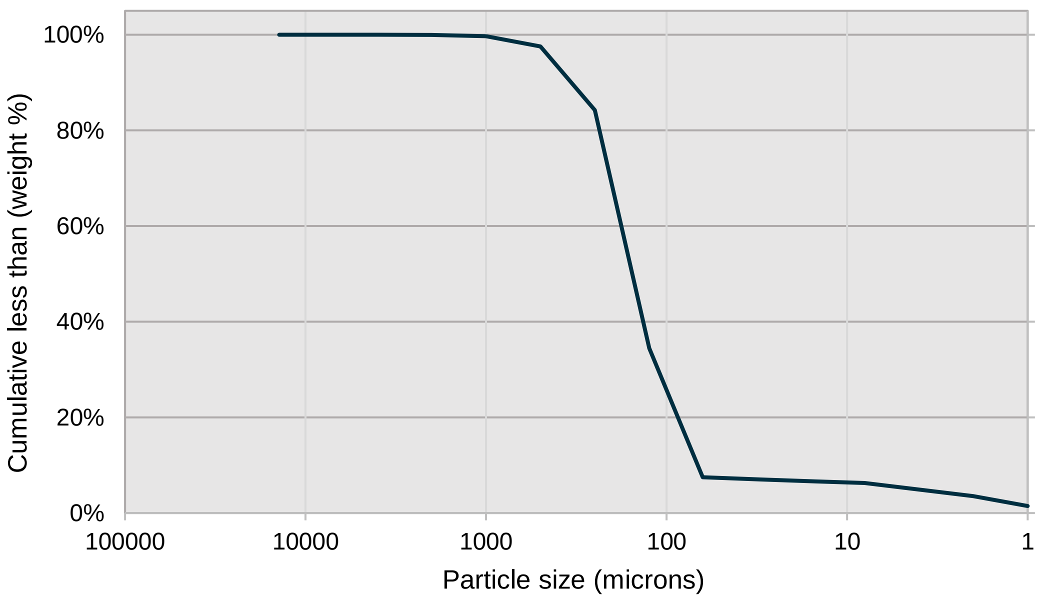
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Lochaline Mine

Lochaline Quartz Sand Ltd

Location: Lochaline, Morvern, Scotland
Sample Description: Fines directly from plant hydrosizer

Primary Production: Silica sand
Sample Code: MPLY363
Date Sampled: 04/10/2022

GEOLOGICAL CONTEXT

The silica sand at Lochaline is produced from the Cretaceous Lochaline White Sandstone Formation. The formation consists of very pure white to pale yellow-brown, well-sorted, medium-grained quartz sandstone. This formation was deposited under shallow marine conditions in a nearshore environment with the actions of tidal currents contributing to the well sorted and chemically pure nature of the deposit. This is overlain by Tertiary aged basalt that has protected the sandstone from erosion. It is the purest silica sand in the UK and is currently used as a glass raw material. The main silica sand products are graded by their iron content, including LQS85 (85 ppm Fe_2O_3) and LQS500 (500 ppm Fe_2O_3) material specifications.

Silica sand stockpile at the Lochaline Mine

SUMMARY OF DATA

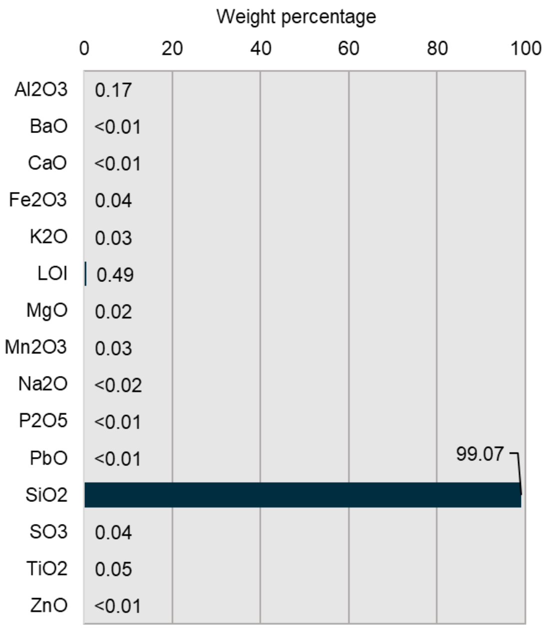
Sample MPLY363 from Lochaline Mine is representative of hydrosizer fines. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of quartz (99.1 wt. %) with small amounts of pyrite and calcite. This is reflected in the chemical analysis of the sample, which is composed of 99.1 wt. % SiO_2 and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include zirconium (126 ppm), cobalt (18 ppm) and neodymium (12 ppm). Most of the sample's mass comprises particles between 250 and 63 µm.

