GSC Scientific Presentation 152 – Presenter's notes

Slide 3

Upper left globe image shows the location of the study area with a red star. Upper right image shows the study area in the Northwest Territories with a red oval. Lower left image shows a typical sample site in open tundra terrain of the northern part of the study area. Lower right image shows a typical sample site with a hand dug shallow (30 – 50 cm) hole in a frost boil. Two sediment samples are collected; a larger ~10 kg sample for indicator minerals and a smaller ~1 kg sample for geochemical analyses.

Slide 4

The primary objective of the research project was to evaluate the mineral potential of a proposed new National Park in Canada. Results were published in the following Geological Survey Canada Open File report:
Mineral and energy resource assessment of the proposed Thaidene Nene National Park Reserve in the area of the east arm of Great Slave Lake, Northwest Territories, Wright, D F (ed.); Ambrose, E J (ed.); Lemkow, D (ed.); Bonham-Carter, G (ed.); Geological Survey of Canada, Open File 7196, 2013, 656 pages, https://doi.org/10.4095/292447.
In addition to the resource assessment (Open File 7196), the comparison of pXRF spectrometry to multiple laboratory methods was examined. Results are published in the following open access report:
Portable XRF spectrometry of surficial sediment samples in the region of East Arm, Great Slave Lake, Northwest Territories, Canada. Kjarsgaard, B A; Knight, R D; Plourde, A P; Reynen, A M G; Geological Survey of Canada, Open File 7607, 2014, 38 pages, https://doi.org/10.4095/293951.
A summary of the research findings are also available in the following Open Access Journal: An analytical protocol for determining the elemental chemistry of Quaternary sediments using a portable X-ray fluorescence spectrometer. Knight, R D; Kjarsgaard, B A; Russell, H A J; Applied Geochemistry vol. 131, 105026, 2021 p. 1-15, https://doi.org/10.1016/j.apgeochem.2021.105026.

Slide 5

Photographic images depicting the northern boreal forest in the southern part of the research area and the transition northward to open tundra. Central map depicts generalized geology.

Slave Craton (>2.50 Ga): granite, granodiorite, diorite, gneiss, minor felsic to mafic volcanic and volcanoclastic rocks
Churchill Province (Rae Domain, ca. 3.0 – 1.8 Ga): Granite to syenite, mylonite, amphibolite gneiss, metasedimentary gneiss, anorthosite, pyroxenite, gabbro, diorite, monzodiorite,
Talston Magmatic/Tectonic Zone (ca. 1.97 - 1.90 Ga): mylonite, gneiss, anorthosite, granite to tonalite, granulite to migmatite schist,
Thelon Tectonic Zone (ca. 2.0 -1.95 Ga): granite, granitic gneiss, amphibolite gneiss, metasedimentary gneiss, gabbro,
East Arm sedimentary basin (ca. 1.93 -1.27 Ga): coarse clastic sedimentary rocks, shale,

siltstone, limestone, dolostone, conglomerates, megabreccia, gabbro sills, mafic to felsic volcanic rocks. Approximately 80km to the east of the map is a large sedimentary basin (Thelon Basin) with friable sandstone that contributes to the high quartz-rich sand content of the sediment transported into the study area during the last glaciation.

Detailed bedrock geology is contained in the following publications:

Bedrock Geology of the western Churchill Province and Taltson and Thelon Magmatic-Tectonic Zones, Thaidene Nene MERA Study area, Tella, S; Kjarsgaard, B A; Lemkow, D, in Mineral and Energy Resource Assessment of the proposed Thaidene Nene National Park Reserve in the area of the east arm of Great Slave Lake, Northwest Territories; Wright, D F (ed.); Ambrose, E J (ed.); Lemkow, D (ed.); Bonham-Carter, G (ed.); Geological Survey of Canada, Open File 7196, 2013 p. 27-45, https://doi.org/10.4095/292450

Slave Craton bedrock geology, Thaidene Nene MERA study area, Kjarsgaard, B A; Marshall, J; Pearson, D G; Lemkow, D; van Breemen, O; DuFrane, A; Heaman, L, in Mineral and Energy Resource Assessment of the proposed Thaidene Nene National Park Reserve in the area of the east arm of Great Slave Lake, Northwest Territories; Wright, D F (ed.); Ambrose, E J (ed.); Lemkow, D (ed.); Bonham-Carter, G (ed.); Geological Survey of Canada, Open File 7196, 2013 p. 47-75, https://doi.org/10.4095/292451

