DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 1999/41

Compilation of data sets for a geochemical atlas of West and South Greenland based on stream sediment surveys 1977 to 1997

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Abstract

The stream sediment data compiled to form the basis for producing a geochemical atlas of the Precambrian part of West and South Greenland between 59° and 70°30'N comprises results obtained in 16 individual surveys carried out in the period 1977 to 1993. A comprehensive bibliography provides an overview of the geochemical exploration and mapping activities within this area. Samples were analysed using analytical facilities existing at the time they were collected and many sample batches have been reanalysed at a later date with more modern equipment. Thus, for each sample batch there exists a number of analytical data sets derived from analysis at two to three different laboratories and three to four different methods.

The compilation of data has involved the selection of suitable samples from detailed surveys to match the general density of one sample per 25 to 30 km^2 for West Greenland and one sample per 5-6 km^2 for South Greenland. In addition, a selection of analytical data sets for each element was made to ensure that the most reliable data set is used where samples have been analysed for the same element by different methods. The reliability of analytical results has been monitored by internal standards since 1990. The compatibility of element determinations by various methods has also been investigated using correlation diagrams for whole sample batches.

Analytical bias was found to exist between batches analysed by different methods and between batches analysed by the same method at different times. A calibration, i.e. a correction of the obtained analytical values was applied to eliminate the bias. For batches monitored by internal standards the correction was done by linear regression of values measured in the standards against reference values. For batches analysed without accompanying internal standards a small subset of samples were analysed together with internal standards, and the correction parameters were found by regression of measured original values against the calibrated values. The correction was then applied to the entire analytical batch.

The calibration applied to the measured analytical values ensures that the whole data set for each element is internally consistent. The analysis of a set of eight international standards together with the internal standards enables the data from Greenland to be made directly comparable with geochemical data sets from other parts of the world.

The compilation and calibration efforts have resulted in the production of reliable data sets for 10 major and 32 trace elements.

Introduction

The Geological Survey of Greenland (since 1995 amalgamated with the Geological Survey of Denmark to form the Geological Survey of Denmark and Greenland - GEUS) has carried out geochemical surveys in Greenland over a 25 year period using stream sediment as sample medium. This activity has been funded by the Survey with supplementary contributions from the governments of Denmark and Greenland, and a small contribution from the partially government-owned exploration company Nunaoil A/S. Initially, the collection and analysis of samples were part of local geochemical exploration surveys for specific metals but increasingly larger areas were gradually covered and samples were analysed by multi-element techniques as they became available. At present, a large contiguous area in West and South Greenland has been covered and data have been compiled in order to produce a geochemical atlas of the Precambrian part of West and South Greenland between 59° and 70°30'N. The first geochemical maps of this large area were presented by Steenfelt (1994a, b, 1996).

The compilation has involved the solution of a number of problems as will be shown in this report. Not all samples have been analysed in the same way, and minor or major bias was found between analytical data produced by different methods or different laboratories or between data sets acquired from the same laboratory at different times. Experience has shown that most elements are important for the geological interpretation, hence an effort has been made to include as many elements as possible in the final data set for the entire region. Thus, 108 individual data sets, each comprising 9 to 12 element determinations, have required careful examination and adjustment before they were entered into the database used for producing element distribution maps for the atlas.

The main objective of this report is to demonstrate how the analytical data used to produce the geochemical atlas have been made internally consistent. The report also provides a documentation of the analytical methods employed for stream sediments over the years with an evaluation of the data quality. A second objective is to give an overview of other geochemical exploration activities within the atlas area. Therefore, a list is provided of local geochemical exploration surveys for various purposes together with a bibliography of publications dealing with results of geochemical exploration by the former Geological Survey of Greenland and collaborators.

The geochemical mapping programme also included collection of stream water samples. Their conductivity was measured and a large number were analysed for uranium and fluorine. However, calibration of these data is not possible at the scale of the atlas, and water data are not treated in this report.

All analytical data from the stream sediment surveys are stored in a GEUS database, and the remaining sample material is archived at GEUS and may be retrieved for future analytical treatment.

Sampling and analysis

Record of stream sediment sampling

Sampling of stream sediment in Greenland goes back to Bruno Thomsen who collected the first samples in 1949 and made a reconnaissance sampling of gravel and sand from major rivers in West Greenland (Thomsen 1957). The samples were studied petrographically and minerals were identified and counted. Mineral counting and chemical analyses of reconnaissance samples of stream sand from southern West Greenland have also been used to map the distribution of granulite and amphibolite facies rocks and to estimate the average chemical composition of the Precambrian terrain (Kalsbeek 1971, 1974; Kalsbeek *et al.* 1974). The suitability of stream sediment samples in mineral exploration was tested in East Greenland in 1971 (Kunzendorf 1977). In the years 1973 to 1977, samples of stream sediment and stream water were collected and analysed for use in local (Steenfelt *et al.* 1976) and regional uranium exploration in northern East Greenland (Steenfelt and Kunzendorf 1979).

In South Greenland, ca. 2450 stream sediment samples were collected in 1979 as part of a regional uranium exploration programme (Armour-Brown *et al.* 1982a).

Systematic sampling of stream sediment and stream water at a density of 1 sample station per 20 to 50 km^2 has been carried out since 1981 in central and southern West Greenland and in southernmost South-East Greenland, as listed in Table 1 in chronological order. The sampling has progressed in a very irregular way mostly because it has been logistically tied to other geoscientific investigations, see Fig. 1. However, increasingly coherent sample coverage has been achieved, and in 1993, funds were allocated to sample the last remaining areas within the contiguous region shown in Fig. 1.

In addition to the systematic stream sediment sampling at a reconnaissance scale, a number of high-density geochemical surveys have been undertaken in West and South Greenland. They are listed in appendix 1 as general information. Scattered high-density stream sediment sampling was carried out in connection with the reconnaissance sampling to document local variation or to examine the geochemical response from known mineralised occurrences. These results are not included in the atlas data. More information about such results and those listed in appendix 1 may be obtained from the Department of Economic Geology at GEUS.

Record of sample treatment

Since 1979 all stream sediment samples collected in the reconnaissance geochemical mapping programme have been treated in the same way: they were collected in paper bags, which were dried in the field, wrapped in newspaper, packed in boxes, and subsequently shipped to GGU in Copenhagen. Here the samples were dried at 60°C and sieved into three grain size fractions. The < 0.1 mm fraction has been used for analysis, the fraction from 0.1 to 1 mm has been retained in storage, while the fraction above 1 mm has been discarded. Before 1979 the < 0.15 mm was used for analysis. Thus, among the samples used for the atlas, only 59 (from area G) have been treated slightly differently.

Record of analytical treatment

In the 1970s and beginning of 1980s, samples were analysed for U by Delayed Neutron Counting (DNC) and by X-ray Fluorescence Spectrometry (XRF) for some major and a suite of trace elements at Risø National Laboratory (Risø). In 1985 GGU acquired a new XRF equipment with automatic sample exchanger suitable for analysis of many samples, and from 1986 onwards most stream sediment samples were analysed in the XRF laboratory at GGU. Although the XRF equipment was primarily aimed at determining major element concentrations using glass discs, it turned out to be possible to determine a number of trace element concentrations within the glass discs at the same time (see appendix). The high quality determinations of the complete suite of major element oxides were a major breakthrough for the geological interpretation of the geochemical data (Steenfelt 1994b).

Interest in gold promoted the use of methods capable of determining gold in low concentrations at a reasonable price. The nuclear technique, Instrumental Neutron Activation Analysis (INA), was preferred because this method provides a large number of additional trace element determinations. Therefore, from 1990 onwards all samples were analysed by INA (first at Bondar-Clegg and Co. Ltd. – B-C, and later at Activation Laboratories Ltd. – Act). In addition, samples from earlier campaigns were retrieved from the sample archive and submitted for analysis by INA.

In 1992 the amount of samples exceeded the capacity of the GGU laboratory and samples were submitted to Act for XRF (glass disc) analysis for major elements and XRF (powder pellets) analysis for trace elements.

The idea of producing a geochemical atlas of a large section of West Greenland by compiling existing and coming data sets made it necessary to start a process of upgrading earlier data sets to match the quality of the newer ones. Hence, earlier sample batches were reanalysed, entirely or partially, by the newer methods at a rate permitted by the annual budgets.

Finally, in 1998, sufficient data had been acquired to produce an atlas showing the distribution of 42 elements. The number of samples contributing to the atlas and their analytical treatment is shown in Table 2. Figures 2 to 4 show the distribution of samples analysed by the various methods. Table receives further comment in the section on compilation of data, p.12.

Description of laboratories and methods

The laboratories and methods involved in chemical analyses of the atlas samples are described below. The element suites determined by each method are shown in Table 3 (a and b) together with lower limits of detection (l.l.d.). For each combined laboratory and method an abbreviated name is introduced and shown in brackets. These acronyms are used in all tables and diagrams of this report.

Risø National Laboratory, Roskilde, Denmark

1) Delayed neutron counting (Risø DNC)
2) Radio-isotope excited energy-dispersive X-ray Fluorescence Spectrometry (Risø XRF)
Plutonium source (Risø plu)
Cadmium source (Risø cd)

Comments: The delayed neutron counting technique was automated at the Risø National Laboratory and was adjusted to perform analysis with high precision and accuracy (Kunzendorf *et al*. 1980). The detection limit is low, around 10 parts per billion (ppb).

The Risø XRF system was designed to provide fast results for exploration (Kunzendorf 1979). The sieved sample fractions (<0.15 or <0.1 mm) were poured directly into the sample containers consisting of an aluminium ring with a bottom of thin mylar foil. The sample container would typically contain 20-30 g material, although only the layer close to the mylar foil (area ca. 38 cm^2) would be exposed to the X-rays. The results may have been affected by bias introduced during the filling of samples into the containers because the heavy minerals tend to be concentrated in the bottom layer (closest to the detector). The analyses were monitored by internal lab standards and repeated analysis showed that results were fairly reproducible. The accuracy is variable but, in the author’s experience, results are generally reliable except for Mo, Pb, and V.

Geological Survey of Greenland (GGU),

since 1995 Geological Survey of Denmark and Greenland, Copenhagen, Denmark

1. *X-ray Fluorescence Spectrometry on fused powder (glass discs) prepared with sodium tetraborate as fluxing agent (GGU XRF) for determination of major elements and a short suite of trace elements*
2. *Atomic Absorption Spectrometry (AAS) for determination of Na and Cu*

Comments: The major element determinations are very accurate and performed with high precision (Sørensen 1975, 1976, 1981). They are monitored by international standards. Likewise, the AAS determinations of Na and Cu are of good quality. The trace element determinations on the glass discs reflect the fact that due to sample dilution with the fluxing agent the detection limits are high and there are problems with precision at low concentrations (see appendix). In the author's experience results are reliable for Ba, Cr, Ni, Rb, Sr, V, Zn, and Zr, particularly those obtained from 1993 onwards.

Activation Laboratories Ltd. (Act), Ancaster, Ontario, Canada

1) *X-ray Fluorescence Spectrometry*
   using lithium borate fluxed glass discs (Act XRF, major)

Comments: This method is used for determination of major element concentrations only. The results are comparable in quality to those of GGU XRF. However, the Actlabs results have higher values for loss on ignition, and consequently show slightly lower concentrations of the major elements, notably SiO_2. The precision may be slightly lower than in the GGU analyses.

2) *X-ray Fluorescence Spectrometry on pressed powder pellets (Act XRF, trace)*

Comments: This method is used for determination of 14 trace elements. Generally, the analytical results have high precision and low limit of detection, but the internal standards show that there have been some changes in the background corrections or calibration procedures with time. Results for Ga, Nb and Y have poorer quality and the results for Pb are intermittently unreliable.

3) Instrumental Neutron Activation Analysis (Act INA)

Comments: Results by Act INA have been monitored with our internal standards. The precision varies from element to element but, in general, results are reliable. Diagrams showing temporal variations in analytical values for the internal standards illustrate the reproducibility. See section on compilation of data.

4) Inductively Coupled Plasma Emission Spectrometry (Act ICP)

Comments: This method has been used in the analysis of one of the sample batches included in the atlas. The results compare well with those determined by XRF and INA, as discussed in the chapter on selection of analytical datasets.

Bondar-Clegg and Company Ltd. (B-C), Ottawa, Canada

1) Instrumental Neutron Activation Analysis (B-C INA)

Comments: Same as for Act INA. Note that the lower limit of detection (l.l.d.) is high for Nd, Eu, Yb and Lu, so that most samples have concentrations below l.l.d., in contrast to results from Act INA, where most concentrations are above l.l.d. for these elements (see detection limits in Table 3b).

Geological Institute, University of Copenhagen (KU), Denmark.

1) X-ray Fluorescence Spectrometry using powder pellets (KU XRF)

Comments: This laboratory produces high accuracy results calibrated against international standards. A set of standards has been analysed here to compare the results with those provided from the other laboratories.

Application of standard reference material

Monitoring the reproducibility of analyses by means of internal standards

In 1989 five large samples of fine-grained stream sediment were collected from large rivers in the Disko Bugt area (area C). The samples were dried and sieved and the < 0.1 mm fraction of each sample was homogenised and split into a large number of 7 g samples. Since then these samples have served as internal standards and a numbered set of five standards has accompanied every batch of samples submitted for analysis. After a few years, standard no. 4 was exhausted, and from then on we have used the remaining four.

The standards were collected in rivers draining typical, lithochemically varying rock assemblages. Thus their chemical compositions cover the common element concentration ranges found in stream sediment over Greenland. An example of this is illustrated by Fig. 5, where the range of Ni concentrations of the standards is shown together with Ni concentrations of a selection of samples from the atlas region.

The data resulting from the analyses of the standards over the past seven years give an impression of the reproducibility of the analytical data produced by the various methods. The temporal variability is shown for each element in the diagrams of Figs 6 and 12–14, and will be discussed in the chapters on ‘selection of analytical data’ and ‘calibration of results’.

The internal standards cannot be used to monitor analyses for As, Au, Br, Cs, Mo, Sb, Ta and W because the concentrations of these elements in the standard samples are at or below the detection limit.

Examining the accuracy of analyses by means of international standards

A set of eight international standards from CANMET, Ottawa, Canada, was acquired and used to examine the accuracy of the analytical methods. The stream and lake sediment standards STSD-1, STSD-2, STSD-3, STSD-4, LKSD-1, LKSD-2, LKSD-3, and LKSD-4 were analysed by GGU XRF, KU XRF, Act XRF and Act INA. The result of the test is discussed in the last part of the chapter on “Calibration procedures”.

Compilation of data for West and South Greenland

List of batches and area division

Since the start of the systematic sampling the strategy has been to sample map sheet by map sheet, following the series of topographical maps of Greenland at scale 1:250 000 by the National Survey and Cadastre, Copenhagen. However, there have been several cases where geological or landscape boundaries have been used instead of map boundaries. In addition, there has been complementary sampling in previously scarcely covered areas, and suitably located samples in detailed surveys have been incorporated into the regional collection. For the sake of the overview during the compilation procedure, the atlas region has been divided into area units, mostly outlined by longitudes and latitudes, representing the coverage of the major surveys. Each area has been assigned a letter as area code, starting with A in the north and ending with P in the south-east (Fig. 1; Table 1). Each sample batch has been coded according to the area where the samples were collected (Table 2).

The samples listed in the column headed “Total selected” in Table 2 are those selected for the production of the geochemical maps of the atlas, i.e. duplicates and other samples collected for control of local variation are not included. The number of samples analysed by the various methods varies, and this reflects budget limitations in a few cases, but mostly that some of the samples yielded insufficient material in the fine fraction to permit a full round of analyses.

Selection of analytical data sets for the atlas

Table 2 and Figs 2–4 show that the atlas region has been fully covered with two sets of major element analyses from only two laboratories (GGU XRF and Act XRF) whereas the situation is much more complicated when trace elements are concerned. There is no coherent coverage of one particular suite of trace elements, and the atlas data set for each element must be compiled from analytical data sets from different sources. The first step in this process is to identify the elements for which sufficient data are available. Table 3 lists the elements determined in each of the analytical packages that have been used. Elements shown in blue characters in Table 3b are irrelevant for the atlas because their concentrations in the stream sediment are never or very rarely above the lower limit of detection (l.l.d.). Other elements, shown in parentheses in Table 3b, should be avoided because the quality of the analysis is poor. Of the remaining 32 trace elements, shown in black characters in Table 3b, some have been determined by more than one method, and in order to create one single data set for each element a choice must be made. Table 4 shows the result of the choice and the following gives the reasoning behind it.

Major elements

All sample batches have been analysed for major elements at either GGU or Actlabs. Both laboratories provide analyses of good quality for major elements, which are determined by XRF on glass discs, except Na which at GGU is determined by AAS. Results are given as percentages of major element oxides and loss on ignition. In West and South Greenland loss on ignition mostly reflects the amount of organic material in stream sediment samples. As the aim is to show the regional variation in the chemistry of the minerogenic component of the stream sediment, all major element concentrations are recalculated as volatile free oxides and these data are used for the atlas. However, high loss on ignition may also be caused by high contents of carbonate in the stream sediment. In this case the composition calculated as volatile free oxides would give higher values for the oxides than they should have. In West and South Greenland high concentrations of carbonate are found only locally, in streams draining rare occurrences of marble or carbonatites, and the general distribution patterns for the oxides are not affected. For the purpose of detailed or more accurate studies, the CO_2 concentrations of the stream sediment samples should be measured or the amount of carbonate minerals estimated by microscopy.

Major element determinations provided by the INA and ICP packages and by Risø XRF (powder), see Table 3a, are not used for the atlas.

Trace elements

All samples have been analysed for trace elements by INA and XRF (Table 2, Figs 3, 4); although the latter vary much in quality. For sample batches where elements are determined by XRF at different laboratories or by both XRF and INA the most reliable data set has been selected and used to compile the atlas data.

The evaluation of the analytical quality comprised two kinds of approach. One utilises the results of the repeated analyses of internal standards as shown diagrammatically in Fig. 6 for all trace elements that are determined by more than one method. The other compares results obtained for a whole sample batch which has been analysed with different methods for the same element. The latter is necessary for estimating the compatibility of analyses performed before the introduction of standards, and is illustrated by a number of element correlation diagrams in Figs 7–11.

The sets of five internal standards, which have been submitted for analysis together with sample batches, have been numbered consecutively. Individual standards within a set have been numbered within the ordinary GGU sample numbering system as follows:

Standard set 1	Standard set 2………	Standard set 101	Standardset 102…..
std 1 376101	std 1 376102	std 1 382101	std 1 382102
std 2 376201	std 2 376202	std 2 382201	std 2 382202
std 3 376301	std 3 376302	std 3 382301	std 3 382302
std 4 376401	std 4 376402	std 4 exhausted	
std 5 376501	std 5 376502	std 5 382501	std 5 382502

The analytical data for the standards are stored in the GEUS database under these numbers. The standard sets analysed together with batches contributing to atlas are listed in Table 5. Batches Jx and Ox represent a small selection of samples from each of the areas J and O, which were submitted for Act XRF analysis for calibration purposes.

The diagrams of Fig. 6 show, for each element and method, the results of the analyses of the internal standard sets listed in Table 5. Only the four of the five standards which have been available through the whole period are shown. For each method, the sample batches are arranged from left to right, in the order by which they have been analysed, thus illustrating the temporal variability in the results provided by each method.

The simplest cases in the selection of analytical data for the atlas comprise elements which have been determined by INA only. These are listed in the first five columns of elements of Table 4. Most of the Act INA data but none of the B-C INA have been monitored by internal standards. The correlations between data obtained from a batch analysed by both laboratories are shown in Fig. 7. There are good correlations for all elements except Ba, so that B-C results, when calibrated, can be used together with Act results. However, B-C INA does not determine Nd, and the l.l.d. for Eu, Yb, and Lu is so high that most concentrations are not detected. Therefore, a number of data points are missing in the distribution maps for these elements. The poor correlation for Ba is not important as XRF results for Ba are preferred for the atlas, see below.

In the case of Co, which is determined by both Act XRF and Act INA, the latter results are preferred because they appear to have better precision (Fig. 6b), and because there is complete coverage with INA data. The coverage with XRF data for Co is only partial because GGU XRF does not determine Co.

The analyses for U by DNC are considered of better quality than analyses by INA. In addition, the low l.l.d. for DNC determinations (see Table 3b) is an advantage because U concentrations are very low in large parts of the atlas region. The compatibility of analyses by Act INA and B-C INA with the DNC analyses is illustrated by means of results of samples analysed by both methods, Fig. 8. For all batches, except I1 and I2 in which uranium concentrations do not exceed 10 ppm, a good correlation is demonstrated; hence INA data can be used with confidence together with the DNC data.

The situation is more complicated for trace element data obtained by XRF in that data from Act XRF, GGU XRF and Risø XRF must be combined and supplemented with data from Act INA and Act ICP to acquire full coverage of the atlas region for a particular element (Table 2). In addition, the best combination varies from element to element. The diagrams of Fig. 6 demonstrate that Act XRF analyses generally display the least variation between batches. Therefore, Act XRF is selected as the preferred method for Ba, Cr, Ga, Nb, Ni, Rb, Sr, V, Y, Zn and Zr, also because all Act XRF results have been monitored by standards. There are periodic changes in the concentration levels, but they are ascribed to changes in calibration or background corrections, and most results can be adjusted with confidence. Exceptions are results for Ga, Nb, and Y, which are less stable and are difficult to calibrate, see section on calibration procedures. Fig. 6g illustrates the poor reproducibility in Pb determinations by Act XRF, where even totally invalid results were obtained for the standards accompanying batch K1.

Where Act XRF analyses are not available, supplementary data may be chosen from GGU XRF and Risø XRF, or even Act INA and Act ICP. For batches A, B and I3, GGU XRF data are the only ones available (Ni, Sr, V, Rb, Zn, Zr, Cu) or they are preferred to B-C data (Ba, Cr).

For the remaining batches there is a choice between data from GGU XRF and Risø XRF. Fig. 6 shows that GGU XRF results have relatively good reproducibility for Cr, Cu and Ni, and results are stable for Ba, Rb, Sr, V, Y, Zn and Zr during the later period of analyses of standards, i.e. those accompanying the batches K3, L2, L3, M2, N, M3, M4, K and D. Hence, GGU XRF data for Ba, Cr, Ni, Sr, V, Rb, Zn and Zr are preferred for batches K3, L2, L3 and M4.

Early GGU XRF results, and particularly those concerning sample batches O2, O4, and O5, are very variable for Ba, Cr, Rb, Sr, Y, Zn and Zr. In addition, there are GGU XRF data of uncertain quality because they were obtained before the standards were introduced (batches J1, J2 and L1). For these, it is assumed that the Cr, Ni, Sr and V results were as stable as in the period when they were monitored, and that Rb, Zn and Zr data were less reliable. Therefore, Risø XRF data are preferred for the latter three elements in the batches J1 and J2.

The Risø XRF results and some of the GGU XRF data were obtained before the introduction of standards, and their compatibility with Act XRF results has been investigated by means of samples analysed by two or all three laboratories (Figs 9–11).

Fig. 9 shows that GGU XRF data correlate well with Act XRF for Ba, Cr, Cu, Ni, Rb, Sr, V, Zn and Zr, whereas Risø XRF data only show equally good correlations for Sr and Zr. In addition, the Risø XRF data are considered to have acceptable correlations with Act XRF for Cu, Nb, Ni, Rb and Zn, particularly at higher concentrations. The poor quality of the V results by Risø XRF and the problems with Ga, Pb and Y are clearly seen.

There are several reasons why Risø XRF data are preferred for batches O1–O5. The GGU XRF data were of variable quality during the period these samples were analysed (Fig. 6), and standards were not (by mistake) analysed together with batches O1 and O3. Another reason is that after 2286 samples had been analysed at Risø by DNC and XRF, and 2185 of those additionally analysed by Act INA, there only remained 1095 samples with sufficient material for GGU XRF analyses (compare sample densities in Figs 2 and 4).

The Risø XRF does not include Ba determinations, and Cr data show much scatter (Fig. 9b). Act INA data for these two elements correlate well with Act XRF data (Fig. 10), and they have been selected for the atlas. Since the Risø XRF data for V have poor quality, the GGU XRF data for V are used despite the lower number of analyses. The correlations of Risø XRF data with GGU XRF data for two of the batches in area O are shown in Fig. 11. There are good correlations for Cu, Rb, Sr, Y, Zn and Zr, whereas the correlation for Ni is not so good at low values, as is the case in Fig. 9f.

The Cu analyses obtained by GGU AAS are more stable than the Actlabs XRF Cu analyses and are preferred where available. However, Cu has not been determined in the samples from area J, batch L1, and not in any samples from South Greenland (area O). Risø XRF data are selected as substitutes in areas J and O, but there are no Risø XRF data for batch L1. On the other hand, about 60 % of the samples from batch L1 have been analysed by Act ICP together with standards, hence Cu values are provided from this source.

The geochemical maps of Nb, Y and Ga are inevitably based on data of inferior quality, as indicated by the correlation diagrams. It is not even certain that a map of Ga will be included in the atlas. However, although the geochemical background levels for Nb and Y are poorly defined, there are significant regional variations for elevated values of these elements, which are worth displaying in geochemical maps. GGU XRF determinations of Nb and Y have very high l.l.d., hence, Risø XRF data are preferred where available. For batch L1 the Act ICP data for Y are used.

Calibration procedures

The preceding chapter has described how sub-sets of data have been selected to compose an overall data set for each element for the entire atlas area. In all of the cases where analytical bias has been found between data sub-sets, calibrations are needed to make the overall data set internally consistent. Thus the calibration involves the application of corrections to the analytical data of the sub-sets. This chapter describes the procedures used for calculating and applying these corrections

Data from analyses monitored by internal standards

The result of the analyses of standards submitted together with sample batches used for the atlas is shown in Figs 12 to14. The corresponding batch code is given on the abscissa. The results are listed for each method from left to right in the order they were analysed. In the cases where the curves are conformable, the variation can be ascribed to differences in the analytical conditions and a correction can be applied. In the cases where one or all standards show individual variations for a given element, i. e. curves are non-conformable, the variation is ascribed to analytical uncertainty or to heterogeneity with respect to the particular element in the standard material.

Results for As, Au, Br, Cs, Mo, Sb, Ta and W cannot be calibrated because the concentrations of these elements in the internal standards are below the analytical limit of detection. Thus the raw data are used in the compilation for the geochemical atlas.

Results for Nd, U and Th are not calibrated because of relatively poor precision. The scatter between batches is considerable and it is impossible to demonstrate a temporal change which exceeds this uncertainty and which affects the four standards in the same way (see Figs 13g, 13j and 13k). The Th concentrations show a tendency for an increase with time but it is considered too weak to justify any correction. Anyway, the regional variation in Th concentrations, due to the varying geology, is so strong that a small analytical bias is not visible in the Th distribution map of the atlas.

All other element data are calibrated, and the first step in the calibration procedure is the determination of the reference concentration level, the *reference value*, for each element in each of the four standards. This value is chosen to be close to the levels obtained when large batches were analysed in a period where the results were stable, in order to minimise the amount and magnitude of corrections needed. For the INAA results, the reference values are chosen as the median (excluding outliers) of the sequence of values from batches F1 to L1. The reference values are shown in the diagrams (Figs 12–14) and in Table 6.

In the choice of reference values for trace element analyses by XRF an additional criterion was used, namely that the values should not deviate significantly from the results obtained by XRF at the Geological Institute, University of Copenhagen (John C. Bailey). Results from this laboratory, called KU XRF in this report, are calibrated against international standards and are considered to have high accuracy. Thus, for the XRF data used in the atlas, reference values are determined as the mean of results obtained by analysing the standards accompanying batches H1, H2, E, I1, and I2, except for Cr and Rb, for which reference values are made equal to the results of the KU XRF analyses (Table 6).

The second step is the selection of results which need to be corrected. This is done element by element using the diagrams and tables for the analyses of the standards and element distribution plots. Batches for which the concentration levels of the standards are clearly above or below the reference values (taking the general uncertainty into consideration) need to be adjusted. The batches are corrected individually or in groups whichever appears most appropriate.

The third step is the determination of the correction parameters. The measured values are corrected by linear regression to match the reference values, i.e. the standard values are plotted against the reference values, see Fig. 15. The correction parameters are the constants a and b in the equation of the regression line: $y = ax + b$. Table 7 shows the parameters for all elements and batches.

The actual correction of data sets is the fourth and last step in the calibration procedure. Element distribution plots are made with non-corrected and corrected values and examined visually to check the effect of the corrections made.

Data obtained before the introduction of standards

Major element analyses by GGU XRF.
This concerns batches A, B, I2, I3, J1, J2, L1, O1 and O3.
It is assumed that results for major elements have been stable throughout the period before standards, because major element data from the GGU XRF laboratory are continuously checked against international standards. The standards confirm the stability of the results. The only concerns are Al_2O_3, Na_2O and P_2O_5, which display small variations which could also have affected the non-monitored results.

Trace element analyses by B-C INA of batches A, B and C.
The B-C INA data have been calibrated by means of 25 selected samples which were also analysed by Act INA together with standards. The correlation diagrams are shown in Figure 16. The Act INA results were calibrated against reference values before they were used in the diagrams. There are reasonable correlations for all three batches around $y = x$ for Hf, La and Sc, and corrections were not applied to these elements. The correlation for Co is not well defined and therefore correction of B-C values for Co is not considered meaningful. B-C values for Sm may be corrected by means of a common regression line for the three batches. This is also the case for Th, whereas in the case of Ce the three batches are corrected individually. B-C values for U from all three batches are well correlated with Act INA U values, and batches A and B are also well correlated with Risø DNC values, see Fig. 8a–b. The latter shows that the deviations from the $y = x$ line are insignificant by comparison with the range in regional U concentration, hence corrections are not considered justified.

Trace element analyses by Act INA of batches O1 to O5.

The Act INA analyses of samples from area O were carried out as one batch shortly before the standards were brought into use. None of the samples have been reanalysed together with standards, but it may be assumed that the values for most of elements are lower than the reference values as is the case for the earliest submitted batches accompanied by standards, those from areas I, H and E. Therefore, the correction used for the Act INA elements in Table 7b from area O is the same as that applied to batches H1 and H2.

Trace element analyses by GGU XRF and Risø XRF from area J.

These data can be calibrated by means of 26 samples that have been analysed by Act XRF together with standards. The correlation diagrams for the elements, Fig. 17, show that regressions can be made with confidence for most of the elements. Poor correlations are found for Nb and Y, which should be kept in mind when interpreting the distribution patterns in the geochemical maps for these two elements. The correlation for Ga is so poor that calibration is meaningless, hence the Ga data are left uncalibrated. However, it is noted that the Risø XRF values are in the order of 10 to 15 ppm lower than the values by Act XRF.