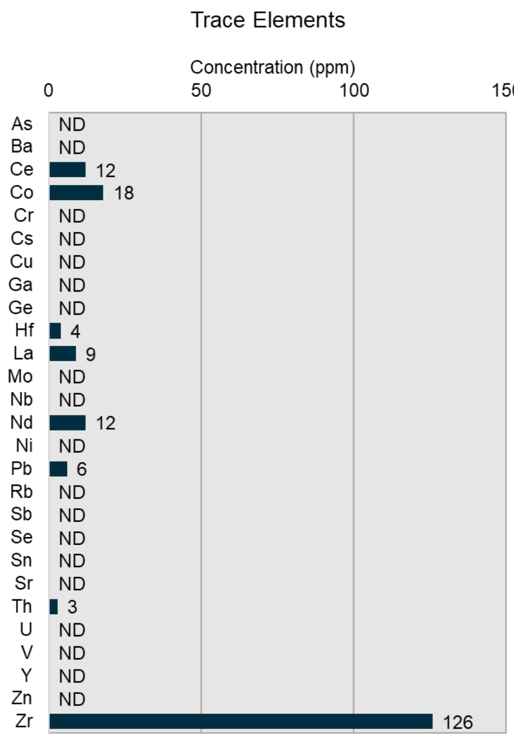
MINERALOGY

Mineral (wt %)	MPLY363
Calcite	<0.5
Pyrite	0.8
Quartz	99.1

nd – not detected (concentration below the effective limit of detection).

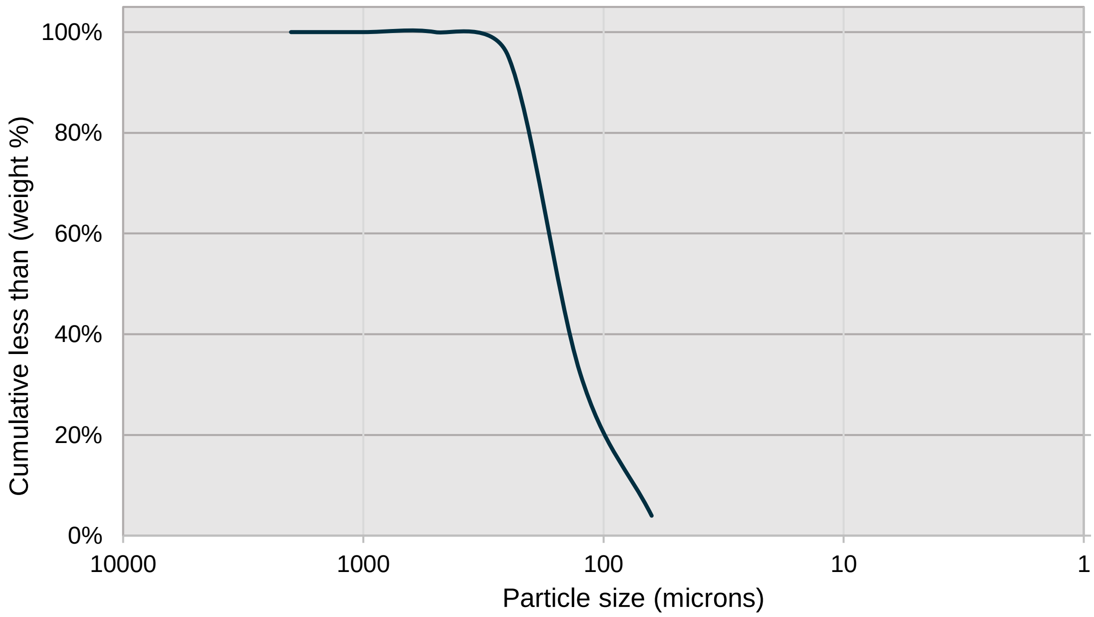
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Lochaline Mine

Lochaline Quartz Sand Ltd

Location: Lochaline, Morvern, Scotland
Sample Description: Fines deposited in the mine

Primary Production: Silica sand
Sample Code: MPLY364
Date Sampled: 04/10/2022

GEOLOGICAL CONTEXT

The silica sand at Lochaline is produced from the Cretaceous Lochaline White Sandstone Formation. The formation consists of very pure white to pale yellow-brown, well-sorted, medium-grained quartz sandstone. This formation was deposited under shallow marine conditions in a nearshore environment with the actions of tidal currents contributing to the well sorted and chemically pure nature of the deposit. This is overlain by Tertiary aged basalt that has protected the sandstone from erosion. It is the purest silica sand in the UK and is currently used as a glass raw material. The main silica sand products are graded by their iron content, including LQS85 (85 ppm Fe_2O_3) and LQS500 (500 ppm Fe_2O_3) material specifications.

