Stream sediment geochemical mapping of Sierra Leone: orientation survey and roadmap to commencement

BGS Global

Open Report OR/20/041

BRITISH GEOLOGICAL SURVEY

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Editor

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Stream sediment sample collection at River No. 2, Freetown Peninsula.

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Foreword

This report on Stream Sediment Geochemical Mapping of Sierra Leone: orientation survey and roadmap to commencement, has been developed by technical experts from the British Geological Survey (BGS) and the Directorate of Geological Survey (DGS) at the National Minerals Agency (NMA). It is the outcome of an orientation survey undertaken by geologists of both BGS and DGS, specifically to guide and inform the planning of the proposed nationwide geochemical mapping of Sierra Leone. The primary objective of this report was to form the basis for the development of protocols and procedures for the three main stages of the proposed nationwide geochemical mapping campaign: sample collection, sample preparation and sample analysis. This report is also expected to provide useful information for the development of the Terms of Reference (ToR) that would be required in the tendering process for a consulting firm to provide technical assistance to the proposed geochemical mapping programme. The orientation survey also provided a platform for the development of hands-on training and upgrade of the knowledge and skills of the geoscientific staff of DGS, in preparation for the proposed geochemical mapping programme. The orientation survey is part of a series of partnership programmes between the BGS and the NMA, that is funded by the UK Department for International Development (DFID). The orientation survey was conducted with the espousal of innovative techniques, relevant skills and equipment, geared towards an efficient and effective field campaign.

In the development of the first Strategic Plan (2013-2017) of the then newly formed National Minerals Agency (NMA) in February 2013, the overarching strategic objective of the Directorate of Geological Survey was to "*Support minerals development in Sierra Leone through the provision of high-quality, comprehensive geological data*." The huge geological data and information gap existing at the time, was quickly identified by the NMA team of geologists as a major inhibiting factor for growth of the minerals sector. Hence, the nationwide airborne geophysical (magnetic and radiometric) survey, geological and geochemical mapping of Sierra Leone were identified as some of the remedial actions to this problem. The proposed nationwide geochemical mapping campaign will serve as an additional layer of geoscientific data that will complement the recently completed nationwide airborne magnetic and radiometric surveys of Sierra Leone, with the aim of generating high quality and reliable geoscientific data at a national scale.

As the head of the Geological Survey Directorate, I believe this report will be relevant for the planning of the proposed geochemical mapping campaign and will also serve as a useful tool to all geoscientific staff that will be participating in this imminent nationwide geochemical mapping of Sierra Leone.

Prince Richard Chea Cuffey
Director of Geological Survey
National Minerals Agency.

Acknowledgements

The work described in this report was carried out as part of the BGS-NMA partnership funded by the UK Department for International Development (DFID) under the Partnerships for Development Programme. Geochemical analysis was funded by the World Bank through the Extractive Industries Technical Assistance Programme Phase 2 (EITAP 2).

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1 Introduction

The National Minerals Agency (NMA) of Sierra Leone aims to undertake a systematic geochemical mapping programme in the near future.

Following a training course in geological and geochemical surveys for exploration that was delivered to the NMA by the British Geological Survey (BGS) in November 2018, the BGS and NMA have been working in collaboration to complete a stream sediment geochemical mapping orientation survey. This work has been supported by the UK Department for International Development (DFID)-funded 'Partnerships for Development' programme. The World Bank (WB) provided funds for analysis of the samples collected during the orientation survey, and may consider funding a systematic geochemical mapping programme as a component of the ongoing EITAP2 (Extractive Industries Technical Assistance Project 2).

An orientation survey is normally conducted before the start of a regional or exploration geochemistry programme, in order to establish methodologies for the survey. Stream sediment is the preferred sample media for conducting large scale reconnaissance exploration and geochemical mapping surveys (Darnley et al. 1995; Johnson et al. 2018a), since a stream sediment sample consists of material weathered from the upstream drainage catchment, and therefore a limited number of distributed stream sediment samples will offer coverage that can be considered to be representative of a relatively large area.

This report summarises the findings of the orientation survey. In consideration of the outcomes and experience gained from it, a roadmap to illustrate the next steps towards commencing a systematic stream sediment geochemical mapping programme in Sierra Leone is provided in the final section (Section 4).

This report is intended to inform the writing of the Terms of Reference (ToR) that would be required in the tendering process for a consultant to provide technical assistance to the eventual geochemical mapping programme. It is also intended to provide a basis for informing decisions that will need to be made in the course of designing the procedures and strategy of such a programme.

Another important outcome of the orientation survey work was that NMA geologists and field staff gained valuable experience in survey and sample collection methods, and NMA laboratory staff gained valuable experience in sample handling and preparation procedures.

Paul Everett and Richard Shaw (BGS) visited Sierra Leone between May 13th and May 24th 2019 to complete the orientation survey in conjunction with a team of NMA geologists. Following the fieldwork, laboratory staff from BGS (Mark Kalra) visited the NMA in June 2019 to assist with preparation of samples collected during the orientation survey. This sample preparation was carried out in the NMA laboratories (New England Ville, Freetown) prior to despatch of prepared sample material to ALS Laboratories for geochemical analysis. The sample handling and data collection procedures align with the development of the NMA's digital Lab Information Management System (LIMS) developed by BGS staff (Tim McCormick, Roman Roth and Rehan Kaleem) in collaboration with the NMA.

2 Orientation Survey: scope and procedures

2.1 OBJECTIVES AND PURPOSE OF THE ORIENTATION SURVEY

A systematic geochemical survey of any type consists of three main stages of work that are completed in sequence; sample collection, sample preparation, and sample analysis. Rigorous procedures must be followed at each stage to ensure that the resulting geochemical data is consistent and of good quality. This means it is vital that the methods for each stage are kept the same throughout the whole survey. Orientation surveys can take various forms, but the primary aim of orientation work of any kind is to trial and confirm the suitability of the intended methods before these are deployed for a systematic survey.

The primary objectives of the orientation survey carried out by the NMA/BGS were:

- To collect wet-sieved stream sediment samples, in duplicate, from a minimum of 20 different sites, distributed across some of the main geological terrains of Sierra Leone.
- To prepare milled powders from these samples that would be suitable for ICP-MS analysis. Prior to milling, each sample to be divided into two replicate samples.
- To despatch the milled samples to an external laboratory for analysis by two different methods (1) sodium peroxide (Na_2O_2) fusion inductively coupled plasma mass spectrometry (ICP-MS) and (2) lithium tetraborate (LiB_4O_7) fusion ICP-MS.

A diagram illustrating the workflow for sample collection, preparation and analysis is provided in Figure 1. Details of the procedures followed at each stage are provided in the following sub-sections. In brief, the reasoning behind the primary objectives is as follows:

Collecting duplicate samples and preparing replicates allows the representivity of the sample collection, preparation and analysis methods to be tested using a nested analysis of variance (ANOVA) statistical technique on the resulting analytical data. ANOVA is an important quantitative test of the suitability of the intended methods for a geochemical survey that is also used to evaluate the quality and representivity of geochemical results. In this case, the ANOVA results should allow the representivity of two different fusion methods to be compared, which can inform the decision as to which analytical methods will eventually be used during the geochemical mapping programme.

The analytical data will also give an indication of the likely ranges of element concentrations that will be encountered in stream sediment samples across the main geological terrains of Sierra Leone. This may also influence the selection of analytical methods to be used going forward, and will be useful for optimising the selection of a suite of reference materials to be included in the analytical schedule for a systematic survey.

A set of secondary objectives were also considered during the orientation survey:

- To collect heavy mineral concentrate (pan) samples at each site.
- To complete qualitative X-ray diffraction (XRD) analysis on a selection of pan samples.
- To collect several bulk (weighing in excess of 1kg) sediment samples (ideally one from each geological terrain).

Although of lower importance to the primary objectives, these can be conveniently completed at the same time, and are worthwhile for the following reasons. Routine collection of pan samples is commonly included in geochemical mapping programmes as it allows for follow-up mineralogical analysis, which can be used to establish the causes of geochemical anomalies and the controls on the patterns evident in the geochemical data. In this case qualitative XRD is used to identify the predominant mineral species present in each sample.

The purpose of collecting bulk stream sediment samples is to provide material that could potentially be used to prepare Secondary Reference Materials (SRMs). This offers a means of improving data quality if SRMs are included in the analytical schedule of the eventual geochemical survey programme. Bulk samples are collected according to the same wet sieving procedure as the routine stream sediment samples, but the target sample weight is considerably greater, in this case in excess of 1kg.

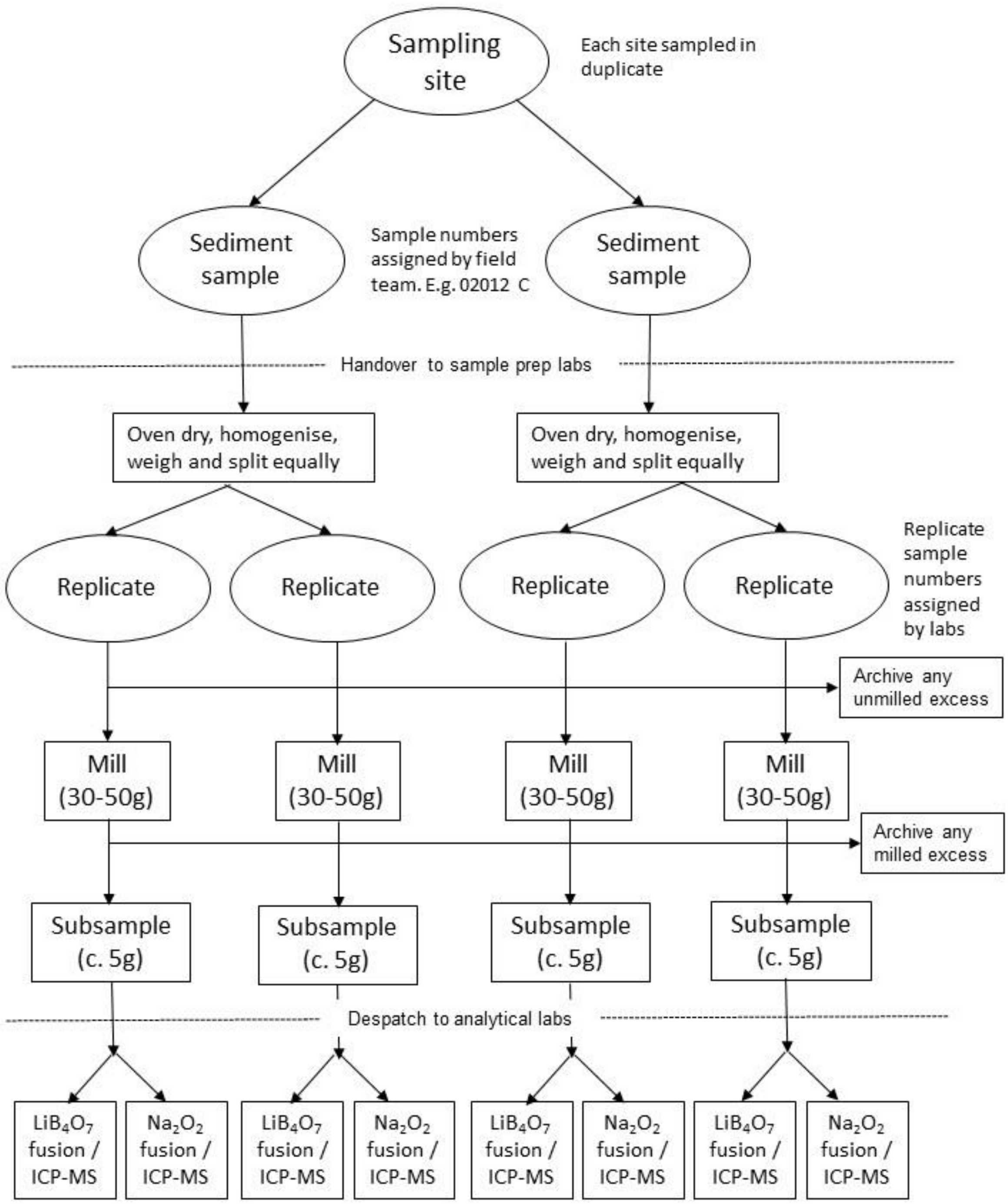

Figure 1. Workflow diagram for collection, preparation and analysis of routine stream sediment samples for the orientation survey

2.2 ITINERARY AND SAMPLING LOCATIONS

The stream sediment samples collected during the orientation survey were distributed across some of the main geological terrains of Sierra Leone. The selection of sampling sites and day to day logistical planning was carried out by the field team during the fieldwork.

The field team consisted of the following NMA staff: J. Lebbie, E Jusu, A L Turay, D Kanu, E Turay, I Jalloh, J Jackson, M Sesay, N Tucker, M Kamara, accompanied by P Everett and R A Shaw of the BGS.

The fieldwork itinerary ran as follows:

Day 1 – (13/5/19): A fieldwork start-up meeting was held at the NMA where BGS staff gave an overview of the aims, objectives and expectations of the geochemical mapping orientation survey. The field team began pre-planning of intended sampling sites and preparation of sieves and packing of field equipment.

Day 2 – (14/5/19): The field team continued equipment preparation and sample site pre-planning at the NMA Laboratory. In the afternoon, a sampling training re-fresher was completed at No.2 River (Freetown Peninsula), where sediment, pan (heavy mineral concentrates) and bulk samples were collected.

Day 3 – (15/5/19): Sampling of sites on Kasila and Bullom Group geology.

Day 4 – (16/5/19): Left for Makeni to sample sites situated on granites within the Archaean basement.

Day 5 – (17/5/19): Visited the Sula Mountains to sample sites situated on greenstone belt, migmatitic gneisses and granites within the Archaean basement.

Day 6 – (18/5/19): Return to Freetown, checked off and deposited samples at the NMA.

Day 7 – (20/5/19): Left Freetown for Kenema and completed sampling en-route to Kenema.

Day 8 – (21/5/19): Conducted sampling of sites situated on Archaean basement gneiss around Kenema.

Day 9 – (22/5/19): Conducted sampling of sites in the diamond area near to Kenema.

Day 10 – (23/5/19): Left Kenema for Freetown. Final samples collected on basement gneiss en-route to Freetown.

Day 11 – (24/5/19): Completed final sample check-off and deposited samples at the NMA, sorted field equipment and completed compilation of field data. Debrief and discussion on next steps.

For each day's sampling, the NMA geochemical mapping team was divided into four groups of two or three. One BGS staff member supervised two groups. All NMA and BGS team members were regularly rotated between different groups to enhance effective participation and learning.

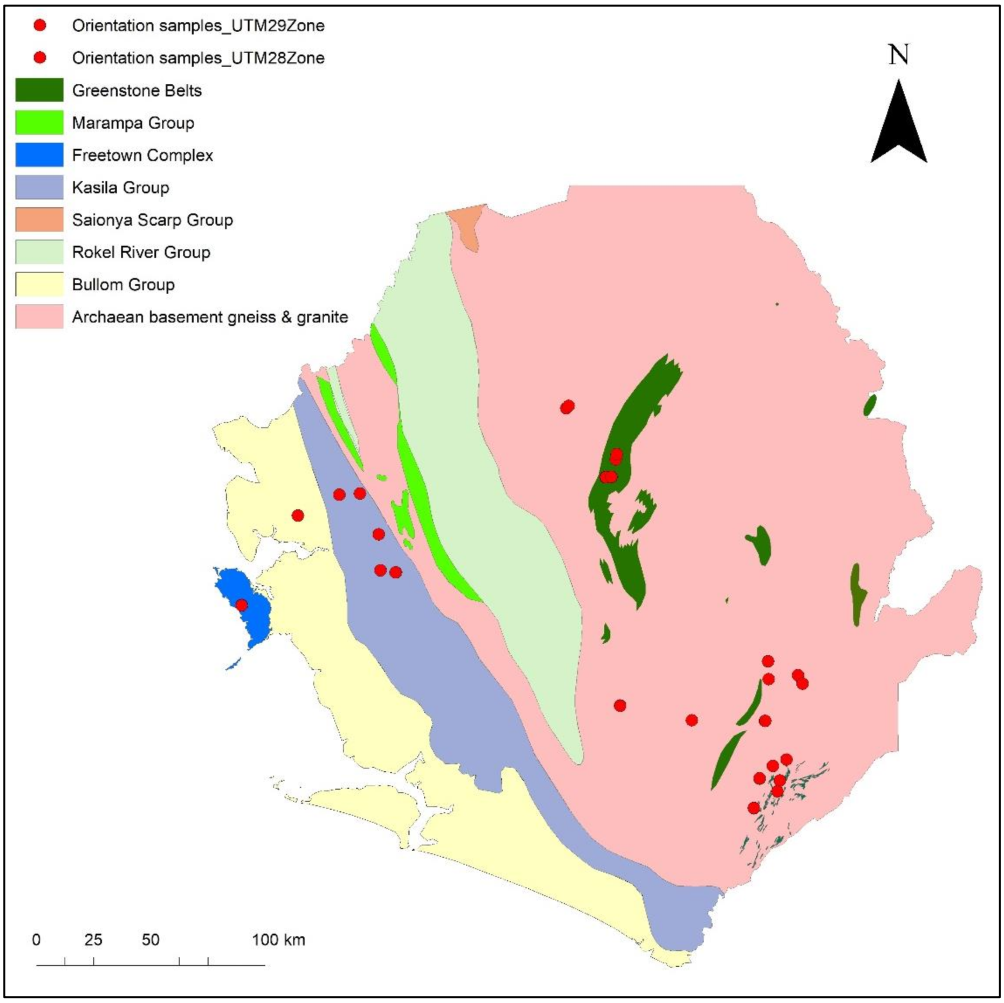

Figure 2. Sampling sites visited during the orientation survey, shown on a simplified national geological map of Sierra Leone.

2.3 SAMPLE COLLECTION METHODS

The sample collection methods described in this section follow those which have been adopted as international standards for regional and global scale geochemical mapping (see for example Darnley et al, 1995, Salminen 2005, Johnson et al. 2018a).

In summary, for routine sampling, stream sediment from 1st – 3rd order streams is wet-sieved at site to collect the <150µm size fraction. For the orientation survey, sediment samples at every site are collected in duplicate. Each sample of <150µm sediment should weigh at least 200g when dry. Important information about each sample is recorded on a field card at site and transferred to a field data spreadsheet later.

A detailed account of the procedures followed during the orientation survey is provided below.

2.3.1 Recording site and sample information

The primary method of data collection in the field is a hardcopy record referred to as a field card. A field card (Figure 3), designed for stream sediment geochemical mapping in Sierra Leone was produced in advance of the orientation survey, and is used to record all of the information about a site and the collected samples. Detailed guidance notes for completing the field card are presented in Appendix 1. These guidance notes were provided to NMA geologists for reference during the orientation survey fieldwork.

Field cards are numbered (with sample ID numbers) prior to fieldwork commencing. At the start of every day, each sampling team is issued with a set of field cards corresponding to the number of sites that team are to sample that day. At this point, a record of which sample ID numbers were allocated to which team is made on a sample allocation list (Appendix 2). On arrival at site, the team use the next numbered blank field card. The sample number on that card is transcribed on to all sample bags at the site, using a permanent marker pen.

The team responsible for collecting the sample is identified by their initials on the field card. The individual responsible for completing the field card lists their initials first. Laminated sheets (Figure 4 and Figure 5) with a summary of the scheme of codes and abbreviations used to complete the field cards is carried by each field team in a Filofax booklet that also holds the field cards. Only acceptable codes and abbreviations are listed, which reduces the amount of free-text information written on each field card.

All sections of the field card are to be completed on location (Figure 6). At the end of each day, each field team is responsible for entering the information recorded on their field cards into a master field data spreadsheet saved on a shared computer.

During the orientation survey, a new method for digitally recording field data, using an android smartphone, was trialled. This method, utilised the same scheme as specified for the field cards and was developed by the NMA, using Open Data Kit (ODK) software, which is a customisable data recording app. This worked well for data recording, but there is a need to streamline procedures for downloading data.

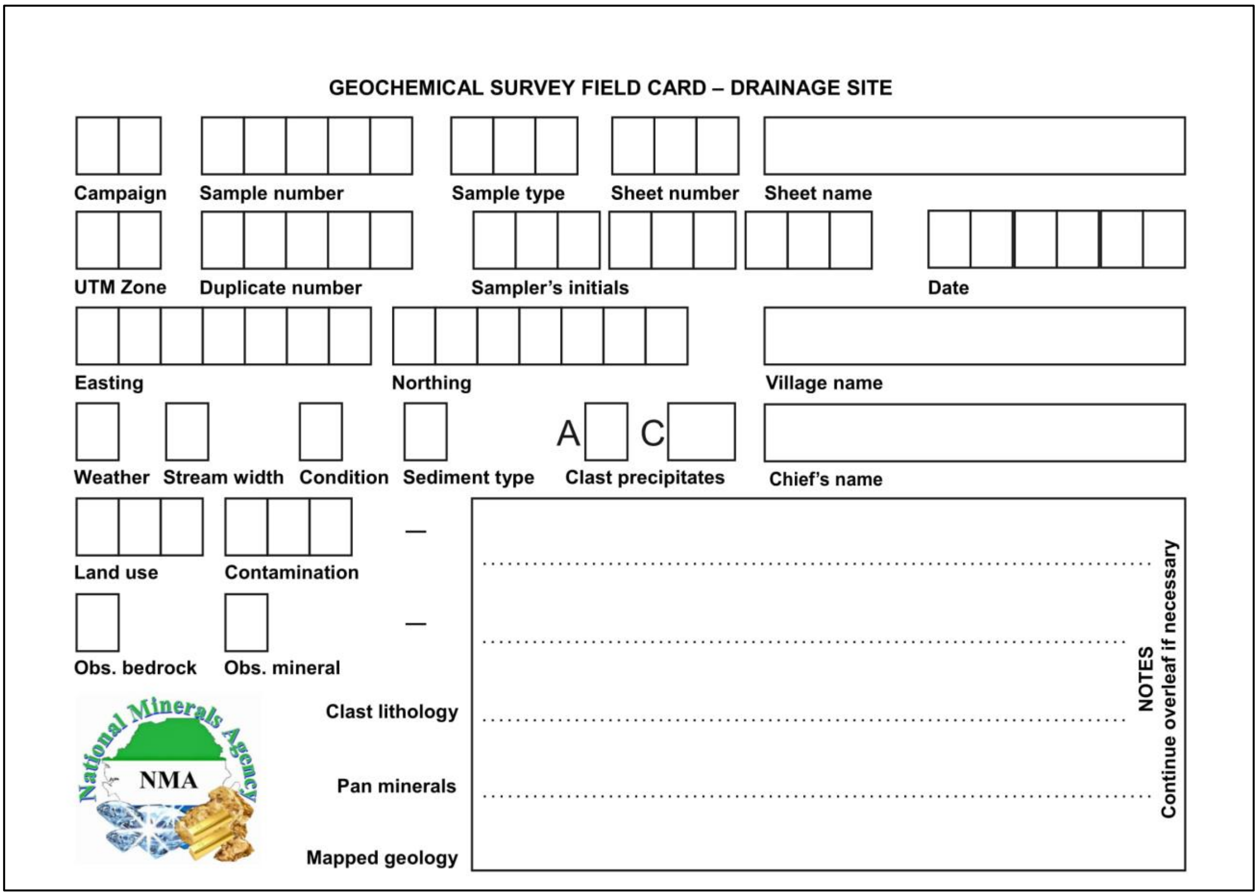

Figure 3. Field data card designed for recording site and sample information for sediment geochemical sampling in Sierra Leone

Codes and descriptions for use with the field card

Campaign
- 01 - training
- 02 - orientation
- 03 - area/campaign 1

Sample Type
- C – stream sediment
- P – heavy mineral concentrate
- B – bulk sediment

Weather
- 1 - Dry
- 2 - Showers/light rain
- 3 - Heavy rain <12 hours
- 4 - Heavy rain <24 hours
- 5 - Heavy rain <48 hours
- 6 - Heavy rain <72 hours

Stream width
- 1 - Small Stream <3m wide
- 2 - Stream 3-10m wide
- 3 - Small River 10-33m wide

Sediment type
- G - gravel or coarse sand
- S - sand
- F - silt or mud

Drainage condition
- 1 - Dry
- 2 - Damp but no water
- 3 - Ponded with dry sections
- 4 - Low flow - stream bed not covered by running water
- 5 - Moderate flow - stream boulders visible only
- 6 - Strong flow - large boulders visible only
- 7 - Channel filled from bank to bank
- 8 - Flood flow

Clast precipitate abundance
- 0 - absent
- 1 - light
- 2 - moderate
- 3 - heavy

Clast precipitate colour
- Bl - Black
- Br - Brown
- O - Orange

Observed bedrock
- 0 - No outcrop
- 1 - Minor outcrop
- 2 - Moderate outcrop
- 3 - Abundant outcrop

Observed mineralisation
- Y - mineralisation present
- N - no mineralisation observed

Land use
- 1 - Rain forest
- 2 - Scrub forest
- 3 - Rock scree
- 4 - Mangrove
- 5 - Arable agriculture
- 6 - Grassland pasture
- 7 - Village
- 8 - Urban
- 9 - Industrial
- 10 – Road

Contamination
- A - Metal
- B - Brick
- C - Concrete
- D - Plastic
- E - Ceramic or pottery
- F - Rubber
- G - Glass
- H - Paint
- I - Mine/industrial waste
- J - Agricultural waste
- K - Household waste
- L - Oils

Figure 4. Lookup card with codes to be used for completing the field card

Abbreviations for lithologies

AND - Andesite	LMPY - Lamprophyre
AMPHB - Amphibolite	LMST - Limestone
BA – Basalt	MARBLE - Marble
BAUX - Bauxite	MDST - Mudstone
BREC - Breccia	MYLO - Mylonite
CALSST - Marl	PDT - Peridotite
CHRMT - Chromitite	PGGN - Pegmatite (Granite)
CLAY - Clay	PPHY - Porphry
CONG - Conglomerate	PSAMM - Psammite
DA - Dacite	QZITE - Quartzite
DI - Diorite	RY - Rhyolite
DOLR - Dolerite	SCH - Schist
DUN - Dunite	SDST - Sandstone
FELS - Felsite	SEPITE - Serpentinite
GB - Gabbro	SLST - Siltstone
GD - Granodiorite	SLTE - Slate
GN - Granite	TUF - Tuff
GNSS - Gneiss	

Abbreviations for minerals

Am - Amphibole	Hem - Hematite
Apy - Arsenopyrite	Ilm - Ilmenite
Brt - Baryte	Mag - Magnetite
Bt - Biotite	Mo - Molybdenite
Bn - Bornite	Mnz - Monazite
Cal - Calcite	Ol - Olivine
Cst - Cassiterite	Py - Pyrite
Ccp - Chalcopyrite	Po - Pyrrhotite
Chr - Chromite	Qtz - Quartz
Cnbr - Cinnabar	Rgr - Realgar
Ctn - Columbite/Tantalite (coltan)	Rt - Rutile
	Sch - Scheelite
Ep – Epidote	Sp - Sphalerite
Fl - Fluorite	Stb - Stibnite
Fsp - Feldspar	Tur - Tourmaline
Gn - Galena	Wmca - White mica
Grt - Garnet	Zr - Zircon
Au - Gold	

Figure 5. Lookup card with abbreviations for lithologies and minerals

2.3.2 Sample collection

Sediment was collected from the active drainage channel of first to third order streams. Although suitable methods for collecting samples from dry stream beds can be used for a systematic geochemical survey, for the orientation survey, if streams were found to be dry, a sample was not collected and an alternative site nearby was visited instead.