Trace element analyses by GGU XRF for batch L1.

No samples from this batch have been analysed by Act XRF, but 154 out of 310 samples have been analysed by Act ICP together with standards. Thus, GGU XRF data for the five elements analysed by both methods may be calibrated as shown in Fig. 18, but it is not possible at the moment to calibrate GGU XRF values for Ba, Cr, Rb and Zr. The Act ICP data provide Cu and Y values for batch L1.

Trace element analyses by Act INA, Risø XRF and GGU XRF from area O.

These data may be calibrated by means of 27 samples submitted for analysis by Act XRF together with standards. Figs 19a–l show that the regression lines are well defined for most elements. The data for Cu (Fig. 19d) show considerable scatter, and the regression line is much influenced by a single point with high Risø XRF Cu. If this point is excluded the regression line has the equation $y = 0.72\,x - 1.4$. In Fig. 19n, where Risø XRF Cu is plotted against GGU AAS Cu, the regression line is very similar, namely $y = 0.71\,x + 3$, and the latter is considered valid for calibrating the Risø XRF Cu data. The Ga diagram does not give a basis for calibration and the Ga data are left uncorrected.

Calibration of V data by GGU XRF presents a more complicated case because the GGU XRF analyses were performed in five batches, see Fig. 19m. The results for batches O1 to O4 appear to follow a common regression line while values for batch O5 fall off the line with higher values. This is in accordance with the situation displayed by the V analysis of the internal standards (Figs 6j and 14i) where the results corresponding to batch O5 form peaks relative to those from batches O2 and O4. As values for V concentrations in standards following batch O5 are close to reference values (see Fig. 14i), V data from batch 5 are not corrected. The non-monitored batches O1 and O3 are corrected in the same way as results for batches O2 and O4 using the regression line based on samples from O1 to O4 (Fig. 19m) with the equation $y = 1.02\,x + 31$. If the values for the standards following batch O4 were used for calibration, the calibration would be very similar in that the regression line for the four standards against reference values has the equation y = 1.03 x + 30. This exercise shows that there is good agreement between calibration parameters obtained using the four internal standards only and parameters obtained using regression of unmonitored against monitored analyses for whole batches.

Effect of calibration

The need for calibration may be illustrated by geochemical maps using uncalibrated and calibrated data. The example, Fig. 20, shows how a shift in concentration level for Cr from one batch to the other (see Fig. 14b) is reflected as false boundaries following the boundaries between batches on the element distribution maps. In the uncalibrated data there appears to be a N-S to NNW-SSE boundary between high and low levels of Cr, while the map of calibrated data shows that the boundary is in fact ENE-WSW trending.

Calibration of atlas data against international standards

The main objective of this report is to demonstrate how the analytical data used to produce the geochemical atlas can be made internally consistent. However, there is a growing demand that surface geochemical data should be made consistent on an international or global scale (Darnley *et al.* 1995), which means that national or regional data should be calibrated against international standards. To be able to do this, a set of eight international standards have been analysed together with our internal standards. The international standards were obtained from the Canadian institute CANMET and comprise the following stream sediment and lake sediment standards: STSD-1, STSD-2, STSD-3, STSD-4, LKSD-1, LKSD-2, LKSD-3, and LKSD-4 (Bowman 1994). The results of the analysis by Act XRF and Act INA are shown in Figs 20 and 21, respectively, while results of analysis by GGU XRF and KU XRF are given in Tables 8 and 9.

Firstly, it is documented how the values used compare with recommended values. As all atlas data are calibrated against the internal reference values, the measured concentrations used in the abscissa of diagrams Figs 21 and 22 have also been calibrated where necessary. The Act XRF data were obtained together with batch Ox, so that the applied corrections are in accordance with those listed in Table 7c. For the Act INA data, a comparison of measured Act INA results with reference values has shown that no corrections are necessary for the elements listed in Table 7b. The CANMET standards were not analysed together with any of the batches used for the atlas, hence the analytical data by Act INA for the accompanying internal standard set (no. 66) are not shown in Fig. 13.

The diagrams, Fig. 21 and 22, show high degrees of correlation for most of the elements. The poorest correlations are found for elements with low concentrations close to the l.l.d. such as Nb, Cs, Eu, Lu and Yb. Also Rb and Zn by INA show poor correlation because of the high l.l.d. for these two elements by this method, see Table 3b. Almost half of the elements are close to y = x, whereas the remainder will require a small correction to be compatible with the international standards.

As expected, the major element analyses by GGU XRF and GGU AAS are very close to the recommended values for the international standards, particularly when calculated as volatile free concentrations (Table 8). Also the trace element analyses by KU XRF are very close to recommended values, except data for Ba, Zn and Zr which are slightly lower than recommended (Table 9). Trace elements by GGU XRF are less accurate because they are determined on glass discs, whereas Cu, determined at GGU by AAS, has good accuracy.

Concluding remarks

Systematic, quality controlled surface geochemical data are increasingly being used by earth and environmental sciences. Hence it is an important task for Geological Survey Organisations to make such data available. In the case of Greenland this has only been economically feasible by using existing data and samples collected originally for mineral exploration purposes. As demonstrated by this report it has required a considerable effort to compile and examine the quality of the existing data, and to produce a reliable, consistent and well documented data set from them. The effort has only been possible because analytical data are stored digitally and can be retrieved easily, and because archived remains of samples could be reanalysed.

The report stresses the need for careful monitoring of analytical data in geochemical mapping programmes by the use of internal as well as international standards.

The way the data have been calibrated is based on an understanding of the nature of the differences between the data sets, obtained by using several kinds of data comparisons, and looking at the analytical conditions element by element. Other more statistically rigorous ways of calibrating data sets have been suggested or used (non-parametric levelling or normalisation, see Darnley et al. 1995) which are based on the assumption that the populations of element concentrations from each of the individual survey areas should be similar. Such methods are attractive because they are faster, but they are not recommended for use here because the size of the survey areas is small compared to the regional lithogeochemical variation so that the assumption about similarity does not hold. In fact, using such kinds of levelling would obscure existing geochemical differences.

The author hopes that the present documentation of data behind the geochemical atlas will convince future users that the distribution patterns displayed by the maps of the geochemical atlas are reliable. In any case, all raw data are accessible and documented, thus permitting any new or better corrections and interpretations to be made as appropriate in the future.

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Appendix 1

Local geochemical exploration within the atlas area

1977 Ndr. Strømfjord stream sediment survey (Watt 1977).
Purpose: uranium exploration. A total of 268 samples were collected in area G, Fig. 1, where uranium anomalies had been recorded by airborne gamma-spectrometry (Secher 1976; Secher 1980). Samples were analysed at Risø National Laboratory (Risø) by Delayed Neutron Counting (DNC) and X-ray Fluorescence Spectrometry (XRF). Later, 60 samples with suitable locations were selected for reanalysis so that they could be included in the reconnaissance survey.

1977 Sarfartôq stream sediment survey (Watt 1977; Secher 1986; Steenfelt 1991).
Purpose: niobium exploration within a carbonatite complex, central part of area I, Fig. 1. A total of 242 stream sediment samples were collected and analysed at Risø by DNC and XRF.

1977 and 1979 Qaqarssuk soil survey (Kunzendorf & Sørensen 1982; Kunzendorf & Secher 1987).
Purpose: niobium and phosphorus exploration within the Qaqarssuk carbonatite complex situated centrally at the western margin of area J, Fig. 1. A total of 190 soil and 61 rock samples were collected and analysed at Risø by DNC and XRF, and at the Geological Survey of Greenland (GGU) by XRF.

1978 Sarfartôq soil survey (Nielsen 1982; Secher 1986).
Purpose: base metal exploration in the vicinity of the Sarfartôq carbonatite complex, central part of area I. A total of 52 soil samples were collected together with heavy mineral concentrates of stream sediment and plant leaves. The samples were analysed at Risø by DNC and XRF.

1982 Maniitsoq district, soil survey (Jensen & Secher 1983; Secher 1983; Secher & Stendal 1989).
Purpose: nickel exploration in noritic intrusions along the western margin of area J. A total of 1059 soil and 112 rock samples were collected and analysed at Geological Institute, University of Copenhagen, by Atomic Absorption Spectrometry (AAS); selected samples were also analysed at Risø by XRF.

1982 and 1984 SYDEX geochemical exploration in South Greenland (Armour-Brown et al. 1984, Nyegaard & Armour-Brown 1986).
Purpose: detailed uranium exploration at a number of selected localities within area O. Sample types include soil, heavy mineral concentrates of stream sediments, water, resin ion sorbents, and rocks. Samples have mostly been analysed at Risø.

1987 Kobberminebugt soil survey (unpublished).

Purpose: gold exploration in the vicinity of two small, abandoned copper mines in area O, just south of 61°N. A total of 207 soil and 15 stream sediment samples were collected and analysed at Bondar-Clegg laboratories Ltd. by Instrumental Neutron Activation Analysis (INA) and at GGU by XRF.

1987 Motzfeldt Sø rock geochemical survey (Thomassen 1988)

Purpose: Assessment of niobium and tantalum mineralisation in the north-eastern part of area O. A total of 928 rock samples were collected systematically over 1.8 km^2 of mountain slope and analysed at Bondar-Clegg and Co. Ltd. by INA for Nb, Ta, U, Th, Ce, La, Y, Be, Li, Sn and Mo. In addition 29 heavy mineral concentrates of stream sediments were collected and analysed.

1991 Bjørnesund stream sediment survey (partly published in Erfurt et al. 1991).

Purpose: gold exploration. A total of 227 samples were collected fairly densely along the shores of Bjørnesund, southernmost part of area M, and analysed at Activation Laboratories Ltd. by INA and AAS, and at GGU by XRF. Data from suitably located samples within this collection were included in the regional geochemical reconnaissance database used for the atlas.

1994 and 1996 Suprasyd reconnaissance prospecting (Swager et al. 1995 and unpublished data).

Purpose: gold exploration. Fine fractions of stream sediment and heavy mineral concentrates were collected at 22 stream localities within South-East Greenland (area P). The samples were analysed at Activation Laboratories Ltd. by INA and by Inductively Coupled Plasma Emission Spectrometry after aqua regia extraction.

Surveys using heavy mineral concentrates of stream sediment.

Panned heavy mineral concentrates of stream sediment have been used for local and regional mineral exploration (Appel 1989; Erfurt *et al*. 1992; Thorning *et al*. 1994; Swager *et al*. 1995).

Appendix 2

Analytical procedures in the Rock Geochemical Laboratory at the Geological Survey of Denmark and Greenland, Copenhagen

Samples are routinely ground in a tungsten carbide ball mill. If specified, samples can be ground in a tungsten carbide or agate swingmill.

Most elements are determined by X-ray fluorescence (XRF) analysis on fused glass discs. The rock powders are dried at 110°C for 2 hours and ignited at 1000°C for 1 hour, with subsequent determination of the loss on ignition. The ignited samples are mixed with sodium tetraborate in the ratio 0.7500 g sample to 5.2500 g borate, and fused in Pt/Au crucibles under continuous agitation for 1–1½ hours. After inspection for homogeneity the melts are poured into Pt/Au molds, creating glass discs with 32 mm diameter. The X-ray fluorescence spectrometer is a Philips PW1606 multichannel instrument with a Rh-anode X-ray tube. Calibration and correction for background and line overlaps are calculated from measurements on synthetic mono-element glass discs, and corrections for matrix effects are calculated either from measurements on synthetic glass discs or from the absorption coefficients of Heinrich (1966) (Sørensen, 1975,1976).

Na_2O and Cu are determined by atomic absorption spectrometry (AAS). Each dried sample (0.25 – 0.5 g) is treated with hydrofluoric acid in a PTFE beaker on a heating plate. After evaporation to dryness the residue is dissolved in a hydrochloric acid/potassium chloride solution, made up to 50 ml, and Na and Cu measured on a Perkin-Elmer PE2280 AAS instrument.

For FeO determination each dried sample (0.1 g) is treated with ammonium vanadate / hydrofluoric acid overnight. Boric acid and a measured amount of iron(II) are added and surplus iron(II) is determined by automatic potentiometric titration using Cr(VII) as titrant. The method is a modification of Wilson (1955).

'Volatiles' is calculated as the loss on ignition corrected for the calculated gain of weight due to oxidation of iron(II) to iron(III) during ignition.

A number of the spectrometer channels are used to measure trace element concentrations in the glass discs at the same time as the major elements are measured. Calibration and correction for background, line overlaps and matrix effects are done as described above for the major elements. The use of glass discs for trace element analysis, in contrast to the normally used pressed powder pellets, poses some problems. Firstly, the weaker signal due to the flux dilution gives higher lower limits of detection (LLD). Secondly, the calculated corrections for backgrounds and spectral overlaps are not always entirely adequate. The method works satisfactorily for the elements V, Cr, Ni, Zn, Sr and Zr whereas there are problems with Rb, Y, Nb and Ba. Other elements measured are Mo, Sn, La and Ce, but these give poor results and are generally not used. Because of the high LLDs, concentrations of Rb, Nb and Y in most geological materials are beyond the limitation of the method.

The determination of trace element concentrations commenced in 1986, and in the beginning there were problems with reproducibility for a number of the elements. In particular, significant absolute variations between different calibrations were observed. Since 1993 the analytical results for the elements shown in the following tables are regarded as reliable at the level of concentrations shown as recommended.

JK & LML

Quality of results

Major elements

Element	Line	Precision wt%	LLD, recommended wt%	LLD, theoretical wt%
SiO_2	Kα	0.15	0.3	0.01
TiO_2	Kα	0.015	0.03	0.002
Al_2O_3	Kα	0.05	0.1	0.05
FeO	-	0.1	0.2	0.0015
Fe_2O_3, tot	Kα	0.1	0.2	-
MnO	Kα	0.003	0.005	0.001
MgO	Kα	0.05	0.10	0.05
CaO	Kα	0.03	0.05	0.0007
Na_2O	-	0.05	0.08	-
K_2O	Kα	0.005	0.01	0.003
P_2O_5	Kα	0.005	0.01	0.002
Volat	-	0.10	-	-

Trace elements

Element	Line	Precision ppm	LLD, recommended ppm	LLD, theoretical ppm	Quality
V	Kα	20	50	10	good
Cr	Kα	40	50	10	good
Ni	Kα	15	50	5	good
Cu	-	2	5	3	good
Zn	Kα	10	50	3	good
Rb	Kα	20	50	3	acceptable
Sr	Kα	20	50	2	good
Y	Kα	20	100	2	variable
Zr	Kα	30	50	2	variable; good from 1993
Nb	Kα	20	50	2	poor
Ba	Kα	60	100	80	acceptable

- Precision: 1 standard deviation based on experimental data (repeated analysis over time of a set of internal standards).
- LLD, recommended: These values (~ 1 standard deviation) are based on user experience with the analytical results and are not calculated figures. They include the facts that the above mentioned corrections are not always adequate for samples with strongly contrasting matrices and that there may be variations between different calibrations. For sets of samples with similar matrices run under the same calibration, the effective LLD will normally be somewhat lower.
- LLD, theoretical: 3 * counting statistic error.

Table 1. *List of stream sediment surveys contributing to the geochemical atlas*

Year of sampling	Area code	Survey name and map sheet	Survey character	Sampling density	Responsible collector
1977	G	Ndr.Str., 67 V1	Local U exploration	Detailed*	M. Watt
1979	L	Ghb 79, 64 V	Local U exploration	Irregular*	A. Steenfelt
1979	O	Syduran, 59-61 V	Regional U exploration	1 per 5-6 km^2	A. Armour-Brown
1981	I	66 V2	Geochemical mapping	1 per 25-30 km^2	A. Steenfelt
1981	K	AST reco, 65 V1	Local U exploration	Irregular*	A. Steenfelt
1981	L	AST reco, 64 V	Local U exploration	Irregular*	A. Steenfelt
1982	I	66 V2	Geochemical mapping	1 per 25-30 km^2	K. Holme
1982	J	65 V2	Geochemical mapping	1 per 25-30 km^2	K. Holme
1985	M	PA reco 63 V1	Tungsten exploration	Irregular*	C. Clausen
1986	B	69-70 V2	Geochemical mapping	1 per 25-30 km^2	A. Steenfelt
1986	I	66 V2	"Filling of gaps"	1 per 25-30 km^2	A. Steenfelt
1986	L	64 V	Geochemical mapping	1 per 25-30 km^2	A. Steenfelt
1988	A	Nuussuaq, 70 V2	Geochemical mapping	1 per 25-30 km^2	A. Steenfelt
1989	C	Ilimanaq, 68 V2	Geochemical mapping	1 per 25-30 km^2	A. Steenfelt
1990	H	67 V2	Geochemical mapping	1 per 25-30 km^2	A. Steenfelt
1991	E	Chr. Håb, 68 V2	Geochemical mapping	1 per 25-30 km^2	J. P. Nielsen
1991	M	Buksefj., 62-63 V	Geochemical mapping	1 per 25-30 km^2	P. Erfurt
1992	F	66+67 V1	Geochemical mapping	1 per 25-30 km^2	A. Steenfelt/J.P. Nielsen
1992	P	Suprasyd, 60-61 Ø	Geochemical mapping	1 per 25-30 km^2	P. Erfurt
1993	D	Aasiaat, 68 V1	Geochemical mapping	1 per 25-30 km^2	A. Petersen
1993	I	66 V2	"Filling of gaps"	1 per 25-30 km^2	A. Steenfelt
1993	K	Maniitsoq, 65 V1	Geochemical mapping	1 per 25-30 km^2	A. Steenfelt
1993	L	64 V	"Filling of gaps"	1 per 25-30 km^2	A. Steenfelt
1993	M	63 V1	"Filling of gaps"	1 per 25-30 km^2	A. Steenfelt
1993	N	Paamiut, 61-62 V1	Geochemical mapping	1 per 25-30 km^2	A. Steenfelt

* *A number of samples with a spacing corresponding to 1 sample per 25 km^2 were selected for the atlas.*

Table 2. *List of samples selected for the atlas and their analytical treatment by area and batch.*

Area code	Batch code	Survey name or map sheet	Year of sampling	Stream sediment sample series	Total selected	Total major		Total trace							
						GGU XRF	Act XRF	Act XRF	GGU XRF	GGU *Cu	Risø XRF	Risø DNC	Act INA	B-C INA	Act ICP
A		Nuussuaq	1988	330701-836	90	*89*			*89*	*89*		*56*	8	*73*	
B		69+70 V2	1986	330401-668	266	*265*			*265*	260		*101*	5	*131*	
C		Ilimanaq	1989	330901-971	66	66		43	66	0			8	*60*	
D		Aasiaat	1993	381966-382060	90	88		86	88	88			90		
E		Chr. håb	1991	380001-303	266	247		219	247	247			266		
F		66+67 V1	1992	380401-381149	706		582	679					693		
G		Ndr.Str.	1977	193001-598	59		48	48			*59*	*59*	59		
H		67 V2	1990	368001-367	352	342		262	342	342			351		
I	I1	66 V2	1981	306001-150,306201-251	175	174		125	174	174	*175*	*175*	163		
	I2	66 V2	1982	306401-548	123	*123*		112	*123*	*123*	*123*	*123*	121		
	I3	66 V2	1986	330670-695	10	*10*			*10*	*10*		*2*		*2*	
J		65 V2	1982	309101-700,301701-754	392	*387*		26	*387*	0	*390*	*392*	185	*354*	
K	K1,K2	65 V1	1993	381742-965	213	185		173	185	185			211		
	K3	AST reco	1981	306301-336	4	4			4	4	*4*	*4*	3		
L	L1	64 V1+2	1986	330001-330340	312	*311*			*310*	0		*123*	159	*98*	154
	L2	Ghb 79	1979	263124-392	24	24			24	24	*24*	*24*	24		
	L3	AST reco	1981	306337-367	4	4			4	4	*4*	*4*	3		
	L4	64 V1+2	1993	381725-741	17	11		7	11	11			17		
M	M1,M2	63 V1+2	1991	386001-500	273	219		209	219	219			273		
	M3	63 V1	1993	381692-724	31	31		22	31	31			31		
	M4	PA reco	1985	329501-583	27	24			11	11			19		
N		Paamiut	1993	381401-691	275	216		211	216	216			275		
O		Syduran	1979	280002-282926	2456	1096		27	1095	1094	*2286*	*2330*	*2185*		
P		Suprasyd	1992	386701-845	141		132	140					141		
Grand total					6372	3916	762	2389	3901	3132	3065	3393	5290	718	154

Numbers in italics mark analyses made without internal standards.

Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);* Risø *(Risø National Laboratory);* B-C *(Bondar-Clegg and Co. Ltd.).*

Methods: XRF *(X-ray Fluorescence Spectrometry);* DNC *(Delayed Neutron Counting);* INA *(Instrumental Neutron Activation);* ICP *(Inductively Coupled Plasma Emission Spectrometry). * Cu analyses at GGU are made by Atomic Absorption Spectrometry.*

Table 3a. *Major elements determined in analytical packages used for the atlas.*

XRF glass		XRF powder	AAS	INA		ICP
GGU	Act	Risø plu	GGU	Act	B-C	Act
SiO_2	SiO_2					
TiO_2	TiO_2	Ti				Ti
Al_2O_3	Al_2O_3					Al
Fe_2O_3	Fe_2O_3			Fe	Fe	
MnO	MnO	Mn				Mn
MgO	MgO					Mg
CaO	CaO	Ca				Ca
	Na_2O		Na	Na	Na	
K_2O	K_2O	K				K
P_2O_5	P_2O_5					P
L.o.i.	L.o.i.					

L.o.i.: *Loss on ignition.*

Methods: XRF *(X-ray Fluorescence Spectrometry);* plu *(XRF with plutonium source);* AAS *(Atomic Absorption Spectrometry);* INA *(Instrumental Neutron Activation);* ICP *(Inductively Coupled Plasma Emission Spectrometry).*

Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);* Risø *(Risø National Laboratory);* B-C *(Bondar-Clegg and Co. Ltd.).*

Table 3b. *Trace elements determined in analytical packages used for the atlas.*

XRF glass		**XRF powder**						**INA**				**ICP**	
GGU		**Act**		**Risø plu**		**Risø cd**		**Act**		**B-C**		**Act**	
	l.l.d.		l.l.d.		l.l.d.		l.l.d.		l.l.d.		l.l.d.		l.l.d.
								Ag	5	**Ag**	5	**Ag**	0.5
								As	2	**As**	1		
								Au	0.005	**Au**	0.005		
Ba	100	**Ba**	5					**Ba**	100	**Ba**	100		
								Br	1	**Br**	1		
										Cd	10	**Cd**	0.5
								Ce	3	**Ce**	10		
		Co	5					**Co**	5	**Co**	10		
Cr	50	**Cr**	5	**Cr**	50			**Cr**	10	**Cr**	50		
								Cs	2	**Cs**	1		
***Cu**	5	**Cu**	5	**Cu**	10							**Cu**	1
								Eu	0.2	**Eu**	2		
		Ga	5	**Ga**	10								
								Hf	1	**Hf**	2		
								Hg	1				
								Ir	5	**Ir**	100		
								La	1	**La**	5		
								Lu	0.05	**Lu**	0.5		
						(Mo)	20	**Mo**	5	**Mo**	2	**Mo**	2
(Nb)	50	**Nb**	2			**Nb**	20						
								Nd	5				
Ni	50	**Ni**	5	**Ni**	10			**Ni**	50	**Ni**	20	**Ni**	1
		(Pb)	5	**(Pb)**	10							**Pb**	5
Rb	50	**Rb**	2			**Rb**	20	**Rb**	30	**Rb**	10		
								Sb	0.2	**Sb**	0.2		
								Sc	0.1	**Sc**	0.5		
								Se	5	**Se**	10		
								Sm	0.1	**Sm**	0.2		
								Sn	100	**Sn**	200		
Sr	50	**Sr**	2			**Sr**	20	**Sr**	500			**Sr**	1
								Ta	1	**Ta**	1		
								Tb	**0.5**	**Tb**	1		
										Te	20		
								Th	0.5	**Th**	0.5		
				****U**	0.016			**U**	0.5	**U**	0.5		
V	50	**V**	5	**(V)**	50							**V**	2
								W	4	**W**	2		
(Y)	100	**Y**	2			**Y**	20					**Y**	2
								Yb	0.2	**Yb**	5		
Zn	50	**Zn**	5	**Zn**	10			**Zn**	50	**Zn**	200	**Zn**	1
Zr	50	**Zr**	5			**Zr**	20			**Zr**	500		

Lower limits of detection (l.l.d.) in ppm. Elements in blue are never or very rarely above l.l.d.
Elements in parentheses have poor precision.
** Cu determined by Atomic Absorption Spectrometry.*
*** U determined by Delayed Neutron Counting.*
Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);* Risø *(Risø National Laboratory);* B-C *(Bondar-Clegg and Co. Ltd.).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* plu *(XRF with plutonium source);* cd *(XRF with cadmium source);* DNC *(Delayed Neutron Counting);* INA *(Instrumental Neutron Activation);* ICP *(Inductively Coupled Plasma Emission Spectrometry).*

Table 4. *Analytical data sets selected for the atlas.*

Batch code	**Major elements**	**Non-calibratable trace elements by INA and DNC**			**Calibratable trace elements by INA**		**Calibratable trace elements mainly by XRF**		
		As,Au,Br,Cs, Mo,Sb,Ta,W	Nd,Lu	U	Eu,Yb	Ce,Co,Hf,La, Sc,Sm,Th	Ba,Cr	Ni,Sr	V
A	GGU*	B-C INA	Act INA (few)	Risø DNC	Act INA (few)	B-C INA*	GGU XRF*	GGU XRF*	GGU XRF*
B	GGU*	B-C INA	Act INA (few)	Risø DNC	Act INA (few)	B-C INA*	GGU XRF*	GGU XRF*	GGU XRF*
C	GGU	B-C INA	Act INA (few)	B-C INA*	Act INA (few)	B-C INA*	Act XRF	Act XRF	Act XRF
D	GGU	Act INA	Act INA	Act INA	Act INA	Act INA	Act XRF	Act XRF	Act XRF
E	GGU	Act INA	Act INA	Act INA	Act INA	Act INA	Act XRF	Act XRF	Act XRF
F	Act	Act INA	Act INA	Act INA	Act INA	Act INA	Act XRF	Act XRF	Act XRF
G	Act	Act INA	Act INA	Risø DNC	Act INA	Act INA	Act XRF	Act XRF	Act XRF
H1,H2	GGU	Act INA	Act INA	Act INA	Act INA	Act INA	Act XRF	Act XRF	Act XRF
I1	GGU	Act INA	Act INA	Risø DNC	Act INA	Act INA	Act XRF	Act XRF	Act XRF
I2	GGU*	Act INA	Act INA	Risø DNC	Act INA	Act INA	Act XRF	Act XRF	Act XRF
I3	GGU*	B-C INA	no data	Risø DNC	no data	B-C INA*	GGU XRF*	GGU XRF*	GGU XRF*
J1, J2	GGU*	Act INA	Act INA	Risø DNC	Act INA	Act INA	GGU XRF*	GGU XRF*	GGU XRF*
I4, K1, K2	GGU	Act INA	Act INA	Act INA	Act INA	Act INA	Act XRF	Act XRF	Act XRF
K3	GGU	Act INA	Act INA	Risø DNC	Act INA	Act INA	GGU XRF	GGU XRF	GGU XRF
L1	GGU*	Act INA	Act INA	Act INA+B-C INA	Act INA	Act INA	GGU XRF*	GGU XRF*	GGU XRF*
L2, L3	GGU	Act INA	Act INA	Risø DNC	Act INA	Act INA	GGU XRF	GGU XRF	GGU XRF
L4	GGU	Act INA	Act INA	Act INA	Act INA	Act INA	Act XRF	Act XRF	Act XRF
M1,M2,M3	GGU	Act INA	Act INA	Act INA	Act INA	Act INA	Act XRF	Act XRF	Act XRF
M4	GGU	Act INA	Act INA	Act INA	Act INA	Act INA	GGU XRF	GGU XRF	GGU XRF
N1, N2	GGU	Act INA	Act INA	Act INA	Act INA	Act INA	Act XRF	Act XRF	Act XRF
O1 to O5	GGU*	Act INA	Act INA	Risø DNC	Act INA*	Act INA*	Act INA*	Risø XRF*	GGU XRF
P	Act	Act INA	Act INA	Act INA	Act INA	Act INA	Act XRF	Act XRF	Act XRF

* analysed without standards

Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);* Risø *(Risø National Laboratory);* *B-C (Bondar-Clegg and Co. Ltd.).*

Methods: XRF *(X-ray Fluorescence Spectrometry);* DNC *(Delayed Neutron Counting);* INA *(Instrumental Neutron Activation);* ICP *(Inductively Coupled Plasma Emission Spectrometry);* AAS *(Atomic Absorption Spectrometry).*

Table 4 *(continued)*

Batch code	**Calibratable trace elements mainly by XRF**				
	Rb,Zn,Zr	Nb	Y	Ga	Cu
A	GGU XRF*	GGU XRF(poor)	GGU XRF(poor)	no data	GGU AAS
B	GGU XRF*	GGU XRF(poor)	GGU XRF	no data	GGU AAS
C	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
D	Act XRF	Act XRF	Act XRF	Act XRF	GGU AAS
E	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
F	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
G	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
H1,H2	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
I1	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
I2	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
I3	GGU XRF*	GGU XRF(poor)	GGU XRF(poor)	no data	GGU AAS
J1, J2	Risø XRF*	Risø XRF*	Risø XRF*	Risø XRF*	Risø XRF*
I4, K1, K2	Act XRF	Act XRF	Act XRF	Act XRF	GGU AAS
K3	GGU XRF	Risø XRF*	Risø XRF*	Risø XRF*	GGU AAS
L1	GGU XRF*	GGU XRF(poor)	Act ICP	no data	Act ICP
L2, L3	GGU XRF	Risø XRF*	Risø XRF*	Risø XRF*	GGU AAS
L4	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
M1,M2,M3	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF
M4	GGU XRF	GGU XRF	GGU XRF	no data	GGU AAS
N1, N2	Act XRF	Act XRF	Act XRF	Act XRF	GGU AAS
O1 to O5	Risø XRF*	Risø XRF*	Risø XRF*	Risø XRF*	Risø XRF*
P	Act XRF	Act XRF	Act XRF	Act XRF	Act XRF