Proterozoic geology of the East Arm Basin with emphasis on Paleoproterozoic magmatic rocks, Thaidene Nene MERA study area, Kjarsgaard, B A; Pearson, D G; DuFrane, A; Heaman, L, in Mineral and Energy Resource Assessment of the proposed Thaidene Nene National Park Reserve in the area of the east arm of Great Slave Lake, Northwest Territories; Wright, D F (ed.); Ambrose, E J (ed.); Lemkow, D (ed.); Bonham-Carter, G (ed.); Geological Survey of Canada, Open File 7196, 2013 p. 77-117, https://doi.org/10.4095/292452

Digital Supplement 1. Bedrock geology of the proposed Thaidene Nene National Park Reserve in the area of the East Arm of Great Slave Lake, Northwest Territories, scale 1:500,000, in Mineral and Energy Resource Assessment of the proposed Thaidene Nene National Park Reserve in the area of the east arm of Great Slave Lake, Northwest Territories; Wright, D F (ed.); Ambrose, E J (ed.); Lemkow, D (ed.); Bonham-Carter, G (ed.); Geological Survey of Canada, Open File 7196, 2013 p. 27-45, https://doi.org/10.4095/292450

Slide 6

Sample location map with mineral showing **(ADD MERA references here; certainly digital supplement ?#3?).**

Black dots represent unconsolidated sediment (till) sample sites. Note that most mineral showings occur either along the boundary between the Slave craton and the Talston magmatic / tectonic zone where the boundary is defined by the McDonald fault (red line) or the Slave Craton and rocks (mainly carbonates) of the East Arm sedimentary basin outcrop along the western shore of Artillery Lake. Note the two yellow diamondiferous kimberlites (Gahcho Kué Mine) located in the northwest of the study area. Many of the till sample sites have an adjacent sample collected from the large array of eskers that bisect the area, originating in the east with transport direction to the west. For further information on the glacial evolution of the area see the following open access reports:

Regional stagnation of the western Keewatin ice sheet and the significance of meltwater corridors and eskers, northern Canada. Sharpe, D R; Lesemann, J -E; Knight, R D; Kjarsgaard, B A; Canadian Journal of Earth Sciences vol. 58, issue 10, 2021

p. 1-22, https://doi.org/10.1139/cjes-2020-0136
Glacial dispersal and flow history, East Arm area of Great Slave Lake, NWT, Canada. Sharpe, D R; Kjarsgaard, B A; Knight, R D; Russell, H A J; Kerr, D E; Quaternary Science Reviews no. 165, 2017 p. 49-72, https://doi.org/10.1016/j.quascirev.2017.04.011.
Digital Supplement 3. Digital geoscience database: A contribution to the mineral and energy resource assessment of the area of interest for the proposed Thaidene Nene National Park Reserve, D. Lemkow and D.F. Wright, in Mineral and Energy Resource Assessment of the proposed Thaidene Nene National Park Reserve in the area of the east arm of Great Slave Lake, Northwest Territories; Wright, D F (ed.); Ambrose, E J (ed.); Lemkow, D (ed.); Bonham-Carter, G (ed.); Geological Survey of Canada, Open File 7196, 2013 p. 27-45, https://doi.org/10.4095/292450;

Slide 7

A – although both the <2mm and <0.063 mm size fractions were analyzed by aqua regia, multi-acid (4 –acid) digestion and lithium metaborate/tetraborate fusion methods only the <0.063 mm size fraction will be discussed in this presentation.

B – pXRF spectrometry was carried out both Mining and Soil modes all 4 types of sample preparations listed however this presentation will concentrate on method 2) shaking and vibrating the sample prior to analyses utilizing granular convention to sort the sample into various grain sizes.