View of the Lochaline mine adit.

SUMMARY OF DATA

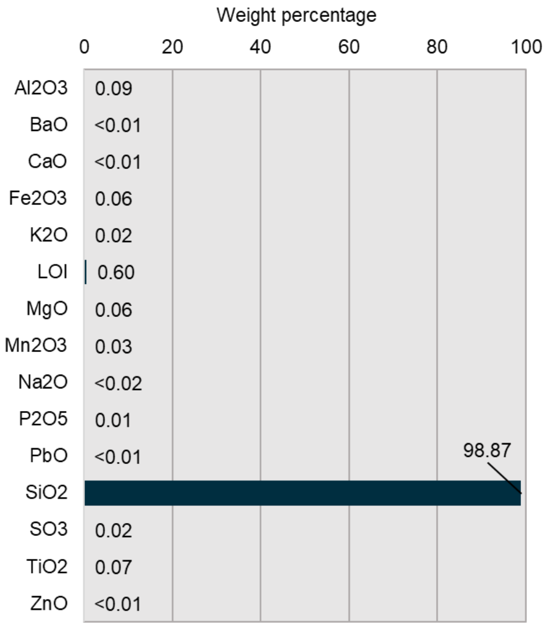
Sample MPLY364 from Lochaline Mine is representative of mine fines. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of quartz (98.9 wt. %) with small amounts of pyrite. This is reflected in the chemical analysis of the sample, which is composed of 98.9 wt. % SiO_2 and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include zirconium (281 ppm), cobalt (12 ppm) and zinc (8 ppm). Most of the sample's mass comprises particles between 500 and 63 µm.

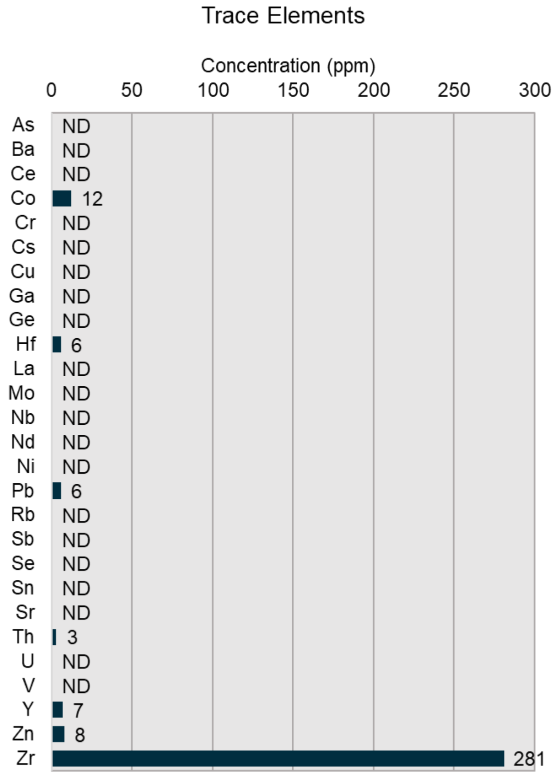
MINERALOGY

Mineral (wt %)	MPLY364
Calcite	nd
Pyrite	1.1
Quartz	98.9

nd – not detected (concentration below the effective limit of detection).