Table 5. *Identification numbers for sets of internal standards submitted together with sample batches and international standards (CANMET)*

Batch code	Stream sediment sample numbers	GGU XRF major+ trace	Act XRF major	Act XRF trace	Act INA trace	B-C INA trace	Risø XRF trace	Risø DNC U	Act ICP trace	GGU AAS Cu
		std id#	**std id#**	**std id#**	**std id#**	**std id#**	**std id#**	**std id#**	**std id#**	**std id#**
A	330701-836	none			98	none				155
B	330401-668	none			98	none				155.1,2
C	330901-971	11.0		148	98	none				
D	381966-382060	90		89	88					
E	380001-303	24.0		103	21					
F1	380401-600		53	52	51					
F2	380602-800		56	55	54					
F3	380801-381000		59	58	57					
F4	381001-149		62	61	60					
G	193001-598		72	71	25		none	none		
H1	368001-221	13.0		102	14					
H2	368222-367	13.1		102	14					
I1	306001-150,201-251	17		104	06,07,08		none	none		
I2	306401-548	none		104	06,07,08		none	none		
I3	330670-695	none				none		none		
J1	301701-754	none			135	none	none	none		
J2	309101-700	none			135	none	none	none		
K1	381742-900	85		84	83					
K2	381901-965	90		89	88					
K3	306301-337	75			76		none	none		
L1	330001-330340	none			133	none			133	
L2	263201-276,320-386	74			76		none	none		
L2	263124-200,278-298	75			76		none	none		
L3	306337-367	75			76		none	none		
L4	381725-741	81		148	87					
M1	386001-170	29		147	22					
M2	386171-500	29		148	22					
M3	381692-724	81		148	87					
M4	329501-583	75			76					
N1	381401-550	77		79	78					
N2	381551-691	81		82	80					
O1	280002-607	none			none					
O2	280608-281000	11.1			none					
O3	281002-281518	none			none					
O4	281519-835	24.1			none					
O5	281836-282926	18			none					
P	386701-845		49	48	47					
Jx	26 selected			156						
Ox	27 selected+CANMET			165						
	CANMET				66					
	CANMET	169								

Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);* Risø *(Risø National Laboratory);* B-C *(Bondar-Clegg and Co. Ltd.).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* DNC *(Delayed Neutron Counting);* INA *(Instrumental Neutron Activation);* ICP *(Inductively Coupled Plasma Emission Spectrometry);* AAS *(Atomic Absorption Spectrometry).* std #*: identification number of a standard set; see text for explanation of full id-numbers of individual standards within a set.*

Table 6. *Reference values for calibration of analytical values*

Major elements

Levels represent means of GGU XRF analyses of standard sets 74 to 94 calculated as volatile free.

	std 1	std 2	std 3	std 5
SiO_2	67.95	67.37	62.94	54.28
TiO_2	0.454	0.408	0.913	1.508
Al_2O_3	14.06	13.93	13.04	14.31
Fe_2O_3	4.32	4.70	6.76	11.25
MnO	0.08	0.09	0.10	0.17
MgO	2.80	3.64	5.14	8.54
CaO	4.36	3.24	5.43	6.72
Na_2O	3.67	3.66	3.16	1.59
K_2O	1.78	2.31	2.10	1.01
P_2O_5	0.18	0.11	0.20	0.14

Trace elements

XRF. Values represent medians of Act XRF analyses of standard sets 102 to 104, except for Cr, Zn and Rb.

	std 1	std 2	std 3	std 5	Comments
Ba	436	534	653	256	
Cr	205	249	668	1242	values are set equal to data by KU XRF
Cu	14.3	22.7	44	76	
Ga	very poor reproducibility, no calibration by regression				
Nb	10	6	4.7	9	
Ni	76	137	150	296	
Pb	very poor reproducibility, data not included in atlas				
Rb	60	78	48	28	values are set equal to data by KU XRF
Sr	255	251	269	168	
V	69	60	176	258	
Y	23.7	19.7	18.7	24.7	
Zn	40.3	58	43.7	77	reference is mean of std 52 to 61
Zr	378	165	456	231	

INA. Values are determined as medians of standard sets 51 to 135; or they are the same as for XRF.

	std 1	std 2	std 3	std 5	
Ba	436	534	653	256	
Co	16	20	29	50	
Cr	205	249	668	1242	values are set equal to data by KU XRF
Hf	15	6	17	8	
Rb	60	78	48	28	values are set equal to data by KU XRF
Sc	13	11	22	not used	
Th	no obvious changes in the concentrations levels, corrections not justified				
U	corrections not justified				
La	28.27	28.91	43.4	18.25	
Ce	48.6	48.67	72.8	36.27	
Nd	very poor reproducibility, no calibration attempted				
Sm	3.74	3.45	4.5	not used	
Eu	1.09	0.9	1.34	not used	
Yb	2.9	2	2.1	3.17	
Lu	poor reproducibility, no calibration attempted				

Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* INA *(Instrumental Neutron Activation).*

Table 7a. *Regression line parameters for calibration of major element volatile-free oxide data determined by X-ray Fluorescence Spectrometry.*

Batch code	**Stream sediment sample numbers**		**SiO_2**		**TiO_2**		**Al_2O_3**		**Fe_2O_3**	**MnO**	**MgO**	**CaO**		**Na_2O**		**K_2O**	**P_2O_5**	
			a	**b**	**a**	**b**	**a**	**b**				**a**	**b**	**a**	**b**		**a**	**b**
A	330701-836	GGU*	n						n	n	n	n		n		n		
B	330401-668	GGU*	n						n	n	n	n		n		n		
C	330901-971	GGU	n				0.9	1.2	n	n	n	n		0.93	0.15	n	1.02	-0.015
D	381966-382060	GGU	n						n	n	n	n		n		n	n	
E	380001-303	GGU	n						n	n	n	n		n		n	0.78	0.03
F1	380401-600	Act	1.044	-1.922	0.979	-0.04			n	n	n	0.97	-0.1	0.89	0.34	n	1.1	-0.026
F2	380602-800	Act	1.044	-1.922	0.979	-0.04			n	n	n	0.97	-0.1	0.89	0.34	n	1.1	-0.026
F3	380801-381000	Act	1.044	-1.922	0.979	-0.04			n	n	n	0.97	-0.1	0.89	0.34	n	1.1	-0.026
F4	381001-149	Act	1.044	-1.922	0.979	-0.04			n	n	n	1.07	-0.84	0.89	0.34	n	1.1	-0.026
G	193001-598	Act	n		1.022	-0.06			n	n	n	0.95	0.06	0.89	0.34	n	n	
H1,H2	368001-367	GGU	n		n		0.94	0.95	n	n	n	n		1.05	-0.04	n	n	
I1	306001-150,201-251	GGU	n		n		0.95	0.96	n	n	n	n		n		n	n	
I2	306401-548	GGU*	n		n		n		n	n	n	n		n		n	n	
I3	330670-695	GGU*	n		n		n		n	n	n	n		n		n	n	
J1,J2	301701-754,309101-700	GGU*	n		n		n		n	n	n	n		n		n	n	
I4,K1,K2	381742-965	GGU	n		n		n		n	n	n	n		n		n	n	
K3,L2,L3	306301-367, 263124-392	GGU	n		n		n		n	n	n	n		n		n	n	
L1	330001-330340	GGU*	n		n		n		n	n	n	n		n		n	n	
L4,M3	381692-741	GGU	n		n		n		n	n	n	n		n		n	n	
M1,M2	386001-500	GGU	n		0.918	0.02	n		n	n	n	n		1.07	-0.05	n	n	
M4	329501-583	GGU	n		n		n		n	n	n	n		n		n	n	
N1,N2	381401-691	GGU	n		n		n		n	n	n	n		n		n	n	
O1	280002-607	GGU*	n		n		n		n	n	n	n		n		n	n	
O2	280608-281000	GGU	n		n		0.94	0.95	n	n	n	n		0.93	0.15	n	n	
O3	281002-281518	GGU*	n		n		n		n	n	n	n		n		n	n	
O4	281519-835	GGU	n		n		n		n	n	n	n		n		n	n	
O5	281836-282926	GGU	n		n		0.89	1.4	n	n	n	n		n		n	0.91	0.03
P	386701-845	Act	0.98	0.97	1.037	0.02	0.8	2.55	n	n	n	0.96	0.03	0.81	0.58	n	0.83	0.05

Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);*

a, b*: parameters in the equation for the regression line y=ax+b used for calibrating measured concentrations to reference concentration levels.*

n: *no correction required. * analysed without standards.*

Table 7b. *Regression line parameters for calibration of trace element data determined mostly by Instrumental Neutron Activation Analysis.*

Batch	Stream sediment		Co		Ce		Hf		La		Sc		Sm		Th			Eu		Yb			U
code	sample numbers	INA	a	b	a	b	a	b	a	b	a	b	a	b	a	b	INA	a	b	a	b		
A	330701-836	B-C[1]	n		0.75	5.1	n		n		n		0.74	-0.34	0.73	0.43	no data					Risø DNC	n
B	330401-668	B-C[1]	n		0.9	27.2	n		n		n		1.26	-1.72	0.73	0.43	no data					Risø DNC	n
C	330901-971	B-C[1]	n		1.27	-12.2	n		n		n		1.26	-1.72	0.73	0.43	no data					B-C INA	n
D	381966-382060	Act	n		1.22	-0.7	n		n		n		1.28	-0.56	n		Act	n		0.81	0.33	Act INA	n
E	380001-303	Act	1.23	-0.36	n		n		1.1	1.46	1.26	-1.5	1.14	0	n		Act	1.33	-0.17	n		Act INA	n
F1	380401-600	Act	n		n		n		n		n		1.08	0.47	n		Act	1.28	-0.1	0.88	0.48	Act INA	n
F2	380602-800	Act	n		n		n		n		n		0.51	1.8	n		Act	0.79	0.13	0.93	-0.06	Act INA	n
F3	380801-381000	Act	n		n		n		n		n		n		n		Act	n		n		Act INA	n
F4	381001-149	Act	n		n		0.86	0.5	n		n		n		n		Act	n		n		Act INA	n
G	193001-598	Act	1.15	-0.44	1.42	-5	n		1.14	0.17	n		1.08	0.47	n		Act	1.55	-0.3	1.27	-0.03	Risø DNC	n
H1,H2	368001-367	Act	1.02	1.8	1.15	1.44	1.2	0.28	1.1	1.46	1.18	1.3	1	1	n		Act	1.28	0	1.09	0.19	Act INA	n
I1	306001-150,201-251	Act	1.13	0	1.15	1.44	1.2	0.28	1.1	1.46	1.18	1.3	1	1	n		Act	1.28	0	1.09	0.19	Risø DNC	n
I2	306401-548	Act	1.13	0	1.15	1.44	1.2	0.28	1.1	1.46	1.18	1.3	1	1	n		Act	1.28	0	1.09	0.19	Risø DNC	n
I3	330670-695	B-C[1]	n		0.9	27.2	n		n		n		1.26	-1.72	0.73	0.43	no data					Risø DNC	n
J1	301701-754	Act	n		n		n		n		n		1.67	-1.9	n		Act	n		1.08	0.09	Risø DNC	n
J2	309101-700	Act	n		n		n		n		n		1.67	-1.9	n		Act	n		1.08	0.09	Risø DNC	n
K1	381742-900	Act	n		n		0.8	0.2	n		0.92	-0.6	n		n		Act	0.8	0.1	0.81	0.33	Act INA	n
K2	381901-965	Act	n		1.22	-0.7	n		n		n		1.28	-0.56	n		Act	n		0.81	0.33	Act INA	n
K3,L2,L3	306301-367, 263124-392	Act	n		n		n		n		n		n		n		Act	n		1.23	-0.17	Risø DNC	n
L1	330001-330340	Act	n		0.76	6.2	n		n		n		0.69	0.66	n		Act	0.79	0.13	0.73	0.61	Act INA	n
L4,M3	381692-741	Act	n		n		0.9	0.6	n		n		n		n		Act	n		0.81	0.33	Act INA	n
M1,M2	386001-500	Act	1.06	-1.25	n		n		n		n		n		n		Act	n		n		Act INA	n
M4	329501-583	Act	n		n		n		n		n		n		n		Act	n		1.23	-0.17	Act INA	n
N1	381401-550	Act	n		n		0.99	-1.3	n		n		n		n		Act	n		0.81	0.22	Act INA	n
N2	381551-691	Act	n		n		1.05	1	n		n		n		n		Act	n		1.1	0.13	Act INA	n
O1- O5	280002-282926	Act*	1.13		1.15	1.44	1.2	0.28	1.1	1.46	1.18	1.3	1	1	n		Act*	1.28	0	1.09	0.19	Risø DNC	n
P	386701-845	Act	1.02	1.7	1.14	0.65	1.3	-0.5	1.14	0.17	n		1.08	0.47	n		Act	1	0.2	1.27	-0.03	Act INA	n
A,B,C	25 selected	Act	n		1.22	-0.7	n		n		n		1.28	-0.56	n		Act	0.79	0.28	0.98	0.04	ActINA	n

Laboratories: Act *(Activation Laboratories Ltd.);* B-C *(Bondar-Clegg and Co. Ltd.);* Risø *(Risø National Laboratory).*
Methods: INA *(Instrumental Neutron Activation);* DNC *(Delayed Neutron Counting)*
a, b*: parameters in the equation for the regression line y=ax+b used for calibrating measured concentrations to reference concentration levels.* n*: no calibration required;*

[1] Calibrated via 25 samples analysed at Act INA together with standards; * same calibration as batch I1.

Table 7c. *Regression line parameters for calibration of trace element data determined mostly by X-ray Fluorescence Spectrometry.*

Batch	Stream sediment		Ba		Cr			Ni		Sr			V	
code	sample numbers		a	b	a	b		a	b	a	b		a	b
A	330701-836	GGU XRF	imp		imp		GGU XRF	imp		imp		GGU XRF	imp	
B	330401-668	GGU XRF	imp		imp		GGU XRF	0.99	-15	1.24	-24	GGU XRF	0.86	18
C	330901-971	Act XRF	0.93	28	n		Act XRF	n		1.05	-1	Act XRF	n	
D	381966-382060	Act XRF	1.22	-24	n		Act XRF	0.85	9	n		Act XRF	1.056	-20
E	380001-303	Act XRF	n		1	-50	Act XRF	n		1.07	-8	Act XRF	n	
F1	380401-600	Act XRF	1.22	-100	1	35	Act XRF	n		1.09	-1	Act XRF	1.36	-13
F2	380602-800	Act XRF	1.22	-100	1	35	Act XRF	n		1.09	-1	Act XRF	1.36	-13
F3	380801-381000	Act XRF	1.22	-100	1	35	Act XRF	n		1.09	-1	Act XRF	1.36	-13
F4	381001-149	Act XRF	1.22	-100	1	35	Act XRF	n		1.07	-8	Act XRF	1.36	-13
G	193001-598	Act XRF	1.28	-71	1	35	Act XRF	n		1.07	-8	Act XRF	0.92	31
H1,H2	368001-367	Act XRF	n		1	-50	Act XRF	n		n		Act XRF	n	
I1	306001-150,201-251	Act XRF	n		1	-50	Act XRF	n		n		Act XRF	n	
I2	306401-548	Act XRF	n		1	-50	Act XRF	n		n		Act XRF	n	
I3	330670-695	GGU XRF	imp		imp		GGU XRF	imp		imp		GGU XRF	imp	
J1, J2	301701-754,309101-700	GGUXRF[1]	1.25	-180	1.05	29	GGUXRF[1]	1.08	-23	1.04	-16	GGUXRF[1]	0.72	29
I4,K1,K2	381742-965	Act XRF	1.216	-24	1	15	Act XRF	0.85	9	n		Act XRF	1.056	-20
K3,L2a,L3	306301-367,263124-200,263278-298	GGU XRF	0.83	24	n		GGU XRF	0.9	27	1.37	-76	GGU XRF	1.12	-20
L2b	263201-276,263320-386	GGU XRF	0.83	24	n		GGU XRF	0.9	27	1.35	-98	GGU XRF	1.12	-20
L1	330001-330340	GGU XRF	imp		imp		GGU XRF	0.99	-15	1.235	-24	GGU XRF	0.86	18
L1							Act ICP	1.14	-11	1.3	-18	Act ICP	1.05	6
L4,M2,M3	381692-741,386171-500	Act XRF	0.93	28	1.3	-36	Act XRF	1.05	0	1.05	-1	Act XRF	n	
M1	386001-170	Act XRF	1.17	-68	1.3	-36	Act XRF	n		n		Act XRF	n	
M4	329501-583	GGU XRF	0.83	24			GGU XRF	0.9	27	1.37	-76	GGU XRF	1.12	-20
N1,N2	381401-691	Act XRF	1.216	-24	n		Act XRF	0.85	9	1.07	-8	Act XRF	1.05	-20
O1-O4	280002-281835	Act INA[2]	0.96	39	0.99	-10	Risø XRF[2]	0.84	8	0.93	34	GGU XRF[2]	1.02	31
O5	281836-282926	Act INA[2]	0.96	39	0.99	-10	Risø XRF[2]	0.84	8	0.93	34	GGU XRF[2]	n	
P	386701-845	Act XRF	1.197	-46	n		Act XRF	1.05	2	1.13	-4	Act XRF	1.36	-13
Jx	26 selected	Act XRF	1.09	0	1.4	-18	Act XRF	1.08	2	n		Act XRF	n	
Ox	27 selected+CANMET standards	Act XRF	n		1	15	Act XRF	0.94	16	n		Act XRF	n	

Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);* Risø *(Risø National Laboratory);*
Methods: XRF *(X-ray Fluorescence Spectrometry);* INA *(Instrumental Neutron Activation);*
ICP *(Inductively Coupled Plasma Emission Spectrometry);* AAS *(Atomic Absorption Spectrometry)*
a, b*: parameters in the equation for the regression line y=ax+b used for calibrating measured concentrations to reference concentration levels.* n: *no calibration required;* imp: *calibration impossible.*

[1] Calibrated via 26 samples analysed at Act XRF together with standards; [2] Calibrated via 27 samples analysed by Act XRF together with standards

Table 7c *(continued)*

Batch		Rb		Zn		Zr			Nb			Y			Ga			Cu	
code		a	b	a	b	a	b		a	b		a	b		a	b		a	b
A	GGU XRF	imp		imp		imp		GGU XRF	imp		GGU XRF	imp		no data			GGU AAS	0.79	-1
B	GGU XRF	imp		0.77	9	imp		GGU XRF	imp		GGU XRF	imp		no data			GGU AAS	0.79	-1
C	Act XRF	n		n		n		Act XRF	n		Act XRF	n		Act XRF	n		Act XRF	n	
D	Act XRF	n		n		n		Act XRF	n		Act XRF	n		Act XRF	n		GGU AAS	0.79	-1
E	Act XRF	n		n		n		Act XRF	n		Act XRF	n		Act XRF	n		Act XRF	n	
F1	Act XRF	n		1.03	-7.5	1.14	-9	Act XRF	1	-2	Act XRF	1	-1	Act XRF	n		Act XRF	1.08	-7
F2	Act XRF	n		1.03	-7.5	1.14	-9	Act XRF	1	-2	Act XRF	1	-1	Act XRF	1	2	Act XRF	1.08	-7
F3	Act XRF	n		1.03	-7.5	1.14	-9	Act XRF	1	-2	Act XRF	1	-1	Act XRF	1	2	Act XRF	1.08	-7
F4	Act XRF	n		1.03	-7.5	1.14	-9	Act XRF	1	-2	Act XRF	1	-1	Act XRF	1	2	Act XRF	1.08	-7
G	Act XRF	n		1.13	-19	n		Act XRF	n		Act XRF	1	1	Act XRF	1	-1	Act XRF	n	
H1,H2	Act XRF	n		n		n		Act XRF	n		Act XRF	n		Act XRF	n		Act XRF	n	
I1	Act XRF	n		n		n		Act XRF	n		Act XRF	n		Act XRF	n		Act XRF	n	
I2	Act XRF	n		n		n		Act XRF	n		Act XRF	n		Act XRF	n		Act XRF	n	
I3	GGU XRF	imp		imp		imp		GGU XRF	imp		GGU XRF	imp		no data			GGU AAS	0.79	-1
J1, J2	Risø XRF[1]	0.46	20	1.25	-8	0.87	31	Risø XRF[1]	0.8	-2	Risø XRF[1]	0.32	12	Risø XRF[1]	imp		Risø XRF[1]	1.23	11
I4,K1,K2	Act XRF	n		n		n		Act XRF	n		Act XRF	n		Act XRF	n		GGU AAS	0.79	-1
K3,L2a,L3	GGU XRF	1.46	-12	0.72	14	1.06	5	Risø XRF	imp		Risø XRF	imp		Risø XRF	imp		GGU AAS	0.79	-1
L2b	GGU XRF	1.46	-12	0.72	14	1.06	5	Risø XRF	imp		Risø XRF	imp		Risø XRF	imp		GGU AAS	0.79	-1
L1	GGU XRF	imp		0.77	9	imp		GGU XRF	imp		Act ICP	n		no data			Act ICP	0.86	2
L1	Act ICP	not an		0.99	-6	not an			not an										
L4,M2,M3	Act XRF	n		n		n		Act XRF	n		Act XRF	n		Act XRF	n		Act XRF	n	
M1	Act XRF	n		n		n		Act XRF	n		Act XRF	n		Act XRF	n		Act XRF	n	
M4	GGU XRF	1.46	-12	0.72	14	1.06	5	GGU XRF	imp		GGU XRF	imp		no data			GGU AAS	0.79	-1
N1,N2	Act XRF	n		n		n		Act XRF	n		Act XRF	n		Act XRF	1	-2	GGU AAS	0.79	-1
O1-O4	Risø XRF[2]	0.6	10	n		0.96	41	Risø XRF[2]	0.76	2.2	Risø XRF[2]	0.7	8.9	Risø XRF[2]	n		Risø XRF[2]	0.71	3
O5	Risø XRF[2]	0.6	10	n		0.96	41	Risø XRF[2]	0.76	2.2	Risø XRF[2]	0.7	8.9	Risø XRF[2]	n		Risø XRF[2]	0.71	3
P	Act XRF	n		1.03	-7.5	1.14	-9	Act XRF		-2	Act XRF	1	5	Act XRF	n		Act XRF	1.06	-13
Jx	Act XRF	n		n		n		Act XRF	n		Act XRF	n		Act XRF	n		Act XRF	n	
Ox	Act XRF	n		0.98	-7.2	n		Act XRF	n		Act XRF	n		Act XRF	n		Act XRF	n	

Table 8. *Results of analysis of international standards by GGU XRF,* GGU AAS *and recommended values (Rec.).*

	SiO_2		TiO_2		Al_2O_3		Fe_2O_3		MnO		MgO		CaO		Na_2O		K_2O		P_2O_5		l.o.i.		Sum	
	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.
STSD-1	44.83	42.5	0.67	0.8	9.22	9.0	6.46	6.5	0.52	0.5	2.30	2.2	3.77	3.6	1.88	1.8	1.32	1.2	0.40	0.4	27.85	31.6	99.22	100.1
STSD-2	55.13	53.7	0.77	0.8	16.32	16.1	7.52	7.5	0.14	0.1	3.19	3.1	4.26	4.0	1.81	1.7	2.21	2.1	0.33	0.3	7.59	10.3	99.26	99.7
STSD-3	50.94	48.6	0.65	0.7	11.22	10.9	6.19	6.2	0.36	0.3	2.25	2.2	3.39	3.3	1.65	1.5	1.89	1.8	0.39	0.4	20.31	23.6	99.24	99.5
STSD-4	59.83	58.9	0.69	0.8	12.26	12.1	5.62	5.7	0.20	0.2	2.15	2.1	4.04	4.0	2.80	2.7	1.62	1.6	0.23	0.2	9.53	11.6	98.97	99.9
LKSD-1	41.24	40.1	0.50	0.5	7.95	7.8	4.01	4.1	0.09	0.1	1.80	1.7	10.87	10.8	2.13	2.0	1.16	1.1	0.16	0.2	26.70	29.9	96.61	99.9
LKSD-2	59.71	58.9	0.56	0.6	12.25	12.3	6.02	6.2	0.26	0.3	1.73	1.7	2.25	2.2	1.98	1.9	2.72	2.6	0.30	0.3	11.25	13.6	99.04	100.6
LKSD-3	59.86	58.5	0.50	0.5	12.42	12.5	5.81	5.7	0.19	0.2	2.01	2.0	2.38	2.3	2.41	2.3	2.30	2.2	0.25	0.2	11.23	13.4	99.36	99.8
LKSD-4	44.13	41.6	0.35	0.4	5.97	5.9	4.00	4.1	0.07	0.1	0.96	0.9	1.88	1.8	0.80	0.7	0.87	0.8	0.35	0.3	39.73	43.6	99.11	100.2
volatile free																								
STSD-1	62.81	62.0	0.94	1.2	12.92	13.1	9.04	9.5	0.73	0.7	3.22	3.2	5.28	5.3	2.63	2.6	1.85	1.8	0.56	0.6				
STSD-2	60.14	60.1	0.84	0.9	17.80	18.0	8.20	8.4	0.15	0.1	3.48	3.5	4.65	4.5	1.97	1.9	2.41	2.3	0.36	0.3				
STSD-3	64.54	64.0	0.82	0.9	14.22	14.4	7.84	8.2	0.46	0.4	2.85	2.9	4.29	4.3	2.09	2.0	2.39	2.4	0.49	0.5				
STSD-4	66.89	66.7	0.77	0.9	13.71	13.7	6.28	6.5	0.22	0.2	2.40	2.4	4.52	4.5	3.13	3.1	1.81	1.8	0.25	0.2				
LKSD-1	58.99	58.6	0.71	0.7	11.38	11.4	5.73	6.0	0.13	0.1	2.58	2.5	15.55	15.8	3.05	2.9	1.65	1.6	0.23	0.3				
LKSD-2	68.02	67.7	0.63	0.7	13.95	14.1	6.86	7.1	0.30	0.3	1.97	2.0	2.57	2.5	2.26	2.2	3.10	3.0	0.34	0.3				
LKSD-3	67.92	67.7	0.56	0.6	14.10	14.5	6.59	6.6	0.22	0.2	2.28	2.3	2.70	2.7	2.73	2.7	2.61	2.5	0.28	0.2				
LKSD-4	74.32	73.5	0.58	0.7	10.06	10.4	6.73	7.2	0.11	0.2	1.62	1.6	3.17	3.2	1.35	1.2	1.46	1.4	0.59	0.5				

	Ba		Cr		Cu		Nb		Ni		Rb		Sr		V		Y		Zn		Zr	
	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.	GGU	Rec.
STSD-1	527	630	73	67	38	36	0	5	4	24	28	30	199	170	92	98	40	42	129	178	235	218
STSD-2	517	540	127	116	53	47	0	20	33	53	90	104	434	400	95	101	27	37	226	246	184	185
STSD-3	1451	1490	85	80	41	39	0	12	13	30	63	68	264	230	130	134	33	36	187	204	210	196
STSD-4	1958	2000	105	93	71	65	0	9	9	30	26	39	377	350	108	106	8	24	79	107	184	190
LKSD-1	421	430	32	31	47	44	0	7	0	16	22	24	225	250	59	50	20	19	281	331	128	134
LKSD-2	733	780	67	57	39	37	0	8	2	26	68	85	257	220	79	77	24	44	194	209	249	254
LKSD-3	693	680	94	87	39	35	0	8	25	47	63	78	270	240	79	82	8	30	128	152	173	178
LKSD-4	309	330	47	33	32	31	0	9	14	31	12	28	130	110	48	49	4	23	152	194	95	105

Laboratory: GGU *(Geological Survey of Greenland).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* AAS *(Atomic Absorption Spectrometry) for Na and Cu.*
l.o.i: *loss on ignition*

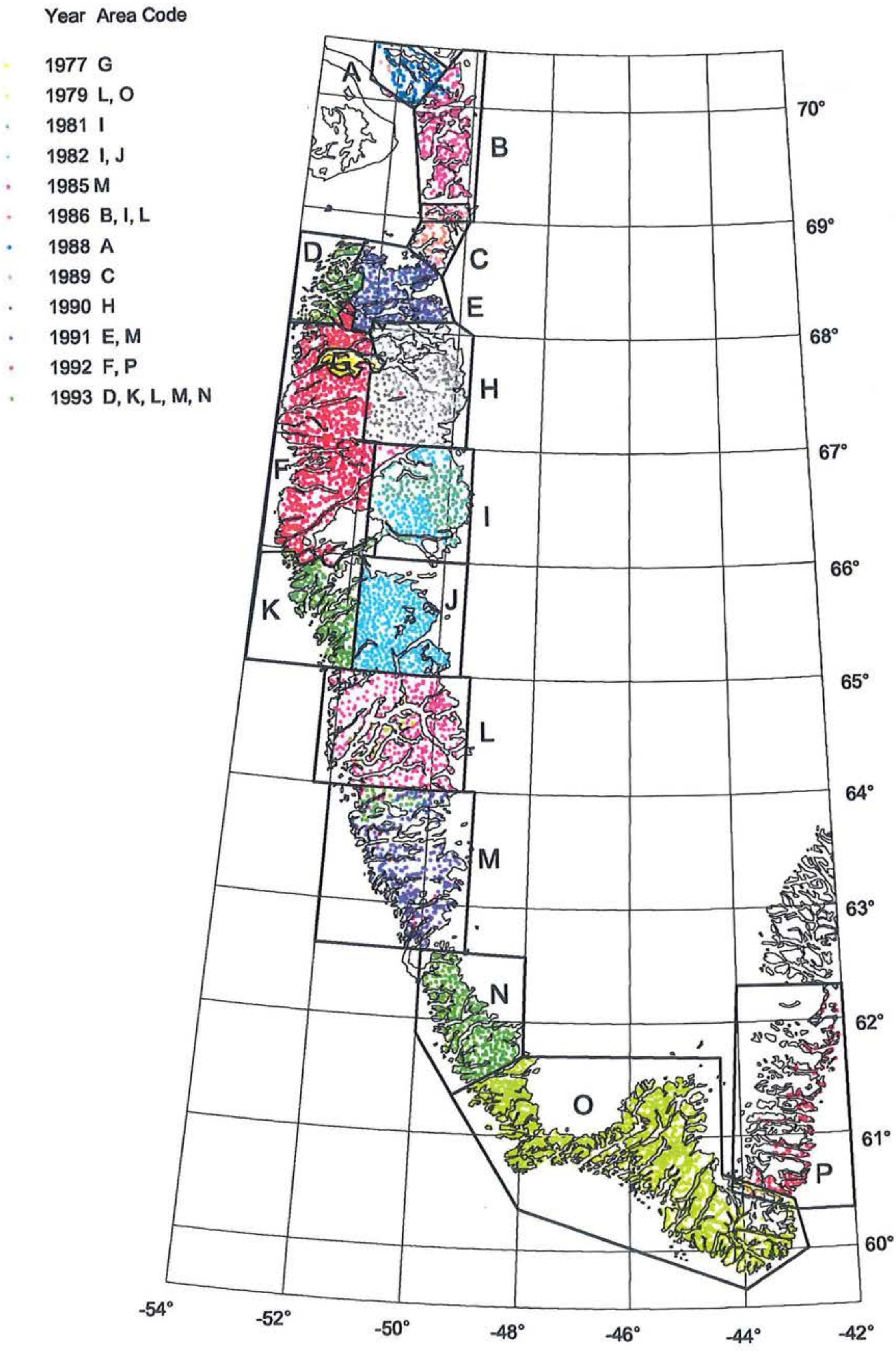
Table 9. *Results of analysis of international standards by KU XRF and recommended values (Rec.).*