Slide 8

Analytical protocols for the three laboratory methods used in this presentation are discussed further in the following Open Access reports:
Till Geochemistry Studies of the Thaidene Nene MERA Study area, Kjarsgaard, B A; Knight, R D; Sharpe, D R; Kerr, D E; Cummings, D I; Russell, H A J; Lemkow, D, in Mineral and Energy Resource Assessment of the proposed Thaidene Nene National Park Reserve in the area of the east arm of Great Slave Lake, Northwest Territories; Wright, D F (ed.); Ambrose, E J (ed.); Lemkow, D (ed.); Bonham-Carter, G (ed.); Geological Survey of Canada, Open File 7196, 2013 p. 313-337, https://doi.org/10.4095/292459
Geochemistry of till samples, NTS 75-I, 75-J, 75-O, 75-P (Mary Frances Lake - Whitefish Lake - Thelon River area), Northwest Territories
Kjarsgaard, B A; Knight, R D; Plourde, A P; Sharpe, D R; Lesemann, J -E; Geological Survey of Canada, Open File 7351, 2013, 26 pages, https://doi.org/10.4095/292390

Slide 9

pXRF analyses in both Mining and Soil mode was carried out on a split of the original sample sent for laboratory geochemistry using 4 methods

1) Air-dried unprocessed original sample
2) Air-dried and sieved to <2mm. Image on the left of the slide shows an example of granules and small pebbles removed during the <2mm sieving process (Plourde et al., 2013). Removing sediment <2mm reduces the potential for a nugget affect.

3) Air-dried and vibrated/ shaken. The original sample was placed in a 100 ml vial (left side of image, labelled original sample) and subjected to granular convection through vibrating the sample in order to separate the dried sediment into a graded fine to coarse fraction as shown in the right side of the image (labelled coarse grains and fine grains). This sample preparation method is used to compare results with laboratory methods as shown in later slides. Sample vials where inverted prior to vibrating in order to concentrate the finer fraction at the open end of the vial that was subsequently covered with a 6 micron film.
4) Air-dried and sieved to <0.063mm

Analytical protocols for pXRF methods are discussed further in the following Open Access reports:

Portable XRF spectrometry of surficial sediments, NTS 75-I, 75-J, 75-O, 75-P (Mary Frances Lake - Whitefish Lake - Thelon River area), Northwest Territories
Plourde, A P; Knight, R D; Kjarsgaard, B A; Sharpe, D R; Lesemann, J -E; Geological Survey of Canada, Open File 7408, 2013, 25 pages, https://doi.org/10.4095/292714
Note that in this report (Open file 7408) Plourde et al sieves the sample to <2mm prior to shaking to eliminate any nugget affect. This is a modified version of the shaking/vibrating method used for sediment samples reported in this presentation.

Geochemistry of regional surficial sediment samples from the Thelon River to the East Arm of Great Slave Lake, Northwest Territories, Canada
Kjarsgaard, B A; Plourde, A P; Knight, R D; Sharpe, D R; Geological Survey of Canada, Open File 7649, 2014, 17 pages, https://doi.org/10.4095/295195

Portable XRF spectrometry of surficial sediment samples in the region of East Arm, Great Slave Lake, Northwest Territories, Canada
Kjarsgaard, B A; Knight, R D; Plourde, A P; Reynen, A M G; Geological Survey of Canada, Open File 7607, 2014, 38 pages, https://doi.org/10.4095/293951

For further information on the development of pXRF analytical protocols and application see Table 1 in the following publication:

Lithology and geochemistry of sediment cores, Pickering area, southern Ontario
Knight, R D; Stepner, D A J; Kjarsgaard, B A; Sharpe, D R; Crow, H; Gerber, R; Geological Survey of Canada, Open File 8511, 2021, 19 pages, https://doi.org/10.4095/328101

Slide 10

Results comparing the 4 sample preparation methods used for pXRF analyses (y-axis; as discussed in the previous slide), compared to laboratory fusion data (x-axis). Dashed line represents a 1:1 relationship. Solid black line represents the linear regression. Note the increasing r2 from the left side (original) to the right side (<0.063 mm). Shaking/vibrating method using granular convection results in an r2 greater than processing the sample to the <2mm size fraction but not nearly as good as conventional processing the sediments to <0.063mm. .

Slides 11

Comparison of pXRF (<0.063 mm, soil mode, y-axis) with laboratory ICP-ES/MS aqua regia, multi-acid acid (multi-acid), and lithium metaborate/tetraborate fusion methods (x-axis). Note that the correlation between pXRF (a total analyses) and aqua regia (a partial digestion analyses) is typically poor for most elements. Although the range in concentration for aqua regia is considerably lower than multi acid and fusion methods, the spatial distribution in some cases can reflect similar patterns as the other two methods, (shown in later slides).