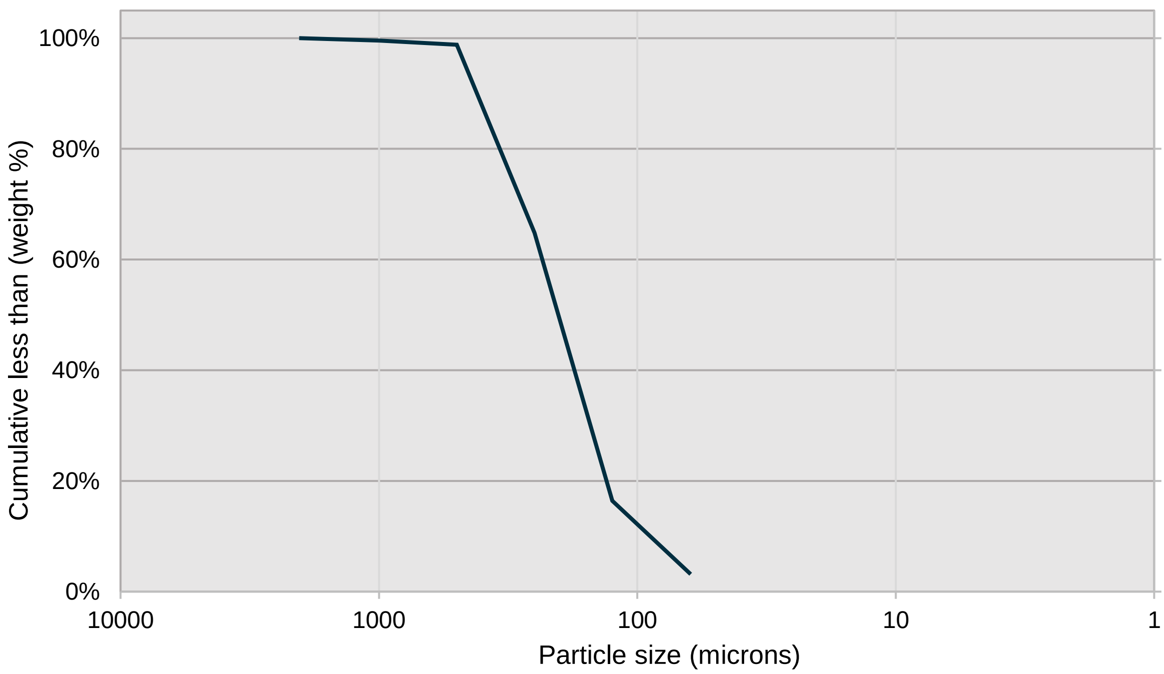
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Hemerdon Mine

Tungsten West

Location: Plymouth, Devon
Sample Description: Tailings from lagoon

Primary Production: Tungsten
Sample Code: MPLY293
Date Sampled: 14/09/2022

GEOLOGICAL CONTEXT

The Hemerdon deposit is centred upon a sub-vertical, >100 m wide, NNE-SSW striking, Early Permian granite dyke and outlying intrusion (The Hemerdon Ball granite) hosted by Devonian metasedimentary and metavolcanic rocks known regionally as killas. Fractures in the granite and killas have been penetrated by mineralising fluids crystallised as metallic ores in the area around the mine. Mineralisation is associated with moderately to steeply NW-dipping, greisen-bordered, quartz-ferberite ($FeWO_4$) and cassiterite (SnO_2) sheeted veins. Two types of vein are discernible with three orientations. Quartz and quartz-feldspar veins form a stockwork with minor mineralisation, whilst greisen-bordered veins are found in a sheeted vein system with ferberite and minor cassiterite mineralisation. Mineralisation begins at surface and extends to depths of at least 400 m.

View of the open pit at Hemerdon Mine, Devon

SUMMARY OF DATA

Sample MPLY293 from Hemerdon Mine is representative of tailings. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of quartz (55.9 wt. %), muscovite (35.8 wt. %) and orthoclase (5.4 wt. %) with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 71.2 wt. % SiO_2, 15.7 wt. % Al_2O_3 and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include rubidium (520 ppm), arsenic (438 ppm) and tin (326 ppm). Most of the sample's mass comprises particles between 1 000 and 10 µm.