	Ba		Ce		Co		Cr		Cu		Ga		La		Nb		Nd		Ni	
	KU	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**
STSD-1	592	630	44	51	18	17	59	67	32	36	10		27	30	6	5	31	28	25	24
STSD-2	508	540	77	93	22	19	114	116	49	47	19		48	59	21	20	42	43	60	53
STSD-3	1281	1490	49	63	16	16	71	80	39	39	13		29	39	11	12	31	33	33	30
STSD-4	1517	2000	36	44	12	13	89	93	70	65	14		20	24	8	9	23	21	33	30
LKSD-1	344	430	24	27	9	11	29	31	39	44	8		12	16	4	7	15	16	17	16
LKSD-2	715	780	110	108	19	17	56	57	41	37	14		69	68	10	8	63	58	30	26
LKSD-3	648	680	92	90	31	30	90	87	33	35	14		50	52	9	8	46	44	55	47
LKSD-4	264	330	41	48	11	11	30	33	24	31	5		23	26	4	9	24	25	32	31

	Pb		Rb		Sc		Sr		V		Y		Th		Zn		Zr	
	KU	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**	**KU**	**Rec.**
STSD-1	36	35	29	30	15	14	171	170	89	98	38	42	4	4	153	178	192	218
STSD-2	69	66	97	104	18	16	417	400	102	101	40	37	16	17	219	246	176	185
STSD-3	43	40	62	68	14	13	231	230	126	134	35	36	8	9	180	204	178	196
STSD-4	17	16	36	39	14	14	349	350	101	106	24	24	3	4	99	107	168	190
LKSD-1	68	82	21	24	8	9	232	250	47	50	19	19	3	2	262	331	115	134
LKSD-2	41	44	78	85	16	13	225	220	79	77	44	44	12	13	189	209	250	254
LKSD-3	30	29	74	78	14	13	240	240	83	82	30	30	12	11	132	152	170	178
LKSD-4	85	91	22	28	8	7	103	110	44	49	21	23	6	5	149	194	88	105

Laboratory: KU *(Geological Institute, University of Copenhagen).*
Method: XRF *(X-ray Fluorescence Spectrometry).*

Sample locations in stream sediment surveys by year

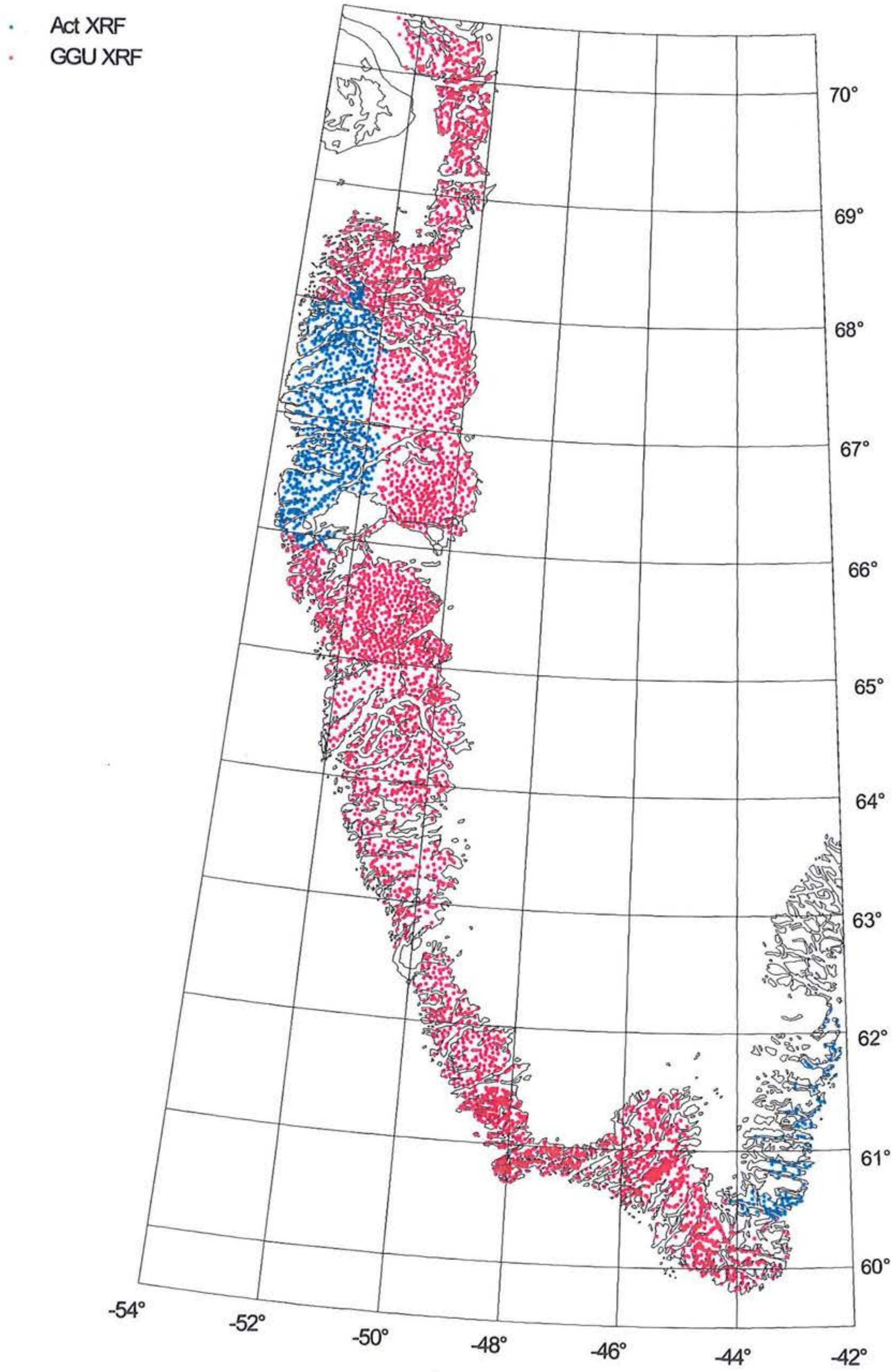


UTM Zone 23, WGS84
Topographic base: G/250 Vector, Copyright Kort & Matrikelstyrelsen, 1998.

Figure 1

Stream sediment samples analysed for major elements by Act XRF and GGU XRF

X-ray Fluorescence (XRF) at Activation Laboratories Ltd. (Act)
and Geological Survey of Greenland (GGU).

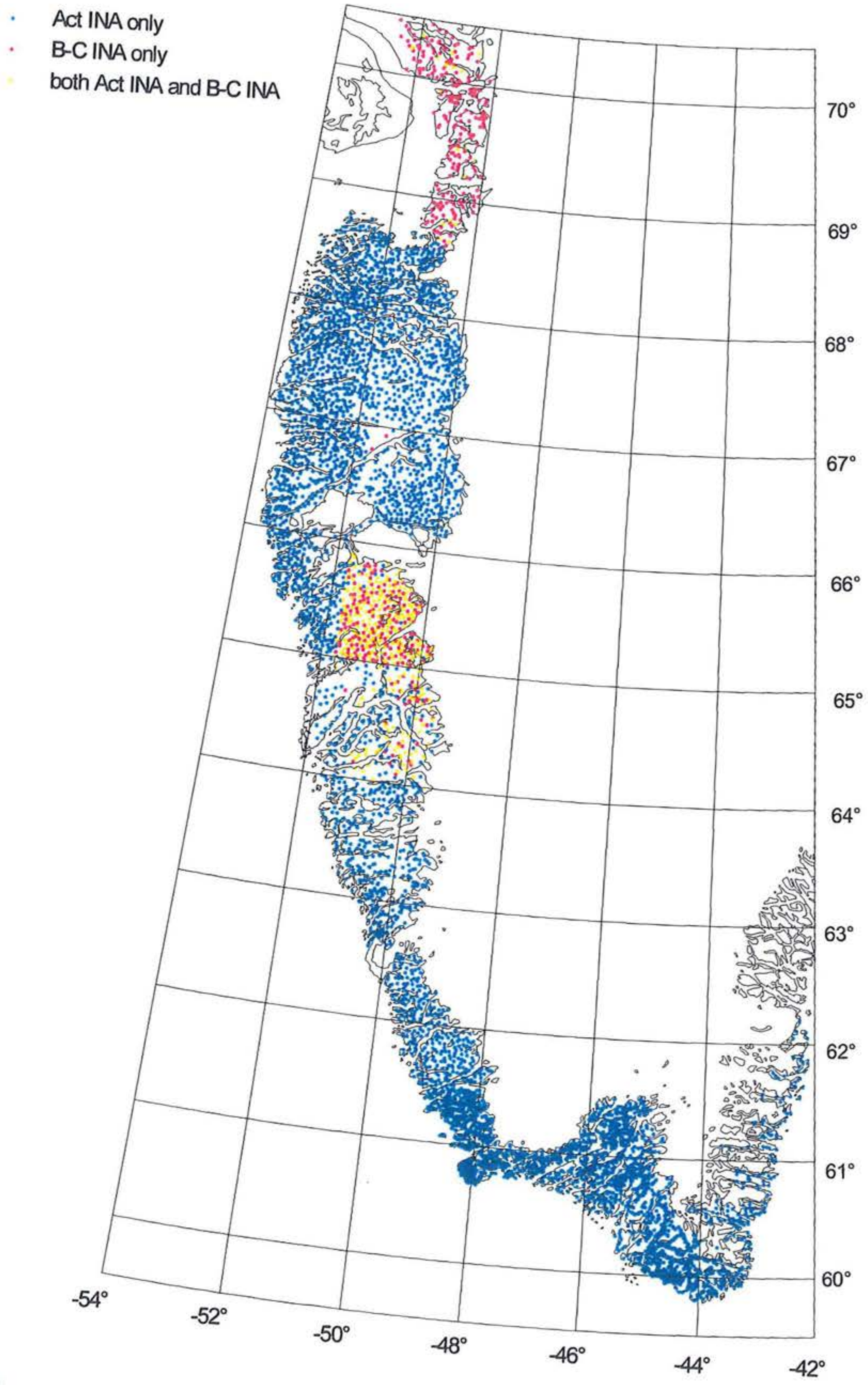


UTM Zone 23, WGS84
Topographic base: G/250 Vector, Copyright Kort & Matrikelstyrelsen, 1998.

Figure 2

Stream sediment samples analysed for trace elements by Act INA and B-C INA

Instrumental Neutron Activation Analysis (INA) at Activation Laboratories Ltd. (Act) and Bondar - Clegg & Co. Ltd. (B-C).

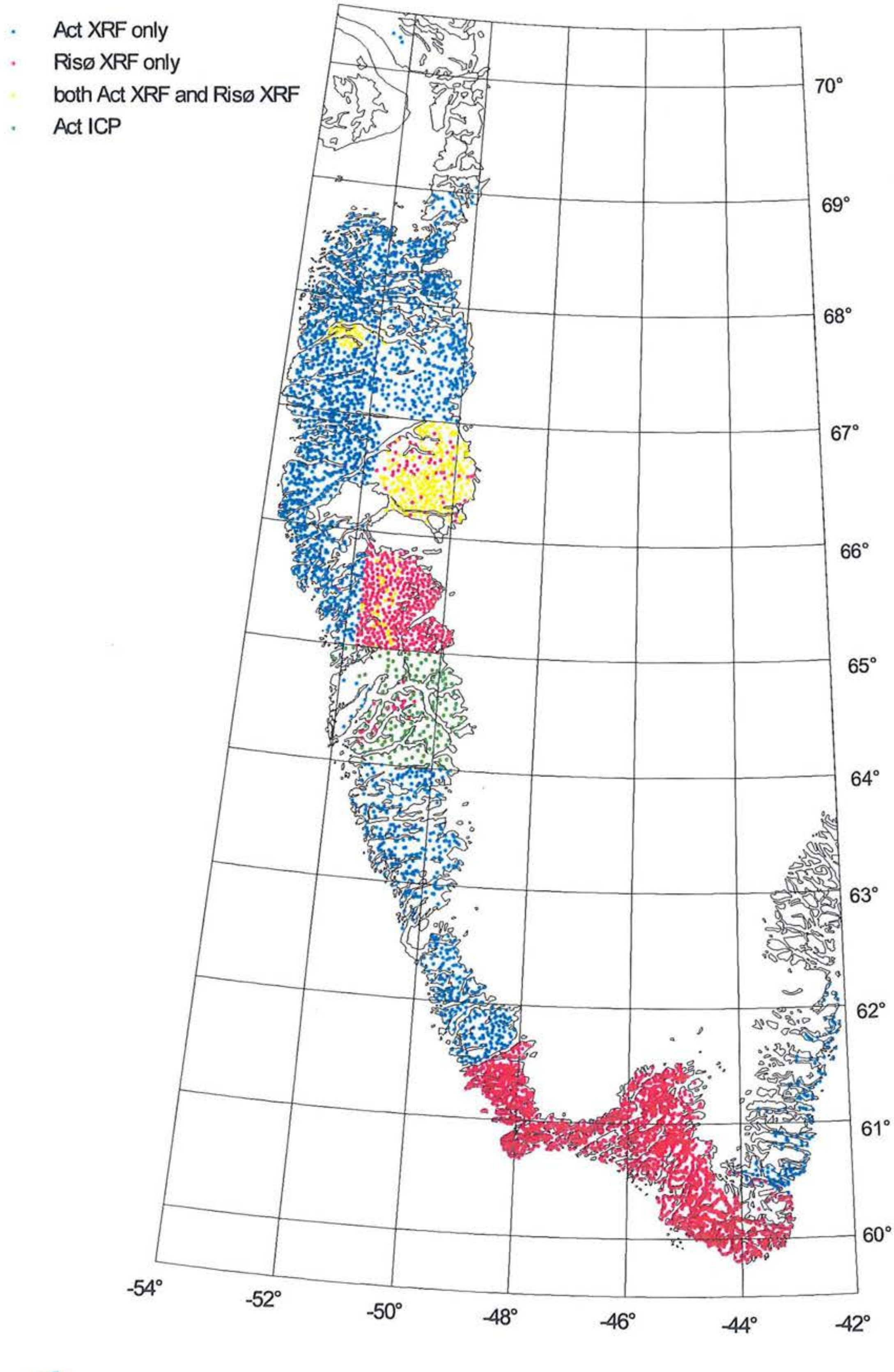


UTM Zone 23, WGS84
Topographic base: G/250 Vector, Copyright Kort & Matrikelstyrelsen, 1998.

Figure 3

Stream sediment samples analysed for trace elements by Act XRF, Risø XRF and Act ICP

X-ray Fluorescence Spectrometry (XRF) and Inductively Coupled Plasma Emission Spectrometry (ICP) at Activation Laboratories Ltd. (Act) and Risø National Laboratory (Risø).



UTM Zone 23, WGS84
Topographic base: G/250 Vector, Copyright Kort & Matrikelstyrelsen, 1998.

Figure 4

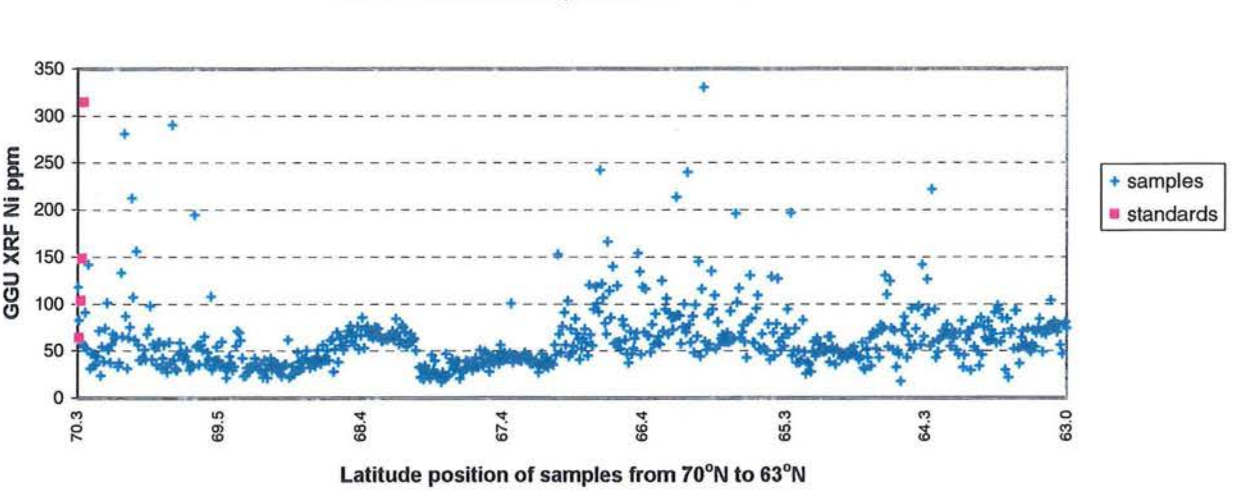


Figure 5. *Range of Ni concentrations measured in standards and in samples within a longitudinal section through the atlas region. Laboratory:* GGU *(Geological Survey of Greenland). Method:* XRF *(X-ray Fluorescence Spectrometry).*

Figure 5

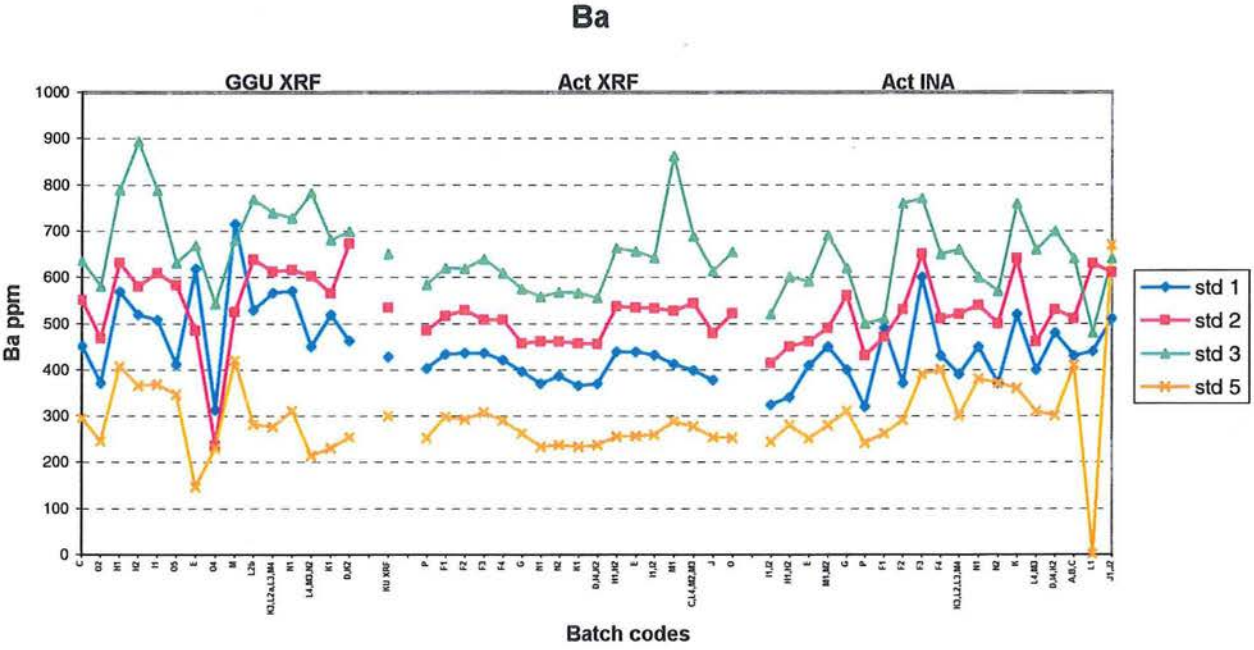


Figure 6a

Figure 6a-m. *Variability of analytical results from various sources as monitored by standards. Laboratories:* GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);* KU *(Geological Institute, University of Copenhagen). Methods:* XRF *(X-ray Fluorescence Spectrometry);* INA *(Instrumental Neutron Activation);* ICP *(Inductively coupled Plasma Emission Spectrometry).*

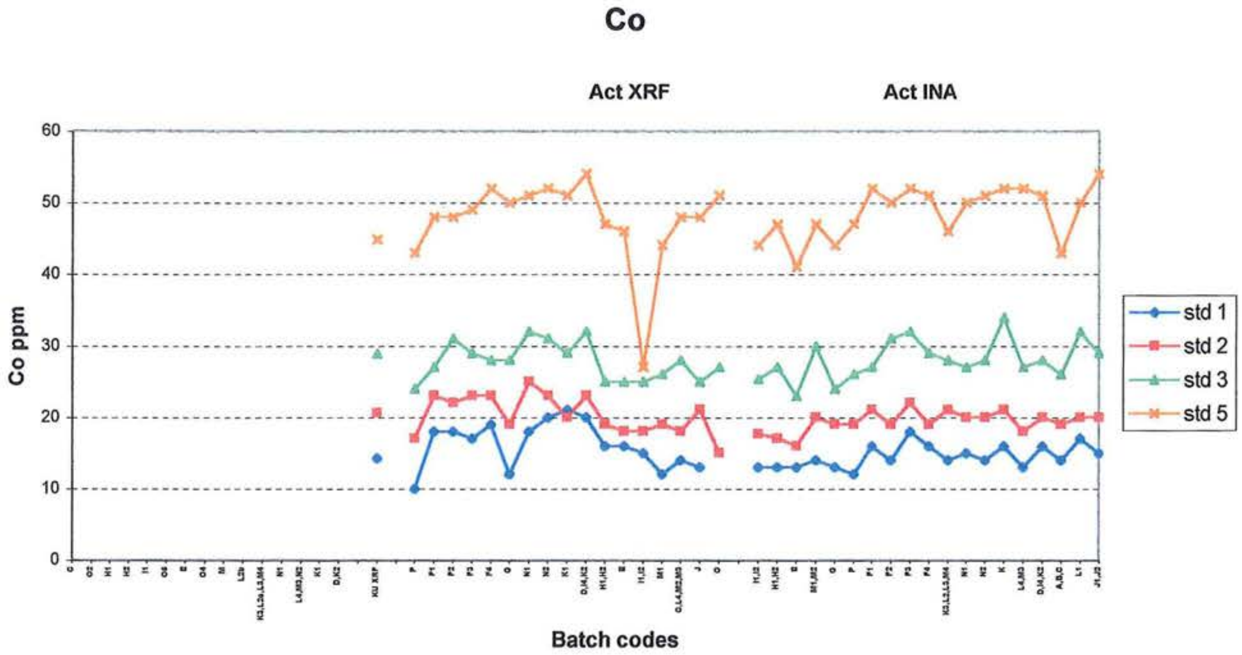


Figure 6b

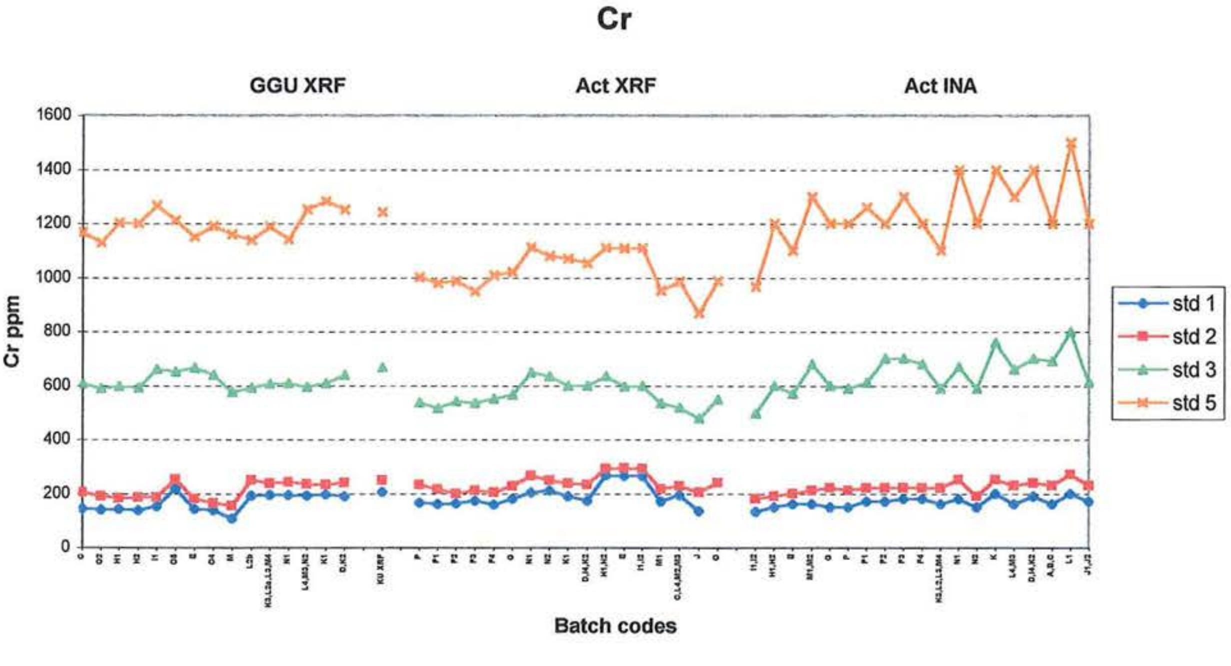


Figure 6c

Figure 6a-m. *Variability of analytical results from various sources as monitored by standards.*
Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);*
KU *(Geological Institute, Copenhagen University).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* INA *(Instrumental Neutron Activation);*
ICP *(Inductively coupled Plasma Emission Spectrometry).*

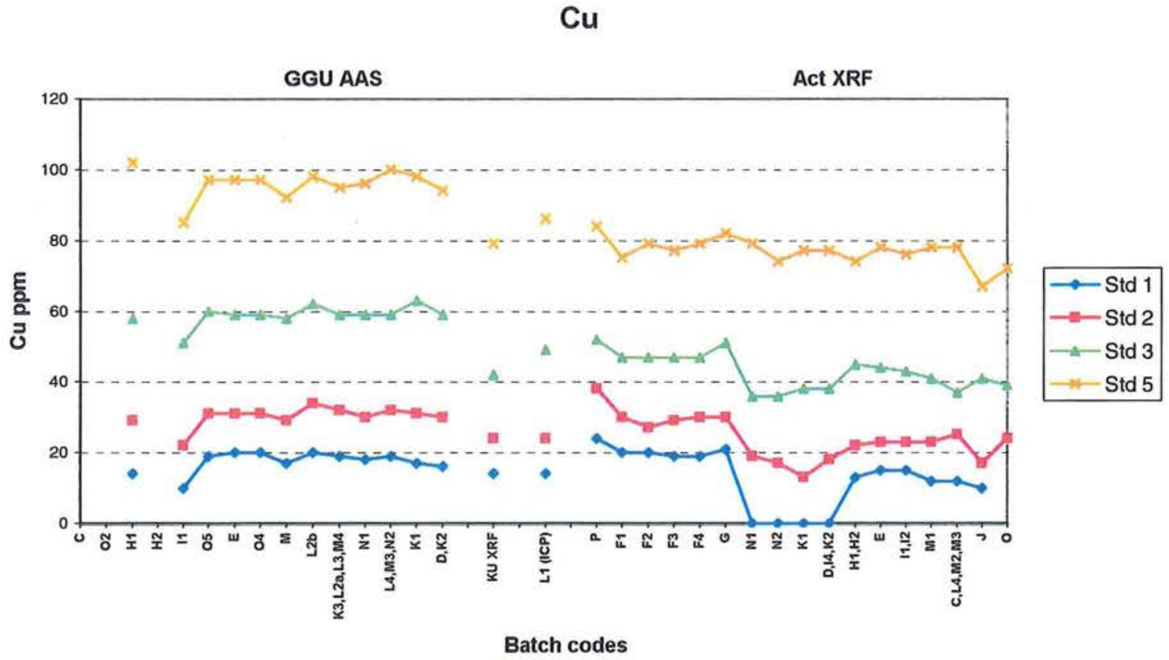


Figure 6d

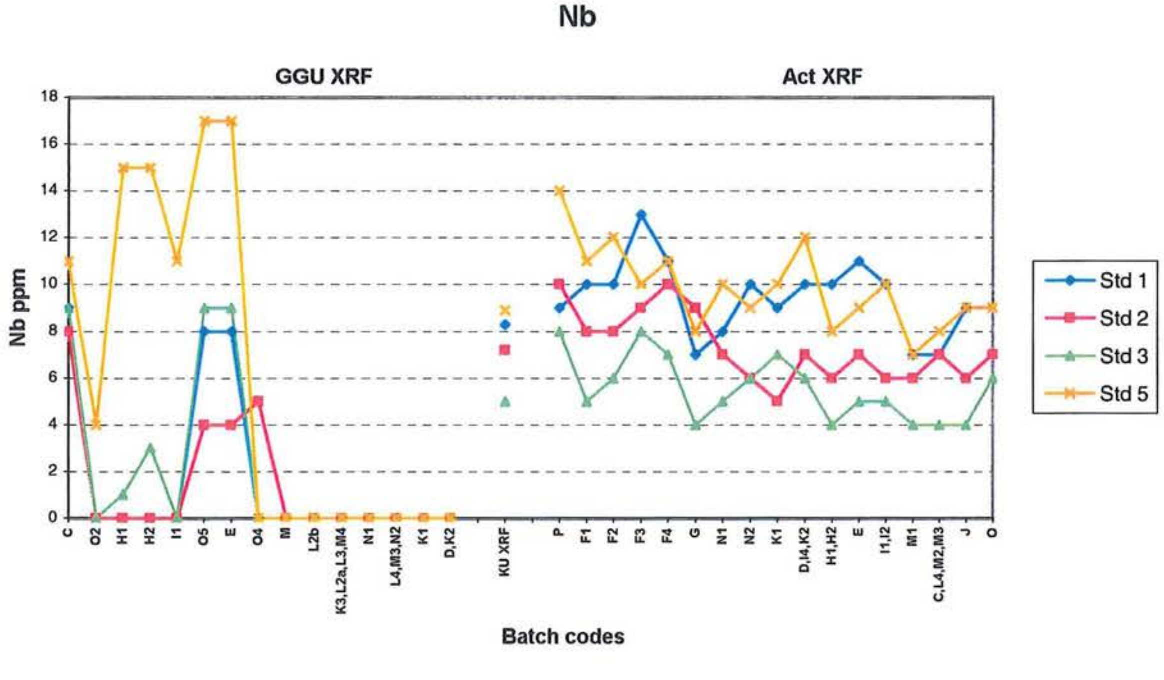


Figure 6e

Figure 6a-m. *Variability of analytical results from various sources as monitored by standards.*
Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);*
KU *(Geological Institute, University of Copenhagen).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* INA *(Instrumental Neutron Activation);*
ICP *(Inductively coupled Plasma Emission Spectrometry).*