Slide 12

It is important to note that the natural neighbour interpolated surface geochemical maps have a relative concentration scale. For these maps the percentile profile of the data is fixed. This is important when comparing the spatial distribution maps generated using aqua-regia to multi-acid, fusion, and pXRF methods. For the following slides x-y scattergrams are presented comparing pXRF of the original air-dried shaken sediment sample (y-axis) to multi-acid and fusion methods. Scattergram comparison using aqua-regia data are not shown on the x-y plots but are presented on the spatial distribution maps.

Slide 13

Red dashed line represents a 1:1 relationship. Solid black line and data presented in the lower right corner of the graph represents the regression line derived using the standard least squares method where x-axis data is assumed to be dependant and y-axis data is assumed to be variable or independent. n = number of sample represented on the graph. Solid blue line and data presented in the upper left corner of the graph represent the regression line determined by a reduced major axis method where both x- and y-axis data are assumed to be variable or independent.
For further information see:
Portable XRF spectrometry of surficial sediment samples in the region of East Arm, Great Slave Lake, Northwest Territories, Canada
Kjarsgaard, B A; Knight, R D; Plourde, A P; Reynen, A M G; Geological Survey of Canada, Open File 7607, 2014, 38 pages, https://doi.org/10.4095/293951
An analytical protocol for determining the elemental chemistry of Quaternary sediments using a portable X-ray fluorescence spectrometer
Knight, R D; Kjarsgaard, B A; Russell, H A J; Applied Geochemistry vol. 131, 105026, 2021 p. 1-15, https://doi.org/10.1016/j.apgeochem.2021.105026

Slide 14

Interpolated spatial distribution maps for the Ca data shown in the previous slide. It is important to note that geochemical maps have a relative concentration scale. Fusion and pXRF methods are very similar. Multi-acid method lacks some of the subtle spatial transitions whereas aqua-regia shows only areas of high and low concentration.
For further information see:

Digital Supplement 4. Contoured single element maps of till geochemical data, East Arm MERA study area
Knight, R; Plourde, A, in Mineral and Energy Resource Assessment of the proposed Thaidene Nene National Park Reserve in the area of the east arm of Great Slave Lake, Northwest Territories; Wright, D F (ed.); Ambrose, E J (ed.); Lemkow, D (ed.); Bonham-Carter, G (ed.); Geological Survey of Canada, Open File 7196, 2013 p. 1-3, https://doi.org/10.4095/292476

Slide 15

Note the variable concentration scales with aqua regia being considerably lower in concentration than the other 3 analytical methods. pXRF, multi-acid and fusion methods are similar in spatial distribution.

Slide 16

Note the missing K high concentration in the aqua regia map (inside black circle) that is present in the other 3 analytical methods. The anomaly within the black cycle represents a vein sphalerite galena showing on the west side of Artillery Lake (name not shown). The K map represents an alteration vector for the Pb/Zn showing inside the black circle.

Slide 17

Red dashed line represents a 1:1 relationship. Solid black line and data presented in the lower right corner of the graph represents regression derived using the standard least squares method where x-axis data is assumed to be dependant and y-axis data is assumed to be variable or independent. n = number of sample represented on the graph. Solid blue line and data presented in the upper left corner of the graph represent the regression line determined by a reduced major axis method where both x- and y-axis data are assumed to be variable or independent.
For further information see:
Portable XRF spectrometry of surficial sediment samples in the region of East Arm, Great Slave Lake, Northwest Territories, Canada
Kjarsgaard, B A; Knight, R D; Plourde, A P; Reynen, A M G; Geological Survey of Canada, Open File 7607, 2014, 38 pages, https://doi.org/10.4095/293951
An analytical protocol for determining the elemental chemistry of Quaternary sediments using a portable X-ray fluorescence spectrometer
Knight, R D; Kjarsgaard, B A; Russell, H A J; Applied Geochemistry vol. 131, 105026, 2021 p. 1-15, https://doi.org/10.1016/j.apgeochem.2021.105026

Slide 18

All 4 analytical methods show similar spatial distribution however some of the general transitions, in the east (right) side of the map area, for pXRF are missing.

Slide 19

Note the Ba high located within the black circle in aqua regia map. This spike represents a Ba signature from carbonate rocks that is blended into background values where the overall concentration of Ba is magnitudes higher for other analytical methods. The aqua regia map clearly delineates the Slave Craton from the Talston Magmatic/Tectonic Zone, Churchill Province (Rae Domain) as shown in slide number 5. Multi-acid, fusion and pXRF interpolated maps are very similar in spatial distribution of Ba.