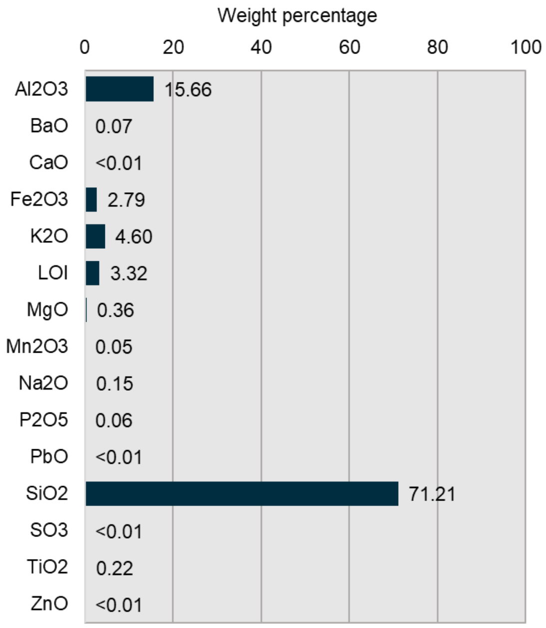
MINERALOGY

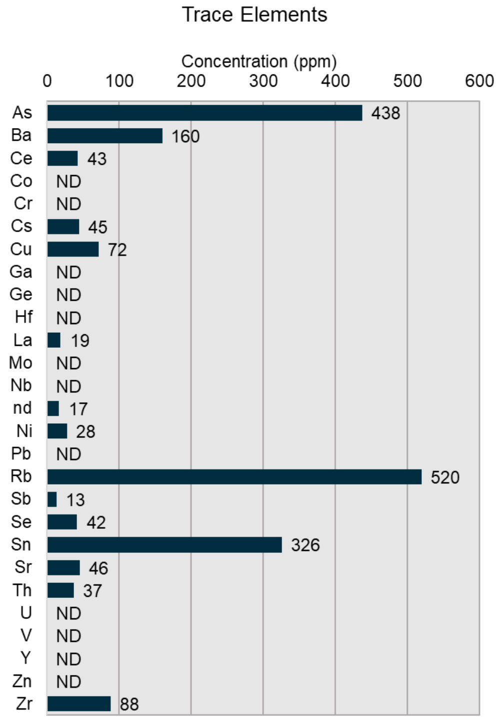
Mineral (wt %)	MPLY293
Hematite	<0.5
Kaolinite	2.1
Muscovite	35.8

Mineral (wt %)	MPLY293
Orthoclase	5.4
Pyrite	<0.5
Quartz	55.9

nd – not detected (concentration below the effective limit of detection).

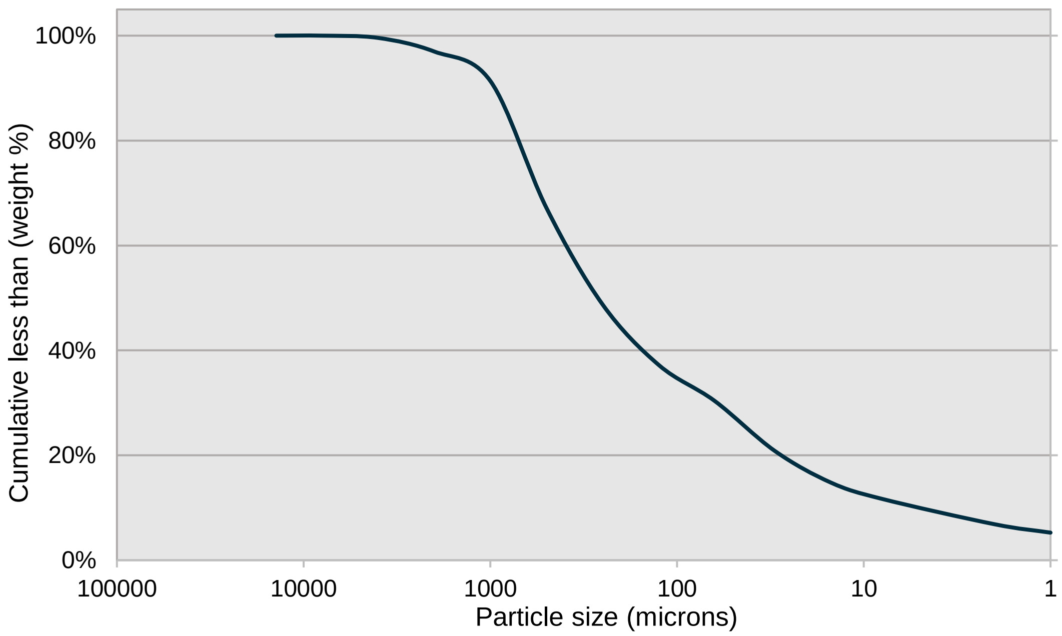
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Hemerdon Mine

Tungsten West

Location: Plymouth, Devon
Sample Description: Tailings from lagoon

Primary Production: Tungsten
Sample Code: MPLY294
Date Sampled: 14/09/2022

GEOLOGICAL CONTEXT

The Hemerdon deposit is centred upon a sub-vertical, >100 m wide, NNE-SSW striking, Early Permian granite dyke and outlying intrusion (The Hemerdon Ball granite) hosted by Devonian metasedimentary and metavolcanic rocks known regionally as killas. Fractures in the granite and killas have been penetrated by mineralising fluids crystallised as metallic ores in the area around the mine. Mineralisation is associated with moderately to steeply NW-dipping, greisen-bordered, quartz-ferberite ($FeWO_4$) and cassiterite (SnO_2) sheeted veins. Two types of vein are discernible with three orientations. Quartz and quartz-feldspar veins form a stockwork with minor mineralisation, whilst greisen-bordered veins are found in a sheeted vein system with ferberite and minor cassiterite mineralisation. Mineralisation begins at surface and extends to depths of at least 400 m.