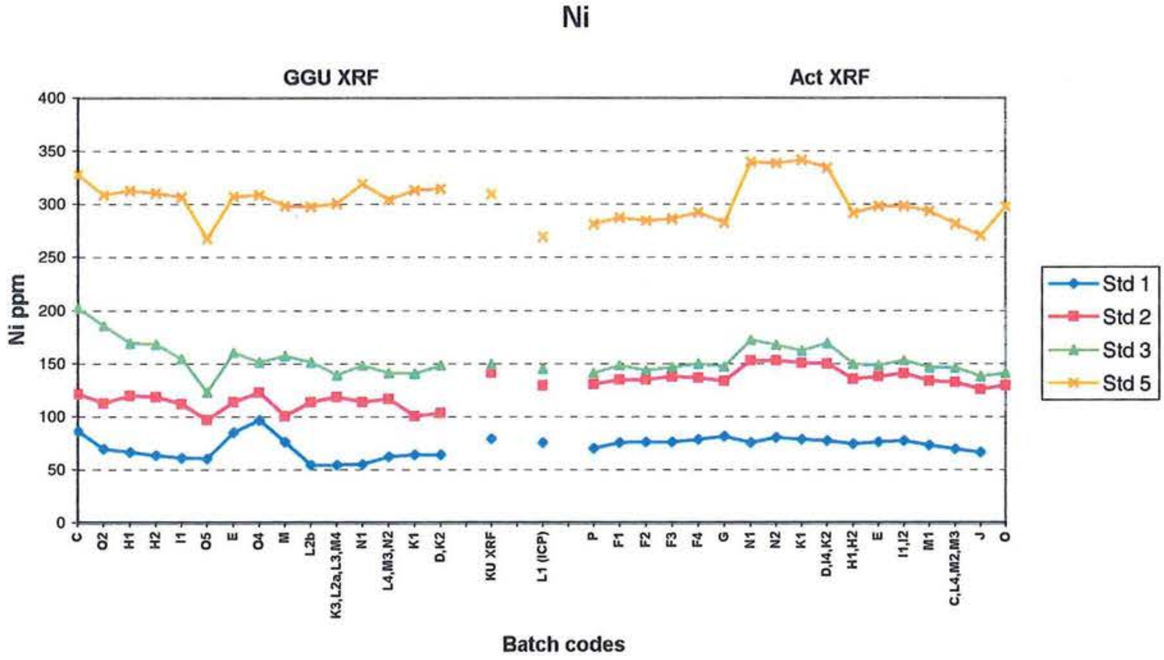


Figure 6f

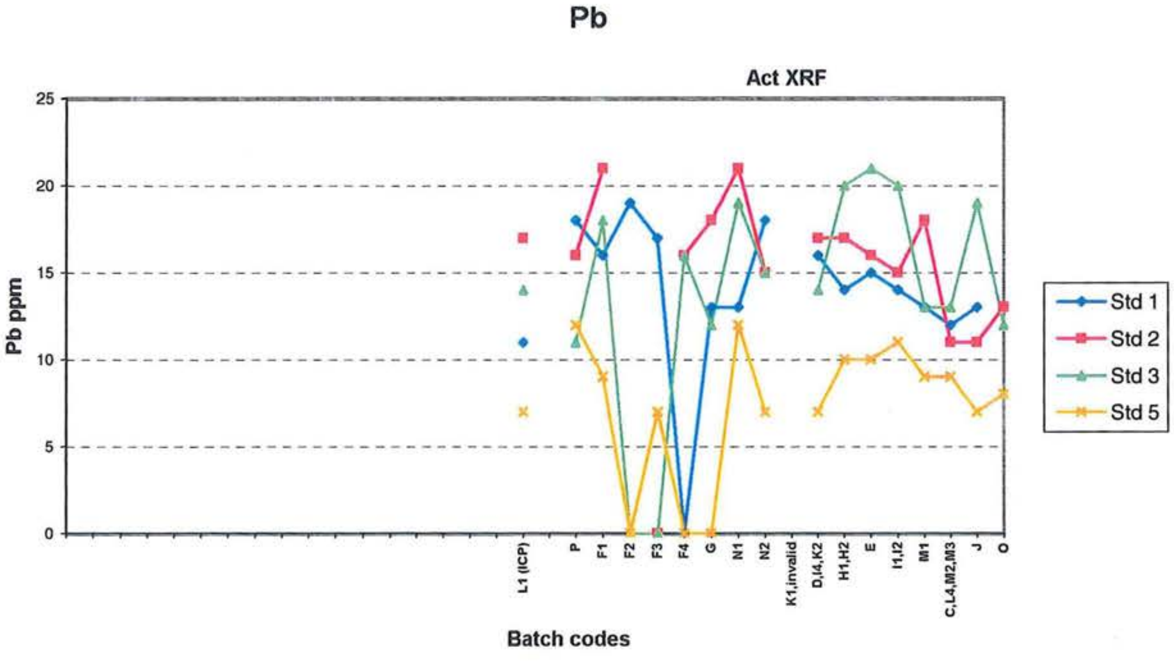


Figure 6g

Figure 6a-m. *Variability of analytical results from various sources as monitored by standards.*
Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);*
KU *(Geological Institute, University of Copenhagen).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* INA *(Instrumental Neutron Activation);*
ICP *(Inductively coupled Plasma Emission Spectrometry).*

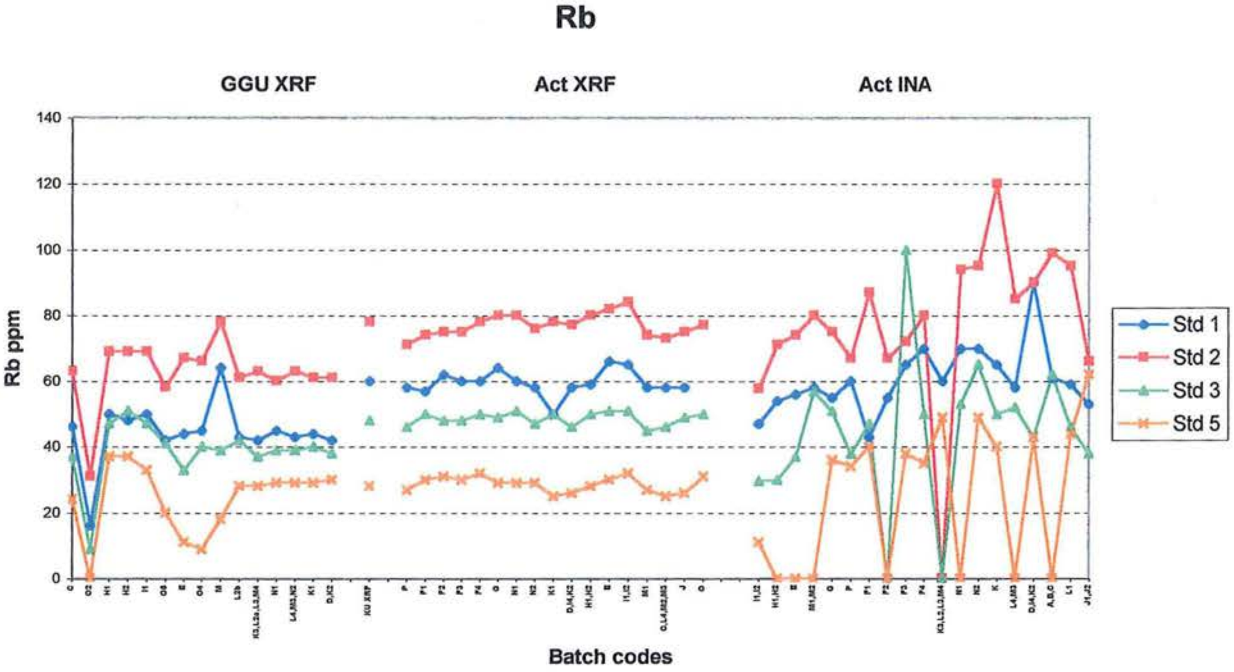


Figure 6h

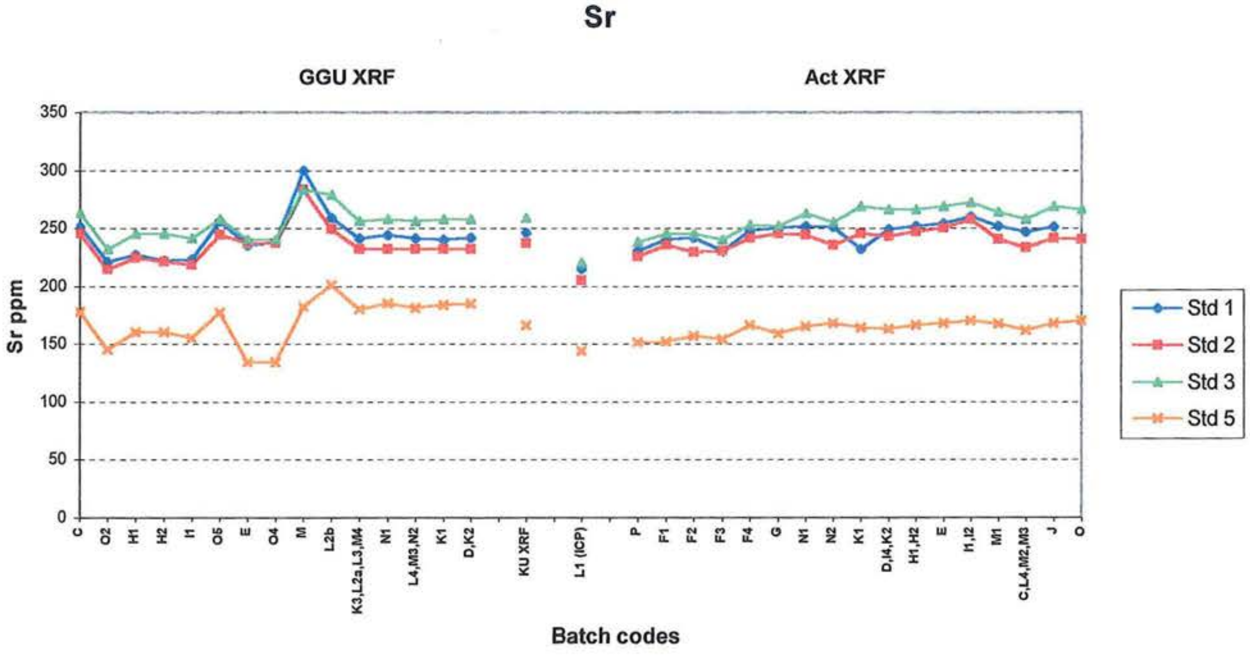


Figure 6i

Figure 6a-m. *Variability of analytical results from various sources as monitored by standards.*
Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);*
KU *(Geological Institute, University of Copenhagen).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* INA *(Instrumental Neutron Activation);*
ICP *(Inductively coupled Plasma Emission Spectrometry).*

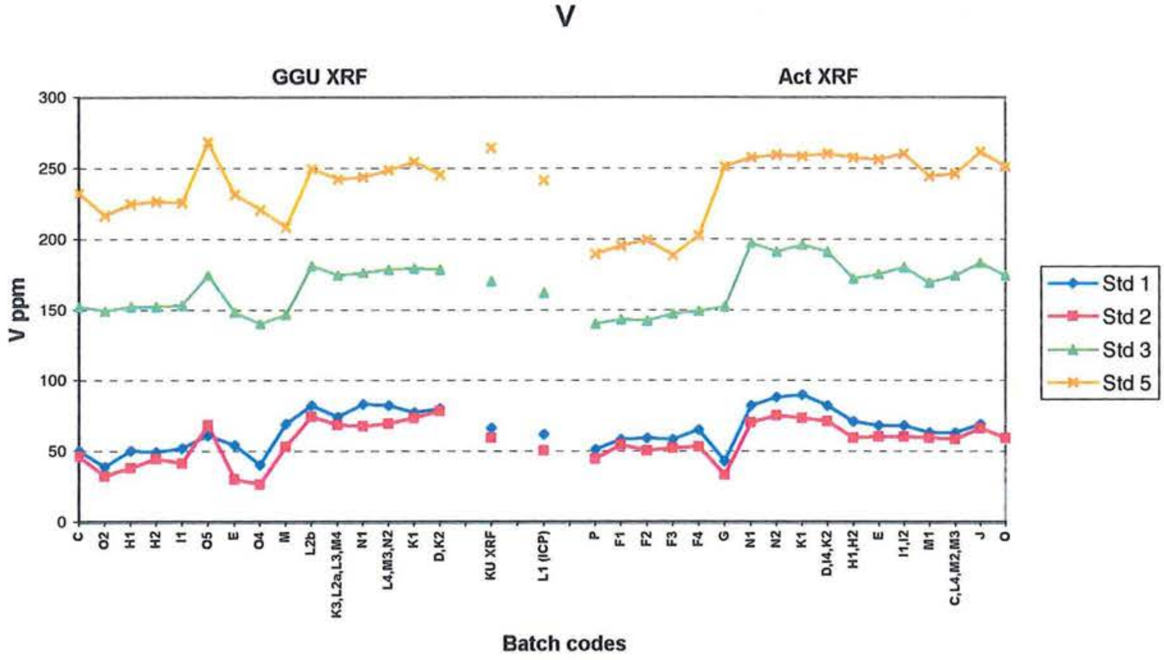


Figure 6j

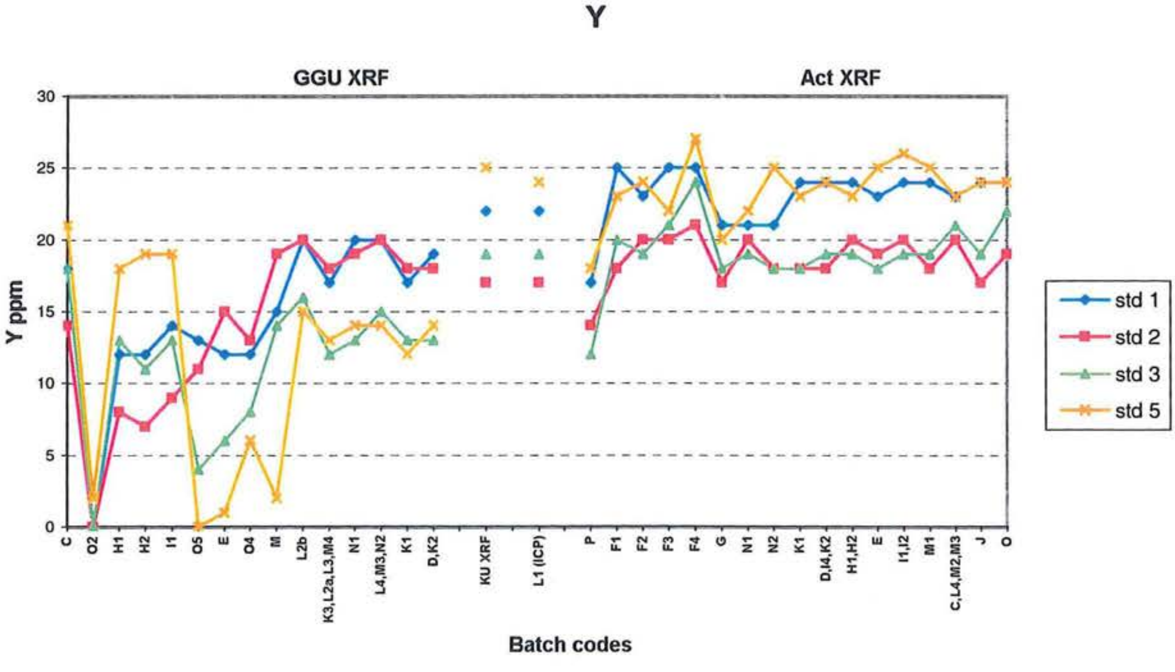


Figure 6k

Figure 6a-m. *Variability of analytical results from various sources as monitored by standards. Laboratories:* GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);* KU *(Geological Institute, University of Copenhagen).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* INA *(Instrumental Neutron Activation);* ICP *(Inductively coupled Plasma Emission Spectrometry).*

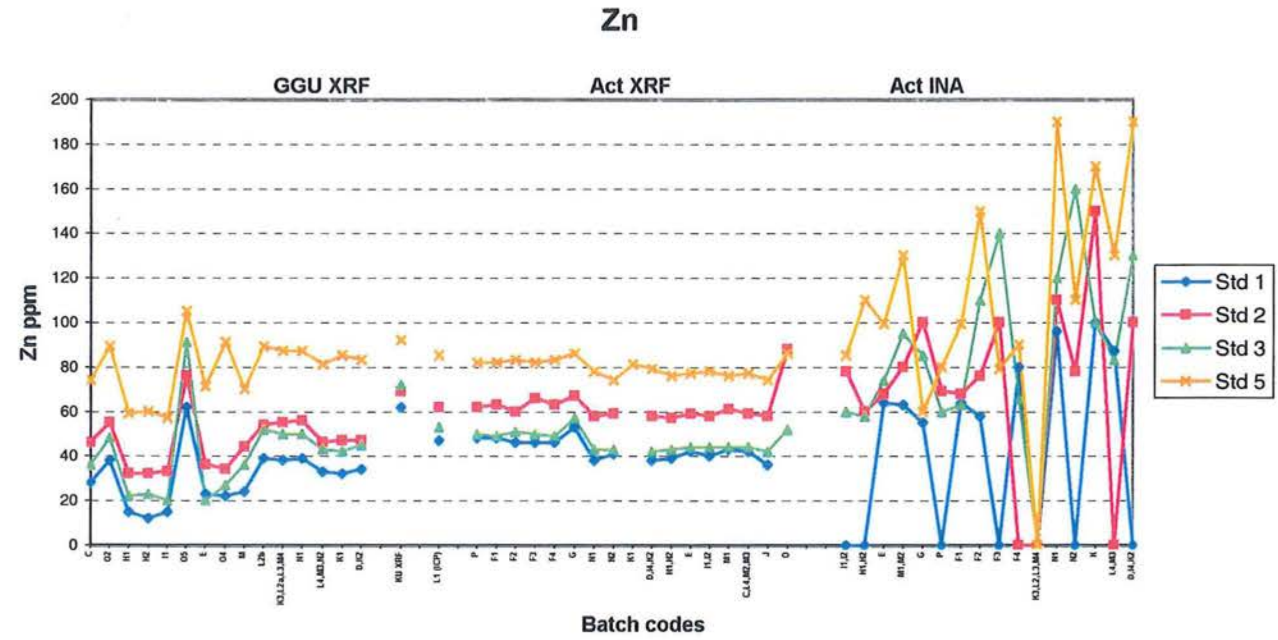


Figure 6l

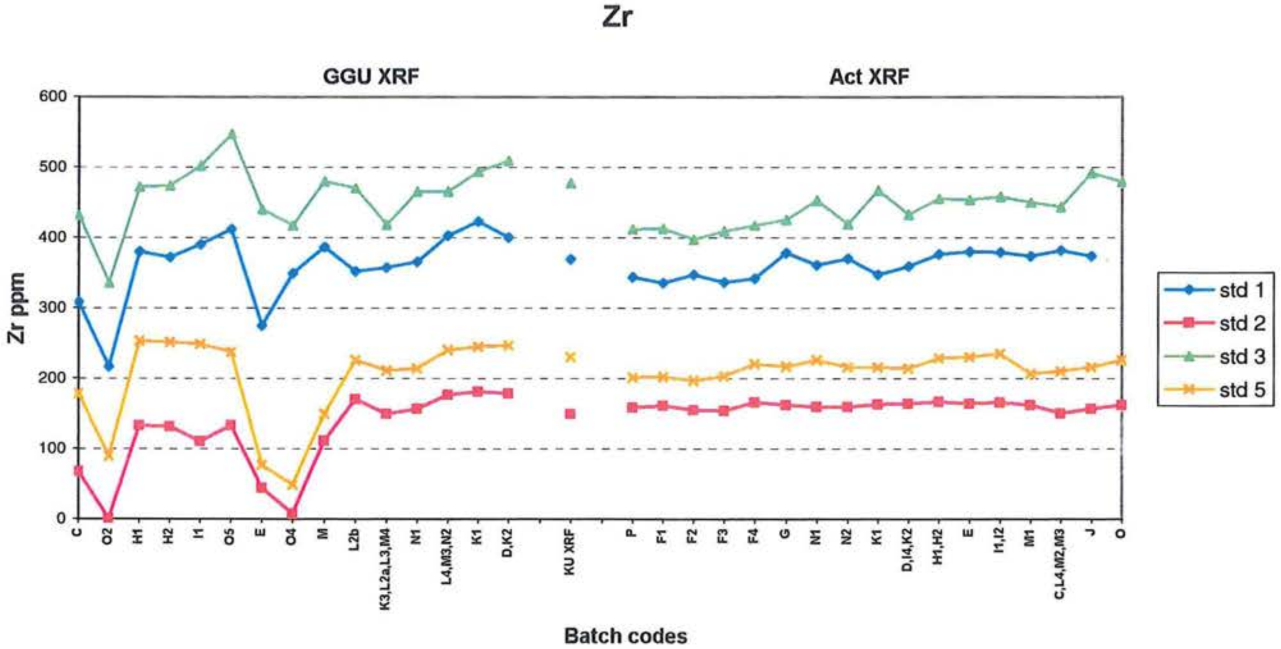


Figure 6m

Figure 6a-m. *Variability of analytical results from various sources as monitored by standards. Laboratories:* GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);* KU *(Geological Institute, University of Copenhagen).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* INA *(Instrumental Neutron Activation);* ICP *(Inductively coupled Plasma Emission Spectrometry).*

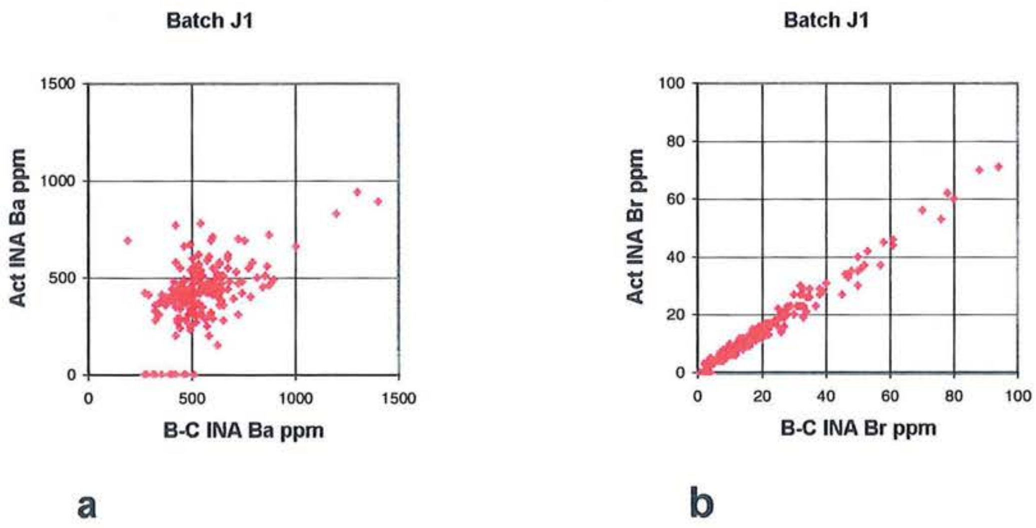


Figure 7a, b

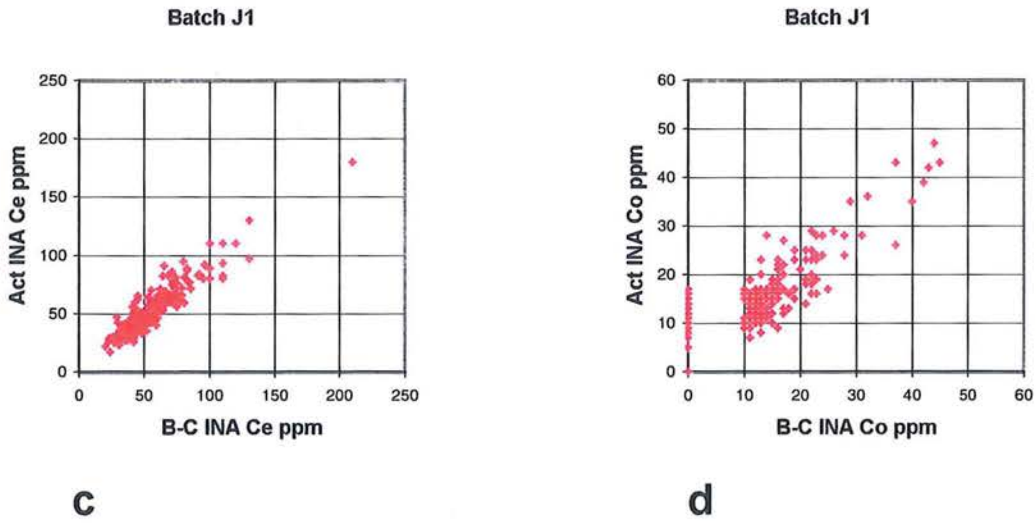


Figure 7c, d

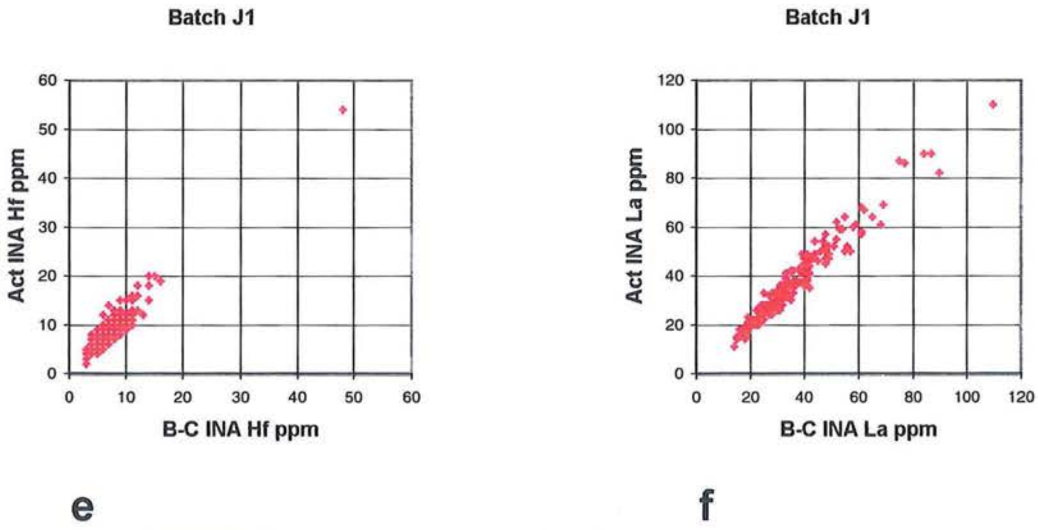
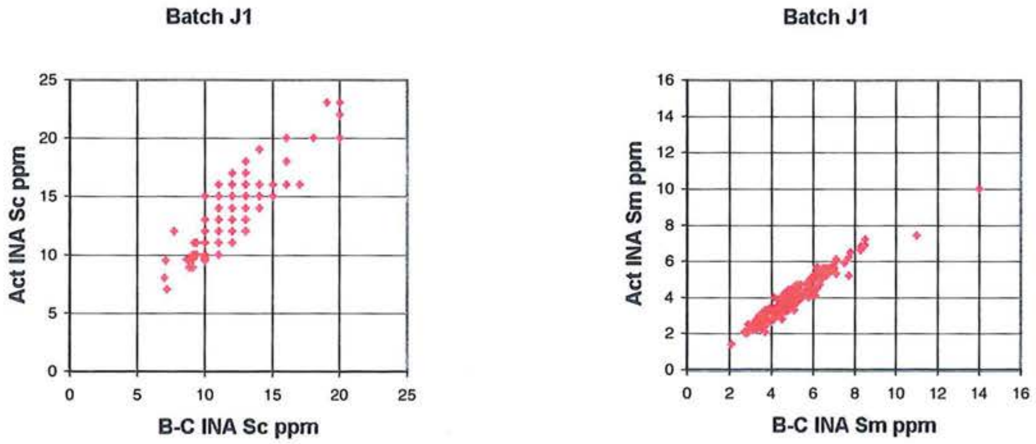