Slide 20

Red dashed line represents a 1:1 relationship. Solid black line and data presented in the lower right corner of the graph represents regression derived using the standard least squares method where x-axis data is assumed to be dependant and y-axis data is assumed to be variable or independent. N = number of sample represented on the graph. Solid blue line and data presented in the upper left corner of the graph represent the regression line determined by a reduced major axis method where both x- and y-axis data are assumed to be variable or independent.
For further information see:
Portable XRF spectrometry of surficial sediment samples in the region of East Arm, Great Slave Lake, Northwest Territories, Canada
Kjarsgaard, B A; Knight, R D; Plourde, A P; Reynen, A M G; Geological Survey of Canada, Open File 7607, 2014, 38 pages, https://doi.org/10.4095/293951
An analytical protocol for determining the elemental chemistry of Quaternary sediments using a portable X-ray fluorescence spectrometer
Knight, R D; Kjarsgaard, B A; Russell, H A J; Applied Geochemistry vol. 131, 105026, 2021 p. 1-15, https://doi.org/10.1016/j.apgeochem.2021.105026

Slide 21

pXRF, multi-acid, and fusion analytical methods are spatially very similar. Aqua regia concentrations are lower with 3 anomalies (shown inside black circle) that are not visible in the pXRF, multi-acid, or fusion interpolated maps.

Slide 22

pXRF, multi-acid, and fusion analytical methods are spatially very similar. Aqua regia concentrations are significantly lower and show anomalies (inside black circle) that are not visible in the pXRF, multi-acid, and or fusion interpolated maps.

Slide 23

Blue dashed lines represent the limit of detection. Yellow dots represent data where values where retuned using pXRF lower than the detection limit. Red dashed line represents a 1:1 relationship. Solid black line and data presented in the lower right corner of the graph represents regression derived using the standard least squares method where x-axis data is assumed to be dependant and y-axis data is assumed to be variable or independent. N = number of sample

represented on the graph. Solid blue line and data presented in the upper left corner of the graph represent the regression line determined by a reduced major axis method where both x- and y-axis data are assumed to be variable or independent.
For further information see:
Portable XRF spectrometry of surficial sediment samples in the region of East Arm, Great Slave Lake, Northwest Territories, Canada
Kjarsgaard, B A; Knight, R D; Plourde, A P; Reynen, A M G; Geological Survey of Canada, Open File 7607, 2014, 38 pages, https://doi.org/10.4095/293951
An analytical protocol for determining the elemental chemistry of Quaternary sediments using a portable X-ray fluorescence spectrometer
Knight, R D; Kjarsgaard, B A; Russell, H A J; Applied Geochemistry vol. 131, 105026, 2021 p. 1-15, https://doi.org/10.1016/j.apgeochem.2021.105026

Slide 24

All interpolated maps are similar suggesting that Cu is in the form of Cu sulphide that is dissolved in all 3 lab methods. Note that the pXRF interpolated map shows an minor anomaly (inside the black circle) that does not show in the 3 laboratory methods.

Slide 25

All interpolated maps are similar suggesting that Pb is dissolved in all 3 lab methods. For the aqua regia map concentrations within the black circle are lower than the 3 other analytical methods. For the fusion map both a high and low concentration areas (shown in the black circle) are not visible in the other interpolated maps. Low concentrations depicted in the pXRF map (within the black circle) are not as defined using the laboratory analytical methods.

Slide 26

Blue dashed lines represent the limit of detection. For the Zn scattergrams the red dashed line represents a 1:1 relationship. Solid black line and data presented in the lower right corner of the graph represents regression derived using the standard least squares method where x-axis data is assumed to be dependant and y-axis data is assumed to be variable or independent. N = number of sample represented on the graph. Solid blue line and data presented in the upper left corner of the graph represent the regression line determined by a reduced major axis method where both x- and y-axis data are assumed to be variable or independent.
Data for Zr did not generate any viable regression lines.
For further information see:
Portable XRF spectrometry of surficial sediment samples in the region of East Arm, Great Slave Lake, Northwest Territories, Canada
Kjarsgaard, B A; Knight, R D; Plourde, A P; Reynen, A M G; Geological Survey of Canada, Open File 7607, 2014, 38 pages, https://doi.org/10.4095/293951
An analytical protocol for determining the elemental chemistry of Quaternary sediments using a portable X-ray fluorescence spectrometer
Knight, R D; Kjarsgaard, B A; Russell, H A J; Applied Geochemistry vol. 131, 105026, 2021 p. 1-15, https://doi.org/10.1016/j.apgeochem.2021.105026

Slide 27

All interpolated maps are very similar. Interpolate maps for aqua regia and pXRF fail to show anomalies (inside black circle) that are present when using multi-acid and fusion methods.