View of the open pit at Hemerdon Mine, Devon

SUMMARY OF DATA

Sample MPLY294 from Hemerdon Mine is representative of tailings. Mineralogical analysis (X-ray diffraction) indicated that the sample is mainly composed of quartz (61.5 wt. %), muscovite (30.4 wt. %) and orthoclase feldspar (6.2 wt. %) with a variety of minor minerals. This is reflected in the chemical analysis of the sample, which is composed of 74.8 wt. % SiO_2, 13.5 wt. % Al_2O_3 and a variety of other major oxides and volatiles below 5 wt. %. The three most abundant trace elements in the sample include rubidium (493 ppm), tin (432 ppm) and arsenic (309 ppm). Most of the sample's mass comprises particles between 1 000 and 10 µm.

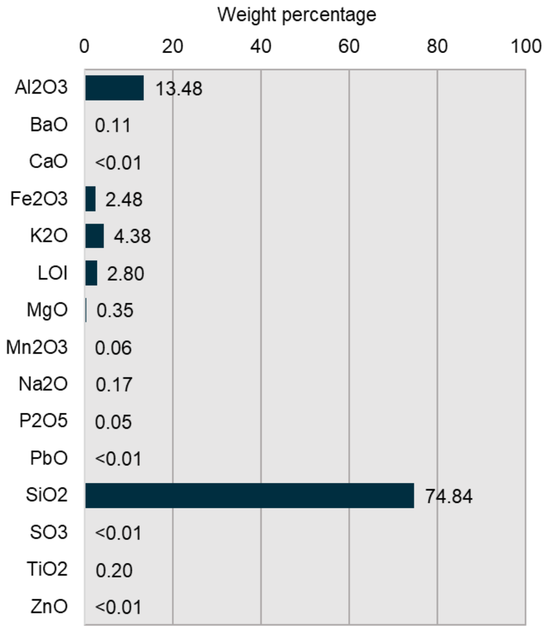
MINERALOGY

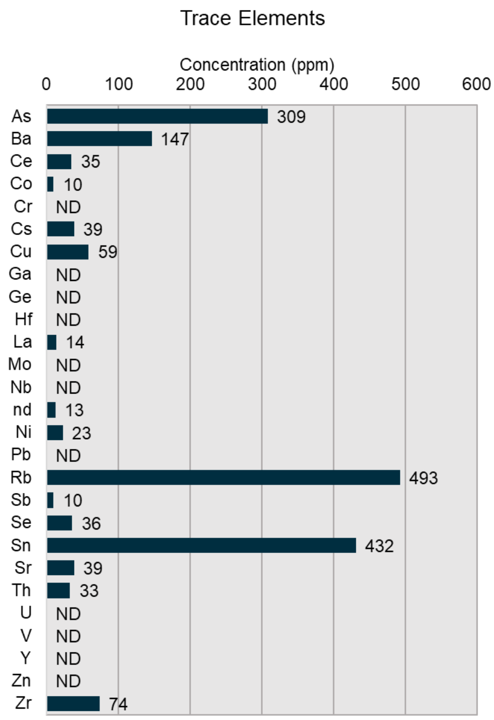
Mineral (wt %)	MPLY294
Hematite	<0.5
Kaolinite	1.2
Muscovite	30.4

Mineral (wt %)	MPLY294
Orthoclase	6.2
Pyrite	<0.5
Quartz	61.5

nd – not detected (concentration below the effective limit of detection).