Obvious contamination was avoided. For example, sites were located >100 m upstream of stream confluences, and away from road intersections, habitations and livestock access points to the streams. Every attempt was made to collect active sediment from the middle of the stream channel (Figure 7). One member of the field team walked 50–100 m upstream (along the bank) from each intended site to check for any localised contamination, prior to initiating sample collection.

A nested sieve set (Figure 8), consisting of an outer and inner sieve that sit above a sediment collection dish was used for the collection of the samples. The sediment was wet sieved firstly through the 2 mm nylon screen in the outer sieve (Figure 9) and then a 150 µm nylon screen in the inner sieve (

Figure 10). The fine (150 µm) stream sediment passing through to the collection dish was then allowed to settle for around 20–40 minutes (Figure 11), before excess water in the dish was discarded and the sediment collected in the bottom of the dish was transferred to a pre-labelled Kraft paper bag using a funnel. The Kraft paper bag was then placed inside a polythene bag for protection during transport from the field.

The 2 mm - 150 µm fraction from the sieving of the sediment was panned on site in a wooden or fibreglass pan (Figure 12). A full pan was panned down to give a constant volume in the centre of the pan. The heavy minerals were examined for evidence of mineralisation.

For the orientation survey, sample collection was duplicated at every sample site. The duplicate sediment was collected about 25 m upstream of the original. Although the collection of a duplicate pan concentrate was not essential, at the majority of sites this was completed for training purposes.

On return to the NMA offices, samples were removed from the outer polythene bags, checked off, and then hung outside on a line to air dry inside the Kraft paper envelopes.

Checking off was carried out by two people; one person to check the numbers marked on samples and call them out, and the second to mark off the checklist (Appendix 3), with a diagonal line in the boxes corresponding to each sample. Before marking off on the check list, the number and sample-type code on each sample were checked for legibility and any obvious inconsistency with other samples from that site. When required, corrections were made clearly in black marker pen.

Any sediment or panned samples that required re-bagging (usually due to the Kraft paper bag bursting in transit) were dealt with immediately. It was ensured that a batch of spare paper sample bags and marker pens were to hand during the checking-off process to allow this.

When dried, samples were removed from the drying line. Each dried sample was placed in a clean, protective polythene bag, and stored. On completion of the sample collection programme, every sample number was double checked before the samples were handed on to the NMA labs for sample preparation. For each sample-type, every individual sample was identified and checked off again on the sample checklist (using a diagonal stroke perpendicular to the original).

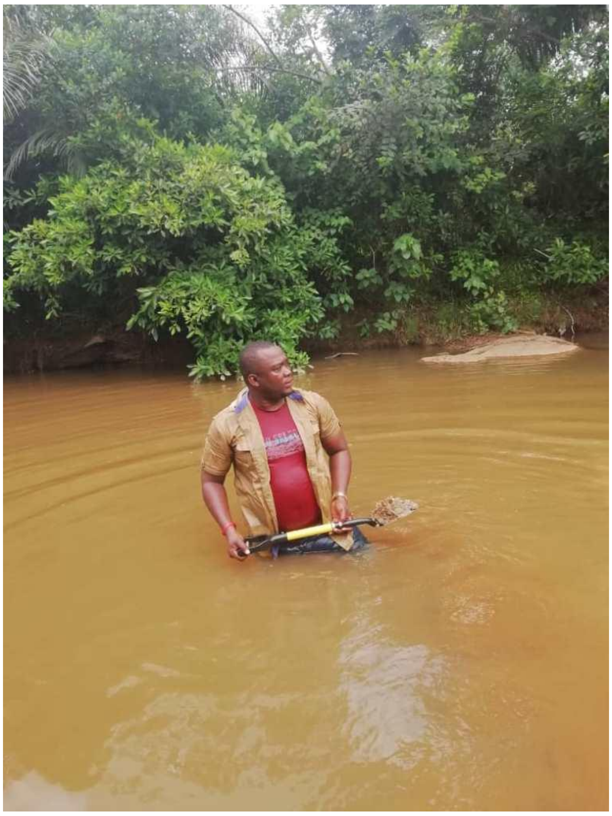

Figure 6 (left). Completion of the field card at site. Figure 7 (right). Digging sediment from the centre of the stream channel

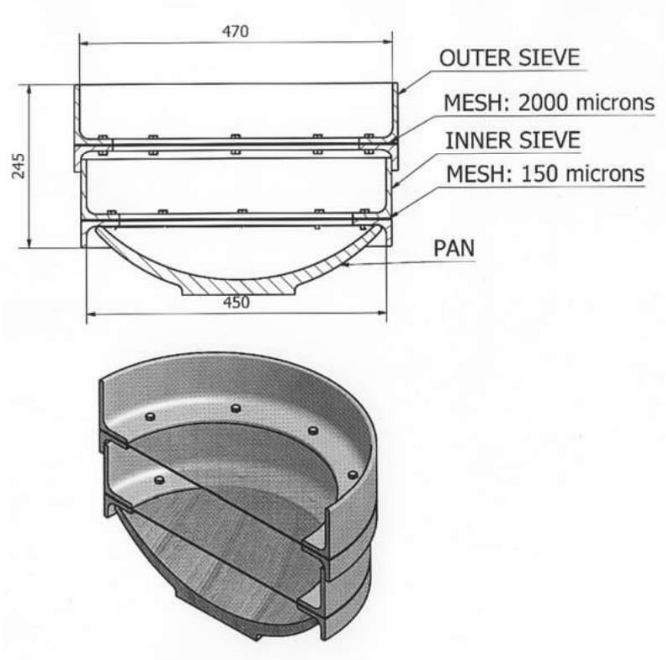

Figure 8. Diagram of a nested sieve set used for stream sediment sampling. Top: cross-section plan view (dimensions in mm). Bottom: cut-away 3-D visualisation (from engineering drawing by Humphrey Wallis, BGS for ABS (acetyl butyl styrene) polymer plastic sieve sets). Taken from Johnson et al. (2018a).

Figure 9 (left). Sediment being rubbed through the 2 mm screen in the outer sieve.
Figure 10 (right). Sediment being rubbed through the 150 µm screen in the inner sieve

Figure 11 (left). After sieving, the sediment in the collection dish is left to settle before bagging. Figure 12 (right). The heavy mineral concentrate is panned using a fibreglass pan

2.4 SAMPLE PREPARATION

On hand-over of the samples to the NMA laboratories, the heavy mineral concentrate samples were oven-dried and stored for further study (including XRD analysis as detailed in Section 3.4). Bulk sediment samples were large enough to fill multiple Kraft paper sample bags; the bags for each sample were combined and oven dried in a metal tray. Reporting on further work associated with the preparation of bulk sediment samples is outwith the scope of this document.

This remainder of this section provides a summary of the sample preparation for the routine stream sediment samples only. A more detailed, step-by-step procedural document for sample preparation of stream sediment samples at the NMA laboratories was produced by Mr A Amara; this is reproduced in Appendix 4.

Firstly, the entire batch of stream sediment samples were removed from their Kraft paper bags, oven dried at 80℃ on metal trays, disaggregated by hand using a mortar and pestle, and then weighed.

At this point the dry sample weights were reviewed and the decision was made to exclude any samples where one or both of the field duplicate pair weighed <60g from further preparation and analysis. This was done primarily to limit the possibility of ineffective milling that could result from loading milling pots with low sample weights. This was deemed particularly relevant as only larger (500 ml) milling pots were available at the NMA labs.

According to the design of the orientation survey (Figure 1) two replicates of each sediment sample were made and milled separately. To prepare these replicates, each sample was first homogenised. For samples weighing in excess of 100 g, an approximately 100 g subsample was made by cone-and-quartering, and then riffle split to provide two approximately equal 50 g portions for milling. Samples that weighed 60–100 g were riffle split directly, to provide two approximately equal 30–50 g portions for milling. In each case, the 'original' sample number used in the field (e.g. 02002C) was used for one of these portions, while the second was assigned the same number prefixed with the letter 'R' (e.g. R02002C) to designate it as a replicate of the same sample.

Each of the replicate portions was then milled. Milling was completed using a Fritsch Planetary Ball Mill with 500 ml tempered steel pots loaded with 25 balls. Initial QC results indicated that milling 50 g of stream sediment for 30 minutes at 300 rpm produced material that passed 99.7 % through a 63 µm sieve in a wet sieve test, and that 200 and 250 rpm speeds passed around 84 %, so it was decided that milling would proceed at 300 rpm for 30 minutes. The mill was prone to overheating when constantly running at this speed for the full 30 minutes duration, so it was sometimes necessary to run it for 10 minutes, pause to allow cooling, run for a further 10 minutes, pause again for cooling, and then run for a final 10 minutes.

An approximately 5 g subsample of each milled sample was then removed for despatch to the analytical labs, and the remainder of the milled sample material was archived at the NMA.

2.5 SAMPLE ANALYSIS

High-precision, multi-element geochemical analytical methods, such as X-ray fluorescence spectrometry (XRFS), inductively coupled plasma mass spectrometry (ICP-MS) and inductively coupled plasma atomic emission spectroscopy (ICP-AES) are typically favoured for geochemical mapping studies. The NMA usually commission such analyses from commercial companies that specialise in providing analytical services to clients in the mining and mineral exploration sector. There are no labs with the facilities for these analytical methods in Sierra Leone, so international shipping of the orientation survey samples was necessary.

Analytical options from six different companies were reviewed; Bureau Veritas Minerals, MS Labs, ALS labs (based in Canada), SGS (based in Australia) Alfred H Knight (UK), and Intertek (Global). ALS were selected to provide the analysis for the orientation survey samples, as they provided a competitive quote, offered analytical packages which were a good fit to the requirements of the project, and had previously established a good business relationship with the NMA.

Analysis using two separate methods offered by ALS as two different ‘packages’ was commissioned:

- **Sodium peroxide (Na_2O_2) fusion ICP-MS** (ALS code: MS-MS89L). Analytes determined: Ag, As, Ba, Be, Bi, Ca, Cd, Ce, Co, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Ge, Ho, In, K, La, Li, Lu, Mn, Mo, Nb, Nd, Ni, Pb, Pr, Rb, Re, Sb, Se, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn
- **Lithium borate (LiB_4O_7) fusion ICP-MS** (ALS code: ME-MS81). Analytes determined: Ba, Ce, Cr, Cs, Dy, Er, Eu, Ga, Gd, Hf, Ho, La, Lu, Nb, Pr, Rb, Sm, Sn, Sr, Ta, Tb, Th, Tm, U, V, W, Y, Yb, Zr

The rationale for selecting these two methods was;

- The Na_2O_2 fusion method allows determination of a wide range of elements, including lithium.
- The addition of the LiB_4O_7 fusion method will provide results for Cr, Hf, Zr.
- The considerable overlap between the two methods, whereby most elements in the LiB_4O_7 fusion method are also included in the Na_2O_2 fusion method, will allow a direct comparison of the quality of data produced by each method.

It was found that none of the companies considered offered any single-method package that could be thought of as ‘ideal’ in terms of measuring the entire range of elements that might be desired for inclusion in the analytical schedule of a geochemical mapping project. Also noteworthy is that the multi-element analytical packages on offer were overwhelmingly based on ICP-MS/AES methods instead of XRFS, which may reflect a trend towards ICP methods becoming preferred by the industry.

3 Orientation Survey: results and outcomes

3.1 SAMPLES OBTAINED AND PROCESSED

In total, the inventory of samples collected in the field (Table 1) consists of: 58 paired samples (from 29 different streams/sites) obtained during the orientation survey fieldwork (numbers 02001-02058); bulk samples from 4 locations (numbers 02097-02100); and 7 from locations visited during an earlier (November 2018) training exercise (numbers 0100xx).

At one location visited for the orientation survey (02001), a heavy mineral concentrate was collected, but due to an oversight a sediment sample was not collected, meaning that a total of 64 routine (not including bulk) stream sediment samples were obtained. Some of these sediment samples were excluded from further stages of sample preparation (replication and milling):

- 6 sediment samples where one or both of the duplicate pairs weighed less than 60g.
- Only 3 of the 7 samples collected during an earlier (November 2018) training exercise were fully prepped for analysis. The remainder were used for assessing different milling procedures.

This meant that 54 replicate samples were fully prepared and submitted for analysis, resulting in a suite of 108 analytical samples (Table 2). Analyses were reported for 107 of these samples (Appendix 5); one sample (R02047-C) was excluded from analysis. The analytical labs listed this sample as 'not received'- the sample prep labs had recorded the weight of this sample as 1.7g, so it is likely that the sample volume provided was insufficient for analysis.

It is noted that only 15 of the 64 routine sediment samples met the original target sample weight of >200 g, while 2 of the 4 bulk samples collected met the target sample weight of >1 kg. As the collected sediment is bagged wet and the resulting sample volume only becomes clear once the bags are dry, the ability to judge the required volume is something that samplers must gain from experience.

3.2 SUMMARY OF ANALYTICAL RESULTS

The full analytical results for the orientation survey samples are reproduced in Appendix 5. Analyte concentrations were reported by the analytical labs in ppm (parts per million), or as a percentage for major elements. A tabulated summary of key information for each analyte is presented in Table 3 (Na_2O_2-fusion method) and Table 4 (LiB_4O_7-fusion method).

Table 1. Inventory of samples collected in the field.

If applicable, the number of each sample's duplicate partner (which was collected at another position within the same site) is indicated in the second column. The sample types collected are indicated thus: C – <150µm sieved sediment; P – pan concentrate; B – bulk <150µm sieved sediment, according to the letters used to identify these on sample bags. The final column indicates which <150µm sieved sediment samples were replicated and milled for analysis.

Sample number	Duplicate number	Sed.	Pan	Bulk	Date collected	UTM zone	Easting	Northing	Sed. weight (g)	Rep & mill
010005	010037	C	P		22/11/2018	28	758786	954376	75	Y
010013	N/A	C	P		23/11/2018	28	699732	922960	160	N
010022	N/A	C	P		23/11/2018	28	699693	923047	145	N
010037	010005	C	P		22/11/2018	28	758786	954376	95	Y
010075	N/A	C	P		23/11/2018	28	699679	923009	124	N
010083	N/A	C	P		22/11/2018	28	757964	953575	ND	N
010099	N/A	C	P		22/11/2018	28	758786	954376	139	Y
02001	N/A		P		14/05/2019	28	699590	923309	N/A	N
02002	N/A	C	P		14/05/2019	28	699596	923270	129	Y
02003	02004	C	P		14/05/2019	28	699652	923144	93	Y
02004	02003	C	P		14/05/2019	28	699675	923112	103	Y
02005	02006	C	P		15/05/2019	28	750560	972091	234	Y
02006	02005	C	P		15/05/2019	28	750560	972091	160	Y
02007	02008	C	P		15/05/2019	28	741719	971543	75	Y
02008	02007	C	P		15/05/2019	28	741730	971584	203	Y
02009	02010	C	P		15/05/2019	28	723774	962308	213	Y
02010	02009	C	P		15/05/2019	28	723772	962306	328	Y
02011	02012	C			15/05/2019	28	721604	963458	35	N
02012	02011	C	P		15/05/2019	28	721604	963458	39	N
02013	02014	C	P		16/05/2019	29	179985	1009724	99	Y
02014	02013	C	P		16/05/2019	29	179985	1009724	74	Y
02015	02016	C	P		16/05/2019	29	181130	1010812	203	Y
02016	02015	C	P		16/05/2019	29	181133	1010812	226	Y
02017	02018	C	P		17/05/2019	29	196896	979593	166	Y
02018	02017	C	P		17/05/2019	29	196985	979599	134	Y
02019	02020	C	P		17/05/2019	29	199416	979658	246	Y
02020	02019	C	P		17/05/2019	29	199385	979728	111	Y
02021	02022	C	P		17/05/2019	29	201381	987274	309	Y
02022	02021	C	P		17/05/2019	29	201319	987284	359	Y
02023	02024	C	P		17/05/2019	29	201755	989499	135	Y
02024	02023	C	P		17/05/2019	29	201755	989499	112	Y
02025	02026	C	P		17/05/2019	29	188153	972289	54	N
02026	02025	C	P		17/05/2019	29	188161	972264	157	N
02027	02028	C	P		17/05/2019	29	188217	972349	45	N
02028	02027	C	P		17/05/2019	29	188224	972367	62	N
02029	02030	C	P		20/05/2019	28	766336	937930	165	Y
02030	02029	C			20/05/2019	28	766327	937909	161	Y
02031	02032	C	P		20/05/2019	28	759715	938805	200	Y

Sample number	Duplicate number	Sed.	Pan	Bulk	Date collected	UTM zone	Easting	Northing	Sed. weight (g)	Rep & mill
02032	02031	C			20/05/2019	28	759708	938775	97	Y
02033	02034	C	P		21/05/2019	29	262800	848002	70	Y
02034	02033	C	P		21/05/2019	29	262812	848009	77	Y
02035	02036	C	P		21/05/2019	29	271579	847112	134	Y
02036	02035	C	P		21/05/2019	29	271594	847097	275	Y
02037	02038	C	P		21/05/2019	29	274467	856142	176	Y
02038	02037	C	P		21/05/2019	29	274447	856201	220	Y
02039	02040	C	P		21/05/2019	29	260224	835108	195	Y
02040	02039	C	P		21/05/2019	29	260205	835128	200	Y
02041	02042	C	P		21/05/2019	29	268570	853441	85	Y
02042	02041	C	P		21/05/2019	29	268531	853435	63	Y
02043	02044	C	P		21/05/2019	29	270493	842368	161	Y
02044	02043	C	P		21/05/2019	29	270498	842356	70	Y
02045	02046	C	P		22/05/2019	29	266702	898961	83	Y
02046	02045	C	P		22/05/2019	29	266709	898949	100	Y
02047	02048	C	P		22/05/2019	29	265326	873065	93	Y
02048	02047	C	P		22/05/2019	29	265343	873070	157	Y
02049	02050	C	P		22/05/2019	29	266956	891218	94	Y
02050	02049	C	P		22/05/2019	29	266930	891210	128	Y
02051	02052	C	P		22/05/2019	29	279663	892922	254	Y
02052	02051	C	P		22/05/2019	29	279684	892914	127	Y
02053	02054	C	P		22/05/2019	29	281663	889208	79.6	Y
02054	02053	C	P		22/05/2019	29	281675	889218	184	Y
02055	02056	C	P		23/05/2019	29	202490	880083	293	Y
02056	02055	C	P		23/05/2019	29	202476	880062	66	Y
02057	02058	C	P		23/05/2019	29	233541	873475	151	Y
02058	02057	C	P		23/05/2019	29	233531	873480	110	Y
02097				B	22/05/2019	29	266708	898946	524	N
02098			P	B	20/05/2019	28	759834	938850	1257	N
02099			P	B	16/05/2019	29	179746	1009771	1270	N
02100			P	B	14/05/2019	28	699684	923021	324	N

Table 2. List of samples prepared for analysis ('analytical' samples).

Duplicate/replicate sets each consist of four samples designated DUP A, REP A, DUP B and REP B. (see Section 3.3 for further details), all of which originate from the same site; these are known as 'control samples' due to their role in quality control monitoring. Details of the samples in each set are arranged consecutively in the table below. N.B. the weight of some milled samples was not recorded (appearing below as 'nr') by the sample prep labs.

Sample number	Control sample	Milled weight (g)
010005-C	DUP A	nr
R010005-C	REP A	nr
010037-C	DUP B	nr
R010037-C	REP B	nr
010099-C	-	nr
R010099-C	-	nr
02002-C	-	50.4
R02002-C	-	50.9
02003-C	DUP A	39.5
R02003-C	REP A	48.1
02004-C	DUP B	47.8
R02004-C	REP B	47.7
02005-C	DUP A	53.5
R02005-C	REP A	55.7
02006-C	DUP B	52.3
R02006-C	REP B	51.8
02007-C	DUP A	35.8
R02007-C	REP A	35.2
02008-C	DUP B	51.3
R02008-C	REP B	52.4
02009-C	DUP A	51.3
R02009-C	REP A	52.4
02010-C	DUP B	50.3
R02010-C	REP B	46.5
02013-C	DUP A	47.6
R02013-C	REP A	47.9
02014-C	DUP B	36.3
R02014-C	REP B	35.7
02015-C	DUP A	49.2
R02015-C	REP A	50.3
02016-C	DUP B	48.2
R02016-C	REP B	48.5
02017-C	DUP A	50.6
R02017-C	REP A	48.1
02018-C	DUP B	50.4
R02018-C	REP B	48.3
02019-C	DUP A	58.3
R02019-C	REP A	59.1
02020-C	DUP B	49.4
R02020-C	REP B	47.5
02021-C	DUP A	48.4
R02021-C	REP A	47.6
02022-C	DUP B	50.7
R02022-C	REP B	50.5
02023-C	DUP A	50.0
R02023-C	REP A	51.5
02024-C	DUP B	50.8
R02024-C	REP B	51.6
02029-C	DUP A	51.8
R02029-C	REP A	51.2
02030-C	DUP B	50.4
R02030-C	REP B	49.3
02031-C	DUP A	47.6
R02031-C	REP A	47.9

Sample number	Control sample	Milled weight (g)
02032-C	DUP B	47.7
R02032-C	REP B	47.6
02033-C	DUP A	34.0
R02033-C	REP A	32.7
02034-C	DUP B	36.6
R02034-C	REP B	36.8
02035-C	DUP A	49.6
R02035-C	REP A	47.8
02036-C	DUP B	52.9
R02036-C	REP B	54.2
02037-C	DUP A	51.7
R02037-C	REP A	51.3
02038-C	DUP B	50.8
R02038-C	REP B	48.8
02039-C	DUP A	50.7
R02039-C	REP A	49.6
02040-C	DUP B	49.9
R02040-C	REP B	48.9
02041-C	DUP A	41.0
R02041-C	REP A	40.2
02042-C	DUP B	30.4
R02042-C	REP B	31.0
02043-C	DUP A	51.5
R02043-C	REP A	51.2
02044-C	DUP B	33.8
R02044-C	REP B	34.0
02045-C	DUP A	39.7
R02045-C	REP A	40.7
02046-C	DUP B	47.2
R02046-C	REP B	47.8
02047-C	DUP A	44.2
R02047-C	REP A	1.7
02048-C	DUP B	48.1
R02048-C	REP B	47.1
02049-C	DUP A	44.8
R02049-C	REP A	44.0
02050-C	DUP B	50.1
R02050-C	REP B	50.4
02051-C	DUP A	49.9
R02051-C	REP A	48.5
02052-C	DUP B	50.0
R02052-C	REP B	49.2
02053-C	DUP A	38.5
R02053-C	REP A	38.9
02054-C	DUP B	53.2
R02054-C	REP B	52.8
02055-C	DUP A	53.4
R02055-C	REP A	51.2
02056-C	DUP B	nr
R02056-C	REP B	32.3
02057-C	DUP A	nr
R02057-C	REP A	50.9
02058-C	DUP B	nr
R02058-C	REP B	52.9