Figure 7e, f

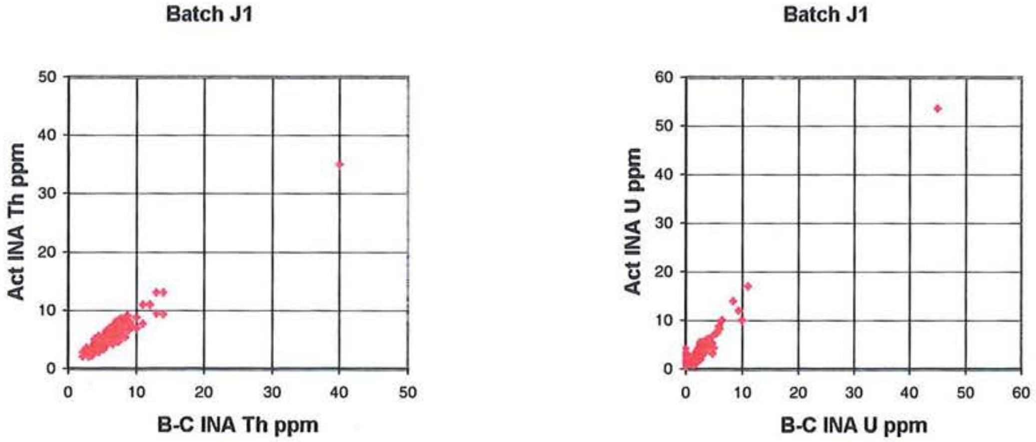
Figure 7a-j. *Compatibility of analyses of samples from area J provided by two different laboratories.*
Laboratories: B-C *(Bondar-Clegg and Co. Ltd.);* Act *(Activation Laboratories Ltd.).*
Method: INA *(Instrumental Neutron Activation).*



g

h

Figure 7g, h

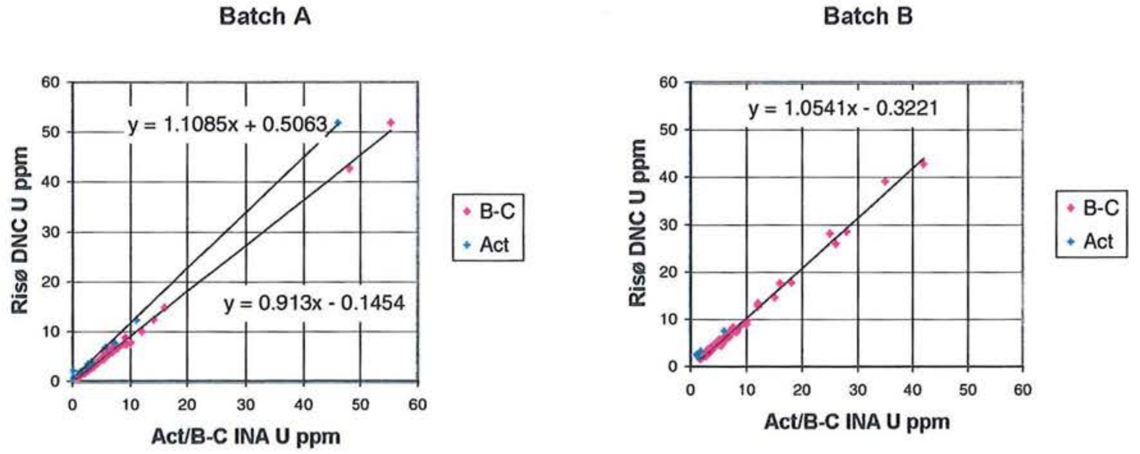


i

j

Figure 7i, j

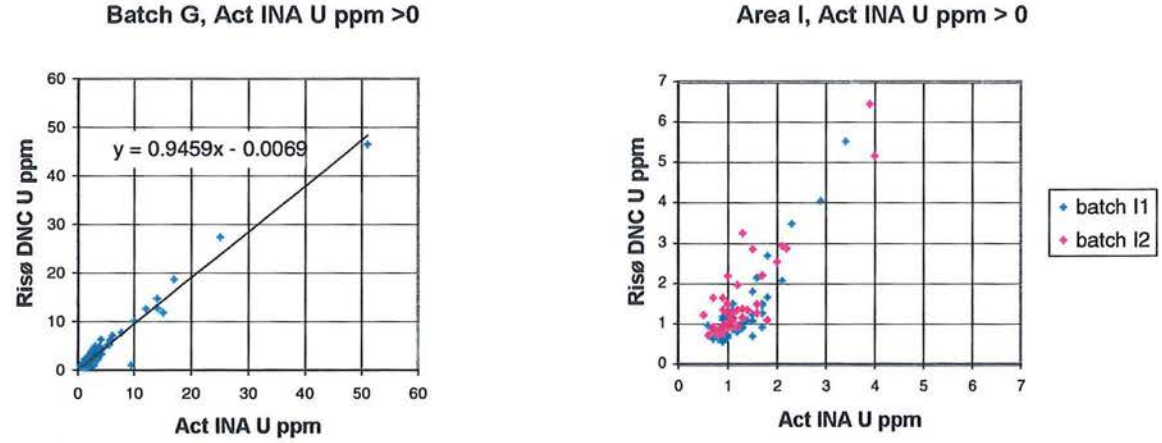
Figure 7a-j. *Compatibility of analyses of samples from area J provided by two different laboratories.*
Laboratories: B-C *(Bondar-Clegg and Co. Ltd.);* Act *(Activation Laboratories Ltd.).*
Method: INA *(Instrumental Neutron Activation).*



a

b

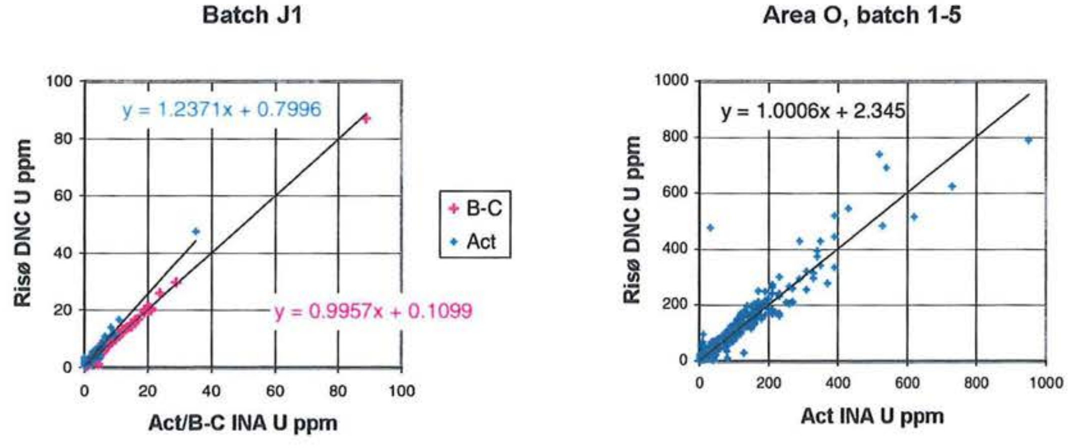
Figure 8a, b



c

d

Figure 8c, d

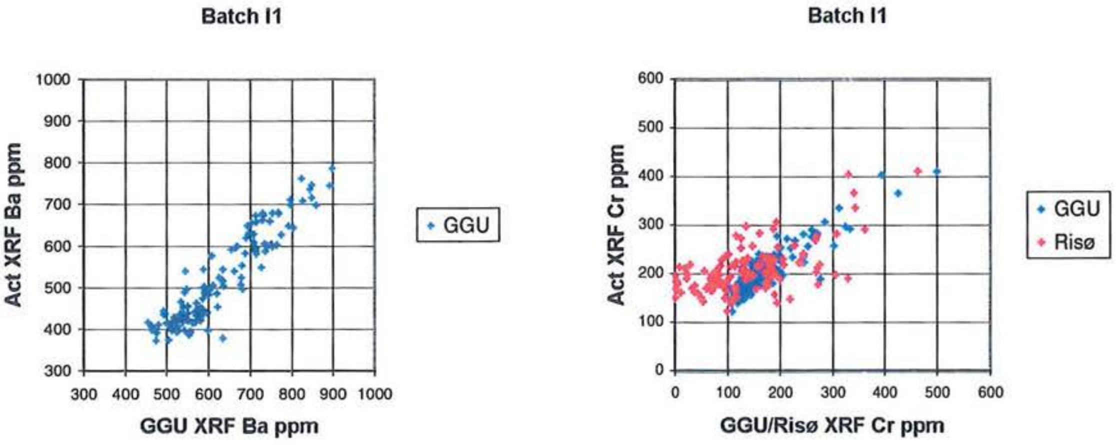


e

f

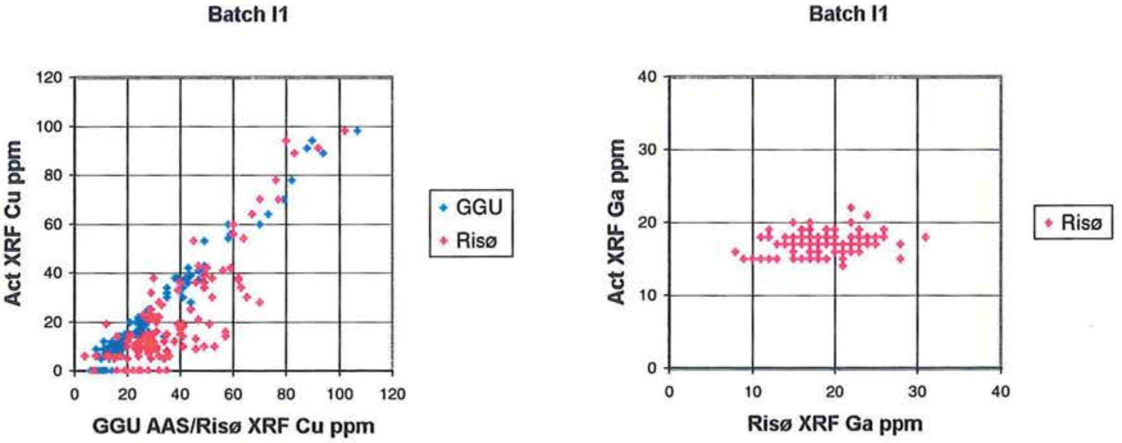
Figure 8e, f

Figure 8a-f. *Compatibility of uranium concentrations determined by two different laboratories in samples from various batches.*
Laboratories: Risø *(Risø National Laboratory);* Act *(Activation Laboratories Ltd.).*
Methods: XRF *(Delayed Neutron Counting);* INA *(Instrumental Neutron Activation)*



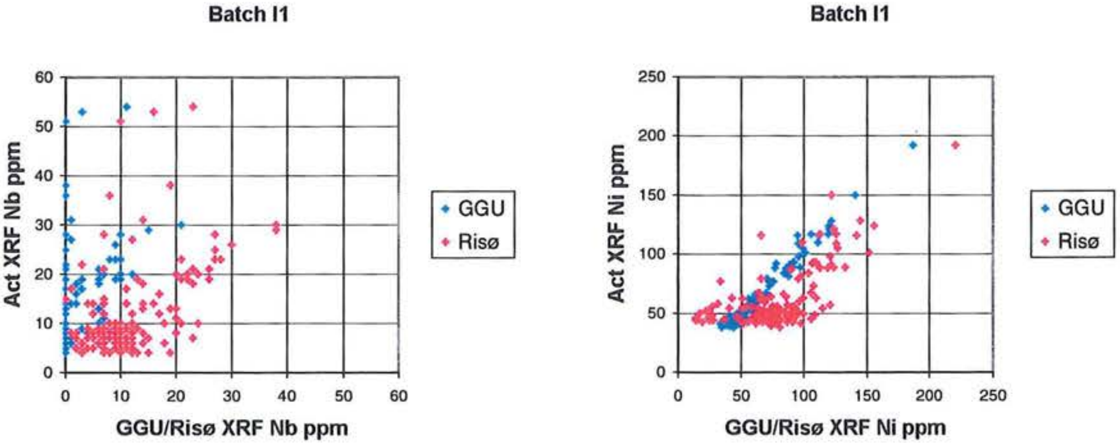
a **b**

Figure 9a, b



c **d**

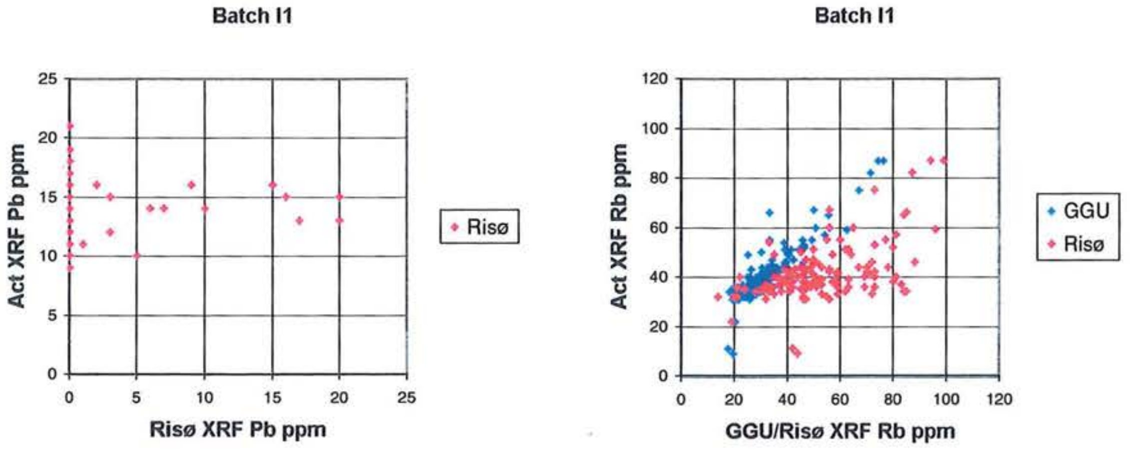
Figure 9c, d



e **f**

Figure 9e, f

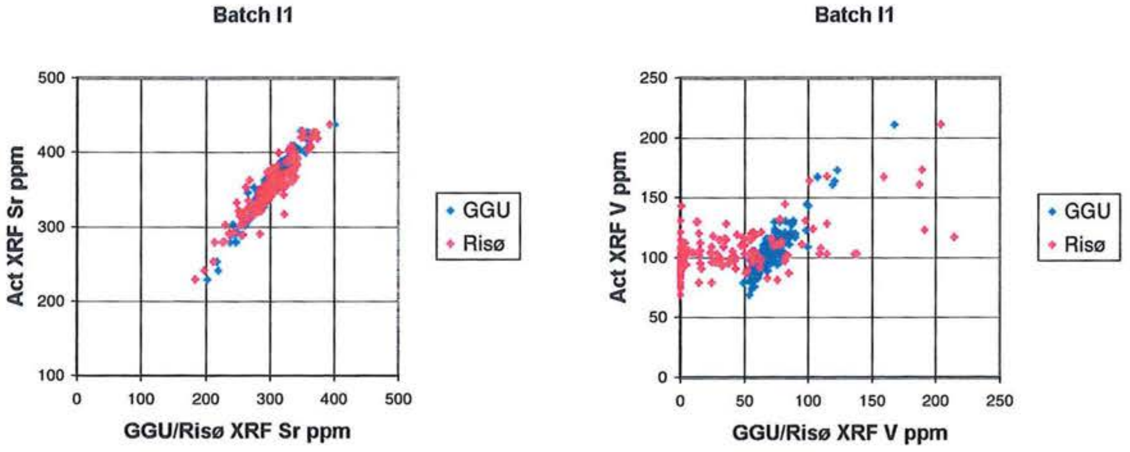
Figure 9a-m. *Compatibility of analyses of samples from area I provided by three different laboratories.*
Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);* Risø *(Risø National Laboratory). Methods:* XRF *(X-ray Fluorescence Spectrometry);* AAS *(Atomic Absorption Spectrometry).*



g

h

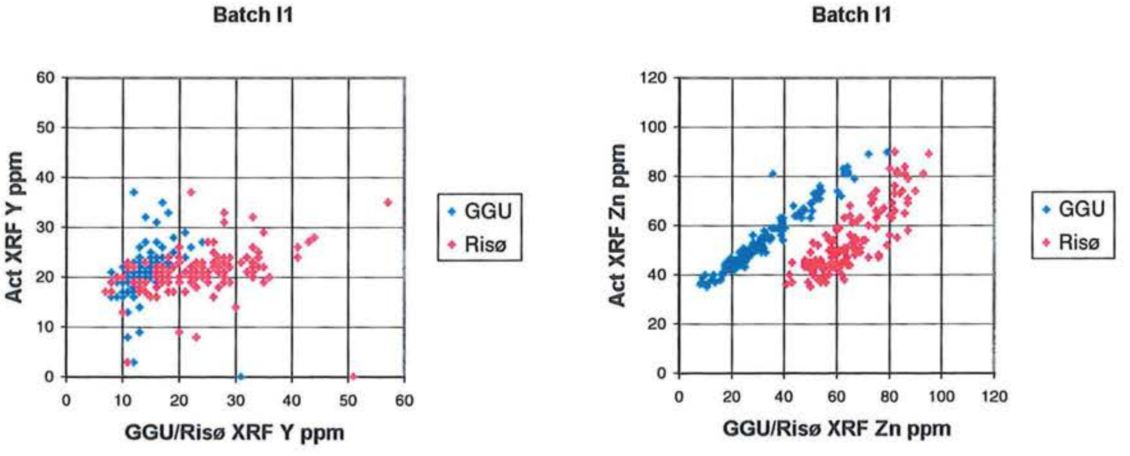
Figure 9g, h



i

j

Figure 9i, j

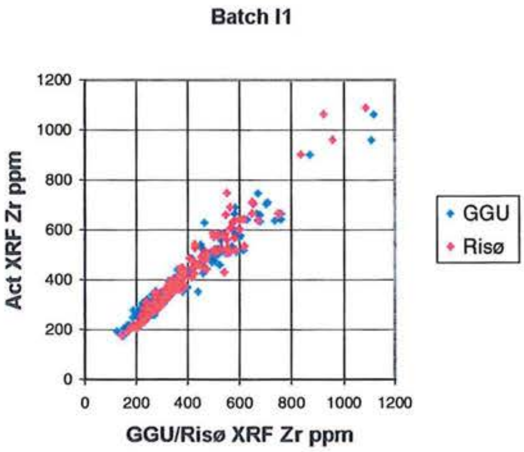


k

l

Figure 9k, l

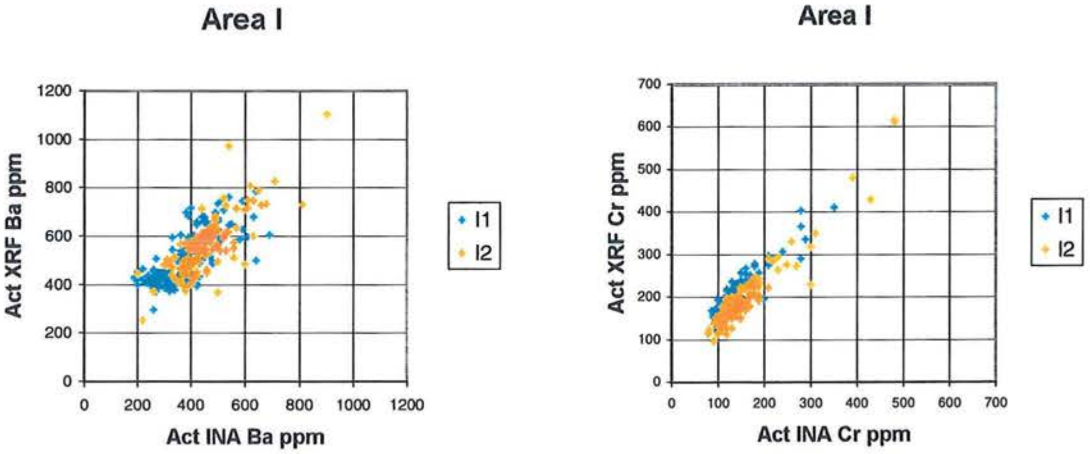
Figure 9a-m. *Compatibility of analyses of samples from area I provided by three different laboratories.*
Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);* Risø *(Risø National Laboratory). Method:* XRF *(X-ray Fluorescence Spectrometry).*



m

Figure 9m

Figure 9a-m. *Compatibility of analyses of samples from area I provided by three different laboratories.*
Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);* Risø *(Risø National Laboratory). Method:* XRF *(X-ray Fluorescence Spectrometry).*

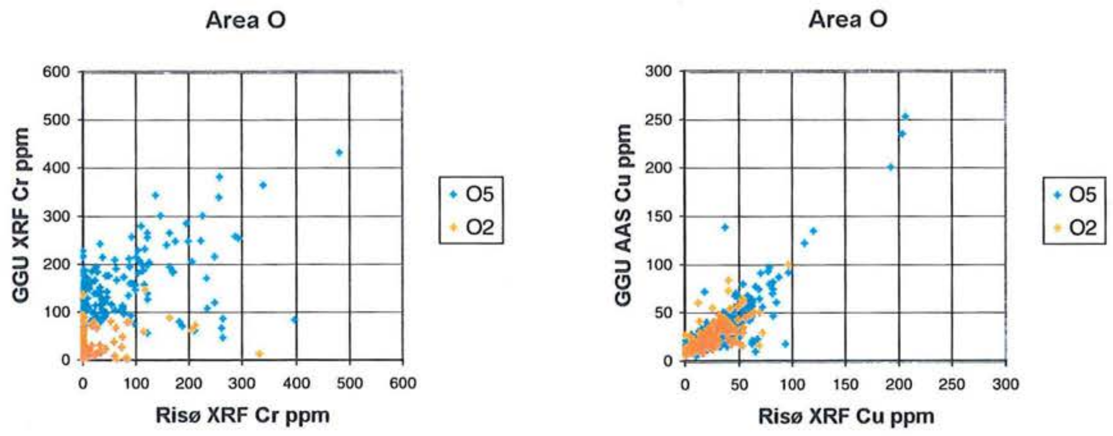


a

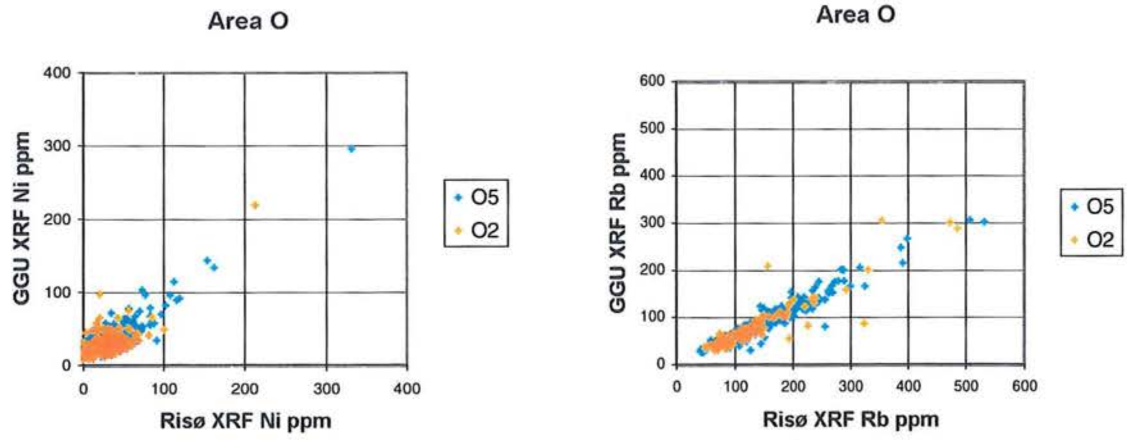
b

Figure 10a-b. *Compatibility of analyses of samples from area I provided by two different analytical methods.*
Laboratory: Act *(Activation Laboratories Ltd.).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* INA *(Instrumental Neutron Activation)* .

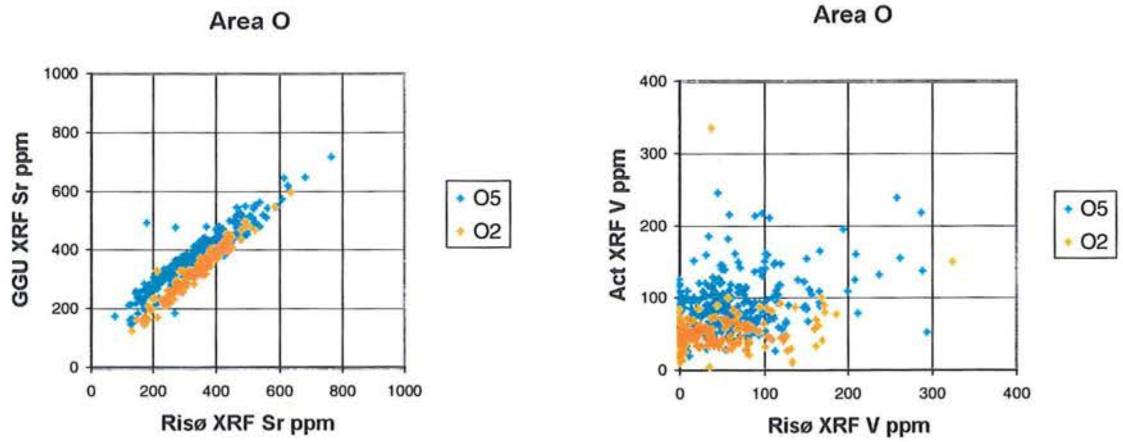
Figure 10a, b



a **b** **Figure 11a, b**



c **d** **Figure 11c, d**



e **f** **Figure 11e, f**

Figure 11a-i. *Compatibility of analyses of samples from two batches within area O provided by two different laboratories.*
Laboratories: GGU *(Geological Survey of Greenland);* Risø *(Risø National Laboratory).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* AAS *(Atomic Absorption Spectrometry).*

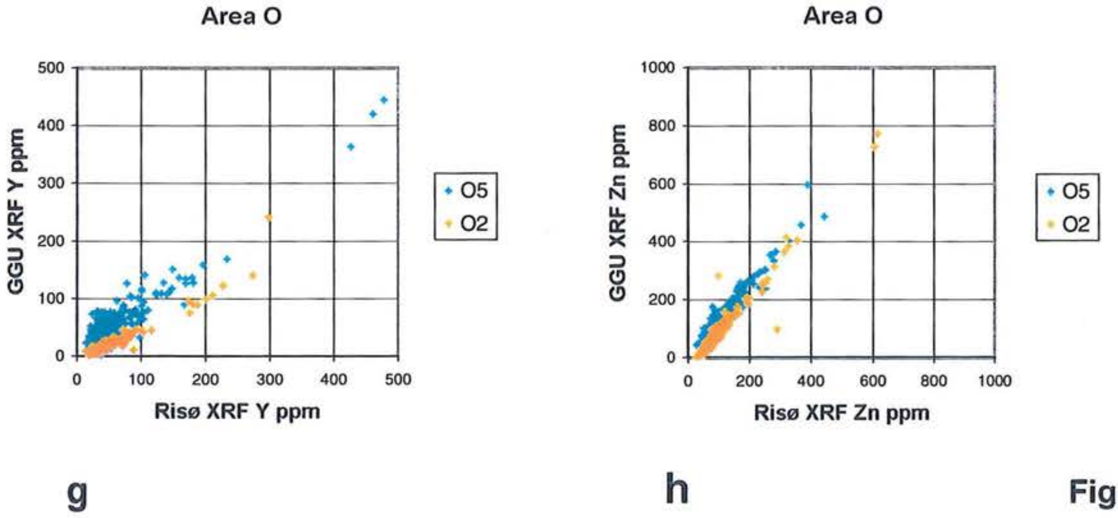


Figure 11g, h

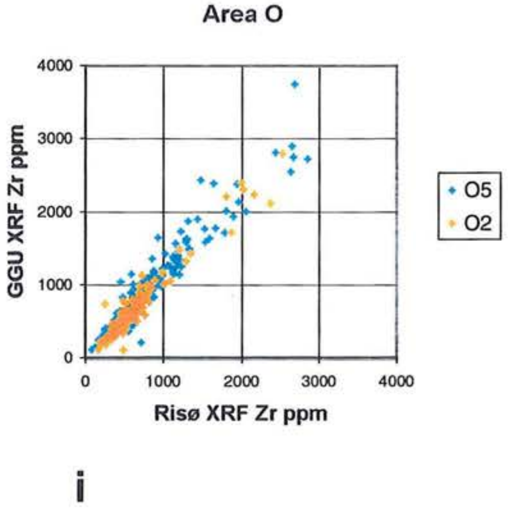


Figure 11i

Figure 11a-i. *Compatibility of analyses of samples from two batches within area O provided by two different laboratories.*
Laboratories: GGU *(Geological Survey of Greenland);* Risø *(Risø National Laboratory).*
Method: XRF *(X-ray Fluorescence Spectrometry).*

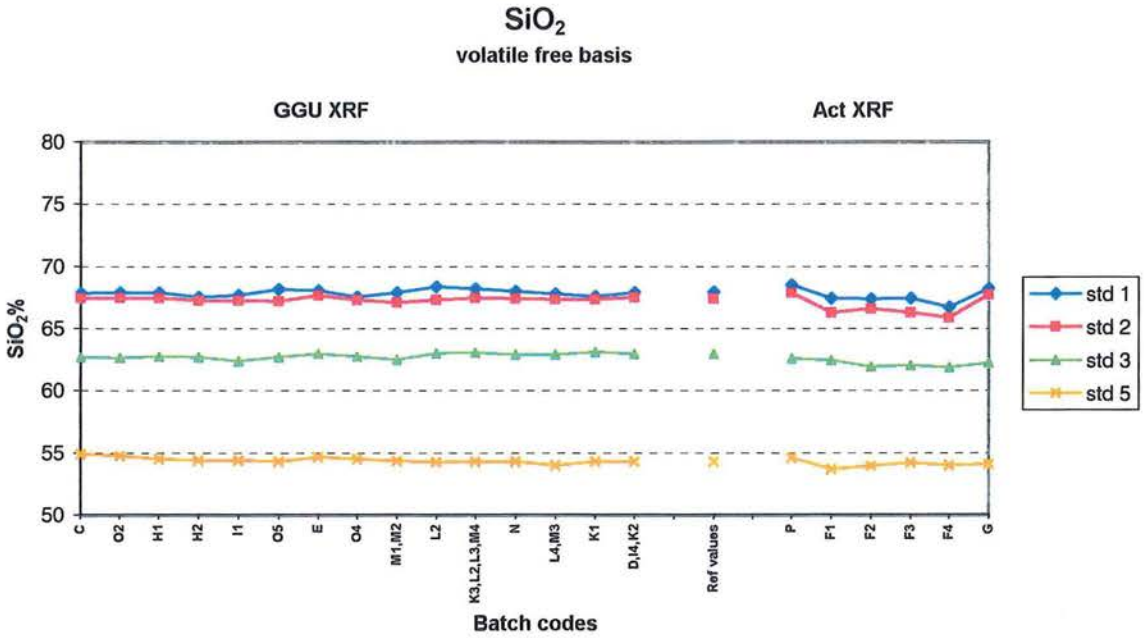


Figure 12a

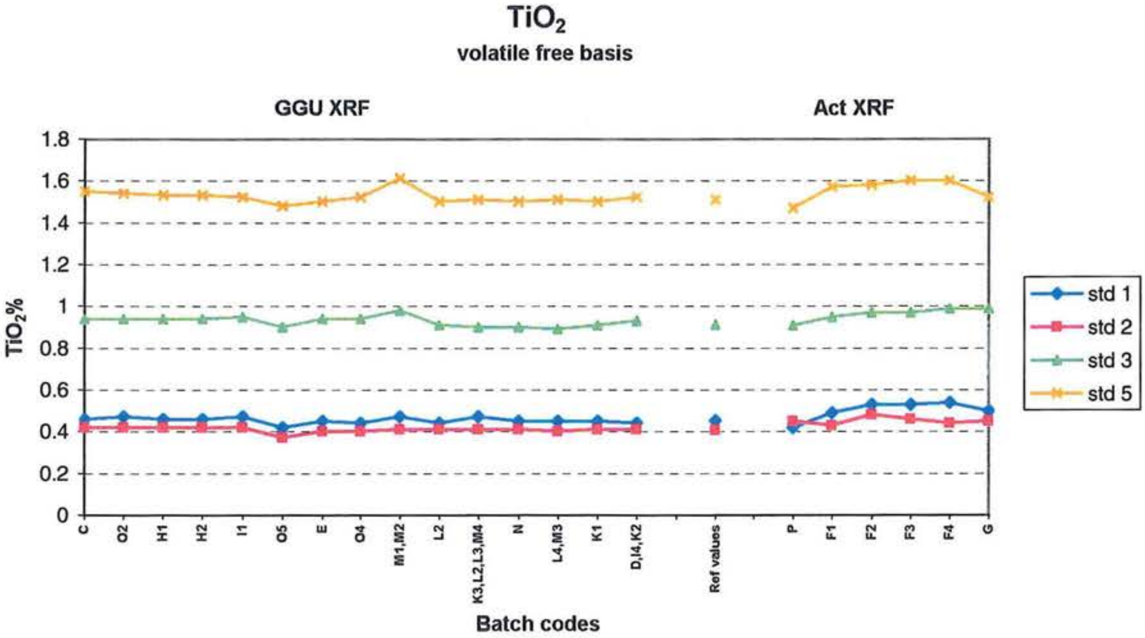


Figure 12b

Figure 12a-j. *Variability of major element data selected for the atlas as monitored by standards.*
Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);*
Methods: XRF *(X-ray Fluorescence Spectrometry).*
Ref values: reference values (Table 6).