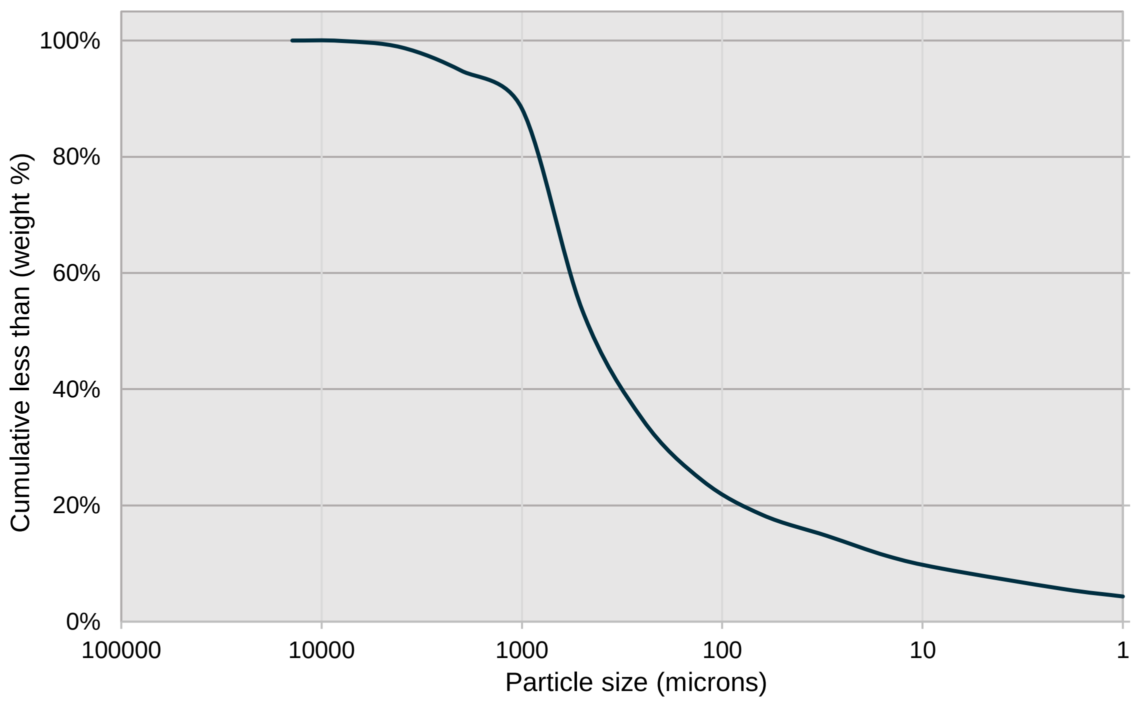
CHEMISTRY





ND – not detected (concentration below the effective limit of detection).

PARTICLE SIZE DISTRIBUTION



Appendix 2 Analytical Methodology

UK MINERAL OPERATION VISITS

Between 2019 and 2023, the BGS conducted mineral operation visits across the UK as part of the TransFIRe project, to investigate UK mineral waste and to collect samples for chemical, mineralogical and particle size characterisation. The locations of the mineral waste samples collected and analysed are presented in **Figure 1** and are categorised by the primary commodity production. Location numbers refer to the sample numbers of each UK mineral waste factsheet found in Appendix 1.

The samples collected were prepared for laboratory analysis and characterised by chemical (X-ray fluorescence), mineralogical (X-ray diffraction) and particle size distribution (wet-sieving and Sedigraph) methods. Due to analytical issues, any additional samples collected within this period have not been characterised by the methods described in subsequent sections.

X-RAY FLUORESCENCE (XRF)

XRF major and minor element analyses of the samples were completed by X-ray Mineral Services UK Limited.

XRF bead major element analysis

Samples for XRF major element analysis using the bead method were dried in an oven at 80°C. Approximately 5 g of sample was crushed by hand using a stainless-steel percussion mortar to achieve a fine particle size for analysis as a bead. This produced enough sample material for 2 beads for quality control purposes. Sample material ground to a fine powder was stored in sealed sample bags within a desiccator prior to further steps. Approximately 1.2 g of milled sample was placed into a ceramic crucible of known mass (Wc) and then remeasured to 4 decimal places (Ws) for each sample.

The crucible was heated in a furnace to 1050°C for a duration of 1 hour and 15 minutes, then cooled and then remeasured (mass recorded as Wa). Loss on Ignition (LOI %) was calculated through the following equation: LOI % = 100 x [(Ws-Wa) / (Ws-Wc)]. Approximately 5 g of lithium borate flux and 0.5 g of calcined sample was mixed in a cleaned platinum crucible. The bead was then made using a Vulcan 4MA Automatic Fusion Machine and measured with a calibrated WD-XRF Rigaku Supermini200, comprised of a 12-position automatic sample changer and Rigaku 25x operating software.

When fused bead sample preparation was not possible, the sample was prepared as a pressed pellet and measured on the ED-XRF instrument outlined below using a non-calibrated program. Out of the samples analysed, MPLY781 was the only sample measured using a non-calibrated program. Therefore, the major element results for this sample should be treated as indicative only.