Table 3. Summary information for Na_2O_2-fusion ICP-MS analysis

Element	n <LLD *	Detection range	Min	Median	Max	Units
Ag	70 (65%)	5 - 12,500	<5	<5	14	ppm
As	15 (14%)	4 - 25,000	<4	8	45	ppm
Ba	0 (0%)	2 - 25,000	58	409	2410	ppm
Be	14 (13%)	0.4 - 25,000	<0.4	0.9	3	ppm
Bi	18 (17%)	0.1 - 25,000	<0.1	0.2	7.2	ppm
Ca	16 (15%)	0.1 - 25	<0.1	0.2	1.1	%
Cd	56 (52%)	0.8 - 25,000	<0.8	<0.8	1.6	ppm
Ce	0 (0%)	0.2 - 25,000	27.2	127	1570	ppm
Co	0 (0%)	0.5 - 25,000	6.7	15.7	186	ppm
Cs	0 (0%)	0.1 - 25,000	0.2	0.9	4.9	ppm
Cu	2 (2%)	20 - 25,000	<20	40	130	ppm
Dy	0 (0%)	0.03 - 25,000	1.88	4.39	15.4	ppm
Er	0 (0%)	0.02 - 25,000	1.19	2.79	9.4	ppm
Eu	0 (0%)	0.03 - 25,000	0.4	1.05	3.93	ppm
Fe	0 (0%)	0.05 - 25	2.54	6.57	19.15	%
Ga	0 (0%)	0.5 - 25,000	5.2	23.8	54	ppm
Gd	0 (0%)	0.03 - 25,000	1.62	5.28	19.25	ppm
Ge	1 (1%)	0.5 - 25,000	<0.5	1.6	3.4	ppm
Ho	0 (0%)	0.01 - 25,000	0.37	0.83	2.83	ppm
In	93 (87%)	0.3 - 25,000	<0.3	<0.3	0.4	ppm
K	2 (2%)	0.05 - 25	<0.05	0.65	3.5	%
La	0 (0%)	0.08 - 25,000	11	70.3	964	ppm
Li	0 (0%)	2 - 25,000	2	9	30	ppm
Lu	0 (0%)	0.05 - 25,000	0.11	0.57	1.85	ppm
Mn	0 (0%)	10 - 25,000	190	790	3210	ppm
Mo	6 (6%)	2 - 25,000	<2	4	16	ppm
Nb	0 (0%)	0.8 - 25,000	8.5	25.8	65.6	ppm
Nd	0 (0%)	0.07 - 25,000	8.44	44.5	412	ppm
Ni	0 (0%)	10 - 25,000	20	60	770	ppm
Pb	0 (0%)	0.5 - 25,000	9.5	24.2	59.1	ppm
Pr	0 (0%)	0.03 - 25,000	2.47	13.55	153.5	ppm
Rb	0 (0%)	0.5 - 25,000	2.1	18.2	105	ppm
Re	78 (73%)	0.01 - 25,000	<0.01	<0.01	0.06	ppm
Sb	31 (29%)	0.3 - 25,000	<0.3	0.4	3.9	ppm
Se	58 (54%)	3 - 25,000	<3	<3	15	ppm
Sm	0 (0%)	0.04 - 25,000	1.52	6.81	42.8	ppm
Sn	41 (38%)	3 - 25,000	<3	3	19	ppm
Sr	13 (12%)	20 - 25,000	<20	40	190	ppm
Ta	0 (0%)	0.04 - 25,000	0.49	2.09	12.45	ppm
Tb	0 (0%)	0.01 - 25,000	0.24	0.74	2.43	ppm
Te	82 (77%)	0.5 - 25,000	0.025	0.025	1.2	ppm
Th	0 (0%)	0.1 - 25,000	3.7	35.6	321	ppm
Ti	0 (0%)	0.005 - 25	0.189	1.27	4.24	%
Tl	3 (3%)	0.02 - 25,000	0.01	0.15	0.74	ppm
Tm	0 (0%)	0.01 - 25,000	0.07	0.41	1.28	ppm
U	0 (0%)	0.2 - 25,000	0.9	6.5	16.4	ppm
V	0 (0%)	1 - 25,000	24	179	684	ppm
W	0 (0%)	0.3 - 25,000	0.3	1.2	83.2	ppm
Y	0 (0%)	0.2 - 25,000	9.9	25.1	77.1	ppm
Yb	0 (0%)	0.02 - 25,000	1.19	3.63	10.65	ppm
Zn	0 (0%)	10 - 25,000	20	100	640	ppm

* Percentages are rounded to the nearest whole number.

Table 4. Summary information for LiB_4O_7-fusion ICP-MS analysis

element	n <LLD or >ULD **	detection range	min	median	max	units
Ba	0 (0%)	0.5 - 10,000	68.1	462	2390	ppm
Ce	0 (0%)	0.1 - 10,000	31.4	129.5	1705	ppm
Cr	0 (0%)	10 - 10,000	80	400	2850	ppm
Cs	0 (0%)	0.01 - 10,000	0.18	0.78	5.03	ppm
Dy	0 (0%)	0.05 - 1,000	2.1	4.49	13.95	ppm
Er	0 (0%)	0.03 - 1,000	1.26	2.97	8.72	ppm
Eu	0 (0%)	0.03 - 1,000	0.47	1.12	3.57	ppm
Ga	0 (0%)	0.1 - 1,000	7.2	22.8	35.4	ppm
Gd	0 (0%)	0.05 - 1,000	1.81	5.54	19.85	ppm
Hf	0 (0%)	0.2 - 10,000	2.4	91	387	ppm
Ho	0 (0%)	0.01 - 1,000	0.39	0.91	2.85	ppm
La	0 (0%)	0.1 - 10,000	13.8	72.6	1020	ppm
Lu	0 (0%)	0.01 - 1,000	0.22	0.64	2	ppm
Nb	0 (0%)	0.2 - 2,500	8.7	26.2	68.5	ppm
Nd	0 (0%)	0.1 - 10,000	11.3	45	449	ppm
Pr	0 (0%)	0.03 - 1,000	3.12	13.15	163	ppm
Rb	0 (0%)	0.2 - 10,000	1.9	17.6	99.4	ppm
Sm	0 (0%)	0.03 - 1,000	2.26	7.39	46.4	ppm
Sn	0 (0%)	1 - 10,000	1	3	11	ppm
Sr	0 (0%)	0.1 - 10,000	9.3	47.6	185.5	ppm
Ta	1 (1%)	0.1 - 2,500	0.05	2.4	13.4	ppm
Tb	0 (0%)	0.01 - 1,000	0.31	0.75	2.33	ppm
Th	0 (0%)	0.05 - 1,000	4.27	39.8	352	ppm
Tm	0 (0%)	0.01 - 1,000	0.2	0.46	1.46	ppm
U	0 (0%)	0.05 - 1,000	0.87	6.93	16.75	ppm
V	0 (0%)	5 - 10,000	16	160	649	ppm
W	0 (0%)	1 - 10,000	1	2	74	ppm
Y	0 (0%)	0.1 - 10,000	9.9	24.1	70.3	ppm
Yb	0 (0%)	0.03 - 1,000	1.35	3.5	10.55	ppm
Zr	19 (18%)	2 - 10,000	89	3840	>10000	ppm

** Values beyond detection range were below the LLD, with the exception of those for Zr, which were all above the ULD. Percentages are rounded to the nearest whole number.

3.3 ANALYSIS OF VARIANCE (ANOVA)

Analysis of Variance (ANOVA) is a valuable procedure for evaluating the quality and representivity of geochemical data. It provides a quantitative statement of the variability in geochemical data that can be assigned to different identifiable components of variance, which can be used to evaluate sources of uncertainty in the results.

The purpose of the sampling design of the orientation survey, whereby site duplicate and field replicate samples were collected (Figure 13) is to allow a balanced nested model of ANOVA to be used to calculate ***between site*** (representing the natural distribution of elements in stream sediments), ***between sample*** (representing the natural variability of sediment composition from place to place within a site, as well as any variability introduced as a result of sample collection) and ***within sample*** (representing any inhomogeneity introduced during sample preparation, sub-sampling and analysis) components of variance. The variance that is attributed to each of these components is presented as a percentage of the total variance. ANOVA is a useful test of the validity of the methods used by the survey, as it can determine how much variability can be attributed to genuine spatial differences between sites. For the methods of a geochemical survey to be considered valid, the variation in results between different sites should be much more than the variation in results from samples collected at the same site (which can be considered akin to experimental 'error').

The ANOVA was performed using an MSExcel procedure designed by Johnson (2002), to which the reader is referred for further details on the applicability and limitations of the method. This procedure uses a macro based on the equations described by Sinclair (1983) to calculate the variance components for each variable (in this case each element/analyte). In the first stage of the macro, the data are converted to $\log_{10}$ because geochemical data does not typically follow a normal Gaussian frequency distribution. An advantage of the excel procedure is that specialist statistical software is not required. A copy of the macro-enabled spreadsheet was provided to the NMA for future use.

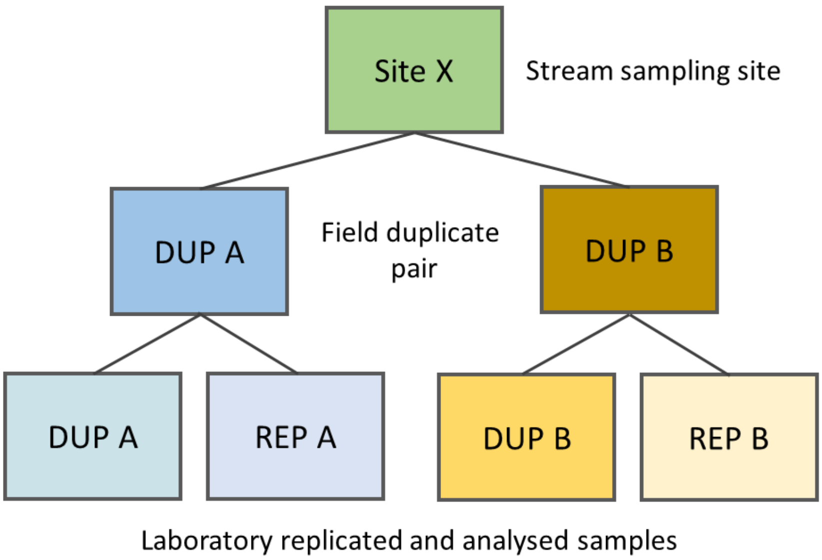

Figure 13. Sampling design for balanced nested model of ANOVA as used in the orientation survey.

3.3.1 Performing ANOVA on the orientation survey geochemical data

The ANOVA was performed using the orientation survey data for a total of 25 duplicate/replicate sets (100 of the 107 analysed samples). Due to the following issues (see also section 3.2), data for seven of the analysed samples could not be included in the ANOVA:

- 02002-C and R02002-C were excluded as a duplicate sample was not collected at site.
- 010099-C and R010099-C were also excluded from the ANOVA. 010075-C (which was collected at the same site as 02002-C and could have therefore served as its duplicate pair) ought to have been replicated and included in place of 010099-C, but this did not happen due to an error in communication.
- As data for sample R02047-C was not obtained (the sample was listed as 'not received' by the analytical labs; see Section 3.1); the data for its corresponding duplicate/replicate partners (02047-C, 02048-C and R02048-C could not be used for the ANOVA.

While these errors unfortunately reduced the amount of analytical data that could be used for the ANOVA testing, it is noted that the data excluded as described above are otherwise valid for other purposes and have therefore been presented as such elsewhere in this report. As samples comprising 25 duplicate/replicate sets were analysed. This achieved, and exceeded, the original objective of including data from at least 20 different sites.

The ANOVA method requires all the input data to have a numeric value (as do most statistical tests). This means that data reported as being below the LLD or above the ULD must be excluded from the dataset or modified prior to performing the test:

- The ANOVA was not performed for certain analytes where <LLD values comprised >50 % of the data (Ag, Cd, In, Re, Se and Te by Na_2O_2-fusion; Table 3). For other analytes (Bi, Ca, Sb, and Sn by Na_2O_2-fusion) where <LLD (or >ULD in the case of Zr by LiB_4O_7-fusion) values comprised 15-50 % of the data (Table 3 and Table 4), a filtering process was employed whereby duplicate/replicate sets that contained any <LLD or >ULD values were excluded from the data processed in the ANOVA test. For these elements, ANOVA was therefore performed on a reduced number of duplicate/replicate sets (as indicated in Table 5 and Table 6).
- For the remaining analytes, where <LLD values comprised <15 % of the data, any data that were reported to be below the detection limit for any element were set to half the detection limit prior to performing the ANOVA test. This procedure is known as data 'censoring' and although somewhat arbitrary, it is common practice in the treatment of geochemical survey data (Johnson et al. 2018), since a numerical value is required for statistical analysis, and it can broadly be accepted that the true value probably lies between the detection limit and zero. In this case, censoring has nonetheless been limited to only those elements with a relatively small proportion of <LLD values, to avoid generating misleading ANOVA results.

The results of the ANOVA test are presented in Table 5 (for Na_2O_2-fusion data) and Table 6 (for LiB_4O_7-fusion data). Data quality issues for these results are highlighted in these tables:

- For any element where <80 % of the total variance is attributed to **between site** variance, the methods applied may not be ideal for geochemical mapping of this element's spatial distribution (see Section 3.3.2 next) – the same is true for those elements where >50 % of the reported values were <LLD. *These elements are **highlighted in orange** in Table 5 and Table 6.*

- For any element where >4 % of the total variance is attributed to **within sample** variance, imprecision due to analytical limitations is likely not ideal (see Section 3.3.2 next). *These results are indicated with **red font** in Table 5 and Table 6.*

Table 5 ANOVA results for stream sediment analyses by Na_2O_2 fusion ICP-MS.

Element	Between Site %	Between Sample %	Within Sample %	Total %	DUP/REP sets
Ag	-	-	-	-	-
As	24.9	5.4	69.7	100	25
Ba	98.1	0.5	1.4	100	25
Be	38.3	3.1	58.5	100	25
Bi	87.4	2.5	10.1	100	15
Ca	87.2	8.2	4.6	100	17
Cd	-	-	-	-	-
Ce	93.8	5.2	1.0	100	25
Co	94.7	3.3	2.0	100	25
Cs	90.1	3.5	6.5	100	25
Cu	80.6	11.5	7.9	100	25
Dy	85.5	7.2	7.3	100	25
Er	85.8	10.6	3.6	100	25
Eu	86.0	3.6	10.4	100	25
Fe	90.7	4.1	5.2	100	25
Ga	60.1	2.4	37.5	100	25
Gd	87.3	7.1	5.7	100	25
Ge	31.9	-37.1	105.2	100	25
Ho	87.2	7.3	5.6	100	25
In	-	-	-	-	-
K	96.4	2.8	0.7	100	25
La	94.1	4.5	1.4	100	25
Li	78.8	3.9	17.3	100	25
Lu	83.8	10.6	5.6	100	25
Mn	81.2	17.6	1.1	100	25
Mo	69.5	19.4	11.1	100	25
Nb	89.7	4.1	6.2	100	25
Nd	92.9	5.1	2.0	100	25
Ni	81.3	1.8	16.9	100	25
Pb	82.9	8.7	8.4	100	25
Pr	92.9	4.2	2.9	100	25
Rb	96.1	3.1	0.9	100	25
Re	-	-	-	-	-
Sb	50.3	30.7	19.0	100	9
Se	-	-	-	-	-
Sm	90.6	7.1	2.3	100	25
Sn	13.3	31.3	55.5	100	9
Sr	93.3	-2.8	9.6	100	25
Ta	80.2	6.4	13.4	100	25
Tb	83.0	6.5	10.5	100	25
Te	-	-	-	-	-
Th	91.6	7.0	1.4	100	25
Ti	93.4	6.5	0.2	100	25
Tl	81.5	-6.6	25.0	100	25
Tm	79.1	3.4	17.5	100	25
U	90.2	8.8	1.0	100	25
V	92.4	4.3	3.2	100	25
W	89.6	4.7	5.7	100	25
Y	84.9	7.4	7.7	100	25
Yb	83.7	10.2	6.1	100	25
Zn	76.1	3.7	20.2	100	25

Table 6. ANOVA results for stream sediment analyses by LiB_4O_7 fusion ICP-MS.

Element	Between Site %	Between Sample %	Within Sample %	Total %	DUP/REP sets
Ba	98.29	1.15	0.56	100	25
Ce	93.94	5.31	0.75	100	25
Cr	90.28	8.59	1.13	100	25
Cs	87.78	11.18	1.04	100	25
Dy	88.95	9.31	1.74	100	25
Er	87.19	11.06	1.75	100	25
Eu	90.12	8.26	1.61	100	25
Ga	64.09	30.14	5.78	100	25
Gd	89.16	10.03	0.80	100	25
Hf	92.41	7.36	0.24	100	25
Ho	88.42	9.01	2.57	100	25
La	94.21	5.08	0.71	100	25
Lu	86.86	10.47	2.67	100	25
Nb	88.82	7.25	3.93	100	25
Nd	93.46	6.20	0.34	100	25
Pr	93.66	5.81	0.53	100	25
Rb	96.81	2.96	0.23	100	25
Sm	92.17	7.28	0.55	100	25
Sn	65.51	13.04	21.45	100	25
Sr	95.99	2.71	1.30	100	25
Ta	56.17	5.13	38.70	100	25
Tb	89.52	8.66	1.83	100	25
Th	91.62	7.65	0.73	100	25
Tm	86.46	10.42	3.11	100	25
U	89.97	8.90	1.13	100	25
V	89.27	6.68	4.05	100	25
W	88.25	0.90	10.85	100	25
Y	87.29	9.70	3.01	100	25
Yb	87.73	10.61	1.67	100	25
Zr	90.66	9.01	0.33	100	19

3.3.2 Discussion and synthesis of the ANOVA results

In geochemical surveys, for data above the detection limit, the ***between site*** variance should ideally account for >80 % of the total variance. This allows high confidence that the data genuinely represents spatial differences in geochemistry across the study area. The ***between sample*** variance should therefore not exceed 20 %, and where it does this reflects either natural compositional inconsistency between pairs of samples taken from the same site, or inconsistent sample collection methods. ***Within sample*** variance should ideally account for <4 % of the total variance; higher within sample variances can reflect either analytical imprecision, inconsistencies introduced during later (post-replication) sample preparation procedures, or the 'nugget effect' in the case of elements that occur as discrete mineral grains and so can divide unequally into replicates.

The thresholds for variance components given above were proposed by Ramsey et al. (1992), and have since become accepted more widely as a benchmark for data quality in geochemical mapping; see for example Johnson et al. (2018b) and Eggen et al. (2019). The reader should note that within the literature the ***between site*** variance is sometimes referred to as the *'geochemical'* or *'regional'* variance; the ***between sample*** variance as the *'sampling'* or *'site'* variance and the ***within sample*** variance as the *'analytical'* or *residual'* variance.

In this context, the following conclusions can be drawn based on the ANOVA results for the orientation survey data (Table 5 and Table 6);

- For most analytes/elements, >80 % of the variability in the dataset is attributed to ***between site*** variance, which demonstrates that the procedures are robust for mapping the distribution of these elements in stream sediment.
- For a large proportion of those analytes/elements (including As, Be, Ga, Ge, Li, Sn, Tm and Zn by Na_2O_2-fusion, Sn, Ta and W by LiB_4O_7-fusion) where the ***between site*** variance is <80 %, the ***within sample*** variance exceeds the ***between sample*** variance. In many other cases where ***between site*** variance is acceptable at >80 %, (including Bi, Ca, Cs, Cu, Dy, Eu, Fe, Gd, Ho, Lu, Nb, Ni, Pb, Sr, Ta, Tb, Tl, Tm, W, Y, Yb by Na_2O_2-fusion, and V and W by LiB_4O_7-fusion) the ***within sample*** variance exceeds the recommended 4 % threshold. Both of these observations reveal that, with reference to these elements, the uncertainty introduced during sample preparation or analysis stages is more significant than any uncertainty introduced during sample collection.
- The conclusion made in the previous point demonstrates that the sample collection procedures should be robust, but that a review of the analytical procedures would be beneficial as there may be room for improvement.
- For several elements/analytes (including As, Be, Bi, Ca, Cu, Mo, Sb, Se, Sr, Tl, by Na_2O_2-fusion, and Sn by LiB_4O_7-fusion), the lower than ideal (<80 %) ***between site*** and/or higher than ideal (>4 %) ***within sample*** variance can be attributed to the fact that a high proportion of the measured concentrations are below or near the LLD (and potentially the related data censoring or filtering in the case of Bi, Ca, Sb, and Sn by Na_2O_2-fusion). It may therefore not be reasonable to expect robust results for these elements in a geochemical survey of Sierra Leone that follows the same methods. However, if higher values are reported these are likely to be genuine. This also applies to Ag, Cd, In, Re, Se, and Te (for which <LLD values comprised >50 % of the data and the ANOVA was not performed).
- For all of the elements mentioned in the previous point, in most cases these are present in naturally low abundances, so it will not necessarily possible to improve the methodology to produce more robust results. However, the LLD values for a few elements (As, Ag, Cu, Sn) measured by the Na_2O_2-fusion package are relatively high. It may be worthwhile considering the use of an analytical method/package with greater sensitivity for these elements, as this would be expected to improve results.
- Some elements were analysed by both fusion methods; of these elements, the ***within sample*** variance for Ba, Ce, Cs, Dy, Eu, Ga, Gd, Ho, La, Lu, Nb, Nd, Pr, Rb, Sm, Sn, Sr, Tb, Th, Tm, Y, Yb was lower for the LiB_4O_7-fusion results, and for Ta, U, V, W the ***within sample*** variance was lower for the Na_2O_2-fusion results. It is clear that the selection of the analytical package has made a difference to the quality of results and for most of these elements, only one of the analytical packages has provided a result below the 4 % threshold for ***within sample*** variance.
- This lends support to the interpretation that the more aggressive LiB_4O_7-fusion digest will, in general, probably result in more reproducible and precise results for the majority of elements. However, this may only apply to the specific analytical packages offered by ALS, and also relies on the assumption that the same (or another of equal sensitivity) ICP-MS instrument was used to deliver each analytical package.

- If the interpretation in the above point is correct, it is also reasonable to speculate that a LiB_4O_7-fusion digest package could also improve results for a number of elements that were only analysed via Na_2O_2-fusion. Although (as noted above), it may not be possible for a different analytical package to improve results for elements of low natural abundance, it may be worth trialling a LiB_4O_7-fusion digest method to assess whether or not it would produce better results for several elements including As, Cu, Ni, Pb, Zn, which should have natural abundances within consistently measurable ranges, and which are all also highly indicative of mineralisation.
- The reported data for some elements/analytes (Cu, Mn, Ni, Sr, Zn, by Na_2O_2-fusion and Cr by LiB_4O_7-fusion) appears to have been rounded to the nearest 10 ppm. It may be assumed that the instrument readings will have been made to the nearest ppm, but the analytical lab has rounded the reported figures with the aim of providing a dataset that honestly conveys the inherent experimental imprecision. Such rounding can however bias statistical examination, and ideally for geochemical mapping the laboratory would provide all instrument readings without any rounding. This may have biased the ANOVA test for these elements, but it is impossible to establish how without possessing un-rounded instrument readings. In any case, it will be important to request that non-rounded figures are supplied by the analytical laboratory for the eventual geochemical mapping project.
- For a number of elements, including Fe, Ga, Li, Pb, Ta, W the cause of lower than ideal (<80 %) ***between site*** and/or higher than ideal (>4 %) ***within sample*** variance is not immediately clear from a review of the analytical data. On the basis of a single set of ANOVA results alone it is often not possible to determine about which possible cause of variance is responsible for the observed results.

In summary, this discussion and synthesis of the ANOVA results shows that the sample collection and sample preparation procedures followed throughout the orientation survey should be fit for purpose for a geochemical mapping campaign, and were completed to a standard where results are demonstrated to be robust. With respect to the large majority of elements measured, the same can be said for the analytical methods used, however certain improvements or different analytical methods can probably be made to achieve more robust and better quality results for certain elements, as described above.

For the orientation survey, determination of as wide a range of elements as possible was sought using only a restricted number of analytical packages, whereas the nature of geochemical analysis means that certain methods are optimal for certain elements. The value of the orientation survey is that the review of these initial results shows where improvements may be possible. A determination of which improvements to pursue should also bear in mind what the strategic priority elements will be for the eventual geochemical survey.

3.4 XRD ANALYSIS OF HEAVY MINERAL CONCENTRATE (PAN) SAMPLES

Qualitative XRD (X-Ray Diffraction) analysis was performed on a selection of 19 heavy mineral concentrate (pan) samples that were collected during the orientation survey. A representative portion of each of these pan samples was taken to the BGS XRD labs in Keyworth for analysis, while the remainder of the sample material was retained by the NMA.

The results of the XRD analysis are presented in Table 7. This provides a useful indication of the predominant mineral phases encountered in the sampled stream sediment. With respect to heavy minerals, the common presence of abundant zircon, rutile and ilmenite can be associated with the typically high concentrations of Zr, Fe and Ti in the geochemical analyses of the fine sediment fraction.

It is also evident that monazite is making some contribution to Ce, La, Nd and Th concentrations measured in the fine stream sediment - some of the highest values of these elements in the geochemical data are from samples where monazite was found in the heavy mineral concentrates.

Table 7. Qualitative XRD results for a selection of heavy mineral concentrate samples

Relative abundances of each identified mineral phase are expressed as high (H), moderate (M), low (L) or trace (T).