Slide 28

All analytical methods have different upper concentrations and show differences in spatial distribution demonstrating the resistance of Zr to digestion by aqua regia, and to a lesser extent by the multi-acid method, as well as the potential nugget effect of Zr using pXRF spectrometry. For Zr, fusion is the preferred method. Note the higher concentrations of Zr in the east side of the fusion interpolated map reflecting the distribution of Zr originating form friable quartz arenites associated with the Thelon sedimentary rocks outcropping approximately 80 km to the east of the map area.

Slide 29

For bullet point 3 it should be noted that the authors use the term “in-field” to reflect using the pXRF in a field camp-based laboratory configuration where the pXRF is house in a test stand. From previous studies the authors have concluded that direct in-field data collection has too many uncontrolled variables and can be costly when data collection is helicopter supported. An example of unprocessed vs processed pXRF sediment sample analyses on a continuous borehole has been released in the following open access report:

Portable XRF spectrometry of insitu and processed glacial sediment from a borehole within the Spiritwood buried valley, southwest Manitoba
Plourde, A P; Knight, R D; Russell, H A J; Geological Survey of Canada, Open File 7262, 2012, 30 pages, https://doi.org/10.4095/291922

Analytical protocols for pXRF methods are discussed further in the following Open Access reports:

Portable XRF spectrometry of surficial sediments, NTS 75-I, 75-J, 75-O, 75-P (Mary Frances Lake - Whitefish Lake - Thelon River area), Northwest Territories
Plourde, A P; Knight, R D; Kjarsgaard, B A; Sharpe, D R; Lesemann, J -E; Geological Survey of Canada, Open File 7408, 2013, 25 pages, https://doi.org/10.4095/292714

Portable XRF spectrometry of surficial sediment samples in the region of East Arm, Great Slave Lake, Northwest Territories, Canada
Kjarsgaard, B A; Knight, R D; Plourde, A P; Reynen, A M G; Geological Survey of Canada, Open File 7607, 2014, 38 pages, https://doi.org/10.4095/293951

Geochemistry of regional surficial sediment samples from the Thelon River to the East Arm of Great Slave Lake, Northwest Territories, Canada
Kjarsgaard, B A; Plourde, A P; Knight, R D; Sharpe, D R; Geological Survey of Canada, Open File 7649, 2014, 17 pages, https://doi.org/10.4095/295195

Slide 30

For further information including the datasets used to define data classification see the following open access paper:
An analytical protocol for determining the elemental chemistry of Quaternary sediments using a portable X-ray fluorescence spectrometer
Knight, R D; Kjarsgaard, B A; Russell, H A J; Applied Geochemistry vol. 131, 105026, 2021 p. 1-15, https://doi.org/10.1016/j.apgeochem.2021.105026
Initial classification of elements in quality categories was reported in:
Portable XRF spectrometry of reference materials with respect to precision, accuracy, instrument drift, dwell time optimization, and calibration
Knight, R D; Kjarsgaard, B A; Plourde, A P; Moroz, M; Geological Survey of Canada, Open File 7358, 2013, 45 pages, https://doi.org/10.4095/292677
Quality control of pXRF spectrometry
Landon-Browne, A R R; Knight, R D; Kjarsgaard, B A; Russell, H A J; Geological Survey of Canada, Scientific Presentation 53, 2017, 1 sheet, https://doi.org/10.4095/299726

Slide 31

For further information see the datasets and graphical presentation of the data in the Supplemental Material associated with the following open access report:
An analytical protocol for determining the elemental chemistry of Quaternary sediments using a portable X-ray fluorescence spectrometer
Knight, R D; Kjarsgaard, B A; Russell, H A J; Applied Geochemistry vol. 131, 105026, 2021 p. 1-15, https://doi.org/10.1016/j.apgeochem.2021.105026