XRF pellet trace element analysis

Samples for XRF trace element analysis using the pellet method were dried in an oven at 80°C. Sample material was crushed by hand using a stainless-steel percussion mortar and to achieve a fine particle size for analysis as a pellet, approximately 20 g of sample was milled using a Fritsch Pulverisette 6 ball agate mill at 500 rpm for 5 minutes. This produced enough sample material for 2 pellets for quality control purposes. Sample material milled to a fine powder was stored in sealed sample bags within a desiccator prior to further steps.

Milled samples were measured out to 10 g ± 0.2 g and combined in a plastic beaker with a polyvinyl alcohol binder (1 % Moviol) or if water-soluble materials were present a wax binder was used instead of the former. The mixture was pressed at 15 tons for 2 minutes using polished stainless steel platens and a Specac 25 ton press to produce a 32 mm pellet. Pellets were dried in an oven at 80°C for a minimum of 2 hours on a clean and labelled watch glass. The pellet was then analysed with a calibrated Rigaku NEX-DE ED-XRF Analyzer, comprised of a 15 position automatic sample charger, a 60 kV 12W x-ray Tube and QuantEZ RPF-SQX FP software. When large batches greater than 10 samples are processed, one sample from each ten was duplicated at random and run at the same time as the rest of the batch. The results of which are compared to check reliability of preparation and measurement.

Out of the samples analysed, MPLY781 was the only sample measured using a non-calibrated program. Therefore, the trace element results for this sample should be treated as indicative only.

Table 3. Detection limits for the suite of trace elements analysed.

Analyte	Detection Limit (ppm)
As	5
Ba	56
Ce	9
Co	10
Cr	39
Cs	3
Cu	10
Ga	3
Ge	2

Analyte	Detection Limit (ppm)
Hf	4
La	6
Mo	20
Nb	5
Nd	2
Ni	11
Pb	5
Rb	3
Sb	2

Analyte	Detection Limit (ppm)
Se	2
Sn	2
Sr	30
Th	2
U	2
V	37
Y	5
Zn	7
Zr	5

X-RAY DIFFRACTION (XRD)

XRD sample preparation

Samples were dried in a moisture extraction oven at 60ºC, then ground using a pestle and mortar to a nominal < 5 mm grainsize. A 20 g subsample of this crushate was ball milled to a ‘coarse’ powder. In order to provide a finer and uniform particle-size for powder XRD analysis, a 2.7 g portion of each powdered sample was micronised under deionised water for 10 minutes with 10 % (0.3 g) corundum (American Elements - PN:AL-OY-03-P). The addition of an internal standard allows the validation of quantification results and also the detection of any amorphous species present in the samples.

Corundum was selected since its principal XRD peaks are suitably remote from those produced by most of the phases present in the samples. The dried samples were further disaggregated and back-loaded into standard stainless steel sample holders for analysis.

XRD analysis

XRD analysis was carried out using a PANalytical X'Pert Pro series diffractometer equipped with a cobalt-target tube, X'Celerator detector and operated at 45 kV and 40 mA. The micronised powder samples were scanned from 4.5–85°2θ at 2.06°2θ/minute. Diffraction data were initially analysed using PANalytical X'Pert HighScore Plus version 5.1 software coupled to the latest version of the International Centre for Diffraction Data (ICDD) database.

Following identification of the mineral species present in the samples, mineral quantification was achieved using the Rietveld refinement technique (e.g. Snyder & Bish, 1989) using the same HighScore Plus software. This method avoids the need to produce synthetic mixtures and involves the least squares fitting of measured to calculated XRD profiles using a crystal structure databank. Errors for the quoted mineral concentrations calculated from synthetic mixtures of minerals, are better than ±1 % for concentrations >50 wt. %, ±5 % for concentrations between 50 and 20 wt. % and ±10 % for concentrations <10 wt. % (Kemp et al., 2016). Where a phase was detected but its concentration was indicated to be below 0.5 %, it is assigned a value of <0.5 %, since the error associated with quantification at such low levels becomes too large.

PARTICLE SIZE DISTRIBUTION

Samples were wet-sieved at 20 mm, 14 mm, 8 mm, 4 mm, 2 mm, 1 mm, 500 µm, 250 µm, 125 µm and 63 µm. Sample fractions were dried at 60ºC and weighed. Particle size analysis of the <63 µm material was carried out using a 0.05 % 'Calgon' (sodium hexametaphosphate) solution in a Micromeritics Sedigraph III Plus particle-size analyser. The results of Sedigraph analysis are similar to those obtained by Andreasen pipette (stipulated by BS1377: 1190) as both are sedimentation methods utilizing Stokes' Law.

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