	Light minerals			Carbonate		Heavy minerals																		
Sample number	Quartz	Albite	Mica	Dolomite	Calcite	Apatite	Augite	Baryte	Brookite	Epidote	Garnet	Hematite	Ilmenite	Kieserite?	Kyanite	Magnetite	Mg-Amphibole	Monazite	Olivine	Pyrite	Rutile	Sillimanite	Zircon	Total phases
02004-P	M	L					L						M			L			L	H			L	7
02005-P	L			L				M			L	L	M		L						M		H	8
02008-P	M		T									M	H	L	L	M	M				L		M	9
02010-P	H	L		T			L										M				L		L	6
02014-P					T								H				T			T			H	4
02021-P	H										L	L	L			L	L				L		L	7
02026-P	H												L					L					H	3
02027-P	H								L				M				L	L		L	L		H	7
02029-P	M			L	L						L		M							L	M	L	H	8
02031-P	H												M								M	L	M	4
02035-P	M												H		L	L	L	L			L		L	7
02038-P	H				L								H					L			L		M	5
02040-P	M				L			L					H								L		M	5
02043-P	M				L			L					H			L					L		L	6
02046-P	H				L					L			L		L	M	M				L		M	8
02049-P	H	L			L				L				M		L		M				L		M	8
02051-P	L												H		L			L			L		M	5
02054-P	M												H				L	L			L		M	5
02058-P	L							L					H					L					M	4

4 Roadmap to commencing geochemical mapping of Sierra Leone

Regardless of scale, all geochemical survey projects must consist of the following eight dependent, and interdependent components (Demetriades 2014):

(i) Planning;
(ii) Sampling;
(iii) Sample preparation;
(iv) Laboratory analysis;
(v) Quality control;
(vi) Quality assessment, data processing and map plotting;
(vii) Interpretation,
(viii) Report writing

It is therefore vital that the resources to successfully complete all of these steps are available to the NMA within the defined scope of a geochemical mapping project, before this is initiated. The engagement of a consultant with demonstrated experience of managing geochemical mapping projects through all of these stages will be critical. However, involvement of NMA staff throughout each stage is also vital as they are the main stakeholder of the project, which ought to generate a legacy after the consultant's involvement is finished. The nature of the sampling and sample preparation stages means they will necessarily rely on NMA's facilities and be carried out by NMA's own staff or labour, as there is little prospect of a consultant delivering these using entirely their own staff and facilities. This means that the project requires a collaborative effort between a consultant and the NMA – and this dimension of the relationship needs to be considered when putting in place contractual agreements as well as the mechanism by which funds for all necessary expenses in support of the project will be allocated and disbursed.

The most costly and time consuming stages of a geochemical mapping project are generally the sampling, sample preparation and laboratory analysis stages. Importantly, considerably more than at any other stage, the scale of the work involved in these stages increases proportionally to the number of samples collected and, in the case of the sampling stage, the scale of the work also increases if samples are collected further apart (i.e. at lower sampling density).

Therefore, before a stream sediment geochemical mapping programme in Sierra Leone can be implemented, critical consideration needs to be given to the sampling coverage, that is, the area(s) to be sampled, the number of samples to be collected, and the related sampling density.

Selecting an optimal sampling coverage depends on the overall aims of the project, with specific reference to the types of geochemical anomalies or geochemical patterns it aims to resolve and thus the scientific value of undertaking the work. A useful review is provided by Hosseini-Dinani et al. (2019) (see also references therein). The basic premise is that a low sampling density survey can prove inadequate and therefore wasted if it misses small anomalies of interest whereas an overly high sampling density survey can prove to be a more time consuming and less cost-effective way to gain results.

Therefore, economic and logistical factors also mean that the desired sampling coverage needs to be considered in light of the following constraints:

- duration of the project
- available funding

- availability of staff that can be assigned to the field sampling campaign(s)
- sample prep lab throughput
- seasonal climate

Detailed decisions on the sampling strategy and sampling coverage of the geochemical mapping campaign would be best made in conjunction between NMA and their appointed consultant(s), and once informed by a desk study that can also take into account the results of the recently completed geophysical survey of Sierra Leone.

However, because an approximate outline of the sampling coverage will probably need to be considered at the tendering stage, BGS and NMA completed a planning exercise to illustrate example scenarios for a systematic geochemical mapping campaign in Sierra Leone. These are presented in Section 4.1 below.

The authors of this report have also identified a number of important next steps that should be taken prior to implementing a geochemical mapping campaign (Section 4.2). These next steps are highlighted as they are also worthy of consideration by the NMA, their funding partners and the consultant in the tendering stage and/or early in the commencement of the project.

4.1 EXAMPLE SCENARIOS FOR SYSTEMATIC GEOCHEMICAL MAPPING

During a workshop held at NMA in January 2020, a planning exercise was completed to illustrate example scenarios for a systematic geochemical mapping campaign in Sierra Leone. The example scenarios are based around sampling rate calculations. Sampling rate depends on the number of samples that can be collected in a day/week by the field team. The sampling density and the number of staff in the field team are therefore controlling factors.

Therefore, as the first part of the planning exercise, it was necessary to establish a plausible staffing scheme for the field campaign team, which takes into account the likely availability of NMA staff and the demands of the work. The following staffing of the field campaign team was used a basis for the sampling rate calculations:

- 1 x Project manager (senior NMA geologist)
- 1 x Campaign manager (NMA geologist)
- 1 x Deputy campaign manager (NMA geologist)
- 9 x Sampling team leaders (NMA geologist)
- 15 x Team leader's assistants (NMA staff; may be drawn from a pool of mining compliance officers)
- 10 x Drivers with vehicles (hired by the project)
- 8 x Sampling technicians (hired by NMA)

The number of sampling teams on the ground is a determining factor in calculating the sampling rate. It was envisaged that the above level of staffing would support up to 8 sampling teams, while leaving some flexibility for the rotation of staff for leave and other duties. Each sampling team would consist of 1 team leader, 1 team leader's assistant, 1 sampling technician, and 1 driver, with scope for the team leader to hire local labour to assist if necessary on an ad-hoc basis. As they gain experience, team leader's assistants may begin to serve as team leaders, thus freeing up demands on the limited numbers of NMA geologists.

The sampling teams would operate from a field base(s) under the supervision of the campaign manager and deputy campaign manager (each supported by a driver) who will oversee the day-to-day planning and running of the campaign as a whole. As the programme develops, sampling teams may operate from two (or more) field bases concurrently where this proves to offer a logistical advantage. The project manager will have full oversight of the field campaign operations but will also be responsible for management of laboratory activities and the development of the project as a whole through each stage. The project manager will also be advised by, and have to work closely with the consultant(s) to ensure effective delivery of the project.

Sampling rate calculations were compiled for a range of sampling densities, using a spreadsheet (Table 8) that considers the numbers of sampling teams working in the field every week, and the number of samples they can collect. Based on the experience of the orientation survey, it was considered that the average number of samples each sampling team could expect to collect in a day is:

- 5 samples at a sampling density of 1 sample per 2 km^2
- 4 samples at a sampling density of 1 sample per 8 km^2 -16 km^2
- 3 samples at a sampling density of 1 sample per 32 km^2

It was assumed that the sampling teams will work 5 ½ days per week (½ day on Saturdays), however sampling would only take place every alternate Saturday as the other Saturday's work is likely to be taken up by other activities such as moving field base, maintenance of equipment (such as re-meshing sieves) and other necessary tasks in support of the campaign. During the first two weeks of the campaign, the rate calculations also assume that a smaller number of teams (five) will each collect a reduced number of samples, to allow time for effective training and familiarisation with proper procedures before the sampling teams come up to speed.

Table 8. Illustration of sampling rate calculation spreadsheet.

The figures presented below represent an example scenario whereby 100 % sampling coverage of Sierra Leone is completed at a sampling density of 1 sample per 8 km^2

	Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8	Wk9	etc.	Wk55
Sampling teams	5	5	8	8	8	8	8	8	8	*etc.*	8
Sampling days	5.5	5	5.5	5	5.5	5	5.5	5	5.5	*etc.*	5.5
Samples/day	2	4	4	4	4	4	4	4	4	*etc.*	4
Weekly sample total	55	100	176	160	176	160	176	160	176	*etc.*	176
Running sample total	55	155	331	491	667	827	1003	1163	1339	*etc.*	9067
Notes	Training week	Move base		Move base		Move base		Move base		*etc.*	

Using this approach, the following example scenarios were derived:

- to complete 100 % mapping coverage of Sierra Leone (c. 72,900 km^2)
  - @ a density of 1 sample/4 km^2 (c. 17,930 samples) will require around **96 weeks** of fieldwork
  - @ a density of 1 sample/8 km^2 (c. 9,070 samples) will require around **55 weeks** of fieldwork
  - @ a density of 1 sample/16 km^2 (c. 4,520 samples) will require around **28 weeks** of fieldwork
  - @ a density of 1 sample/32 km^2 (c. 2,280 samples) require around **19 weeks** of fieldwork

- an illustration of a ‘hybrid’ density campaign, whereby a more prospective area(s) is sampled at higher density: mapping 44 % of Sierra Leone (c. 32,000 km^2) @ a density of 1 sample per 16 km^2 and mapping 10 % of Sierra Leone (c. 7,290 km^2) @ a density of 1 sample per 2 km^2 will require around **33 weeks** of fieldwork and involve the collection of c. 5,400 samples.

These example scenarios should be taken as basic illustrations of the scale of the work that is likely to be involved and could therefore serve to inform the scale of the tender. A more refined sampling rate calculation, using the approach outlined above, would need to be completed in the project planning stage as the scope of the project and available staffing are confirmed. It should also be borne in mind that the field team will always need some additional time at the end of the campaign to wrap up their work once the sampling is finished.

The sampling rate calculation is also an important basis for estimating the costs of the project. Certain costs, for example analysis and consumables, can be estimated on the basis of a per sample unit rate, and others such as vehicle hire, accommodation, and payments to field staff can be estimated on the basis of a per day unit rate. Enumeration of such costs is however beyond the scope of this report.

Seasonal conditions will mean it is only possible to run a campaign throughout part of each calendar year, and it is noted that the campaign durations presented in the example scenarios above generally exceed what could be completed in a single fieldwork season and in some cases would take several years to complete.

In terms of sampling coverage, density, sample numbers and field team staffing, there are obviously endless permutations that can be considered for a field campaign, but any eventual plan should be supported by a sampling rate calculation as presented here. In this type of planning there is obviously a balance to be struck between the scope of the project and the available budget so it is important that the NMA and their funding partner(s) are aware that this approach to planning is necessary to form a clear understanding of what can realistically be achieved.

4.2 RECOMMENDED NEXT STEPS

Several tasks will need to be undertaken in preparation for a systematic geochemical mapping programme. The details of these tasks will need to be defined and tackled through discussion and collaboration between NMA and their consultant(s).

With this in mind, the authors of this report highlight the importance of addressing the following tasks as part of these preparations at an early stage, as it will be vital that these are completed in advance of the field campaign commencing:

- **Completing a desk study** to inform the sampling strategy and sampling coverage of the geochemical mapping campaign, particularly in terms of: 1) the selection of areas to be surveyed, and the desired sampling density for the survey, and 2) likely element associations for target mineralisation types, so that the analytical strategy can be optimised for these elements, if required. The desk study should take into account the findings of the orientation survey, the results of the recently completed geophysical survey of Sierra Leone as well as a thorough knowledge of the geology of Sierra Leone.
- **The production of a Field Procedures Manual** for the geochemical mapping of Sierra Leone, which should include details of the methods for sample and field data collection and management, as well as an outline of the survey strategy, and an organogram with reporting lines for field staff, field operations managers and

consultants. The descriptions of the methodologies described in this report as well as those in previously published field procedures manuals (e.g. Salminen 2005, Johnson 2005) could be adapted for this purpose.

- **Obtaining a suitable suite of reference materials,** to be analysed with analytical batches of samples, and which are critical to allow for quality control as well as the levelling of the data that will be required for plotting seamless national geochemical maps (particularly if the eventual survey may consist of several phases). This would ideally consist of a blend of internationally recognised certified reference materials as well as in-house reference materials produced by the NMA from sediment collected in Sierra Leone.
- **Procuring equipment and consumables for field sample collection.** Including, but not limited to, the following items which are of particular importance: 1) sieve rings and collection pans, as these will need to be made bespoke by a suitable workshop(s)[1]. 2) Kraft paper sample bags suitable for wet sediment collection, as the manufacturer of those used in the orientation survey is understood to now be out of business. 3) Provision of topographic base maps (preferably at 1:50,000 scale), which should include georeferenced raster images as well as ample printed copies for use by sampling teams in the field.
- **A solution for staffing field teams,** for example, establishing the numbers, contractual basis and wage budget for hiring temporary staff or casual labourers that may work in field teams alongside geologists of the NMA.
- **A solution for providing transport for the field team.** Up to 10 off-road capable 4x4 vehicles (and drivers) may be required to support the field team. Motorbikes may also prove useful when surveying remote areas that are difficult to access via roads. Suitable transport arrangements are vital for the progress and safety of the field team and will necessarily account for a considerable proportion of the project's budget. Compromising on the quality of vehicles to be used and/or the skill of professional drivers in order to save money can ultimately prove to be a false economy if these prove unreliable.
- **A review of the sample preparation lab's capacities.** While it may be a safe assumption that sample preparation labs should be able to process more samples per day than the field teams can collect, the sample throughput at the labs ought to be examined in detail in light of the available lab equipment and staffing. If the project funds can be used to provide some limited investment for lab equipment (for example, more milling pot and ball sets, potentially a second mill) and hire additional technicians for the duration of the project, this ought to significantly expedite the sample preparation stage of the project. Procurement of sufficient lab consumables for the project is also vital.
- **A survey of seasonal stream flow across various terrains.** BGS have already recommended informally to NMA that they seek to monitor seasonal stream flow conditions across Sierra Leone during the course of their routine survey activities. It will not be possible to effectively collect wet-sieved samples of stream sediment during the height of the wet season, or towards the end of the dry season when stream beds are dry, and field campaign scheduling needs to account for this.

This is not an exhaustive list of all preparation and planning that will need to take place but serves to highlight some key considerations.

[1] The technical drawing presented in Figure 8 could be provided to a workshop to serve as an outline specification for producing nested sieve sets.

Appendix 1 Compiling the field data card

Pre-numbered field data cards are used to record information about each sample site. The data from each card will be entered into a MS Excel field database at the field base. This field data will later be integrated with sample analysis results.

The field data card is a form consisting of discrete boxes where observations and key information about a site are entered as individual numbers, single letter codes, and free-text descriptions. Each item of information to be recorded is described below, and the meanings of the codes to be used in specific parts of the form are listed in Table 9. A notes panel on the card provides space to record information about the site that is more difficult to define by codes alone, here free-text may be used. If more space is required, such notes may be continued on the rear of the card, as well as any relevant information about a sample site that is not covered by other sections on the field card.

Consistent use of abbreviations in the notes is encouraged. Abbreviations for commonly encountered lithologies are provided in Table 10, and abbreviations for commonly encountered minerals in heavy mineral concentrate (pan) samples are given in Table 11.

Cards should be completed as follows:

1. The **Campaign number** is a two digit number that corresponds to the phase of the survey and serves to distinguish samples collected in different survey stages or areas. For example, 02 will be the campaign number for the orientation survey (see Table 9). Further campaign numbers may be allocated by campaign managers as required during the course of the geochemical survey programme.

2. **Sample Number**: This is a five-figure unique number attributed to the sample site, i.e. a number between 00001 and 99999. Every site at which a sample is collected will have field card on which this unique number will have been written. Different sample types from the same site will have the same site number, but will be identified by a different sample-type code (see below). The unique sample identification will be a combination of the campaign code, plus the site number, plus the sample-type code, e.g. 02 00123 C.

3. **Sample Type**: Single letter codes are used to identify the sample media collected at the site (see Table 9).

4. **Sheet number**: This is the 2-character code used to identify the 1:50 000 map sheet e.g. 52 is the Lunsar 50K sheet.

5. **Sheet name**: This is the name of the 1:50 000 map sheet e.g. Lunsar.

6. **Duplicate number**: The site number of the corresponding duplicate sample will appear in this box. The duplicate field card needs only to have the sample number, grid coordinates, sample type and the corresponding duplicate sample number recorded on it. Duplicate samples will be allocated to sampling teams as required. For the orientation survey, every sediment sample will be collected in duplicate. For a systematic sampling campaign, usually collecting one duplicate sample in every hundred samples will be adequate.

7. **Sampler's initials**: Each sampler will have a two or three letter identification code, usually derived from his or her initials, e.g. Kathryn Goodenough is KMG and Richard Shaw is RAS. The sampler ID should be unique and the campaign leader will need to keep a list of all samplers and when they worked – this should be included in any field campaign reports.

8. **Date**: The date of sample collection entered in the format dd-mm-yy.

9. The **UTM Zone** on which the map sheet is based.

10. **Easting and Northing**: The UTM grid coordinates for each site will be determined using a handheld GPS unit. Care must be taken to ensure that the GPS is recording accurate grid coordinates by checking the GPS reading on the field map. Field card coordinates should be checked when samplers return to field base. It is important that any discrepancies are dealt with as soon after sample collection as possible. Samplers should remember that a GPS may give inaccurate results under trees and in steep-sided rock gullies. The coordinates and number of each sample site should be recorded as waypoints in the GPS.

11. **Village name**: If the land on which the sample is collected is associated with a named village, recording the name of the village will assist any person navigating to the area to conduct follow-up work (for example, re-visiting a site where results indicate mineral potential).

12. **Chief's name**: If a village chief was consulted in the process of accessing a site, record the chief's name if it is given, as this will inform any person returning to the area for follow up work that previous contact was made and may facilitate any further exchanges with villagers.

13. **Weather**: Record the general nature of the weather in the drainage catchment area. Dry should not be used if there is a temporary break in rainfall, or if previously heavy rain has just stopped (see Table 9).

13. **Stream width**: The average width of the stream being sampled (see Table 9).

13. **Drainage Condition**: The nature of the stream at the sample site (see Table 9).

14. **Sediment Type**: The nature of the stream bed at the sample site (see Table 9).

15. **Clast precipitates**: The abundance of clast precipitates should be entered in the 'A' box, and their colour entered in the 'C' box (see Table 9). The streak test should be used to observe abundance and colour of clast precipitates.

16. **Land Use**: Land use in the area surrounding the sample site (see Table 9). Record any additionally relevant description of land use in the adjacent notes panel.

17. **Contamination**: Any contamination observed at or near the sample site (see Table 9). It is important additional details of contamination are recorded in the adjacent notes panel.

18. Observed **'Obs.' bedrock**: This box should be ticked if there is an outcrop of rock within 50 m of the site (see Table 9). If ticked, record lithology(ies) of outcrop in the adjacent notes panel. Abbreviations for commonly encountered lithologies are provided in Table 10. Any uncertainty can be indicated by entering '?' before the description.

19. **Obs. mineral**: (observed mineralisation): This box should be ticked if there is any evidence of mineralisation at or near the site. If ticked, a description of the mineralisation should be recorded in the adjacent notes panel, or on the rear of the field card if more space is required. The abundance and style (i.e. vein, fault, pod, etc.) of the mineralisation, as well as a description of the minerals present should be recorded.

20. **Clast lithology**: the lithology of clasts present in the stream should be recorded in the appropriate portion of the notes panel. Abbreviations for commonly encountered lithologies are provided in Table 10. Any uncertainty can be indicated by entering '?' before the description.

21. **Pan minerals**: the identity of any mineral grains of interest present in the heavy mineral concentrate (pan) sample should be recorded in the appropriate portion of the notes panel. Abbreviations for commonly encountered minerals are provided in Table 11.

Any uncertainty can be indicated by entering '?' before the description, and/or a generic description can be used (e.g. black octahedral crystals) if the mineral identity is uncertain.

22. **Mapped geology**: the name of the mapped geological unit (if known from the geological map) that forms the bedrock at site should be recorded in the appropriate portion of the notes panel. List the primary lithologies in that unit if this information is included on the map. Abbreviations for commonly encountered lithologies are in Table 10.

Table 9. Codes and descriptions for use with the field data card.

Campaign
01 - training
02 - orientation
03 - area/campaign 1

Sample Type
C – stream sediment
P – heavy mineral concentrate
B – bulk sediment

Stream width
1 - Small Stream <3m wide
2 - Stream 3-10m wide
3 - Small River 10-33m wide

Clast precipitate abundance
0 - absent
1 - light
2 - moderate
3 - heavy

Clast precipitate colour
Bl - Black
Br - Brown
O - Orange

Sediment type
G - gravel or coarse sand
S - sand
F - silt or mud

Drainage condition
1 - Dry
2 - Damp but no water
3 - Ponded with dry sections
4 - Low flow - stream bed not covered by running water
5 - Moderate flow - stream boulders visible only
6 - Strong flow - large boulders visible only
7 - Channel filled from bank to bank
8 - Flood flow

Weather
1 - Dry
2 - Showers/light rain
3 - Heavy rain <12 hours
4 - Heavy rain <24 hours
5 - Heavy rain <48 hours
6 - Heavy rain <72 hours

Contamination
A - Metal
B - Brick
C - Concrete
D - Plastic
E - Ceramic or pottery
F - Rubber
G - Glass
H - Paint
I - Mine/industrial waste
J - Agricultural waste
K - Household waste
L - Oils

Land use
1 - Rain forest
2 - Scrub forest
3 - Rock scree
4 - Mangrove
5 - Arable agriculture
6 - Grassland pasture
7 - Village
8 - Urban
9 - Industrial
10 – Road

Observed bedrock
0 - No outcrop
1 - Minor outcrop
2 - Moderate outcrop
3 - Abundant outcrop

Observed mineralisation
Y - mineralisation present
N - no mineralisation observed

Table 10. Abbreviations for commonly encountered lithologies. Abbreviations follow the BGS Rock Classification Scheme (RCS)

AND - Andesite	DUN - Dunite	PGGN - Pegmatite (Granite)
AMPHB - Amphibolite	FELS - Felsite	PPHY - Porphry
BA – Basalt	GB - Gabbro	PSAMM - Psammite
BAUX - Bauxite	GD - Granodiorite	QZITE - Quartzite
BREC - Breccia	GN - Granite	RY - Rhyolite
CALSST - Marl	GNSS - Gneiss	SCH - Schist
CHRMT - Chromitite	LMPY - Lamprophyre	SDST - Sandstone
CLAY - Clay	LMST - Limestone	SEPITE - Serpentinite
CONG - Conglomerate	MARBLE - Marble	SLST - Siltstone
DA - Dacite	MDST - Mudstone	SLTE - Slate
DI - Diorite	MYLO - Mylonite	TUF - Tuff

DOLR - Dolerite	PDT - Peridotite

Table 11. Abbreviations for minerals of interest commonly encountered in heavy mineral concentrate (pan) samples. Abbreviations follow the scheme proposed by Siivola and Schmid (2007).

Am - Amphibole	Ep – Epidote	Py - Pyrite
Apy - Arsenopyrite	Fl - Fluorite	Po - Pyrrhotite
Brt - Baryte	Fsp - Feldspar	Qtz - Quartz
Bt - Biotite	Gn - Galena	Rgr - Realgar
Bn - Bornite	Grt - Garnet	Rt - Rutile
Cal - Calcite	Au - Gold	Sch - Scheelite
Cst - Cassiterite	Hem - Hematite	Sp - Sphalerite
Ccp - Chalcopyrite	Ilm - Ilmenite	Stb - Stibnite
Chr - Chromite	Mag - Magnetite	Tur - Tourmaline
Cnbr - Cinnabar	Mo - Molybdenite	Wmca - White mica
Ctn - Columbite/Tantalite (coltan)	Mnz - Monazite	Zr - Zircon
	Ol - Olivine	

Appendix 2 Sample allocation list

Sierra Leone geochemical mapping - orientation survey

Sample number allocation list

Campaign number	Sample number range
02	001-100

1		26		51		76	
2		27		52		77	
3		28		53		78	
4		29		54		79	
5		30		55		80	
6		31		56		81	
7		32		57		82	
8		33		58		83	
9		34		59		84	
10		35		60		85	
11		36		61		86	
12		37		62		87	
13		38		63		88	
14		39		64		89	
15		40		65		90	
16		41		66		91	
17		42		67		92	
18		43		68		93	
19		44		69		94	
20		45		70		95	
21		46		71		96	
22		47		72		97	
23		48		73		98	
24		49		74		99	
25		50		75		100	

Notes

Appendix 3 Sample checklist

Sierra Leone geochemical mapping - orientation survey

Sample checklist

Campaign number	Sample number range
02	001-100

	C	P	B				C	P	B				C	P	B				C	P	B		
1						26						51						76					
2						27						52						77					
3						28						53						78					
4						29						54						79					
5						30						55						80					
6						31						56						81					
7						32						57						82					
8						33						58						83					
9						34						59						84					
10						35						60						85					
11						36						61						86					
12						37						62						87					
13						38						63						88					
14						39						64						89					
15						40						65						90					
16						41						66						91					
17						42						67						92					
18						43						68						93					
19						44						69						94					
20						45						70						95					
21						46						71						96					
22						47						72						97					
23						48						73						98					
24						49						74						99					
25						50						75						100					

Field team notes

Sample prep notes

Appendix 4 Sample preparation procedure

DEVELOPING A PROCEDURE FOR GEOCHEMICAL SAMPLE PREPARATION: STREAM SEDIMENTS

EQUIPMENT AND MATERIALS NEEDED

Crushing Machine; Pulveriser; Splitters; Mortar and pestle; Sterilizer(s) and Ovens; X-Ray Fluorescence Spectrometer; Laptops; Two (2) clean A-4 papers per sample; Storage boxes; Self-sealing plastic sample bags; sample spoons; Sieves; Paper towels and tissues; Labels; Electronic balance(s) and Balance Record Book; Vacuum Cleaner; Waste bin(s); Sink for washing up; sample trays; Permanent Makers; etc.

SAFETY EQUIPMENT

Please put on your personal protective equipment (PPE) before commencing work on the samples, including but not limited to the following: Safety boots; Laboratory coats; Eye googles; Hand gloves; Respiratory Masks; etc.