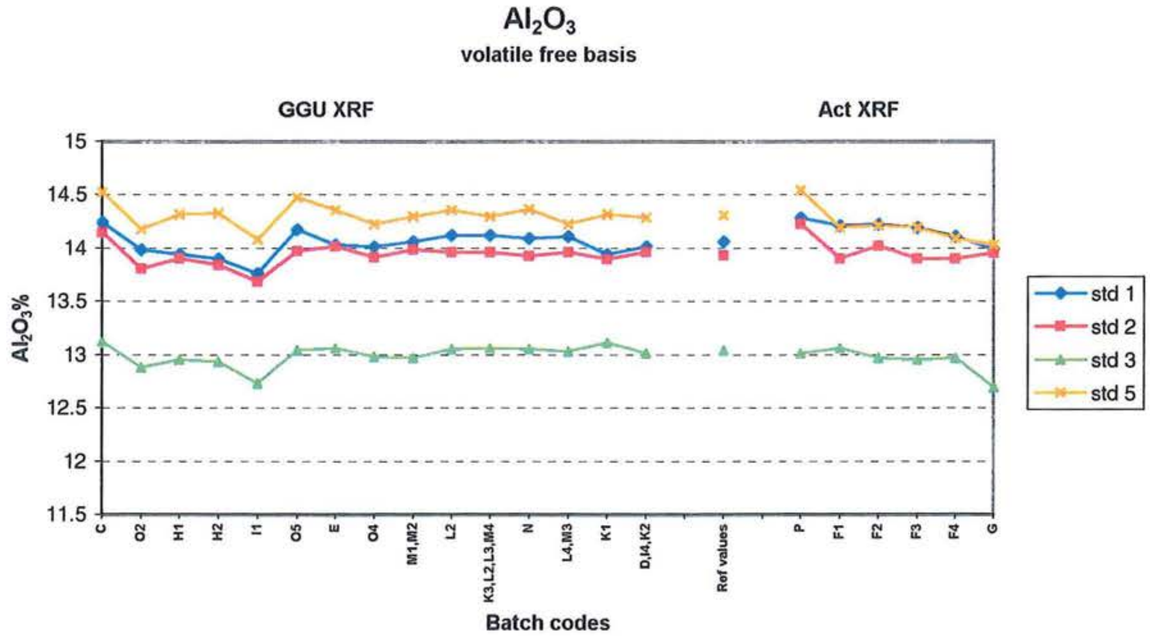


Figure 12c

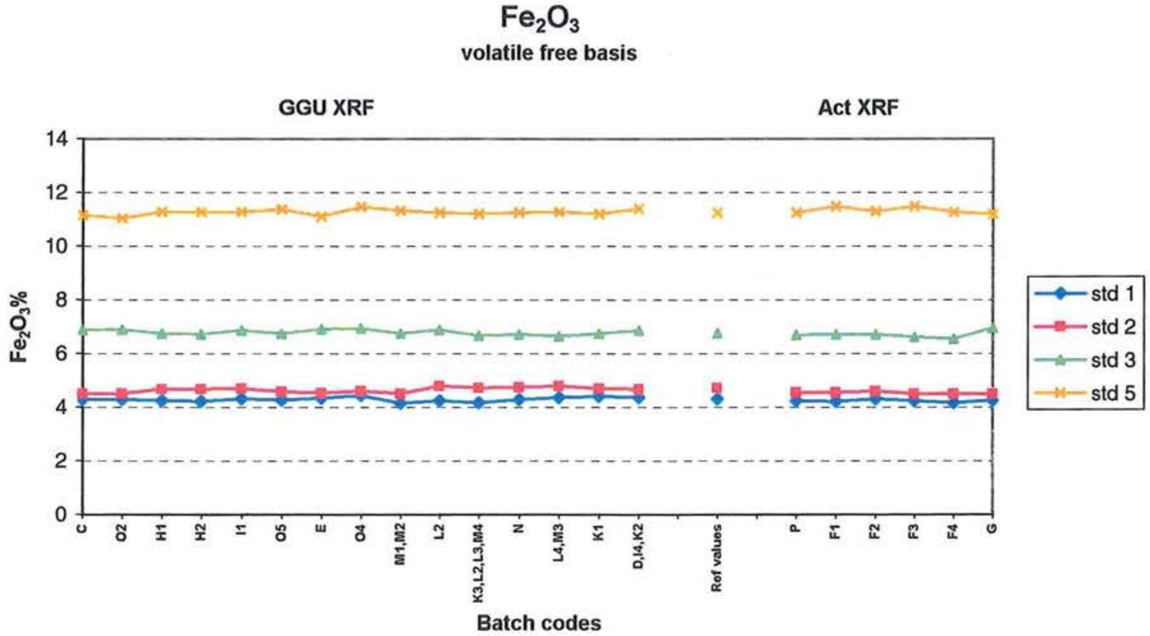


Figure 12d

Figure 12a-j. *Variability of major element data selected for the atlas as monitored by standards.*
Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);*
Methods: XRF *(X-ray Fluorescence Spectrometry).*
Ref values: reference values (Table 6).

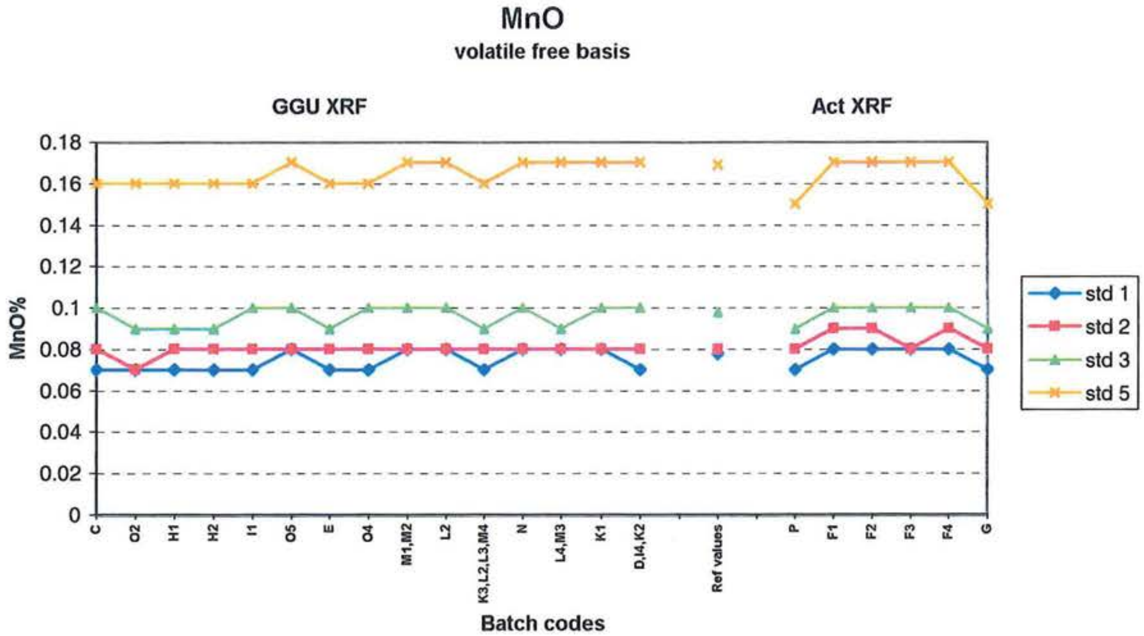


Figure 12e

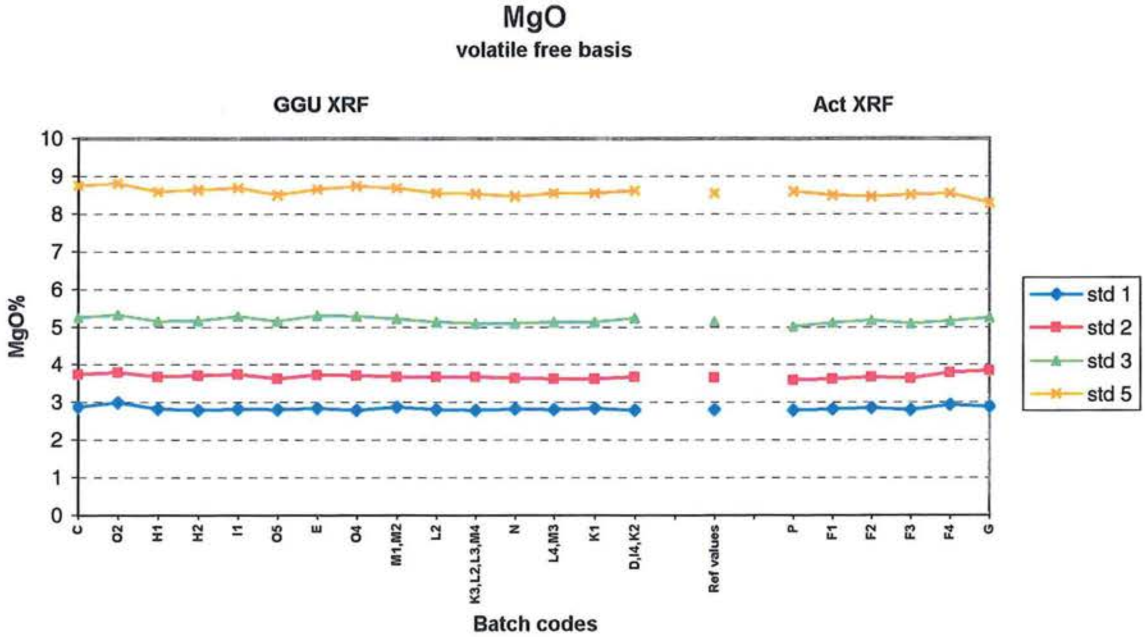


Figure 12f

Figure 12a-j. *Variability of major element data selected for the atlas as monitored by standards.*
Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);*
Methods: XRF *(X-ray Fluorescence Spectrometry).*
Ref values: reference values (Table 6).

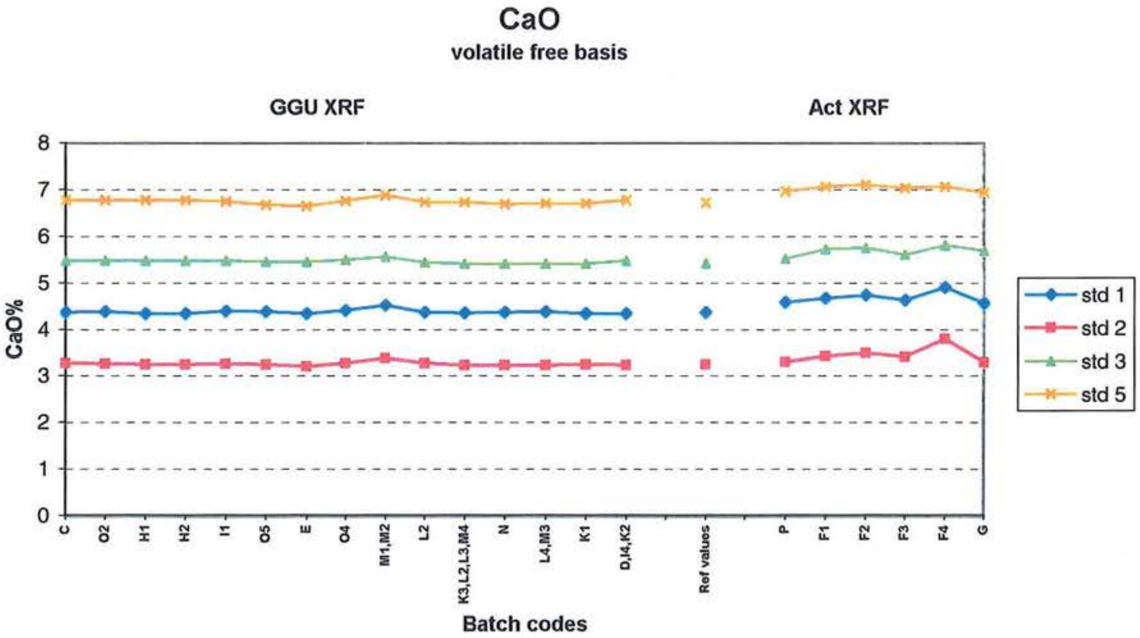


Figure 12g

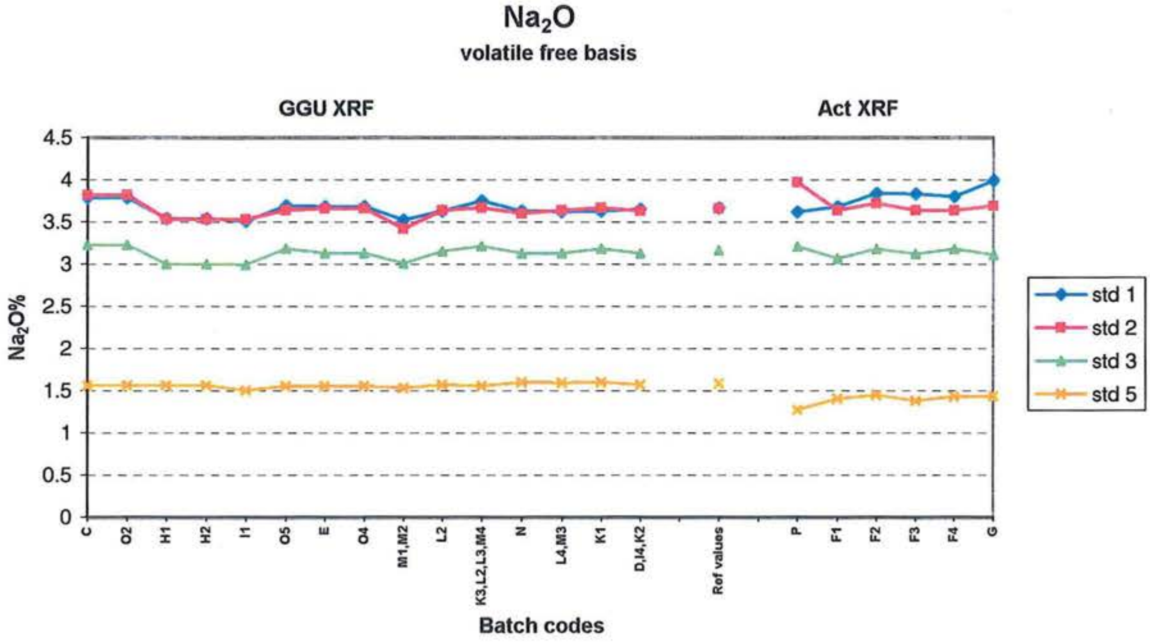


Figure 12h

Figure 12a-j. *Variability of major element data selected for the atlas as monitored by standards.*
Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);*
Methods: XRF *(X-ray Fluorescence Spectrometry).*
Ref values: reference values (Table 6).

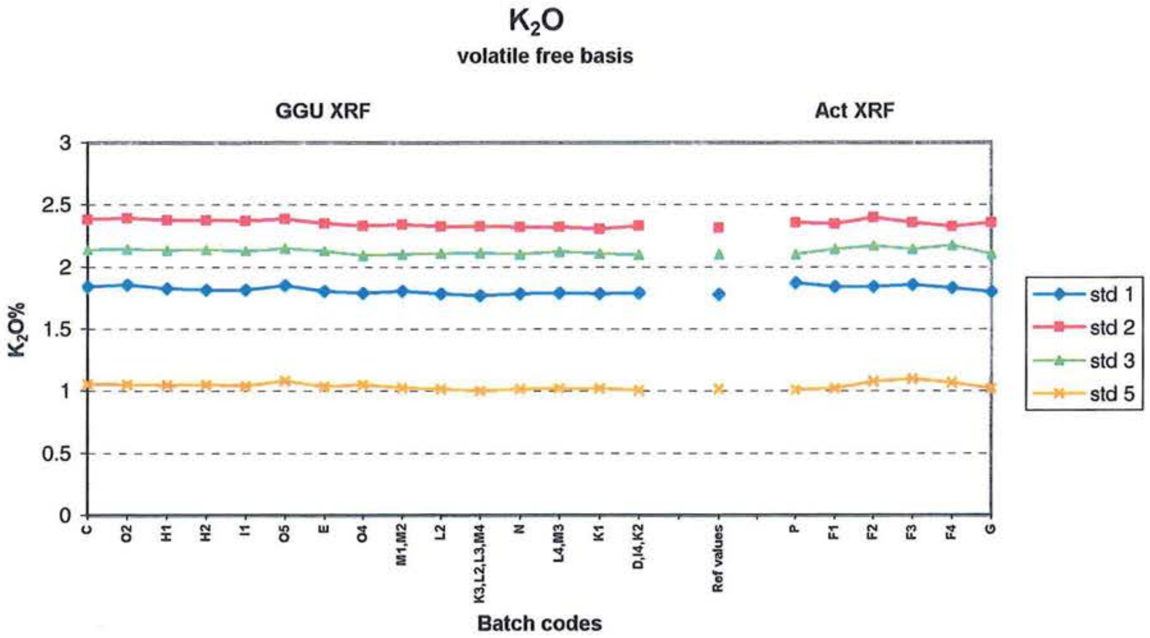


Figure 12i

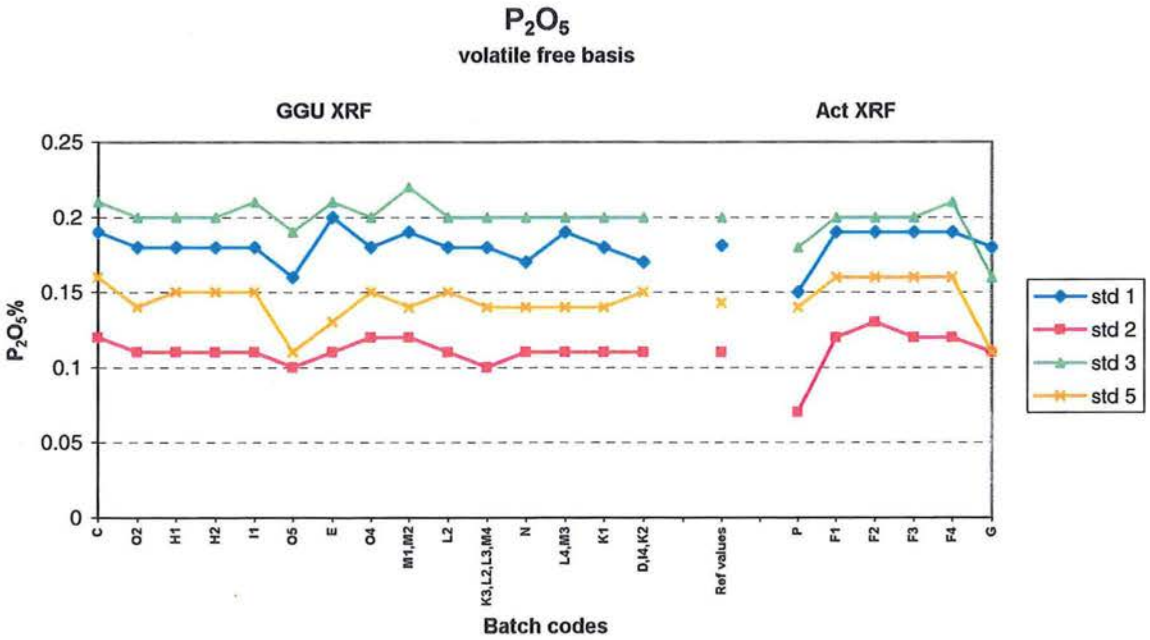


Figure 12j

Figure 12a-j. *Variability of major element data selected for the atlas as monitored by standards.*
Laboratories: GGU *(Geological Survey of Greenland);* Act *(Activation Laboratories Ltd.);*
Methods: XRF *(X-ray Fluorescence Spectrometry).*
Ref values: reference values (Table 6).

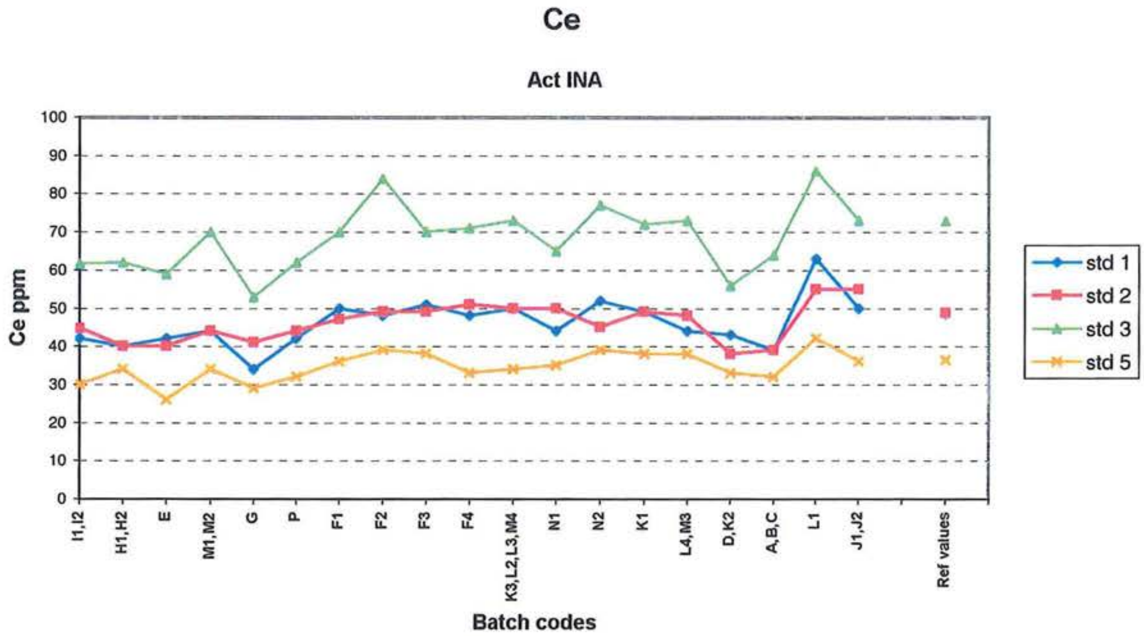


Figure 13a

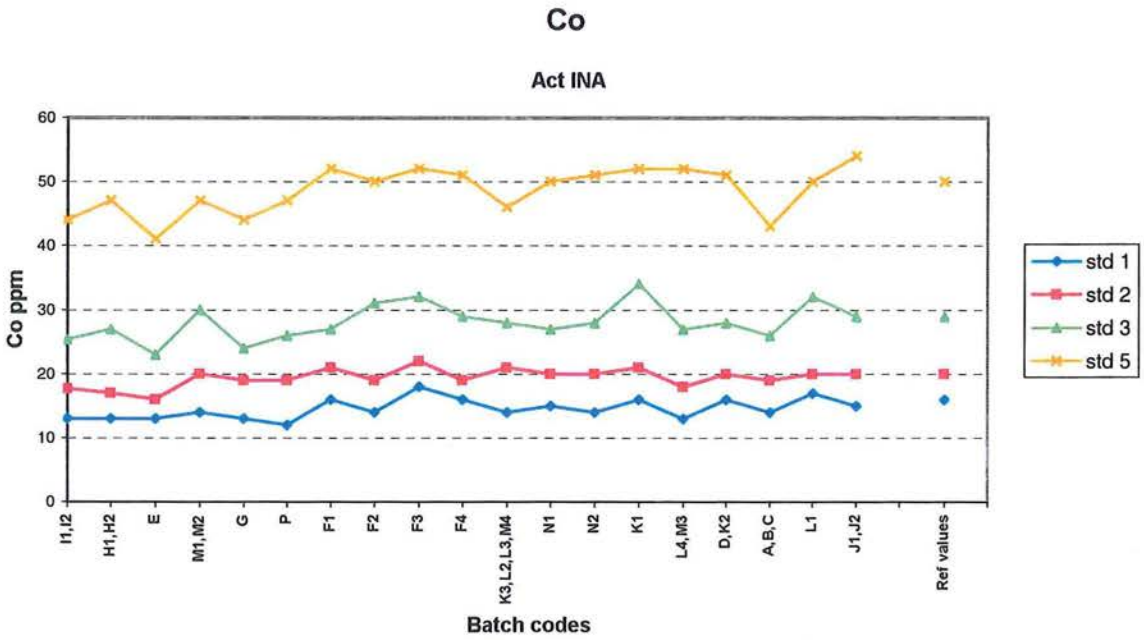


Figure 13b

Figure 13a-l. *Variability of trace element data selected for the atlas as monitored by standards.*
Laboratory: Act *(Activation Laboratories Ltd.).*
Method: INA *(Instrumental Neutron Activation).*
Ref values: reference values (Table 6).

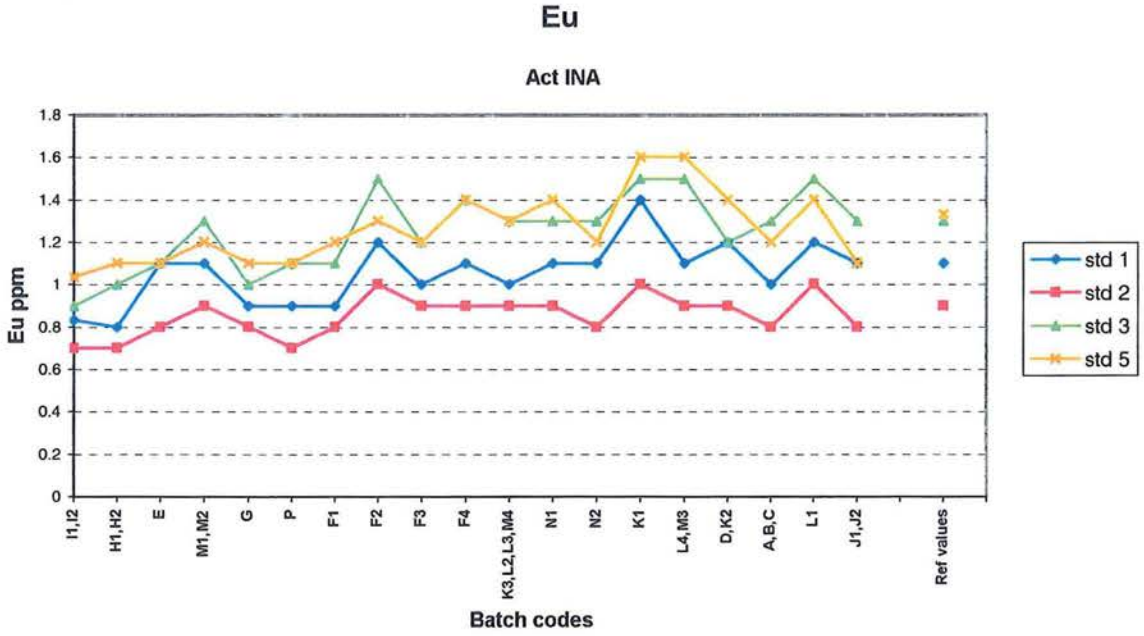


Figure 13c

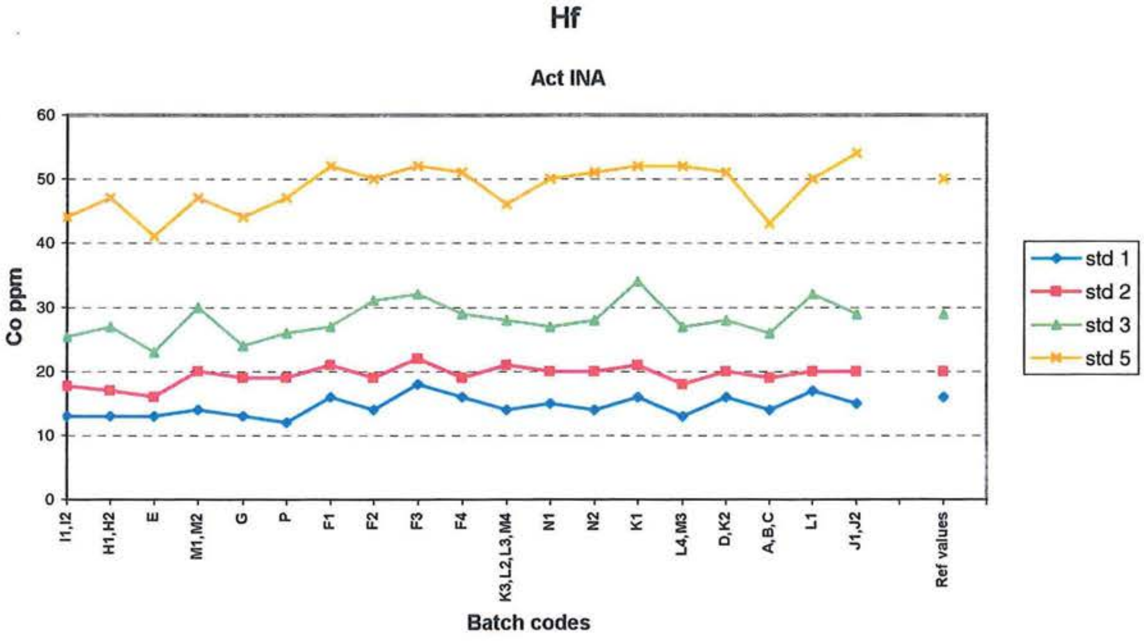


Figure 13d

Figure 13a-l. *Variability of trace element data selected for the atlas as monitored by standards.*
Laboratory: Act *(Activation Laboratories Ltd.).*
Method: INA *(Instrumental Neutron Activation).*
Ref values: reference values (Table 6).