PROCEDURE

a) Clean and dry all working equipment

b) Properly clean your working area using wet paper towels and tissues

c) Check & Verify your samples and generate your worksheet

Note the worksheet should include all the requirements of the Client e.g. temp for drying samples; volume of sample to mill; type of analysis; etc.

d) Check if there are multiple sample bags that need to be combined (this information should be indicated on the field sheet)

e) Disaggregate the samples into metal trays in preparation for drying, ensuring that each bag stays with its sample, while taking absolute care to avoid contamination of other samples. Make sure you treat one sample at a time and ensure that you wash your gloves and clean your workstation between samples.

f) Transfer samples in the trays carefully into Oven and dry at Customer specified temperature

Note that sample trays are loaded into the Oven from top-down and unloaded from the bottom-up to prevent contamination of the samples by spillage

g) While the samples are drying in the Oven, take note to label your plastic or kraft bags in preparation of the next stage;

h) Remove samples from the Oven, while arranging in a definite order to avoid confusion

Note: Make sure you leave space(s) for sample(s) that are still drying up in the Oven

i) Lay out the pre-labelled bags to match the corresponding sample trays;

j) Ensure that the sample in the Kraft bag is completely emptied into the tray and wherever possible remove any traces of the Kraft bag;

k) Take a clean A-4 paper and use it to carefully transfer samples from the tray into corresponding labelled plastic bags

For large samples, this can be done in multiple stages. Discard all spillages to avoid contamination;

l) Seal the plastic bag, ensuring that air is removed;

m) Perform daily balance check;

n) Weigh samples and record the weights before storing samples in a logical order in the crates/shelves;

o) Report sample weights to the Client and wait for further instructions;

p) Complete the worksheet noting the number of samples completed, date, staff involved and other relevant information.

DISAGGREGATION OF SAMPLES

MATERIALS NEEDED

Mortar & pestle; clean A-4 papers; Pre-labelled bags; clean ruler; paper towels; electronic balance and balance record book; etc.

SAFETY EQUIPMENT

Hand gloves; boots; masks; lab coats; Aprons

PROCEDURE

STEP 1

a) Select the first available sample from the storage crates and match it with pre-labelled sample bag;

b) Transfer some of the sample into a clean mortar and disaggregate;

- Disaggregate bulk samples to minus 2mm using the 2mm sieve to measure the size

c) Empty the disaggregated sample on to a clean A-4 paper and repeat step (b) until all the sample is treated;

d) Cone & Quarter the sample where necessary to provide the required sub-sample size

e) Perform daily balance check

f) Weigh portion(s) of the samples for milling

g) Bag and label any original excess and sub-sample portion

h) Store the samples until they are next required;

i) Complete the worksheet noting the number of samples completed, date, staff involved and other relevant information.

MILLING OF SAMPLES AND CREATING REPLICATES

1) Clean and dry gaskets and pots/bowls of the Planetary Ball Mill and ensure that the pots are labelled accordingly

2) Select two (2) samples at a time and heat to less than 80 °C for 10-15 minutes;

3) Take the samples one at a time to the Milling Room and riffle splits to create the replicates;

4) Perform daily balance check

5) Weigh to ensure that the two halves have approximately equal weights

6) Record the weights of the replicate samples on the milling tracking form

7) Assign pot numbers to samples and record it on the milling tracking form

8) Fill assigned pots with associated samples from 1-4

9) Load the pots into the mill, ensuring that opposite weights are approximately equal

10) Run the mill with the required parameters: time, rpm, pause, repetition, etc.

11) Whilst the mill is running, label the sub-sample bags with the appropriate sample IDs

12) Unload and empty each pot in order (1-4) into a clean 4mm sieve placed in a clean tray to separate the balls from the pulp sample

13) Transfer the pulp sample from the tray onto a clean sheet of paper and then into the appropriate pre-labelled sample bag

14) Weigh and record the final weight of the sample

15) Store the samples in numerical order

16) Complete the worksheet noting the number of samples completed, date, staff involved and other relevant information.

Appendix 5 Analytical data

Ag - Er by Na_2O_2-fusion ICP-MS analysis (ALS code ME-MS89L)

Sample Number	Control Sample	Ag ppm	As ppm	Ba ppm	Be ppm	Bi ppm	Ca %	Cd ppm	Ce ppm	Co ppm	Cs ppm	Cu ppm	Dy ppm	Er ppm
010005-C	DUP A	6	5	191	2.2	<0.1	0.2	0.8	84.2	17.5	0.2	50	5.76	4.44
R010005-C	REP A	<5	<4	174	1.8	0.2	0.2	<0.8	88.2	14.5	0.4	50	5.16	4.46
010037-C	DUP B	6	15	138	0.7	<0.1	0.1	<0.8	99	12.6	0.2	40	6.27	6.26
R010037-C	REP B	<5	4	118	<0.4	0.2	0.1	<0.8	85.1	12.3	0.3	40	5.33	5.51
010099-C	N/A	6	5	175	1.6	<0.1	0.2	<0.8	96.8	14	0.4	50	6.74	5.6
R010099-C	N/A	<5	6	156	1.2	0.2	0.2	<0.8	96	12.5	0.5	50	6.12	4.95
02002-C	N/A	5	4	148	1.8	<0.1	0.8	0.9	49.1	143.5	0.6	50	6.42	3.04
R02002-C	N/A	<5	4	137	0.5	0.2	0.9	0.8	56.1	137.5	1	50	5.74	2.66
02003-C	DUP A	<5	<4	175	0.9	<0.1	0.9	0.8	48.3	174.5	1.1	50	4.65	2.61
R02003-C	REP A	<5	5	153	0.9	0.1	1	<0.8	44.8	160.5	0.9	50	4.19	2.07
02004-C	DUP B	<5	5	149	1.8	<0.1	1.1	<0.8	44.7	186	0.6	50	4.43	2.14
R02004-C	REP B	9	4	138	0.7	0.2	1.1	0.9	39.1	159.5	0.7	40	3.23	2.01
02005-C	DUP A	7	7	76	0.8	0.1	0.1	<0.8	110.5	16.2	0.2	40	3.96	3.39
R02005-C	REP A	9	<4	58	<0.4	0.2	<0.1	<0.8	91.3	13.3	0.4	40	2.4	2.89
02006-C	DUP B	5	4	89	0.7	<0.1	0.1	1	68.6	16.3	0.2	50	2.45	1.97
R02006-C	REP B	10	<4	78	0.4	0.1	0.1	<0.8	49.2	13.8	0.3	40	1.9	1.84
02007-C	DUP A	<5	4	153	1.3	<0.1	0.4	<0.8	76.1	44.7	0.4	80	3.57	2.6
R02007-C	REP A	9	4	144	1.1	0.2	0.4	0.9	76.9	45.5	0.6	70	3.86	2.46
02008-C	DUP B	8	5	145	1.6	<0.1	0.5	1.3	74.3	39.5	0.5	120	3.41	2.01
R02008-C	REP B	10	8	138	1.1	0.3	0.5	1.6	71.9	38.7	0.4	110	3.36	2.06
02009-C	DUP A	<5	7	96	1.9	0.2	1.1	0.8	37	10.9	0.9	40	4.99	3.02
R02009-C	REP A	14	6	99	<0.4	0.4	1	1.6	36.9	11	1.1	40	4.63	3.25
02010-C	DUP B	<5	12	116	1.2	0.4	1	0.9	38.1	12.2	1.4	50	5.11	3.42
R02010-C	REP B	<5	7	91	1.5	0.3	1	<0.8	36.3	10.4	1.6	40	4.31	2.77
02013-C	DUP A	<5	<4	2410	2.6	<0.1	0.3	<0.8	228	9.2	1.2	20	14.35	7.49
R02013-C	REP A	<5	<4	1820	1.7	0.3	0.2	1	206	7.8	1.3	20	10.2	6.65
02014-C	DUP B	6	12	2250	3	0.2	0.3	1.2	272	9.8	1.2	30	15.4	9.4
R02014-C	REP B	<5	10	1660	1.6	0.3	0.3	1.1	240	8.4	1.4	20	12.2	7.77
02015-C	DUP A	<5	<4	1370	2.5	<0.1	0.1	<0.8	238	10.8	1.1	<20	9.69	4.58
R02015-C	REP A	8	<4	1060	1.1	0.1	0.1	1.2	221	9.5	1.2	<20	7.62	4.02
02016-C	DUP B	<5	7	1140	2.2	<0.1	0.2	<0.8	247	13.1	1.3	20	9.94	4.35
R02016-C	REP B	5	<4	899	1.3	0.2	0.2	1.2	227	10.9	1.3	20	7.92	4.17
02017-C	DUP A	<5	11	540	1.4	1.4	0.1	0.9	62	32.3	4.1	130	2.93	1.98
R02017-C	REP A	9	8	409	0.8	1.5	0.1	1.6	60.2	29.1	3.9	110	2.7	1.64
02018-C	DUP B	5	14	494	1.1	2.8	0.2	<0.8	68.6	37.5	4.1	130	3.21	2.27
R02018-C	REP B	6	14	385	0.8	2.8	0.2	1	64.5	31	3.3	110	2.84	2.14
02019-C	DUP A	5	38	256	0.9	7	<0.1	0.9	32.2	29.5	1.8	90	2.11	1.56
R02019-C	REP A	<5	30	194	<0.4	7.2	<0.1	1	30.7	25	1.7	80	2.02	1.48
02020-C	DUP B	6	45	264	1	4.8	0.1	0.8	39.9	40.3	2.7	120	3.48	2.01
R02020-C	REP B	5	34	198	0.5	4.6	0.1	<0.8	37.3	34.8	2.9	110	3.07	1.77
02021-C	DUP A	<5	13	701	1.7	0.3	0.1	<0.8	31.1	21.3	2.9	50	2.17	1.48
R02021-C	REP A	<5	13	559	0.4	0.4	0.1	<0.8	29.3	18.2	2.9	50	2.01	1.19
02022-C	DUP B	<5	15	639	1.5	0.3	0.1	<0.8	27.9	17.1	2.7	50	1.88	1.24
R02022-C	REP B	5	10	511	<0.4	0.5	0.2	1	27.9	15.7	2.7	50	2.04	1.26
02023-C	DUP A	<5	9	707	0.8	0.2	<0.1	<0.8	39	8.8	4.9	40	2.44	1.35
R02023-C	REP A	7	<4	570	0.7	0.4	<0.1	0.9	39.5	6.9	4.6	40	2.24	1.31
02024-C	DUP B	<5	6	692	1.5	0.1	<0.1	<0.8	29.3	11.3	3.9	50	2.41	1.31
R02024-C	REP B	<5	9	567	<0.4	0.5	<0.1	<0.8	27.2	10.6	4	50	2.44	1.22
02029-C	DUP A	5	24	331	1	0.1	0.1	<0.8	179	16.3	0.6	40	7.14	5.58
R02029-C	REP A	8	18	271	0.4	0.1	0.1	1.1	168.5	14.5	0.5	40	6.19	4.99
02030-C	DUP B	<5	9	361	1	0.2	0.2	1.2	192.5	16.8	0.4	40	6.68	5.35
R02030-C	REP B	<5	<4	306	0.5	0.2	0.1	0.8	172	16.1	0.5	40	6.83	4.81

Sample Number	Control Sample	Ag ppm	As ppm	Ba ppm	Be ppm	Bi ppm	Ca %	Cd ppm	Ce ppm	Co ppm	Cs ppm	Cu ppm	Dy ppm	Er ppm
02031-C	DUP A	<5	21	94	1.2	0.2	<0.1	<0.8	176	15.8	1.6	40	4.12	2.61
R02031-C	REP A	<5	<4	75	1.3	0.2	<0.1	0.8	157.5	13.5	1.2	40	4.16	2.15
02032-C	DUP B	<5	6	76	0.6	0.3	0.1	1.2	397	17.1	0.7	50	6.02	3.64
R02032-C	REP B	<5	34	58	0.5	0.1	<0.1	<0.8	328	15.7	0.6	50	6.09	3.11
02033-C	DUP A	<5	14	237	0.8	0.2	0.1	1.1	364	20.1	0.6	50	7.35	5.74
R02033-C	REP A	12	6	247	0.8	0.3	0.1	1.4	334	20.8	0.4	50	6.39	5.3
02034-C	DUP B	<5	18	269	0.4	0.2	0.1	1.1	444	20.1	0.5	40	7.57	6.21
R02034-C	REP B	10	<4	250	0.9	0.2	0.1	0.9	404	19.2	0.4	40	7	6.87
02035-C	DUP A	<5	14	662	0.4	0.2	0.3	1.1	167	28.8	0.7	60	3.94	2.2
R02035-C	REP A	6	<4	609	1.2	0.2	0.2	<0.8	133.5	26.1	0.6	50	3.17	1.66
02036-C	DUP B	<5	10	687	0.4	0.2	0.4	<0.8	355	26.7	0.6	40	5.26	2.56
R02036-C	REP B	8	4	671	0.6	0.4	0.3	1	293	26.5	0.4	40	4.52	2.48
02037-C	DUP A	<5	8	910	0.5	0.2	0.2	1	948	14	1	40	5.3	2.47
R02037-C	REP A	7	6	848	0.4	0.2	0.1	<0.8	736	12.2	0.6	30	3.58	2.41
02038-C	DUP B	<5	18	889	<0.4	0.2	0.3	0.8	1570	16.1	0.5	30	7.12	3.09
R02038-C	REP B	5	5	838	<0.4	0.2	0.2	<0.8	1250	14.8	0.4	30	6.07	2.85
02039-C	DUP A	<5	7	350	1.2	0.3	0.1	1.1	201	15.2	1	40	3.82	2.4
R02039-C	REP A	7	4	336	1.4	0.3	<0.1	<0.8	165.5	14.5	1	40	3.24	2.39
02040-C	DUP B	<5	16	310	0.4	0.2	0.1	0.9	286	18.2	0.9	40	4.39	2.79
R02040-C	REP B	6	8	281	0.7	0.2	<0.1	<0.8	225	15.7	1.2	30	3.55	3.01
02041-C	DUP A	<5	23	324	1.4	0.2	0.1	0.9	648	22.2	0.6	40	5.34	3.38
R02041-C	REP A	7	14	305	0.7	0.2	<0.1	<0.8	557	19.6	0.5	30	4.64	2.9
02042-C	DUP B	<5	10	307	0.6	0.1	0.1	0.9	588	22.4	0.7	60	4.87	3.07
R02042-C	REP B	8	8	283	0.4	0.2	0.1	<0.8	512	19.8	0.5	50	4.77	2.97
02043-C	DUP A	<5	6	270	<0.4	0.2	0.1	<0.8	186	13.8	0.6	50	3.23	1.8
R02043-C	REP A	5	7	257	0.5	0.2	<0.1	<0.8	140	13.6	0.5	40	2.61	1.51
02044-C	DUP B	<5	12	348	0.9	0.1	0.1	1.1	218	14.6	0.7	50	4.28	2.31
R02044-C	REP B	<5	20	362	0.9	0.1	0.1	<0.8	217	14.7	0.6	50	4.05	2.56
02045-C	DUP A	<5	10	1500	2.2	0.2	0.9	1.1	103	20.3	1.3	40	3.52	2.38
R02045-C	REP A	<5	5	1580	1.6	<0.1	0.9	<0.8	107.5	20.1	1.5	40	3.82	2.76
02046-C	DUP B	<5	6	2090	1.7	0.1	0.6	<0.8	97.3	24.3	1.6	30	3.15	1.9
R02046-C	REP B	<5	4	1960	2.2	<0.1	0.6	<0.8	96.1	21.1	1.7	30	3.09	1.87
02047-C	N/A	<5	9	597	0.6	0.3	0.2	<0.8	407	17.4	1	40	8.45	5.24
R02047-C	N/A	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
02048-C	N/A	<5	8	514	<0.4	0.3	0.2	<0.8	229	12.6	0.9	30	5.74	3.87
R02048-C	N/A	<5	5	507	1	0.1	0.2	<0.8	223	12.2	0.9	20	5.47	3.77
02049-C	DUP A	<5	5	1280	1.9	0.5	0.5	1.3	69.5	18	2.1	50	4.44	3.46
R02049-C	REP A	<5	9	1250	1.4	0.2	0.5	<0.8	65.3	16.6	1.9	40	4.43	3.38
02050-C	DUP B	<5	9	1380	2.1	0.4	0.4	<0.8	67.6	24.6	2.6	50	4.39	2.83
R02050-C	REP B	<5	21	1220	1.3	0.4	0.4	<0.8	63.2	21.1	2.2	30	3.18	2.61
02051-C	DUP A	<5	20	1890	1.6	0.1	0.4	<0.8	364	12.7	1.1	20	7.98	4.78
R02051-C	REP A	<5	11	1730	0.9	0.1	0.5	<0.8	370	11.5	1	20	7.62	5.25
02052-C	DUP B	<5	5	1790	2.1	0.2	0.5	1.6	257	12.8	1	30	6.73	3.8
R02052-C	REP B	<5	10	1710	2.3	0.2	0.4	<0.8	225	11	1.7	20	6.4	3.43
02053-C	DUP A	<5	14	720	0.6	0.2	0.2	1.2	124	15.5	0.7	30	4.08	2.62
R02053-C	REP A	<5	<4	631	0.6	0.1	0.2	<0.8	98.7	13	1	20	3.55	2.44
02054-C	DUP B	<5	13	661	0.6	0.2	0.2	0.9	127	12.6	0.6	40	4.07	3.24
R02054-C	REP B	<5	7	556	0.8	<0.1	0.2	<0.8	107.5	9.7	0.6	30	3.33	2.91
02055-C	DUP A	<5	5	988	<0.4	0.2	0.1	1.4	180.5	7.9	0.7	30	3.94	2.54
R02055-C	REP A	<5	8	813	<0.4	<0.1	0.1	<0.8	148	6.7	0.9	20	3.35	1.93
02056-C	DUP B	<5	17	745	0.4	0.1	0.1	0.8	115.5	12.9	0.9	40	3.32	1.95
R02056-C	REP B	<5	11	665	0.5	0.1	0.1	<0.8	110.5	11.8	1	30	2.75	1.66
02057-C	DUP A	<5	9	923	0.4	0.1	<0.1	1	266	8.1	0.6	40	7.28	3.3
R02057-C	REP A	<5	13	794	<0.4	<0.1	0.1	<0.8	239	7.5	0.9	30	6.07	3.22
02058-C	DUP B	<5	20	797	0.6	0.2	<0.1	<0.8	311	9.1	0.9	40	8.28	3.78
R02058-C	REP B	<5	6	773	<0.4	<0.1	0.1	<0.8	366	8.7	0.6	40	9.67	4.46

Eu - Mn by Na_2O_2-fusion ICP-MS analysis (ALS code ME-MS89L)

Sample Number	Control Sample	Eu ppm	Fe %	Ga ppm	Gd ppm	Ge ppm	Ho ppm	In ppm	K %	La ppm	Li ppm	Lu ppm	Mn ppm
010005-C	DUP A	0.88	8.24	23.8	5.28	2.4	1.15	<0.3	0.11	47.7	6	1.17	470
R010005-C	REP A	0.98	7.79	23.3	5.1	0.9	1.31	<0.3	0.12	52	8	1.38	420
010037-C	DUP B	0.85	5.8	10	5.79	2	1.38	0.4	0.08	55.8	2	1.62	700
R010037-C	REP B	0.83	5.03	9.3	5.27	0.7	1.45	<0.3	0.07	52.6	5	1.75	590
010099-C	N/A	0.89	9.38	23.9	6.14	1.9	1.37	<0.3	0.11	56.2	6	1.55	480
R010099-C	N/A	0.84	8.22	25.6	6.04	1	1.42	0.3	0.12	58.6	9	1.49	410
02002-C	N/A	1.38	13	27.9	5.97	2.4	1.02	<0.3	0.31	25.7	7	0.28	2310
R02002-C	N/A	1.54	11.9	24.4	6.3	1.5	1.08	<0.3	0.31	30.2	7	0.41	2050
02003-C	DUP A	1.34	14.3	25.6	4.34	2.2	0.73	<0.3	0.31	21.4	6	0.2	2950
R02003-C	REP A	1.16	12.65	23.9	4.44	1.3	0.71	<0.3	0.34	20.5	6	0.3	2550
02004-C	DUP B	1.3	14.45	25.7	5.58	2.6	0.75	0.4	0.27	19.25	8	0.22	3210
R02004-C	REP B	0.97	11.95	18.4	3.61	1.8	0.72	<0.3	0.26	15.9	7	0.28	3020
02005-C	DUP A	0.7	6.67	8.1	4.12	1.6	0.7	0.3	0.05	56.9	2	1.2	530
R02005-C	REP A	0.56	5.23	5.2	3.8	1.1	0.69	<0.3	<0.05	46	4	0.97	470
02006-C	DUP B	0.49	6.55	8.8	3.24	1.8	0.55	0.3	0.07	35.6	3	0.53	460
R02006-C	REP B	0.56	5.23	6.3	2.44	1.3	0.47	<0.3	0.06	24.2	4	0.53	410
02007-C	DUP A	1.23	16.45	27.4	4.67	2.6	0.76	<0.3	0.12	32.9	9	0.49	2570
R02007-C	REP A	1.22	15.95	28.3	4.44	2.2	0.68	<0.3	0.13	31.3	11	0.49	2810
02008-C	DUP B	1.04	19.15	49.4	4.86	2.7	0.7	0.3	0.13	31	10	0.39	1430
R02008-C	REP B	0.99	17.7	36.7	3.79	2.1	0.68	<0.3	0.13	28.7	11	0.36	1500
02009-C	DUP A	0.88	5.11	29.5	3.81	2.7	0.95	<0.3	0.31	18.7	10	0.51	460
R02009-C	REP A	0.82	4.77	22.9	3.62	2	0.85	<0.3	0.3	18.8	11	0.6	500
02010-C	DUP B	0.84	5.47	30.5	4.03	2.4	1	<0.3	0.31	20.4	11	0.54	480
R02010-C	REP B	0.72	4.96	19.3	3.13	1.4	0.85	<0.3	0.32	18.05	12	0.52	460
02013-C	DUP A	3.33	6.1	47.2	15.35	2.7	2.37	<0.3	3.5	136.5	24	1.19	660
R02013-C	REP A	2.72	5.25	27.1	13.1	1.4	1.99	<0.3	3.41	110.5	16	1.14	590
02014-C	DUP B	3.93	6.21	49	18.6	2.6	2.83	0.4	3.15	143	25	1.69	750
R02014-C	REP B	3.19	5.26	29.5	14.6	1.2	2.39	<0.3	3.14	111.5	19	1.61	670
02015-C	DUP A	2.92	8.11	54	11.4	3	1.41	0.4	1.66	112.5	19	0.76	590
R02015-C	REP A	2.62	6.87	30.8	9.89	1.3	1.2	<0.3	1.63	92.3	14	0.55	540
02016-C	DUP B	3.26	9.1	51.4	12.35	2.7	1.48	<0.3	1.3	114.5	20	0.63	900
R02016-C	REP B	2.56	7.91	31.7	9.46	1.1	1.25	<0.3	1.25	93.1	15	0.57	830
02017-C	DUP A	0.9	14.3	36.5	3.13	3.4	0.79	0.4	0.75	19.9	26	0.27	790
R02017-C	REP A	0.8	12.6	21	2.46	1.6	0.66	<0.3	0.74	16.85	18	0.26	720
02018-C	DUP B	1	15.85	27.6	2.9	3.1	0.63	<0.3	0.69	26.2	22	0.41	1380
R02018-C	REP B	0.73	13.6	14.1	3.15	1.6	0.48	<0.3	0.66	22.2	14	0.25	1270
02019-C	DUP A	0.47	12.8	23.9	1.67	3.4	0.53	0.4	0.47	12.75	13	0.35	1000
R02019-C	REP A	0.4	10.8	12.5	1.62	1.4	0.48	<0.3	0.45	11.1	11	0.28	900
02020-C	DUP B	0.89	16.65	32.6	3.45	3.4	0.62	<0.3	0.48	14.9	23	0.38	900
R02020-C	REP B	0.74	14.4	15.7	2.86	1.5	0.66	<0.3	0.5	12.95	16	0.31	830
02021-C	DUP A	0.66	7.71	26.4	2.27	1.8	0.4	<0.3	1.26	13.8	29	0.23	770
R02021-C	REP A	0.63	6.63	15.3	1.86	1.2	0.4	<0.3	1.24	11.6	21	0.19	700
02022-C	DUP B	0.61	9.16	24.1	1.89	2.6	0.43	0.3	1.04	13.05	26	0.11	590
R02022-C	REP B	0.56	8.19	14.2	1.98	1.3	0.42	<0.3	1.01	11.9	18	0.14	560
02023-C	DUP A	0.6	5.03	26.3	2.53	1.2	0.4	<0.3	1.93	18.75	27	0.2	200
R02023-C	REP A	0.65	4.47	12.7	2.23	0.7	0.45	<0.3	1.83	15.2	18	0.2	190
02024-C	DUP B	0.57	5.58	18.6	2.03	1.9	0.37	0.3	1.55	12.75	22	0.21	380
R02024-C	REP B	0.49	4.91	11.1	1.71	0.7	0.48	<0.3	1.54	11	16	0.19	370
02029-C	DUP A	1.04	7.43	18	9.88	1.8	1.52	<0.3	0.15	85.1	5	1.35	960
R02029-C	REP A	1.12	6.68	9.9	8.69	0.6	1.34	<0.3	0.15	72	4	1.43	930
02030-C	DUP B	1.34	7.57	18.8	10.75	2.3	1.44	<0.3	0.2	93.6	6	1.49	860
R02030-C	REP B	1.36	7.5	13.2	9.21	0.7	1.63	<0.3	0.18	75.4	6	1.38	940

Sample Number	Control Sample	Eu ppm	Fe %	Ga ppm	Gd ppm	Ge ppm	Ho ppm	In ppm	K %	La ppm	Li ppm	Lu ppm	Mn ppm
02031-C	DUP A	1.56	6.01	24.8	8.14	2.5	0.83	<0.3	0.1	97.1	11	0.54	380
R02031-C	REP A	1.28	5.54	19	6.98	1.2	0.8	<0.3	0.11	72.4	13	0.45	390
02032-C	DUP B	2.56	6.55	15.2	16.45	1.9	1.14	<0.3	<0.05	209	7	1.03	680
R02032-C	REP B	1.63	6.06	11.1	12.75	0.7	0.94	<0.3	0.05	157	6	0.74	700
02033-C	DUP A	1.24	9.66	20.3	10.85	1.6	1.64	<0.3	0.16	209	5	1.59	1620
R02033-C	REP A	1.48	9.35	26.1	8.7	2.5	1.57	<0.3	0.15	179.5	9	1.54	1820
02034-C	DUP B	1.4	9.16	20.7	11.05	1.7	1.72	<0.3	0.17	261	7	1.85	1820
R02034-C	REP B	1.54	8.69	23.4	10.1	2.2	1.66	<0.3	0.17	221	9	1.81	2090
02035-C	DUP A	1.26	7.83	25.9	6.27	1.9	0.71	<0.3	0.65	93.1	11	0.39	800
R02035-C	REP A	0.98	6.92	24.1	4.37	1.3	0.65	<0.3	0.65	70.3	12	0.26	840
02036-C	DUP B	1.27	7.51	20.1	9.59	1.6	0.86	<0.3	0.79	201	8	0.48	1480
R02036-C	REP B	1.04	7.04	21.1	7.75	1.9	0.89	0.3	0.76	168	9	0.49	1620
02037-C	DUP A	2.28	4.52	26.6	12.45	1.7	0.78	<0.3	0.8	533	12	0.54	660
R02037-C	REP A	1.51	4.08	28.2	9.9	1.8	0.66	<0.3	0.82	402	13	0.43	710
02038-C	DUP B	2.81	5.01	20	19.25	1.4	1.1	<0.3	0.79	964	7	0.79	1120
R02038-C	REP B	2.4	4.71	22.5	16.4	1.8	0.93	<0.3	0.78	764	9	0.68	1230
02039-C	DUP A	1.36	6.12	22.1	5.16	1.7	0.81	<0.3	0.28	121	8	0.59	990
R02039-C	REP A	0.96	5.66	24.6	4.22	2	0.71	<0.3	0.29	96.3	11	0.58	1070
02040-C	DUP B	1.51	7.3	24	6.62	1.6	0.95	<0.3	0.26	172	9	0.77	1340
R02040-C	REP B	1.19	6.55	18.4	4.6	1.5	0.78	<0.3	0.25	134	8	0.64	1440
02041-C	DUP A	1.97	6.58	16.9	10.75	1.6	0.96	<0.3	0.26	359	7	0.94	1050
R02041-C	REP A	1.52	6.1	15.7	8.89	1.6	0.98	<0.3	0.24	297	8	0.85	1170
02042-C	DUP B	1.66	8.33	15.9	10.1	1.3	1	<0.3	0.21	326	7	0.81	1090
R02042-C	REP B	1.68	7.4	13.2	8.57	1.6	0.8	<0.3	0.23	264	7	0.72	1170
02043-C	DUP A	1.28	7.85	16.5	5.93	1	0.67	<0.3	0.2	103.5	5	0.44	960
R02043-C	REP A	0.8	7.05	15.1	4.01	0.9	0.53	<0.3	0.23	81.8	6	0.41	1040
02044-C	DUP B	1.33	6.38	20.5	6.83	1.4	0.82	<0.3	0.33	122.5	9	0.58	810
R02044-C	REP B	1.27	6.2	25.2	6.54	1.4	0.86	<0.3	0.34	121	9	0.56	880
02045-C	DUP A	1.48	5.31	22.3	4.61	1.3	0.75	<0.3	2.31	55.6	20	0.57	720
R02045-C	REP A	1.38	5.39	28.4	4.45	1.6	0.78	<0.3	2.33	59.6	21	0.54	790
02046-C	DUP B	1.23	6.12	31.3	4.59	1.4	0.64	<0.3	2.71	54.5	19	0.5	850
R02046-C	REP B	1.05	5.51	31.1	3.61	1.3	0.6	<0.3	2.79	49.9	17	0.37	860
02047-C	N/A	1.42	8.29	29.5	12.4	1.8	1.53	<0.3	0.97	241	11	1.44	920
R02047-C	N/A	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
02048-C	N/A	1.06	8.64	26.5	7.5	1.4	1.1	<0.3	0.87	137	8	1.1	770
R02048-C	N/A	0.84	8.03	23.8	6.1	1.5	1.04	<0.3	0.9	134	7	0.68	770
02049-C	DUP A	1.09	6.05	31.2	4.38	1.2	1.06	<0.3	2.64	32.7	22	0.91	520
R02049-C	REP A	0.74	5.48	26.8	3.42	1.4	0.92	<0.3	2.7	31.4	23	0.92	510
02050-C	DUP B	1.1	6.18	38.3	4.42	1.8	0.84	<0.3	2.66	34.7	30	0.61	580
R02050-C	REP B	0.69	5.3	27.6	3.67	1.2	0.76	<0.3	2.68	30.4	22	0.54	550
02051-C	DUP A	2.43	5.81	33.7	13.15	1.7	1.43	<0.3	2.68	231	14	1.24	960
R02051-C	REP A	2.2	5.11	27.7	10.35	1.9	1.31	<0.3	2.72	215	13	0.98	930
02052-C	DUP B	2.27	5.52	31.4	9.57	1.8	1.21	<0.3	2.42	147	14	0.8	690
R02052-C	REP B	1.58	4.84	27.9	7.73	1.6	0.9	<0.3	2.43	134.5	17	0.58	660
02053-C	DUP A	0.91	5.13	24.1	4.91	1.9	0.76	<0.3	0.72	69.8	10	0.73	910
R02053-C	REP A	0.87	4.16	14.1	3.35	1.3	0.6	<0.3	0.76	58.5	6	0.43	800
02054-C	DUP B	0.78	5.03	16.7	5.09	1.5	0.76	<0.3	0.68	74	9	0.82	960
R02054-C	REP B	0.82	3.98	9.4	3.61	0.8	0.65	<0.3	0.7	62.3	4	0.67	840
02055-C	DUP A	0.98	3.13	16.7	6.69	1.2	0.73	<0.3	1.06	101	4	0.6	260
R02055-C	REP A	0.62	2.54	8.9	5.06	1.1	0.56	<0.3	1.07	83.9	5	0.39	230
02056-C	DUP B	0.88	4.06	19.6	4.71	1.3	0.58	<0.3	0.81	64.8	8	0.43	360
R02056-C	REP B	0.78	3.5	13.6	3.99	<0.5	0.66	<0.3	0.83	61.8	4	0.37	340
02057-C	DUP A	1.01	7.09	32.3	12.65	1.3	1.19	<0.3	1.02	148	6	0.65	400
R02057-C	REP A	0.64	5.89	22.2	10.45	1	0.99	<0.3	1.07	130.5	3	0.49	370
02058-C	DUP B	0.96	6.57	27.8	15.9	1.5	1.45	0.3	0.92	192	10	0.82	510
R02058-C	REP B	1.05	6.4	19.2	16.5	0.9	1.55	<0.3	0.96	200	4	0.74	550

Mo - Sn by Na_2O_2-fusion ICP-MS analysis (ALS code ME-MS89L)

Sample Number	Control Sample	Mo ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Pr ppm	Rb ppm	Re ppm	Sb ppm	Se ppm	Sm ppm	Sn ppm
010005-C	DUP A	3	30.3	32.8	70	24.6	9.34	6.3	<0.01	0.5	<3	5.14	<3
R010005-C	REP A	3	32	29.9	80	23.5	9.99	6	<0.01	<0.3	<3	5.68	4
010037-C	DUP B	11	32.8	37.1	50	20.9	11.2	3.8	<0.01	0.7	<3	6.77	<3
R010037-C	REP B	10	29.2	29.9	60	20.8	9.55	3.6	<0.01	0.5	<3	5.14	3
010099-C	N/A	3	33.2	34.8	60	23.7	11.2	6.6	<0.01	<0.3	4	6.44	<3
R010099-C	N/A	4	30.3	33.4	70	23.3	10.8	5.4	<0.01	0.4	4	6.28	4
02002-C	N/A	<2	16.7	25.6	770	14	7.45	21.6	<0.01	0.8	12	6.47	<3
R02002-C	N/A	<2	22.8	28.1	760	14.1	7.93	19.7	<0.01	<0.3	<3	6.52	3
02003-C	DUP A	2	33	21.7	760	13.8	5.79	25.9	<0.01	<0.3	<3	4.71	<3
R02003-C	REP A	<2	14.7	18.75	700	14.2	5.17	21	<0.01	<0.3	5	4.54	<3
02004-C	DUP B	<2	18.1	20.1	720	13.4	5.24	16.8	<0.01	<0.3	<3	4.43	<3
R02004-C	REP B	<2	10.3	17.3	600	11.3	3.99	15.7	<0.01	0.3	<3	3.48	<3
02005-C	DUP A	16	42.2	45.8	60	14	13.05	3.6	<0.01	0.3	7	7.71	3
R02005-C	REP A	11	37.4	35.4	60	11.4	9.92	2.1	<0.01	0.7	<3	6.2	3
02006-C	DUP B	14	42.6	28	60	11.2	8.21	3.6	<0.01	0.6	14	4.42	3
R02006-C	REP B	14	24.8	19.1	60	9.5	5.21	3.7	<0.01	0.4	<3	3.34	3
02007-C	DUP A	2	43.9	29	80	17.1	8.17	6.7	<0.01	<0.3	<3	6.19	3
R02007-C	REP A	3	47.3	28.6	90	18.1	7.84	6.6	<0.01	0.6	<3	5.91	7
02008-C	DUP B	3	36.2	28.5	90	18	8.28	7.3	<0.01	0.3	<3	5.43	3
R02008-C	REP B	2	39.7	26.3	90	18.3	7.11	6.5	<0.01	0.5	<3	5.69	9
02009-C	DUP A	3	26	14.2	20	14.6	4.66	15.1	0.03	0.3	<3	4.43	<3
R02009-C	REP A	3	28.3	14.9	40	14.6	4	17	<0.01	0.6	<3	3.9	11
02010-C	DUP B	4	26.4	17.35	30	16.2	4.28	19.1	<0.01	0.9	<3	3.85	<3
R02010-C	REP B	2	26.4	13.35	40	14.1	3.57	18.2	<0.01	<0.3	3	2.91	4
02013-C	DUP A	6	53.3	98.8	30	37.8	30.1	105	<0.01	<0.3	3	18.95	<3
R02013-C	REP A	4	51.4	78.9	40	29.7	22.3	94.3	<0.01	<0.3	14	14.75	8
02014-C	DUP B	7	64.1	117	20	38.4	34.4	105	<0.01	0.8	3	21.3	3
R02014-C	REP B	6	58.9	88.9	30	30.8	25	89.4	<0.01	0.6	3	17.6	9
02015-C	DUP A	6	45.5	86.3	30	31.8	27.1	59.6	<0.01	0.5	<3	14.55	<3
R02015-C	REP A	4	42.6	73.7	40	25.7	21.2	52.2	<0.01	<0.3	<3	13.95	4
02016-C	DUP B	5	41.9	90.6	20	29.8	25.8	51.6	0.04	0.4	6	15.95	<3
R02016-C	REP B	4	38.4	72.3	40	24.5	20	46.5	0.01	<0.3	8	12.85	3
02017-C	DUP A	4	13.3	15.75	110	33.5	4.65	34	<0.01	0.9	<3	2.35	<3
R02017-C	REP A	4	13.1	14	120	26.8	3.98	30.8	<0.01	0.9	<3	2.97	<3
02018-C	DUP B	5	12.1	20.9	120	39.4	6.36	29.5	<0.01	1.2	10	3.79	<3
R02018-C	REP B	3	12.9	17.95	100	31.6	4.91	26.6	0.01	0.8	11	3.62	<3
02019-C	DUP A	2	9.9	11.35	100	21.6	3.01	21.9	<0.01	3.4	<3	1.94	<3
R02019-C	REP A	2	13.7	9.22	90	16.8	2.77	15.9	0.01	3	<3	1.96	<3
02020-C	DUP B	3	12	14.4	150	37.1	3.91	26.7	<0.01	3.9	<3	2.66	<3
R02020-C	REP B	2	11.6	12.4	130	29.8	3.02	23.8	<0.01	2.9	3	2.69	3
02021-C	DUP A	4	11.4	11.1	70	15.9	3.38	53	<0.01	2	6	2.08	<3
R02021-C	REP A	4	11	10.2	70	12.3	2.67	48.9	<0.01	1.3	8	1.93	5
02022-C	DUP B	5	10.1	10.85	60	15.5	3.22	43.3	<0.01	3	<3	1.98	<3
R02022-C	REP B	4	9.9	10.7	70	12.7	2.57	39	<0.01	1.8	5	1.77	<3
02023-C	DUP A	9	14	13.45	40	20.5	4.34	105	<0.01	0.8	<3	2.84	<3
R02023-C	REP A	6	14.7	12	50	17.6	3.61	98.3	<0.01	0.9	13	2.61	3
02024-C	DUP B	12	13.3	11.1	50	15.8	3.26	82.2	<0.01	0.6	<3	2.3	<3
R02024-C	REP B	11	12.2	8.44	50	14	2.47	78.6	<0.01	0.8	<3	1.52	4
02029-C	DUP A	7	53.8	79.7	60	29.3	22.6	8	<0.01	2.4	<3	12.95	11
R02029-C	REP A	6	49.4	68.2	70	20.3	17.75	5.7	<0.01	1.2	10	11.9	10
02030-C	DUP B	4	47.1	82.7	70	19.4	23.7	7.1	0.01	0.3	9	14.3	4
R02030-C	REP B	4	48.4	69.2	60	16.3	18.2	7.7	0.01	0.3	<3	11.95	4

Sample Number	Control Sample	Mo ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Pr ppm	Rb ppm	Re ppm	Sb ppm	Se ppm	Sm ppm	Sn ppm
02031-C	DUP A	3	43.5	70.1	70	19.5	21.9	8.6	<0.01	0.6	6	11.4	4
R02031-C	REP A	2	41.7	58.2	70	15.9	16.4	10.8	<0.01	<0.3	11	9.97	3
02032-C	DUP B	10	65.6	160	70	17.3	49.5	3.8	<0.01	0.5	6	25.2	5
R02032-C	REP B	7	62.2	123.5	60	18.6	34.4	3.7	<0.01	0.9	<3	21.2	5
02033-C	DUP A	5	49.8	118.5	90	32.8	40.1	4.4	0.02	1.1	5	14.7	5
R02033-C	REP A	5	54.1	104.5	80	31	33.2	4.7	<0.01	0.5	<3	13.35	4
02034-C	DUP B	7	52.2	135	80	29.8	47.3	4.8	0.01	0.4	8	15.45	6
R02034-C	REP B	6	57.3	126	70	30.9	39.1	4.7	<0.01	0.3	<3	17.4	7
02035-C	DUP A	3	16.9	55	90	24.7	18.75	16.7	<0.01	0.4	7	8.95	<3
R02035-C	REP A	2	17	44.5	80	22.2	13.25	15.8	<0.01	<0.3	<3	6.93	<3
02036-C	DUP B	2	23.6	115	70	29.1	38.3	14.4	0.01	<0.3	4	16.2	<3
R02036-C	REP B	2	25.4	93.3	60	28.9	29.5	16.1	<0.01	<0.3	<3	12.35	<3
02037-C	DUP A	2	18.6	254	70	43.4	92.3	18.1	<0.01	0.3	13	25.1	3
R02037-C	REP A	2	19.4	189.5	60	40.8	64	18.3	0.01	<0.3	<3	22.3	<3
02038-C	DUP B	2	23.2	412	60	59.1	153.5	14.3	<0.01	<0.3	<3	42.8	<3
R02038-C	REP B	<2	24.4	327	50	58.3	110.5	14.3	<0.01	0.4	<3	35.7	<3
02039-C	DUP A	3	39.4	61.4	70	19.6	21.3	10.2	<0.01	<0.3	10	7.75	4
R02039-C	REP A	2	39.8	51.9	60	18.9	17	9	<0.01	0.3	<3	6.74	3
02040-C	DUP B	2	47.7	86.4	70	27.4	30.2	8.4	<0.01	1.3	8	9.92	5
R02040-C	REP B	2	47.6	67	60	22.7	22.3	9.4	<0.01	0.4	<3	7.7	4
02041-C	DUP A	5	27.5	180	120	36.9	62.2	8.2	0.02	0.7	9	20.7	3
R02041-C	REP A	5	27.8	150	100	36.5	48.8	7.8	<0.01	0.8	<3	19.15	<3
02042-C	DUP B	13	25.8	167	120	32.8	59	7	0.01	1.2	<3	19.25	4
R02042-C	REP B	12	25.8	141.5	110	31.9	46	5.9	<0.01	1.1	<3	17.45	3
02043-C	DUP A	5	27.3	62.4	60	19.5	20.7	6.3	<0.01	<0.3	7	8.88	3
R02043-C	REP A	4	27.9	45.8	50	19.2	14.1	6.9	<0.01	0.5	<3	7.48	<3
02044-C	DUP B	7	24.7	71.9	80	23.5	24.2	8.9	0.01	<0.3	<3	10.1	5
R02044-C	REP B	6	24.6	73.8	120	26	23.4	11.1	<0.01	1.5	15	9.54	4
02045-C	DUP A	4	18.4	34.9	60	36.1	11.2	74.8	<0.01	0.5	3	5.93	5
R02045-C	REP A	3	17.1	36.1	60	34.1	11.2	73.1	<0.01	0.4	<3	6.81	3
02046-C	DUP B	3	17.3	29.2	70	34.6	9.52	89.6	0.01	<0.3	<3	4.94	6
R02046-C	REP B	2	16.1	29.5	50	31.2	9.15	85.1	<0.01	0.3	<3	4.12	3
02047-C	N/A	3	30	127	90	45.6	44.2	31.9	0.01	0.3	15	17.4	4
R02047-C	N/A	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
02048-C	N/A	3	25.7	71.4	80	33	25	26.3	0.01	0.5	3	10.6	<3
R02048-C	N/A	3	23.9	73	70	29.9	22.9	28.5	0.02	<0.3	<3	9.92	<3
02049-C	DUP A	4	19	23.4	80	35.6	6.92	95	<0.01	<0.3	<3	4.57	3
R02049-C	REP A	3	16.4	21	60	33.8	6.4	94.3	<0.01	<0.3	<3	5.03	3
02050-C	DUP B	4	18.1	21.2	90	37.8	6.91	104	0.02	0.4	8	4.41	3
R02050-C	REP B	4	16.1	19.55	70	34.2	5.77	102	<0.01	<0.3	4	3.86	3
02051-C	DUP A	3	38.4	116	50	43.7	39.2	71.1	0.01	1.2	<3	16.2	4
R02051-C	REP A	2	34.4	120	30	37.9	38.2	68.1	0.04	0.4	10	17.85	<3
02052-C	DUP B	4	32.4	84.8	50	35.1	28.6	68.3	<0.01	0.4	3	14.3	3
R02052-C	REP B	3	29.4	75.4	40	29.1	23.6	69.7	<0.01	0.3	12	12.65	19
02053-C	DUP A	7	24.9	44.2	60	24.2	13.55	20	<0.01	0.6	4	6.59	4
R02053-C	REP A	6	19	32.9	40	19.6	10.9	18.2	0.06	<0.3	11	6.05	<3
02054-C	DUP B	9	26.3	42.3	60	22.5	13.85	16.5	0.02	0.6	5	6.38	4
R02054-C	REP B	6	21	34.1	30	17.8	10.95	15	0.02	<0.3	<3	5.21	<3
02055-C	DUP A	11	10.6	61.1	60	23.6	19.75	23.5	0.01	0.6	<3	9.19	3
R02055-C	REP A	8	8.5	51.7	30	18	15.4	22.5	0.02	<0.3	<3	8.54	<3
02056-C	DUP B	10	16.4	41.7	60	27.4	13.2	24	0.02	1.8	10	6.34	4
R02056-C	REP B	9	13.5	40.1	50	21.8	11.55	19.8	0.02	0.7	4	6.31	<3
02057-C	DUP A	3	24.1	97.9	40	34.4	30.7	28.4	<0.01	0.7	4	16.65	5
R02057-C	REP A	2	19.9	88.7	250	28.2	26.4	25.9	0.01	<0.3	<3	16.1	3
02058-C	DUP B	2	26.1	114	40	37	36.4	26.5	<0.01	0.3	<3	19.75	7
R02058-C	REP B	2	25.7	136	30	33.8	40.8	27.4	<0.01	<0.3	<3	22.4	8

Sr - Y by Na_2O_2-fusion ICP-MS analysis (ALS code ME-MS89L)

Sample Number	Control Sample	Sr ppm	Ta ppm	Tb ppm	Te ppm	Th ppm	Ti %	Tl ppm	Tm ppm	U ppm	V ppm	W ppm	Y ppm
010005-C	DUP A	20	9.02	0.74	<0.5	34.3	1.255	0.04	0.62	10.7	311	1.1	40.3
R010005-C	REP A	<20	9.33	0.82	<0.5	35.6	1.28	0.05	0.87	10.7	299	0.9	36
010037-C	DUP B	20	8.52	0.91	0.7	39.1	1.705	0.03	1	15.3	159	1.3	46.5
R010037-C	REP B	<20	8.07	0.74	<0.5	37.1	1.66	0.06	1.01	14	138	1.1	41.1
010099-C	N/A	20	12	1.01	<0.5	43.9	1.315	0.09	0.86	12.4	365	1.3	45.6
R010099-C	N/A	20	11.2	0.81	<0.5	43.1	1.27	0.06	0.95	12	340	0.9	41.4
02002-C	N/A	50	8.06	1.02	<0.5	5.5	0.454	0.09	0.31	1	181	0.7	31.3
R02002-C	N/A	40	7.55	0.84	<0.5	7.1	0.473	0.22	0.4	1.1	177	0.6	29.7
02003-C	DUP A	50	12.45	0.71	<0.5	6.1	0.571	0.17	0.26	1	244	1.1	23.4
R02003-C	REP A	50	5.6	0.79	<0.5	5	0.568	0.28	0.33	0.9	218	0.7	20.4
02004-C	DUP B	60	4.76	0.74	<0.5	4.8	0.63	0.2	0.26	1	250	1	23.4
R02004-C	REP B	40	6.18	0.53	0.5	3.7	0.589	0.19	0.29	0.9	201	0.4	17.6
02005-C	DUP A	<20	6.97	0.57	0.9	33	2.3	0.03	0.59	7.2	187	2	28.4
R02005-C	REP A	<20	6.23	0.45	<0.5	28.1	2.16	0.02	0.55	6.6	148	1.5	21.5
02006-C	DUP B	<20	7.62	0.43	<0.5	19.1	1.615	0.03	0.29	4.2	140	2.2	19.4
R02006-C	REP B	<20	2.79	0.26	0.5	13.7	1.55	<0.02	0.32	4	114	1.4	13.9
02007-C	DUP A	40	3.62	0.78	<0.5	11.8	4.16	0.06	0.16	2.1	589	1.2	19.6
R02007-C	REP A	40	2.95	0.59	0.8	11.8	4.11	0.07	0.42	2.2	567	0.8	19.9
02008-C	DUP B	40	2.09	0.63	<0.5	11.5	3.35	0.03	0.18	2	684	1	17.1
R02008-C	REP B	40	2.61	0.52	1.2	10.7	3.31	0.03	0.3	2.1	637	0.9	16.7
02009-C	DUP A	50	1.84	0.69	<0.5	16	0.921	0.13	0.38	3.9	161	1.5	28.7
R02009-C	REP A	40	1.84	0.57	0.7	16.1	0.844	0.1	0.46	4.3	149	1.2	27.2
02010-C	DUP B	50	2.29	0.6	0.5	16.1	0.928	0.17	0.31	3.7	168	2	28.9
R02010-C	REP B	40	3.04	0.59	<0.5	15.1	0.879	0.11	0.44	3.7	160	1.4	25.1
02013-C	DUP A	120	2.28	2.03	<0.5	40	1.22	0.68	1.06	13.3	73	1.5	67.3
R02013-C	REP A	90	3.44	1.76	<0.5	33.8	1.135	0.46	0.99	11.2	64	0.9	52.3
02014-C	DUP B	120	4.48	2.43	0.5	45.1	1.355	0.58	1.28	16.4	77	1.8	77.1
R02014-C	REP B	80	3.58	2.11	0.5	39.2	1.295	0.48	1.15	14.2	65	2.7	58.5
02015-C	DUP A	90	2.5	1.79	<0.5	25.3	1.155	0.35	0.63	6.5	93	1.4	42
R02015-C	REP A	70	1.83	1.27	<0.5	21.8	1.105	0.27	0.56	5.9	82	1	33.7
02016-C	DUP B	80	4.68	1.57	<0.5	24.6	1.07	0.42	0.68	6.1	89	1.3	40.8
R02016-C	REP B	60	2.12	1.27	<0.5	21.8	0.999	0.34	0.54	5.3	80	0.9	31.9
02017-C	DUP A	20	1.79	0.65	<0.5	16.8	0.799	0.17	0.2	5.7	278	4.4	18.5
R02017-C	REP A	20	1.12	0.45	0.5	14.4	0.781	0.25	0.27	5.3	266	3.2	14.9
02018-C	DUP B	30	3.27	0.54	0.8	18.5	0.909	0.33	0.28	6.9	315	4.5	19.9
R02018-C	REP B	20	1.88	0.49	1.1	17	0.848	0.19	0.26	6	285	3.2	15.3
02019-C	DUP A	20	1.16	0.48	<0.5	8.1	0.854	0.12	0.15	1.8	305	83.2	12.3
R02019-C	REP A	<20	1.28	0.31	<0.5	7.4	0.829	0.14	0.18	1.7	276	56.7	9.9
02020-C	DUP B	20	1.11	0.51	<0.5	6.8	0.882	0.18	0.24	1.8	450	28.4	18.7
R02020-C	REP B	<20	1.33	0.37	<0.5	6.4	0.849	0.17	0.27	1.9	404	24.2	14.9
02021-C	DUP A	50	0.86	0.4	<0.5	8.3	0.662	0.36	0.1	2	188	2.9	12.1
R02021-C	REP A	40	0.74	0.24	<0.5	8.1	0.637	0.31	0.2	2	171	2.6	10
02022-C	DUP B	50	1.09	0.41	<0.5	6.7	0.638	0.32	0.17	2.5	204	4.5	12.5
R02022-C	REP B	40	0.86	0.32	<0.5	6.3	0.593	0.24	0.16	2.4	188	3.9	9.9
02023-C	DUP A	30	1.59	0.46	<0.5	12.6	0.311	0.53	0.15	3.5	60	1.9	15
R02023-C	REP A	20	1.37	0.37	<0.5	12.1	0.29	0.43	0.22	3.4	58	1.9	12
02024-C	DUP B	40	2.99	0.36	<0.5	8.9	0.199	0.43	0.07	3.2	42	2.2	13.3
R02024-C	REP B	30	2.59	0.33	<0.5	7.7	0.189	0.28	0.17	3.1	42	1.1	11.2
02029-C	DUP A	20	6.93	1.22	0.5	43.2	2.99	0.06	0.9	9.1	246	2.3	45.9
R02029-C	REP A	<20	2.86	0.96	<0.5	40.5	2.78	0.07	0.82	9	233	1.8	36.3
02030-C	DUP B	20	3.2	1.09	<0.5	48.6	3.03	0.11	0.97	9.9	284	1.7	44.5
R02030-C	REP B	<20	2.97	1.03	<0.5	42.1	2.87	0.02	0.93	9.5	275	1.5	41.1

Sample Number	Control Sample	Sr ppm	Ta ppm	Tb ppm	Te ppm	Th ppm	Ti %	Tl ppm	Tm ppm	U ppm	V ppm	W ppm	Y ppm
02031-C	DUP A	20	2.96	0.88	<0.5	41.8	2.03	0.08	0.44	5.4	259	2.4	23.5
R02031-C	REP A	<20	2.48	0.76	<0.5	35.8	1.92	0.16	0.38	5.2	245	2	20.6
02032-C	DUP B	<20	4.69	1.45	0.6	93.5	3.06	0.06	0.51	9.9	233	4.2	31.5
R02032-C	REP B	<20	4.11	1.31	<0.5	75	2.89	0.05	0.51	8.5	211	4	25.5
02033-C	DUP A	30	3.6	1.22	<0.5	67.6	3.93	0.07	0.98	10.9	353	1.4	47.7
R02033-C	REP A	20	2.92	1	0.5	64.1	3.79	0.02	1.02	11.8	331	1.4	44.2
02034-C	DUP B	30	3.03	1.25	<0.5	76.3	4.24	0.06	1.04	12.9	279	1.6	52.9
R02034-C	REP B	20	2.95	1.23	0.9	74	4.11	<0.02	1.18	14.1	254	1.7	49.5
02035-C	DUP A	60	1.22	0.58	<0.5	40.8	1.36	0.16	0.24	3.3	236	0.7	20
R02035-C	REP A	50	0.68	0.56	0.5	33.9	1.325	0.14	0.29	2.9	206	0.6	16.1
02036-C	DUP B	70	1.4	0.99	<0.5	94.4	2.67	0.17	0.41	5.7	210	1.1	26.1
R02036-C	REP B	60	1.27	0.91	0.7	82.4	2.61	0.13	0.38	5.4	181	0.9	23.6
02037-C	DUP A	70	1.23	0.97	<0.5	192	1.445	0.12	0.33	5.6	145	0.6	22.7
R02037-C	REP A	60	1.14	0.9	<0.5	152	1.38	0.18	0.32	5.2	127	0.4	19.1
02038-C	DUP B	80	1.27	1.81	<0.5	321	2.23	0.12	0.49	8.8	150	0.3	32.1
R02038-C	REP B	70	0.97	1.34	0.6	272	2.1	0.1	0.47	8.7	130	0.6	28.4
02039-C	DUP A	50	2.19	0.67	<0.5	29.6	2.81	0.12	0.42	5.5	213	0.9	22.9
R02039-C	REP A	40	1.86	0.58	<0.5	26	2.71	0.09	0.35	4.9	188	0.9	18.8
02040-C	DUP B	40	2.55	0.69	<0.5	45	3.84	0.12	0.51	6.9	232	1.2	25.1
R02040-C	REP B	30	2.33	0.54	0.5	37.5	3.69	0.14	0.49	6.8	201	1	22
02041-C	DUP A	40	1.63	1.09	<0.5	146.5	3.11	0.12	0.52	8.3	225	1.1	31.5
R02041-C	REP A	30	1.27	0.98	<0.5	132.5	3.05	<0.02	0.48	8.5	200	1.3	28.5
02042-C	DUP B	40	1.58	0.93	<0.5	130.5	2.98	0.09	0.5	8.2	193	1.6	29.7
R02042-C	REP B	30	1.4	0.89	0.7	114.5	2.9	0.03	0.49	8.1	170	1.6	25.7
02043-C	DUP A	30	1.79	0.59	<0.5	40.8	1.955	0.09	0.32	4.6	213	0.8	18.7
R02043-C	REP A	30	1.5	0.42	<0.5	34.1	1.91	0.07	0.35	4.5	180	0.6	15.1
02044-C	DUP B	40	1.38	0.77	0.6	47.8	1.68	0.12	0.38	4.9	194	0.9	22.9
R02044-C	REP B	40	1.4	0.64	<0.5	43.1	1.745	0.06	0.44	5.1	179	1	24.1
02045-C	DUP A	160	1.15	0.6	<0.5	74.7	0.56	0.58	0.37	9.1	125	1.1	22.9
R02045-C	REP A	170	1.13	0.54	<0.5	70.9	0.566	0.48	0.28	9.9	119	0.8	23.7
02046-C	DUP B	190	1.1	0.58	<0.5	48.4	0.447	0.68	0.34	6.4	127	0.5	18.4
R02046-C	REP B	170	0.9	0.45	<0.5	43.2	0.46	0.48	0.15	5.9	106	0.6	17.4
02047-C	N/A	50	3.44	1.48	<0.5	140	1.615	0.3	0.88	15	206	1.4	49.8
R02047-C	N/A	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
02048-C	N/A	40	2.64	0.89	<0.5	84.8	1.34	0.2	0.58	11.2	194	1.2	33
R02048-C	N/A	40	2.24	0.84	<0.5	73	1.375	0.1	0.46	10.2	168	1.2	32.1
02049-C	DUP A	70	1.78	0.68	<0.5	43.4	0.823	0.53	0.51	15	162	2.3	30.4
R02049-C	REP A	60	1.55	0.67	<0.5	38.3	0.839	0.7	0.4	14.1	136	2.2	26.3
02050-C	DUP B	70	1.37	0.74	<0.5	34.8	0.627	0.74	0.4	11.6	153	2.3	25.2
R02050-C	REP B	60	1.45	0.51	<0.5	28.8	0.64	0.42	0.26	10.4	122	2	22
02051-C	DUP A	180	2.03	1.4	<0.5	111	1.54	0.37	0.85	10.8	128	1.1	45.4
R02051-C	REP A	160	1.93	1.33	<0.5	95	1.585	0.24	0.55	10.8	102	0.9	42
02052-C	DUP B	170	2.09	1.07	0.6	64.6	1.14	0.49	0.59	7.8	125	0.9	36.2
R02052-C	REP B	150	2.49	0.97	<0.5	52.3	1.14	0.41	0.44	7	102	1	32.3
02053-C	DUP A	60	1.72	0.6	<0.5	28.4	1.14	0.22	0.42	7.1	91	1.2	24.2
R02053-C	REP A	40	1.11	0.49	<0.5	20.2	1.185	0.17	0.21	5.7	67	0.9	19.4
02054-C	DUP B	60	2.11	0.55	0.6	30.4	1.385	0.15	0.5	7.9	86	1.4	25.4
R02054-C	REP B	40	1.62	0.49	<0.5	23.7	1.41	0.19	0.33	6.5	59	1.3	21.1
02055-C	DUP A	70	0.73	0.73	<0.5	44.5	0.43	0.15	0.38	8.7	39	0.9	21.9
R02055-C	REP A	50	0.49	0.49	<0.5	33.1	0.436	0.03	0.25	7.1	24	1	17.7
02056-C	DUP B	60	1.33	0.61	<0.5	27.1	0.51	0.21	0.29	5.5	52	1.3	18
R02056-C	REP B	60	0.91	0.52	<0.5	23.1	0.528	0.12	0.18	4.8	40	1.3	17.5
02057-C	DUP A	40	1.57	1.45	<0.5	80.7	0.783	0.18	0.52	8.6	140	0.6	34.4
R02057-C	REP A	40	1.15	1.18	<0.5	65.7	0.817	0.09	0.34	7.7	111	0.5	30.2
02058-C	DUP B	30	2.27	1.71	<0.5	97.3	0.996	0.29	0.65	10	125	0.5	41.9
R02058-C	REP B	30	1.71	1.76	<0.5	94.4	1.01	0.07	0.42	10.7	115	0.6	43.4

Yb - Zn by Na_2O_2-fusion ICP-MS analysis (ALS code ME-MS89L)

Sample Number	Control Sample	Yb ppm	Zn ppm
010005-C	DUP A	7.28	70
R010005-C	REP A	7.11	70
010037-C	DUP B	10.1	50
R010037-C	REP B	9.29	70
010099-C	N/A	9.09	70
R010099-C	N/A	8.31	80
02002-C	N/A	2.5	200
R02002-C	N/A	2.78	270
02003-C	DUP A	2.2	180
R02003-C	REP A	2.15	170
02004-C	DUP B	2.66	180
R02004-C	REP B	1.68	160
02005-C	DUP A	6.19	40
R02005-C	REP A	4.98	40
02006-C	DUP B	3.6	30
R02006-C	REP B	2.61	30
02007-C	DUP A	2.96	150
R02007-C	REP A	2.88	150
02008-C	DUP B	2.46	190
R02008-C	REP B	2.22	180
02009-C	DUP A	4.57	50
R02009-C	REP A	3.83	470
02010-C	DUP B	3.84	80
R02010-C	REP B	3.36	90
02013-C	DUP A	8.66	180
R02013-C	REP A	7.02	170
02014-C	DUP B	10.65	150
R02014-C	REP B	8.47	150
02015-C	DUP A	4.27	120
R02015-C	REP A	3.93	130
02016-C	DUP B	4.96	130
R02016-C	REP B	3.83	140
02017-C	DUP A	2.17	250
R02017-C	REP A	1.92	260
02018-C	DUP B	2.78	640
R02018-C	REP B	1.77	580
02019-C	DUP A	1.92	270
R02019-C	REP A	1.87	260
02020-C	DUP B	2.77	120
R02020-C	REP B	2.23	130
02021-C	DUP A	1.31	50
R02021-C	REP A	1.55	70
02022-C	DUP B	1.55	60
R02022-C	REP B	1.19	80
02023-C	DUP A	1.46	120
R02023-C	REP A	1.27	130
02024-C	DUP B	1.65	90
R02024-C	REP B	1.37	100
02029-C	DUP A	8.54	70
R02029-C	REP A	6.72	110
02030-C	DUP B	8.83	80
R02030-C	REP B	7.22	100
02031-C	DUP A	3.41	60
R02031-C	REP A	2.8	80
02032-C	DUP B	5	60
R02032-C	REP B	4.36	90
02033-C	DUP A	9.18	150
R02033-C	REP A	8.21	140
02034-C	DUP B	9.7	140
R02034-C	REP B	9.96	150
02035-C	DUP A	2.2	90
R02035-C	REP A	1.87	80
02036-C	DUP B	3.14	90
R02036-C	REP B	3.17	90
02037-C	DUP A	2.73	90
R02037-C	REP A	2.35	80
02038-C	DUP B	4.36	90
R02038-C	REP B	3.63	80
02039-C	DUP A	3.44	120
R02039-C	REP A	3.29	110
02040-C	DUP B	4.44	140
R02040-C	REP B	4.09	130
02041-C	DUP A	5.13	110
R02041-C	REP A	4.62	110
02042-C	DUP B	4.52	100
R02042-C	REP B	4.35	110
02043-C	DUP A	2.81	170
R02043-C	REP A	2.09	90
02044-C	DUP B	3.51	90
R02044-C	REP B	3.34	110
02045-C	DUP A	3.65	90
R02045-C	REP A	3.6	100
02046-C	DUP B	2.89	80
R02046-C	REP B	2.48	90
02047-C	N/A	7.87	80
R02047-C	N/A	nd	nd
02048-C	N/A	5.03	70
R02048-C	N/A	5.03	70
02049-C	DUP A	5.44	70
R02049-C	REP A	4.56	70
02050-C	DUP B	3.92	70
R02050-C	REP B	2.64	80
02051-C	DUP A	5.94	90
R02051-C	REP A	6.95	100
02052-C	DUP B	5.27	110
R02052-C	REP B	4.59	100
02053-C	DUP A	4.19	100
R02053-C	REP A	3.34	70
02054-C	DUP B	4.45	60
R02054-C	REP B	4.02	50
02055-C	DUP A	3.51	20
R02055-C	REP A	3.13	30
02056-C	DUP B	2.62	40
R02056-C	REP B	2.7	30
02057-C	DUP A	3.74	120
R02057-C	REP A	3.17	110
02058-C	DUP B	4.37	110
R02058-C	REP B	4.37	120

Ba - Hf by LiB_4O_7-fusion ICP-MS analysis (ALS code ME-MS81)

Sample Number	Control Sample	Ba ppm	Ce ppm	Cr ppm	Cs ppm	Dy ppm	Er ppm	Eu ppm	Ga ppm	Gd ppm	Hf ppm
010005-C	DUP A	205	106.5	650	0.5	6.02	5.18	0.96	22.8	5.82	237
R010005-C	REP A	206	104.5	660	0.45	5.5	4.82	0.96	24.4	5.44	243
010037-C	DUP B	135.5	111.5	1230	0.28	6.04	5.76	0.73	9.4	5.6	332
R010037-C	REP B	128	104	1180	0.24	5.64	5.39	0.7	9.6	5.19	321
010099-C	N/A	184	118.5	760	0.4	6.62	5.85	1.08	23.9	6.16	273
R010099-C	N/A	181	114	750	0.4	6.21	5.47	0.91	25.3	6.32	278
02002-C	N/A	147	59.4	1590	0.79	6.01	3.39	1.39	23.1	6.36	2.8
R02002-C	N/A	148	62.7	1590	0.78	5.74	3.21	1.3	24	6.16	2.5
02003-C	DUP A	174	60.3	1400	0.76	4.71	2.49	1.15	24.4	4.96	2.5
R02003-C	REP A	179	53.1	1410	0.67	4.35	2.3	1.14	26.4	4.68	2.4
02004-C	DUP B	146	54.2	1270	0.68	4.45	2.39	1.19	23.8	4.55	2.7
R02004-C	REP B	145.5	48.2	1260	0.57	4.1	2.26	1.09	23.6	4.43	2.6
02005-C	DUP A	69.5	125	1580	0.19	3.67	3.32	0.74	7.2	4.32	225
R02005-C	REP A	68.1	118.5	1580	0.18	3.29	3.37	0.71	7.6	4.26	230
02006-C	DUP B	89.5	76.1	1200	0.36	2.82	2.23	0.56	8	2.82	118.5
R02006-C	REP B	93	63.5	1610	0.3	2.4	2.17	0.52	8.5	2.76	131
02007-C	DUP A	157.5	95.9	280	0.58	4.16	2.47	1.28	26.8	4.81	63.1
R02007-C	REP A	153	88.1	250	0.51	3.8	2.54	1.19	26.8	5.18	66.7
02008-C	DUP B	147.5	86.8	260	0.43	3.72	2.01	1.21	31	4.46	41.5
R02008-C	REP B	148	81.7	240	0.52	3.29	2.09	1.1	32.7	4.44	46.9
02009-C	DUP A	97.8	43.7	170	1.1	4.9	3.39	0.86	19.7	3.79	47.6
R02009-C	REP A	99.8	41.2	160	1.1	4.88	3.41	0.89	20.6	4.12	54
02010-C	DUP B	111.5	46.8	180	1.32	4.86	3.46	0.9	21	4.06	48.2
R02010-C	REP B	117	47.2	210	1.22	5.52	3.84	0.87	22.6	4.1	53.1
02013-C	DUP A	2390	309	190	1.34	13.05	8.14	3.49	31.2	16.35	222
R02013-C	REP A	2340	285	160	1.25	13.2	8.29	3.44	32.8	15.55	236
02014-C	DUP B	2180	314	230	1.41	13.95	8.72	3.57	31.3	16.25	258
R02014-C	REP B	2080	282	200	1.32	13.3	8.12	3.42	30.6	17.25	279
02015-C	DUP A	1350	294	100	1.28	8.84	4.66	2.8	35	11.5	93.7
R02015-C	REP A	1340	266	80	1.25	8.65	4.59	2.81	35	11.85	100.5
02016-C	DUP B	1130	303	100	1.37	8.85	4.55	2.9	33.7	11.25	80.6
R02016-C	REP B	1145	280	90	1.32	8.74	4.49	2.73	35.4	12.05	87.3
02017-C	DUP A	539	75.5	300	4.38	3.41	2.12	0.88	23.4	3.16	14.3
R02017-C	REP A	341	49.2	190	2.86	2.27	1.52	0.64	15.8	2.34	10.2
02018-C	DUP B	492	80.6	350	3.71	3.43	2.33	0.9	22.5	3.26	38.4
R02018-C	REP B	462	76.4	330	3.59	3.4	2.26	0.86	22.3	3.38	40.5
02019-C	DUP A	254	38.7	400	1.84	2.24	1.56	0.51	20.8	1.81	12.2
R02019-C	REP A	243	38.6	390	1.66	2.24	1.75	0.47	19.5	1.93	14.3
02020-C	DUP B	255	46.3	500	2.77	3.46	2.24	0.85	28	3.17	9.1
R02020-C	REP B	243	44.8	470	2.53	3.35	2.28	0.83	24.5	3.24	10.1
02021-C	DUP A	720	38.8	290	3.53	2.18	1.43	0.62	23.2	2.14	10.9
R02021-C	REP A	597	32.2	240	2.84	2.1	1.27	0.55	18.4	1.93	10.3
02022-C	DUP B	674	36.4	350	2.82	2.22	1.45	0.7	22.4	2.2	8.8
R02022-C	REP B	619	33.2	320	2.48	2.2	1.45	0.58	19.3	2.29	8.8
02023-C	DUP A	744	49.4	520	5.03	2.41	1.58	0.62	22.8	2.6	17.3
R02023-C	REP A	672	45.2	430	4.46	2.44	1.43	0.56	20.4	2.56	18.4
02024-C	DUP B	725	34.1	830	4.5	2.18	1.42	0.54	16.5	2.1	21
R02024-C	REP B	695	31.4	920	4.14	2.2	1.26	0.53	14.5	2.2	22.2
02029-C	DUP A	342	221	840	0.59	6.79	5.49	1.3	16	9.33	300
R02029-C	REP A	330	201	800	0.58	7.29	5.8	1.2	15.5	10.5	320
02030-C	DUP B	398	231	730	0.6	7.04	5.64	1.32	18.7	9.96	317
R02030-C	REP B	383	207	710	0.6	7.65	6.24	1.36	17.4	10.3	351

Sample Number	Control Sample	Ba ppm	Ce ppm	Cr ppm	Cs ppm	Dy ppm	Er ppm	Eu ppm	Ga ppm	Gd ppm	Hf ppm
02031-C	DUP A	103.5	219	340	1.6	4.59	2.87	1.37	26.6	8	95.9
R02031-C	REP A	102.5	215	340	1.48	4.84	2.9	1.41	26.7	7.87	98.3
02032-C	DUP B	77.6	457	920	0.6	6.27	3.64	2.12	16.4	15	212
R02032-C	REP B	74.8	435	780	0.58	6.27	3.56	2.03	15.6	15	210
02033-C	DUP A	267	415	1120	0.35	7.25	5.73	1.24	24.9	9.14	306
R02033-C	REP A	246	358	1090	0.35	6.98	5.85	1.25	22.2	9.55	309
02034-C	DUP B	269	490	1130	0.39	7.57	6.39	1.37	21.5	9.99	359
R02034-C	REP B	252	479	1130	0.4	8.28	6.8	1.36	19.7	11.25	387
02035-C	DUP A	694	188.5	270	0.62	3.42	2.03	1.07	28.3	5.17	34.6
R02035-C	REP A	674	169	270	0.68	3.72	2.14	1.08	26.4	5.72	36.6
02036-C	DUP B	743	406	220	0.5	4.94	2.72	1.23	22.3	8.73	85
R02036-C	REP B	683	358	210	0.52	5.19	2.87	1.17	20.1	9.67	87.9
02037-C	DUP A	974	999	190	0.63	4.71	2.38	1.78	30.2	11.25	101
R02037-C	REP A	819	855	170	0.52	4.49	2.26	1.57	24	10.6	93.7
02038-C	DUP B	986	1705	250	0.39	7.35	3.55	2.71	24.5	18.9	176.5
R02038-C	REP B	901	1645	240	0.37	7.61	3.6	2.5	23.8	19.85	184.5
02039-C	DUP A	379	235	370	0.85	3.94	2.71	1.25	26.7	5	91
R02039-C	REP A	363	212	350	0.83	4.07	2.85	1.2	24.3	5.22	101.5
02040-C	DUP B	340	333	440	0.94	4.25	3.12	1.33	26.4	5.99	149
R02040-C	REP B	304	284	390	0.86	4.29	2.92	1.29	22.3	5.64	148.5
02041-C	DUP A	360	676	2260	0.54	5.54	3.43	1.76	21.2	10.4	162.5
R02041-C	REP A	312	649	2200	0.51	5.57	3.44	1.65	18	10.7	169.5
02042-C	DUP B	322	630	2850	0.53	5.15	3.32	1.73	18.2	9.76	167
R02042-C	REP B	286	594	2590	0.57	5.26	3.22	1.5	15.6	9.59	174
02043-C	DUP A	293	219	500	0.47	3.41	2.14	1.11	20.8	5.3	85.9
R02043-C	REP A	279	195.5	460	0.49	3.66	2.24	0.99	19	5.59	95.6
02044-C	DUP B	380	240	650	0.75	4.03	2.47	1.22	23.6	6.27	80.6
R02044-C	REP B	346	209	600	0.75	4.34	2.84	1.16	21	6.06	85.5
02045-C	DUP A	1745	117.5	410	1.27	3.93	2.69	1.36	29.6	4.54	87.9
R02045-C	REP A	1610	110.5	390	1.22	4.2	2.92	1.32	26.9	5.08	97.1
02046-C	DUP B	2110	106	210	1.18	3.09	1.92	1.22	28.5	3.63	63.3
R02046-C	REP B	1925	102	210	1.23	3.35	1.96	1.17	26.6	4.33	68
02047-C	N/A	607	434	1250	0.97	7.29	5.05	1.19	25.3	10.4	177.5
R02047-C	N/A	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
02048-C	N/A	546	253	1020	0.84	4.91	3.52	0.84	22.7	6.39	122.5
R02048-C	N/A	486	217	1000	0.82	4.86	3.51	0.77	19.5	6.52	125
02049-C	DUP A	1275	69.7	300	1.7	4.26	3.24	0.97	27.2	3.89	78.2
R02049-C	REP A	1205	65.8	280	1.62	4.22	3.31	0.95	24.4	4.04	83.3
02050-C	DUP B	1310	69.2	230	2.03	3.8	2.57	0.87	27.6	3.62	43.7
R02050-C	REP B	1235	64.1	220	1.89	3.82	2.63	0.94	24.6	3.65	46.3
02051-C	DUP A	1905	418	130	0.84	7.29	4.54	2	25.3	10.9	225
R02051-C	REP A	1685	361	130	0.92	7.51	5.11	1.91	22.6	11.3	232
02052-C	DUP B	1785	267	220	0.96	5.72	3.45	1.81	25.1	7.85	129.5
R02052-C	REP B	1605	231	220	0.93	5.98	3.69	1.76	22.7	8.35	137.5
02053-C	DUP A	699	120	470	0.83	3.39	2.42	0.86	17.7	4.14	104.5
R02053-C	REP A	661	110.5	440	0.76	3.63	2.97	1.01	16	4.68	114.5
02054-C	DUP B	640	129.5	700	0.61	3.53	2.6	0.8	13.4	4.25	134
R02054-C	REP B	585	118	540	0.57	3.78	3.07	0.86	11.8	4.45	139
02055-C	DUP A	929	174.5	780	0.31	3.32	2.24	0.77	11.4	5.34	79.1
R02055-C	REP A	800	146	700	0.35	3.12	2.23	0.69	9.8	5.54	78
02056-C	DUP B	780	122	750	0.87	3.04	1.96	0.79	20.7	4.28	45.6
R02056-C	REP B	701	114	710	0.85	3.05	2.05	0.81	18.3	4.53	44.8
02057-C	DUP A	945	299	220	0.55	7.02	3.29	0.91	28.6	11.55	63.2
R02057-C	REP A	823	246	210	0.5	6.87	3.18	0.78	24.2	11.65	61.8
02058-C	DUP B	776	370	210	0.62	9.06	4.57	1.08	24.3	16.05	88.3
R02058-C	REP B	840	370	240	0.64	9.75	4.91	1.12	26.3	18.1	91.1

Ho - Sr by LiB_4O_7-fusion ICP-MS analysis (ALS code ME-MS81)

Sample Number	Control Sample	Ho ppm	La ppm	Lu ppm	Nb ppm	Nd ppm	Pr ppm	Rb ppm	Sm ppm	Sn ppm	Sr ppm
010005-C	DUP A	1.36	62.5	1.59	33.4	37.3	11	5.6	6.4	3	21.7
R010005-C	REP A	1.35	60.9	1.52	33.4	36.5	10.8	5.6	6.53	3	21
010037-C	DUP B	1.57	64.1	2	33	37.7	11.25	3.5	6.63	4	14.7
R010037-C	REP B	1.45	59.4	1.92	31.9	35.9	10.5	3.1	5.89	4	13.1
010099-C	N/A	1.56	70	1.83	35.5	41	11.95	5.9	7.18	4	22.9
R010099-C	N/A	1.53	66.8	1.73	35.4	40.5	11.5	5.5	6.74	3	21.7
02002-C	N/A	1.19	30.8	0.41	18.2	29.2	7.6	20.2	6.96	2	53
R02002-C	N/A	1.14	32	0.45	25.7	30.3	7.82	19.6	7.06	2	50.9
02003-C	DUP A	0.93	26.3	0.36	33	24.1	6.38	22.3	5.51	2	59.6
R02003-C	REP A	0.84	22.7	0.32	17.3	21.7	5.62	21.5	4.73	2	56.7
02004-C	DUP B	0.87	23.5	0.37	14.7	22	5.77	16.3	5.14	2	63.5
R02004-C	REP B	0.76	20.2	0.26	9.3	21.5	5.29	15.4	4.65	2	61
02005-C	DUP A	0.91	65.5	1.13	41	45	13.15	2	7.39	4	9.9
R02005-C	REP A	0.85	62.1	1.06	39.2	43.4	12.45	1.9	6.66	4	9.3
02006-C	DUP B	0.63	39.9	0.65	40	27.8	8.1	3.3	4.36	4	13.4
R02006-C	REP B	0.56	32.9	0.57	25.1	26	6.85	3.5	3.99	5	13
02007-C	DUP A	0.88	39.4	0.56	46	33.4	9.21	6.7	6.95	5	49.1
R02007-C	REP A	0.75	36.1	0.47	43.6	34.9	8.58	6.3	5.93	5	46
02008-C	DUP B	0.71	36.2	0.43	37	31.1	8.42	6.4	6.03	6	47
R02008-C	REP B	0.7	34.5	0.44	37.3	32.3	7.99	6.5	5.98	6	45.3
02009-C	DUP A	1.04	22.2	0.67	27.1	17	4.67	15.1	3.71	4	50.1
R02009-C	REP A	1.01	21.1	0.62	26.1	17.5	4.47	15.2	3.81	4	49.5
02010-C	DUP B	1.11	24	0.69	27.9	18	4.95	16.7	4.09	4	53.5
R02010-C	REP B	1.08	23.5	0.69	29.5	20.1	5	17	3.89	4	53.8
02013-C	DUP A	2.69	173	1.73	56	116	33.8	95.6	21.8	4	125.5
R02013-C	REP A	2.62	156.5	1.63	57.2	124.5	32.6	97.4	22	11	122.5
02014-C	DUP B	2.85	170	1.89	61.8	114.5	33.4	89.3	22.4	4	119.5
R02014-C	REP B	2.58	149	1.75	61.1	121.5	31.8	86.4	21.9	5	115
02015-C	DUP A	1.67	132	0.79	45	93.7	27.4	52.3	17.1	3	95.7
R02015-C	REP A	1.62	125	0.73	45.4	100.5	26.1	51.3	16.65	3	92.5
02016-C	DUP B	1.6	132.5	0.72	42.1	94	27.3	45.8	16.75	3	91.4
R02016-C	REP B	1.56	126.5	0.74	42.2	100.5	26.6	46.1	16.45	3	88.4
02017-C	DUP A	0.71	23.7	0.39	13.5	17.8	5.02	31.3	3.4	5	26.6
R02017-C	REP A	0.45	15	0.23	8.8	12.3	3.24	22.1	2.65	2	16.8
02018-C	DUP B	0.74	30.9	0.48	13	22.5	6.58	28.4	4.05	3	30.2
R02018-C	REP B	0.69	29.1	0.42	12.3	22.2	6.23	28.2	3.95	4	27.9
02019-C	DUP A	0.5	15	0.3	10.5	12.1	3.4	18.7	2.44	2	16.2
R02019-C	REP A	0.49	14.9	0.29	11.4	13	3.42	18.2	2.77	3	14.8
02020-C	DUP B	0.7	17.7	0.39	12	15.6	4.07	23.9	3.63	2	19.5
R02020-C	REP B	0.74	16.7	0.35	11.6	15.7	4.04	23.8	3.46	2	17.6
02021-C	DUP A	0.49	17.3	0.25	11.7	13.8	3.68	52	2.65	2	60.1
R02021-C	REP A	0.39	13.8	0.22	9.7	11.7	3.12	45.1	2.26	1	48.9
02022-C	DUP B	0.45	16.7	0.24	10.6	13.4	3.72	41.2	2.57	1	56.8
R02022-C	REP B	0.46	14.9	0.24	9.9	12.7	3.46	39.6	2.62	2	51.6
02023-C	DUP A	0.55	22.7	0.28	14.8	16.1	4.67	99.4	2.95	4	35.3
R02023-C	REP A	0.47	20.5	0.26	14.1	16	4.35	94.6	2.61	3	31.6
02024-C	DUP B	0.45	15.8	0.27	14.2	11.5	3.29	80.6	2.3	4	38.4
R02024-C	REP B	0.44	14	0.24	13.1	11.3	3.12	78.8	2.54	5	35.7
02029-C	DUP A	1.54	102	1.63	57.4	84.8	23.4	6.6	14.25	11	21.5
R02029-C	REP A	1.54	97.9	1.54	51.6	88.6	22.9	6.7	15.65	11	20.3
02030-C	DUP B	1.58	107.5	1.71	51.9	89.6	24.2	8	15.2	4	27.5
R02030-C	REP B	1.61	99.7	1.63	51.8	90	23.6	7.9	15.6	5	25.8

Sample Number	Control Sample	Ho ppm	La ppm	Lu ppm	Nb ppm	Nd ppm	Pr ppm	Rb ppm	Sm ppm	Sn ppm	Sr ppm
02031-C	DUP A	0.88	111	0.67	47.7	78.2	22.5	9.6	12.8	4	23
R02031-C	REP A	0.96	107	0.61	47.6	76.7	21.9	9.3	12.9	4	22.4
02032-C	DUP B	1.13	244	1	68.5	166.5	47.7	4.5	26.7	5	15
R02032-C	REP B	1.08	232	0.99	68.5	161.5	45.6	4.4	25.5	6	14.4
02033-C	DUP A	1.63	241	1.69	52.4	118	37.8	4.2	14.8	5	32.9
R02033-C	REP A	1.56	204	1.49	49.2	115.5	35.4	3.9	14.15	5	31.1
02034-C	DUP B	1.71	290	1.99	55.2	138	44.6	4.6	16.6	5	31.4
R02034-C	REP B	1.8	256	1.74	54.7	140.5	43.2	4.4	17.7	6	28.6
02035-C	DUP A	0.69	96.8	0.39	17.3	56.1	17.05	16.6	8.02	2	68.5
R02035-C	REP A	0.75	90.9	0.36	16.4	57.3	16.65	16.7	8.7	2	65.3
02036-C	DUP B	0.91	229	0.59	25.5	119	37.8	16.6	15.5	3	81.5
R02036-C	REP B	0.91	201	0.5	24.6	117.5	35.1	15.6	15.45	2	74.2
02037-C	DUP A	0.85	596	0.54	19.3	262	88.8	17.6	27.2	2	76.9
R02037-C	REP A	0.72	516	0.44	16.7	231	75	15.8	23.8	2	63.2
02038-C	DUP B	1.23	1020	0.83	24.6	449	163	15.3	45.1	3	97.3
R02038-C	REP B	1.18	983	0.78	23.9	446	145	14.8	46.4	2	89.1
02039-C	DUP A	0.82	131.5	0.64	42.5	65.4	21	9.2	8.08	4	52.2
R02039-C	REP A	0.84	124	0.59	40.8	66.6	20.3	9.3	8.39	4	48.1
02040-C	DUP B	0.95	201	0.86	51.8	90.6	29.4	9	10.8	5	47.5
R02040-C	REP B	0.83	169	0.69	46.9	86.9	26.6	8.1	10.3	5	41.4
02041-C	DUP A	1.1	407	0.96	28.7	186	61.1	7.1	21.5	3	46
R02041-C	REP A	1.06	358	0.86	26.2	184	58.3	6.4	20.8	3	38.4
02042-C	DUP B	1.03	374	0.91	26.7	177	57.1	6.6	19.55	5	44.8
R02042-C	REP B	0.99	318	0.79	24.6	167.5	52.9	6.3	18.65	4	38.4
02043-C	DUP A	0.67	113.5	0.53	28.4	65.2	20.2	6.8	9.04	3	38.6
R02043-C	REP A	0.68	107	0.5	28.3	68.2	19.7	6.5	9.38	4	36
02044-C	DUP B	0.85	128.5	0.58	26	72.2	22.4	10.2	9.46	4	42.7
R02044-C	REP B	0.81	115	0.54	25.2	71.8	20.8	9.8	9.93	4	38.6
02045-C	DUP A	0.8	63	0.62	19.6	37.7	11.45	72.8	6.14	4	185.5
R02045-C	REP A	0.8	59	0.57	18.9	38.6	11.15	73.9	6.59	3	174.5
02046-C	DUP B	0.64	52.1	0.43	17.1	31.5	9.44	81.3	5.05	3	185.5
R02046-C	REP B	0.59	48.8	0.44	16.7	31.4	9.13	81.5	5.26	3	173
02047-C	N/A	1.54	256	1.35	29.7	124	39.3	29.6	16.5	3	47.6
R02047-C	N/A	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
02048-C	N/A	1.06	143	0.95	25	72	22.8	26.1	10.05	2	42.6
R02048-C	N/A	0.96	126	0.85	23.2	67.8	20.8	25.1	9.9	2	37.6
02049-C	DUP A	0.95	32.3	0.83	18.3	21.4	6.33	89.9	4.67	3	71.4
R02049-C	REP A	0.88	29.4	0.72	17.8	21.9	5.95	88	4.32	3	66.2
02050-C	DUP B	0.8	32.8	0.57	17.5	21.3	6.34	92.6	4.19	3	68.7
R02050-C	REP B	0.77	29.5	0.51	17.2	20.5	5.77	90.8	3.93	3	61.8
02051-C	DUP A	1.41	239	1.14	37.9	121.5	38.1	66.8	17.05	3	178
R02051-C	REP A	1.43	205	1.06	36.7	117.5	35.6	64.1	16.7	3	159.5
02052-C	DUP B	1.15	143	0.75	31	80.4	24.7	64.2	12	3	170
R02052-C	REP B	1.16	127.5	0.7	29.2	80.6	23.4	62.9	12.55	3	153
02053-C	DUP A	0.74	66.7	0.64	23.3	39.1	12.05	19	5.51	3	57.5
R02053-C	REP A	0.75	61.2	0.58	22.9	37.7	11	19.1	5.82	3	54.4
02054-C	DUP B	0.78	72.6	0.79	26.3	41.8	12.65	15.9	6.27	3	55.4
R02054-C	REP B	0.8	65.1	0.68	25	39.9	11.6	15.5	5.85	3	50.1
02055-C	DUP A	0.64	97.1	0.59	10.3	56.7	17.25	22	8.79	2	70.8
R02055-C	REP A	0.61	80.3	0.52	8.7	51.9	14.65	19.9	8.82	2	60.2
02056-C	DUP B	0.66	68	0.44	16.3	40	12.25	22	6.44	3	69.4
R02056-C	REP B	0.61	63.9	0.38	14.8	40.6	11.95	20.9	6.61	3	60.9
02057-C	DUP A	1.2	157	0.62	23.8	100.5	29.5	28.4	16.75	4	47.4
R02057-C	REP A	1.16	133	0.58	21.4	91.1	26	26.6	16.05	4	40.2
02058-C	DUP B	1.55	191	0.87	26.6	139	37.1	23.6	21.7	7	40.9
R02058-C	REP B	1.69	198.5	0.89	27.9	142.5	40	24.5	23.5	8	41.8

Ta - Zr by LiB_4O_7-fusion ICP-MS analysis (ALS code ME-MS81)

Sample Number	Control Sample	Ta ppm	Tb ppm	Th ppm	Tm ppm	U ppm	V ppm	W ppm	Y ppm	Yb ppm	Zr ppm
010005-C	DUP A	10.4	0.93	42.4	0.97	12.45	318	2	38.9	7.83	>10000
R010005-C	REP A	12.6	0.84	39.5	0.93	12.6	327	1	37.6	7.5	>10000
010037-C	DUP B	10.1	0.9	44.4	1.16	16.75	135	2	43.7	9.89	>10000
R010037-C	REP B	9.3	0.86	39.8	1.07	16.1	132	1	41.2	8.89	>10000
010099-C	N/A	13.4	1	51.8	1.08	14.35	364	2	43.7	9	>10000
R010099-C	N/A	13.4	0.92	46.9	1	14.35	361	1	42.2	8.33	>10000
02002-C	N/A	8.8	0.96	6.4	0.49	1.01	169	1	30.2	2.74	96
R02002-C	N/A	8.3	0.96	7.37	0.46	1.11	155	1	30.3	2.93	93
02003-C	DUP A	11.2	0.8	7.39	0.36	1.26	239	1	23.1	2.26	91
R02003-C	REP A	7.6	0.74	5.37	0.35	0.99	244	1	21.6	2.19	89
02004-C	DUP B	3.3	0.72	5.52	0.38	1	236	1	21.1	2.3	100
R02004-C	REP B	2.5	0.65	4.27	0.28	0.87	213	1	20.6	1.95	89
02005-C	DUP A	6	0.61	35.9	0.7	7.57	160	2	25.5	5.84	9950
R02005-C	REP A	6.8	0.55	32.1	0.63	7.43	158	2	24.1	5.32	>10000
02006-C	DUP B	8	0.43	20.6	0.46	4.53	122	2	17.7	3.5	5220
R02006-C	REP B	3	0.37	16.4	0.43	4.19	131	2	16.9	3.47	5280
02007-C	DUP A	4.7	0.68	13.9	0.42	2.49	589	2	20.4	2.89	2840
R02007-C	REP A	2.7	0.61	12.9	0.41	2.27	524	1	19.4	3.19	2810
02008-C	DUP B	2.9	0.63	13.05	0.36	1.99	649	1	16.3	2.41	1880
R02008-C	REP B	2.9	0.62	11.9	0.33	2.03	618	2	16.3	2.53	1985
02009-C	DUP A	2.6	0.7	18.2	0.54	4.05	146	2	27.5	3.96	2060
R02009-C	REP A	2	0.67	17	0.56	4.02	144	2	28	3.96	2170
02010-C	DUP B	2.8	0.74	18.55	0.56	4.11	150	2	28.7	4.21	2050
R02010-C	REP B	3	0.71	18.55	0.53	4.31	152	2	29.8	4.47	2180
02013-C	DUP A	3.7	2.33	47	1.28	14.9	61	2	64.7	9.05	9830
R02013-C	REP A	5.9	2.17	44.6	1.21	14.6	63	2	64.3	9.12	9760
02014-C	DUP B	4.7	2.33	49.1	1.46	16.75	66	2	70.3	10.55	>10000
R02014-C	REP B	4.5	2.19	45.9	1.34	16.5	62	3	68.2	9.73	>10000
02015-C	DUP A	2.5	1.57	28.4	0.68	6.97	79	1	38.4	4.61	4320
R02015-C	REP A	1.8	1.57	26.7	0.69	6.85	74	2	37.7	4.66	4310
02016-C	DUP B	2.5	1.55	27.5	0.68	6.47	77	2	37.8	4.5	3650
R02016-C	REP B	2.2	1.54	26.6	0.66	6.35	75	2	38.1	4.55	3700
02017-C	DUP A	2.7	0.53	18.6	0.34	6.3	266	5	17.1	2.38	612
R02017-C	REP A	<0.1	0.36	11.8	0.2	4.31	164	3	11.2	1.47	399
02018-C	DUP B	2.6	0.55	21.2	0.39	7.18	301	4	18.5	2.74	1710
R02018-C	REP B	2.5	0.47	20.5	0.33	7.06	267	5	16.9	2.59	1700
02019-C	DUP A	1.5	0.33	8.62	0.25	2.11	304	73	12.4	1.89	539
R02019-C	REP A	2.8	0.34	9.2	0.25	1.99	261	74	11.6	1.96	557
02020-C	DUP B	0.7	0.51	7.7	0.35	2.04	432	28	18	2.4	380
R02020-C	REP B	1.3	0.5	7.35	0.35	1.95	379	30	16.6	2.55	382
02021-C	DUP A	1.2	0.36	9.61	0.26	2.4	180	3	12.5	1.46	476
R02021-C	REP A	0.8	0.31	8.29	0.22	1.97	142	3	9.9	1.37	393
02022-C	DUP B	1.2	0.36	7.82	0.21	2.88	196	5	11.9	1.56	387
R02022-C	REP B	1.4	0.36	7.37	0.21	2.57	175	5	10.8	1.43	335
02023-C	DUP A	2.3	0.42	14.6	0.26	4.18	63	2	14.8	1.76	755
R02023-C	REP A	2.1	0.39	14.15	0.23	3.79	49	3	13.1	1.6	695
02024-C	DUP B	3.5	0.34	9.98	0.21	3.58	42	2	13	1.51	904
R02024-C	REP B	3.3	0.38	9.15	0.23	3.32	28	3	12	1.35	843
02029-C	DUP A	7.5	1.21	47.5	1	10.65	259	3	44.3	8.08	>10000
R02029-C	REP A	3.7	1.22	48.7	1.03	9.91	215	3	40.8	8.21	>10000
02030-C	DUP B	3.2	1.2	51	1.06	11.3	302	2	45.8	8.69	>10000
R02030-C	REP B	3.7	1.25	51.1	1.05	10.95	258	3	43.9	8.63	>10000

Sample Number	Control Sample	Ta ppm	Tb ppm	Th ppm	Tm ppm	U ppm	V ppm	W ppm	Y ppm	Yb ppm	Zr ppm
02031-C	DUP A	2.9	0.92	45.5	0.46	6.62	275	3	24.3	3.48	4250
R02031-C	REP A	3.8	0.94	44.2	0.46	6.38	269	3	23.8	3.66	4260
02032-C	DUP B	4.9	1.42	94.6	0.63	11.05	234	5	30.4	5.05	9450
R02032-C	REP B	5.8	1.48	89.4	0.59	10.7	227	5	29.6	4.88	9360
02033-C	DUP A	3	1.21	67.2	1.05	11.95	360	2	46.3	8.48	>10000
R02033-C	REP A	2.8	1.1	64.6	0.96	10.65	305	2	41.1	7.94	>10000
02034-C	DUP B	3.2	1.32	75.9	1.16	13.95	273	2	50.6	9.38	>10000
R02034-C	REP B	3.4	1.33	75.9	1.14	13.65	240	2	47.4	9.13	>10000
02035-C	DUP A	1.9	0.68	40.3	0.33	3.28	242	1	18.3	2.22	1555
R02035-C	REP A	0.9	0.68	39.5	0.3	3.24	210	2	17.6	2.17	1545
02036-C	DUP B	1.6	1.02	94.8	0.44	5.96	190	1	25.4	3.28	3700
R02036-C	REP B	1.3	0.91	92.6	0.4	5.41	177	1	23.8	2.89	3600
02037-C	DUP A	1.5	1.15	203	0.37	6.32	133	1	21.8	2.72	4540
R02037-C	REP A	0.7	0.97	166.5	0.31	5.21	112	1	17.8	2.66	3920
02038-C	DUP B	1.5	1.87	352	0.56	9.81	142	1	32.4	4.49	7960
R02038-C	REP B	1.1	1.77	322	0.53	9.31	131	1	29.6	4.05	7770
02039-C	DUP A	2.5	0.75	30.5	0.44	5.71	208	2	21.7	3.36	4410
R02039-C	REP A	2.7	0.66	30.2	0.41	5.13	193	2	21.2	3.24	4410
02040-C	DUP B	2.9	0.8	45.6	0.58	7.82	252	2	25.3	4.47	7140
R02040-C	REP B	2.7	0.68	41.5	0.5	6.85	193	2	22.6	4.07	6650
02041-C	DUP A	1.7	1.12	148.5	0.58	9.44	208	2	30.5	4.79	7320
R02041-C	REP A	1.7	1.11	146	0.59	8.48	184	2	26.9	4.97	7040
02042-C	DUP B	1.7	1.13	135	0.58	9.17	174	2	28.6	4.6	7570
R02042-C	REP B	1.8	1.03	126.5	0.54	8.21	149	2	25.5	4.45	7130
02043-C	DUP A	1.6	0.63	42	0.4	4.9	198	1	18.1	2.81	3910
R02043-C	REP A	2.1	0.65	42.5	0.36	4.69	182	1	16.7	2.54	4000
02044-C	DUP B	1.3	0.77	46.8	0.43	5.07	179	1	21.5	2.94	3660
R02044-C	REP B	1.8	0.76	44.9	0.4	4.97	153	2	20.8	3.28	3580
02045-C	DUP A	1.3	0.61	77.9	0.43	10.65	120	1	22.7	3.16	3810
R02045-C	REP A	1.3	0.61	77.2	0.41	10.2	105	2	21	3.59	3840
02046-C	DUP B	1.1	0.53	46.5	0.32	6.93	104	2	17.2	2.44	2740
R02046-C	REP B	1.4	0.56	47	0.29	6.66	97	1	16	2.59	2730
02047-C	N/A	3.9	1.27	132	0.88	15.8	180	2	43.6	6.99	7580
R02047-C	N/A	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
02048-C	N/A	2.5	0.84	79.6	0.63	11.45	166	2	30.1	4.98	5290
R02048-C	N/A	2.4	0.79	75.1	0.59	10.2	156	2	27	4.56	4930
02049-C	DUP A	1.4	0.65	39.7	0.55	15.15	140	3	26.8	4.41	3180
R02049-C	REP A	2	0.62	41.2	0.52	14.05	122	3	24.4	4.31	3120
02050-C	DUP B	1.3	0.58	32.3	0.42	11.55	120	2	21.9	3.11	1770
R02050-C	REP B	2.2	0.54	31.1	0.36	10.7	111	3	20.1	2.95	1735
02051-C	DUP A	2.4	1.33	104.5	0.8	11.2	105	1	40.9	5.98	>10000
R02051-C	REP A	2.4	1.3	99.1	0.77	10.5	92	2	36.9	5.8	>10000
02052-C	DUP B	2.4	1.04	58.6	0.58	7.64	102	1	30.9	4.22	6130
R02052-C	REP B	2.4	1.04	55.9	0.53	7.14	90	2	28.2	4.05	5960
02053-C	DUP A	2.1	0.59	25.1	0.44	6.89	78	2	21.4	3.47	4790
R02053-C	REP A	2.1	0.61	24.4	0.42	6.59	65	2	20.2	3.49	4860
02054-C	DUP B	2.1	0.57	28.5	0.48	7.98	68	2	22.5	3.91	6150
R02054-C	REP B	2.3	0.65	27	0.49	7.55	56	2	20.3	3.77	5940
02055-C	DUP A	0.7	0.61	39.6	0.4	8.24	31	1	18.6	3	3280
R02055-C	REP A	0.8	0.54	35.3	0.35	7.14	16	2	15.3	2.67	2970
02056-C	DUP B	0.9	0.56	26.1	0.34	5.62	50	2	17.8	2.31	1930
R02056-C	REP B	1.1	0.6	25.4	0.31	5.1	36	2	15.8	2.34	1825
02057-C	DUP A	1.9	1.43	78.7	0.52	9.04	172	1	33.6	3.42	2530
R02057-C	REP A	1.4	1.35	72.2	0.46	7.84	102	1	27.5	3.35	2310
02058-C	DUP B	2.2	1.87	101.5	0.61	10.45	106	1	39.9	4.59	3200
R02058-C	REP B	1.9	1.98	107.5	0.7	11.45	119	1	43.1	4.56	3310

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