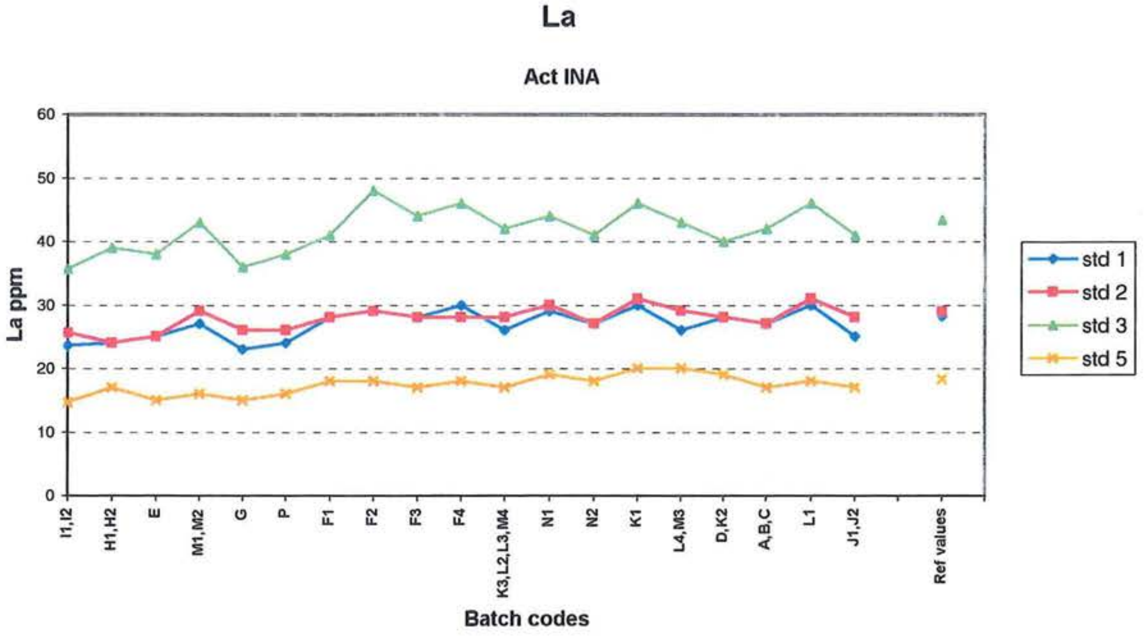


Figure 13e

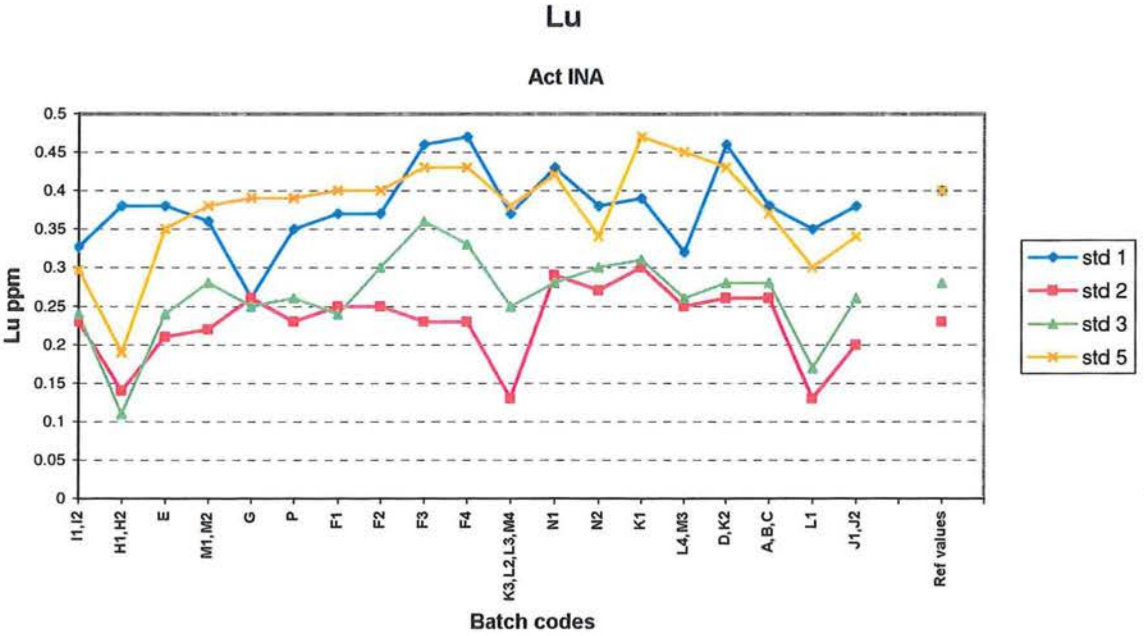


Figure 13f

Figure 13a-l. *Variability of trace element data selected for the atlas as monitored by standards.*
Laboratory: Act *(Activation Laboratories Ltd.).*
Method: INA *(Instrumental Neutron Activation).*
Ref values: reference values (Table 6).

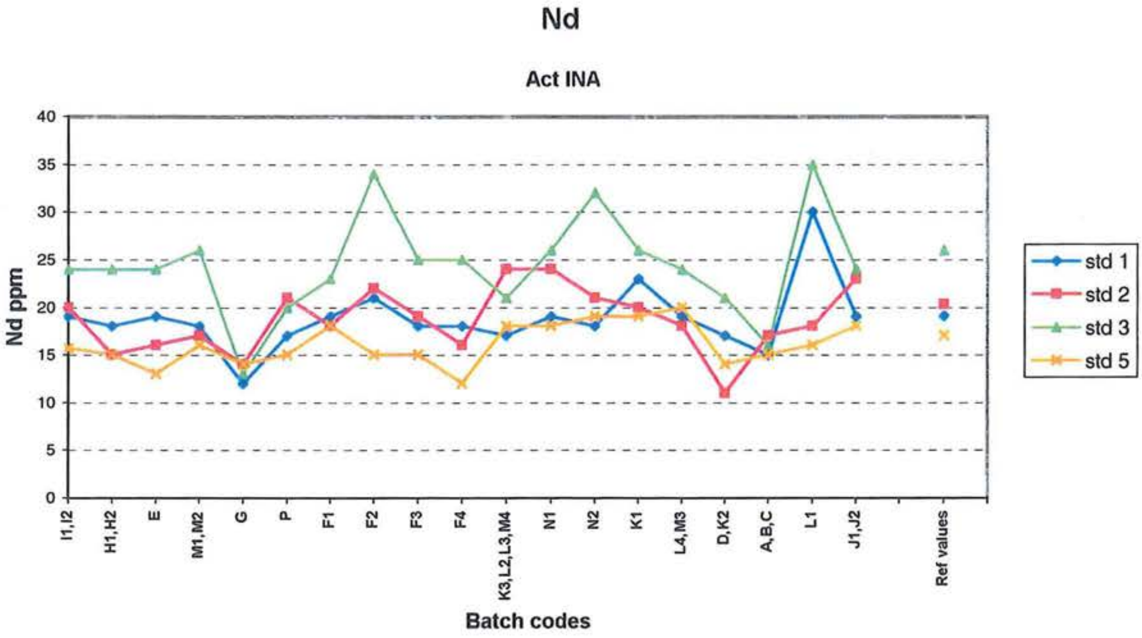


Figure 13g

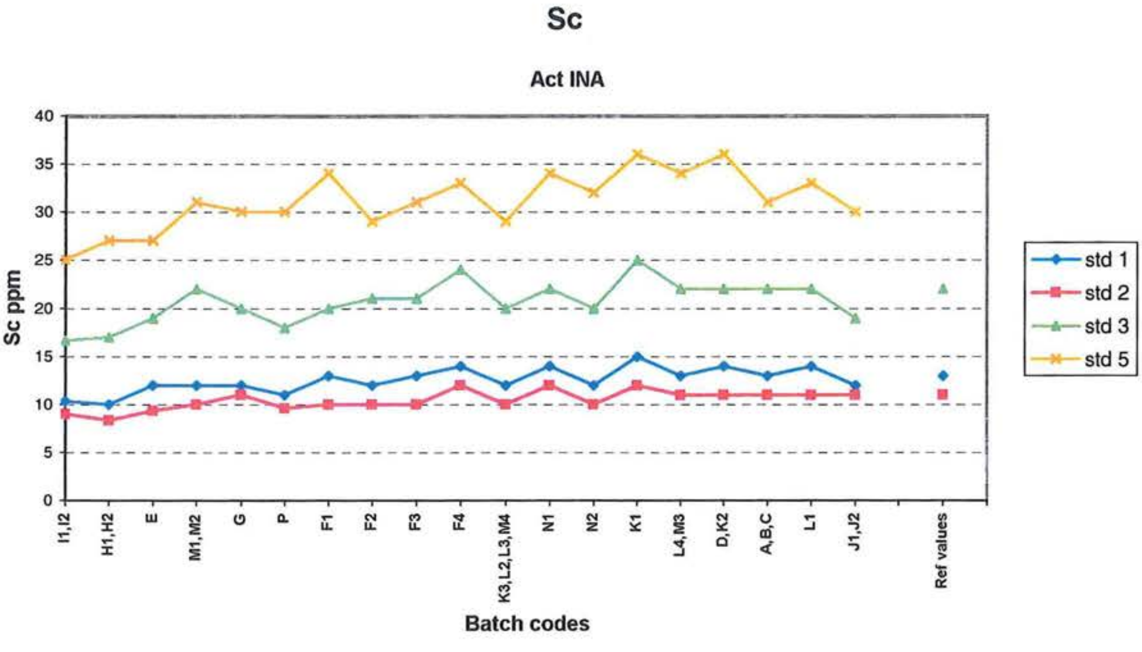


Figure 13h

Figure 13a-l. *Variability of trace element data selected for the atlas as monitored by standards.*
Laboratory: Act *(Activation Laboratories Ltd.).*
Method: INA *(Instrumental Neutron Activation).*
Ref values: reference values (Table 6).

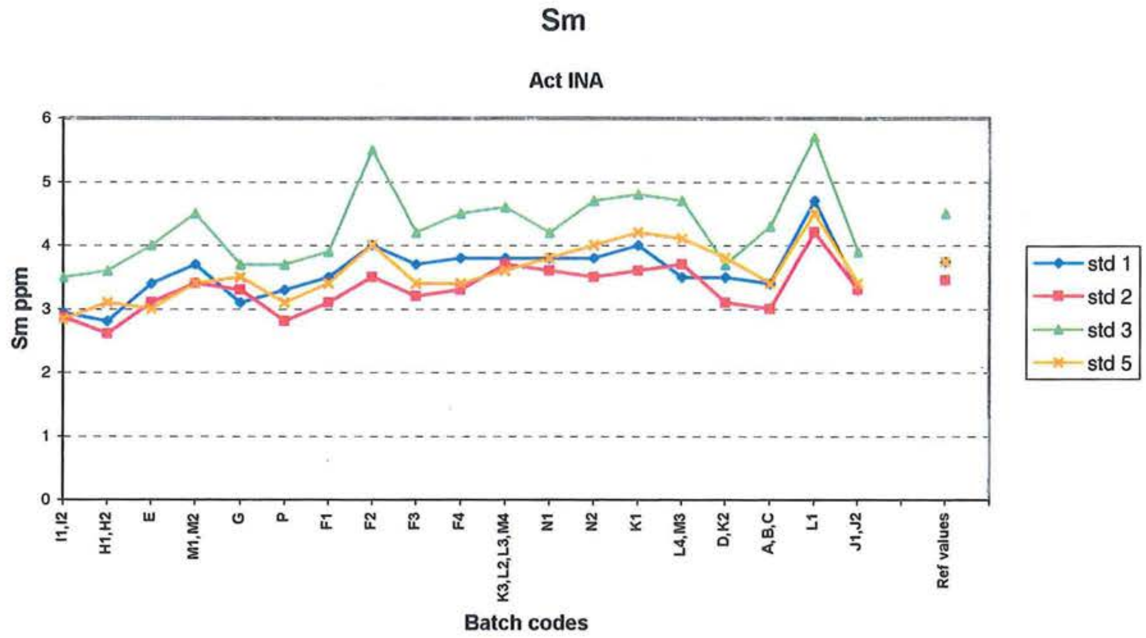


Figure 13i

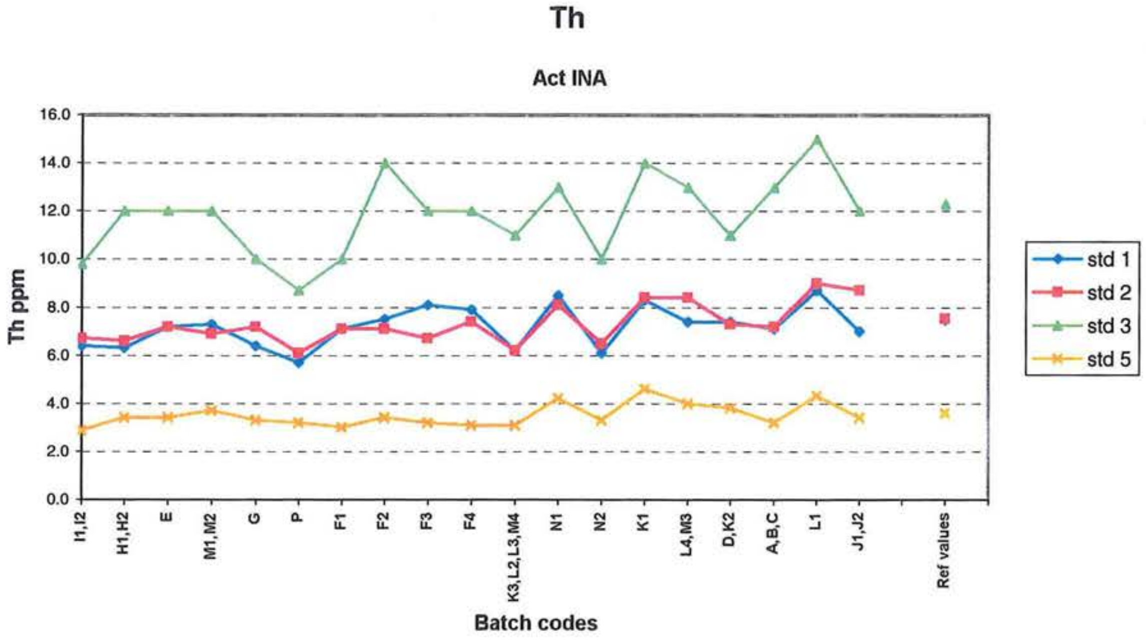


Figure 13j

Figure 13a-l. *Variability of trace element data selected for the atlas as monitored by standards.*
Laboratory: Act *(Activation Laboratories Ltd.).*
Method: INA *(Instrumental Neutron Activation).*
Ref values: reference values (Table 6).

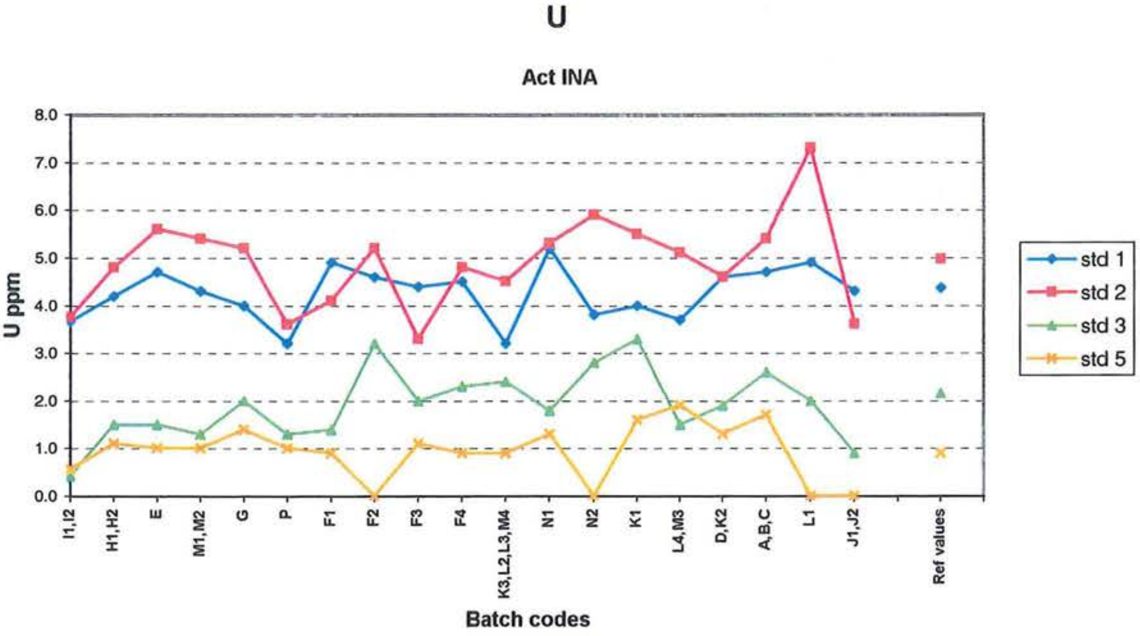


Figure 13k

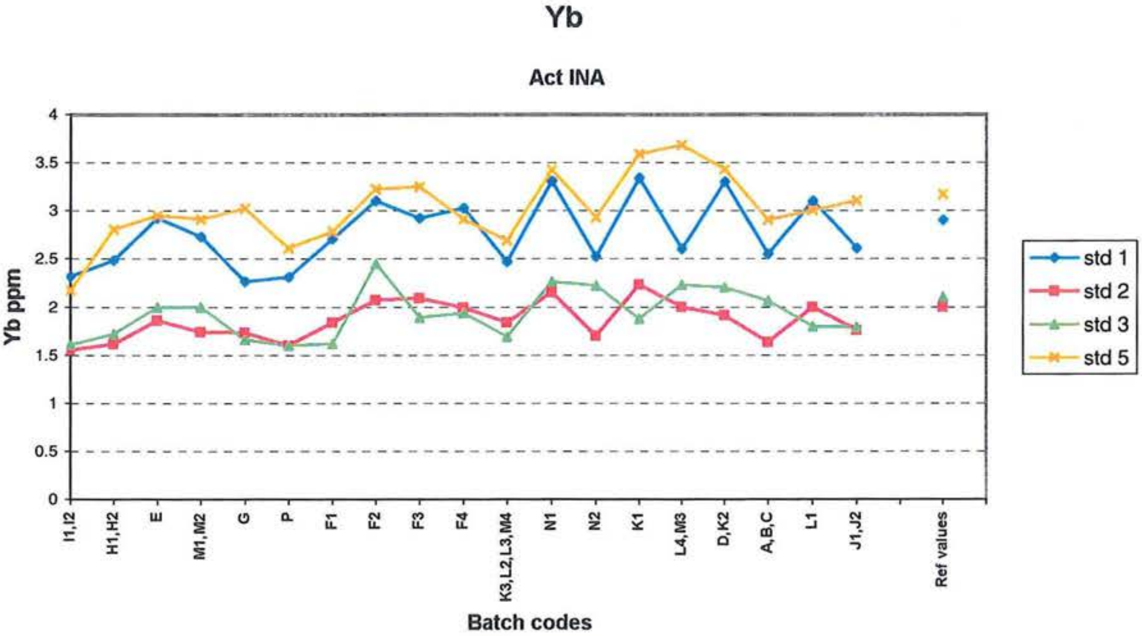


Figure 13l

Figure 13a-l. *Variability of trace element data selected for the atlas as monitored by standards.*
Laboratory: Act *(Activation Laboratories Ltd.).*
Method: INA *(Instrumental Neutron Activation).*
Ref values: reference values (Table 6).

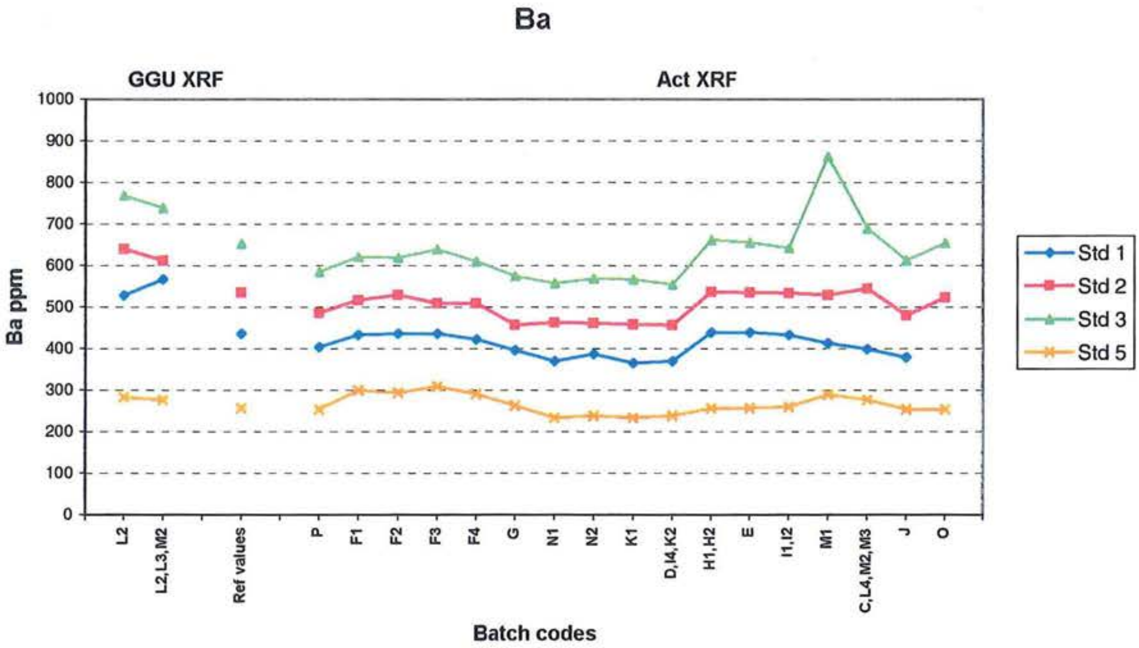


Figure 14a

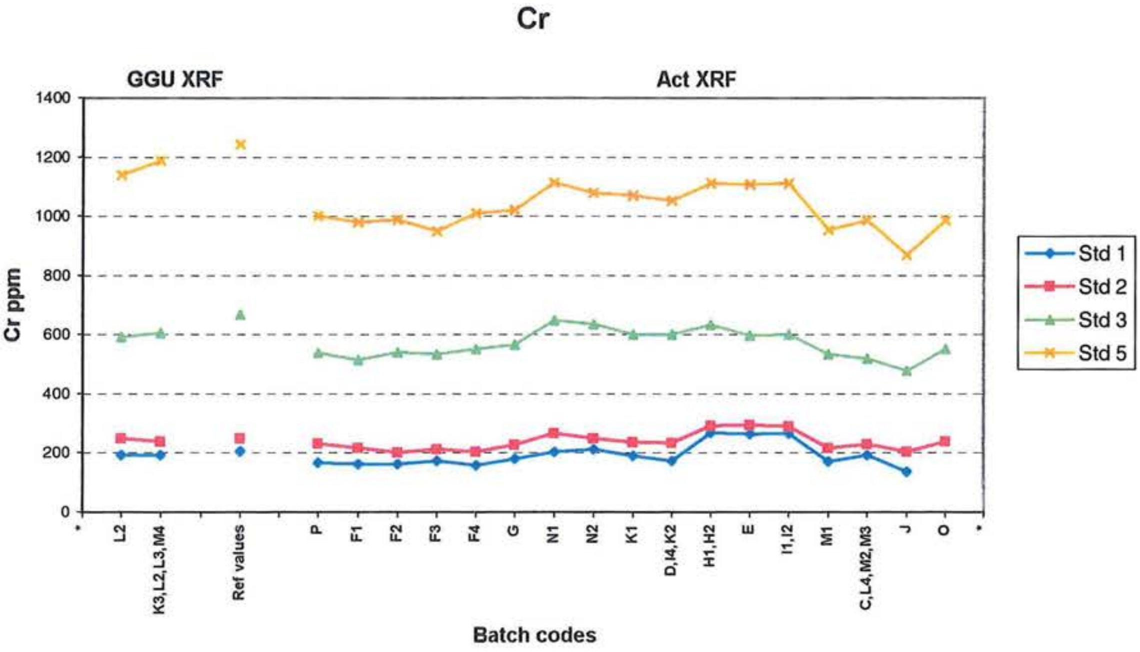


Figure 14b

Figure 14a-l. *Variability of trace element data selected for the atlas as monitored by standards.*
Laboratories: Act *(Activation Laboratories Ltd.);* GGU *(Geological Survey of Greenland).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* AAS *(Atomic Absorption Spectrometry);* ICP *(Inductively Coupled Plasma Emission Spectrometry).*
Ref values: reference values (Table 6).

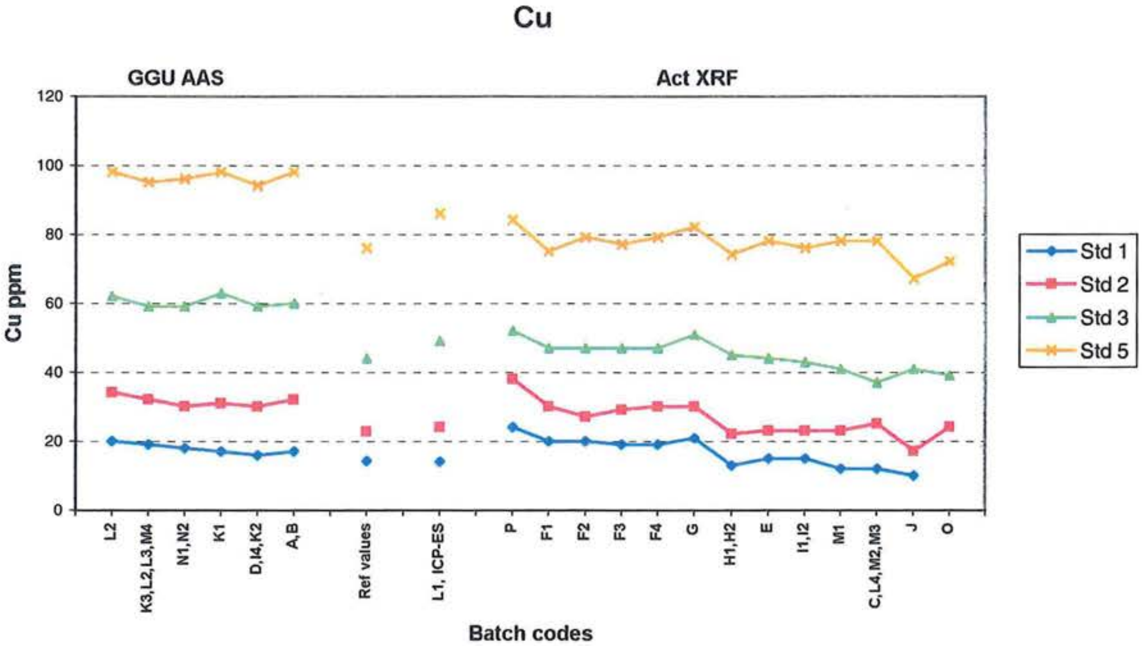


Figure 14c

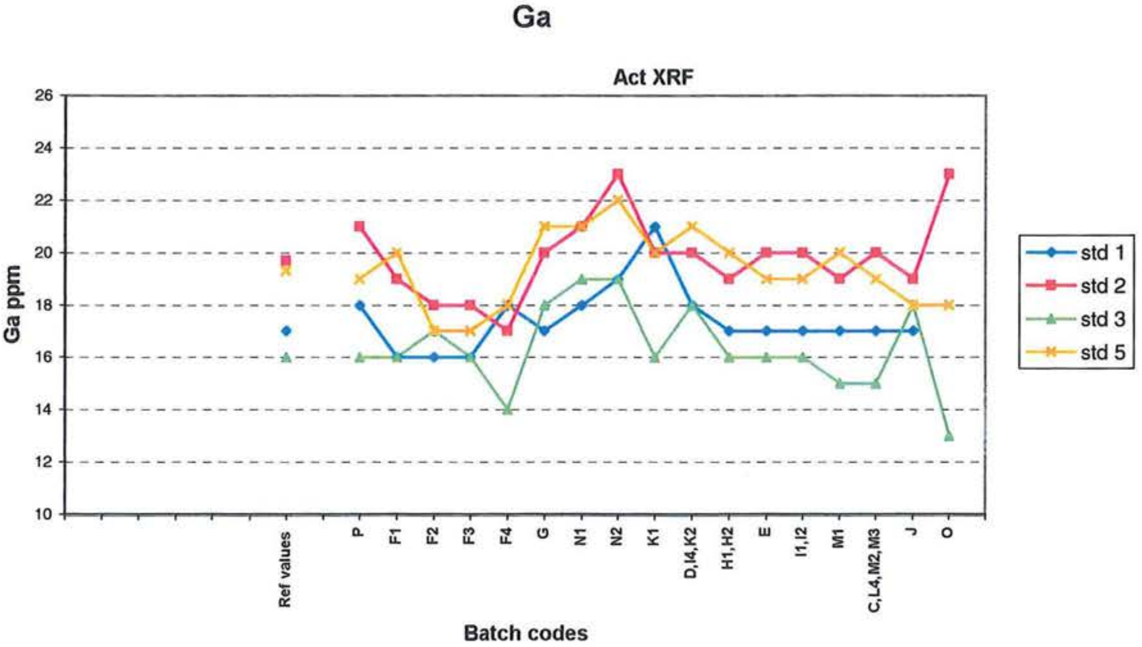


Figure 14d

Figure 14a-l. *Variability of trace element data selected for the atlas as monitored by standards.*
Laboratories: Act *(Activation Laboratories Ltd.);* GGU *(Geological Survey of Greenland).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* AAS *(Atomic Absorption Spectrometry);* ICP *(Inductively Coupled Plasma Emission Spectrometry).*
Ref values: reference values (Table 6).

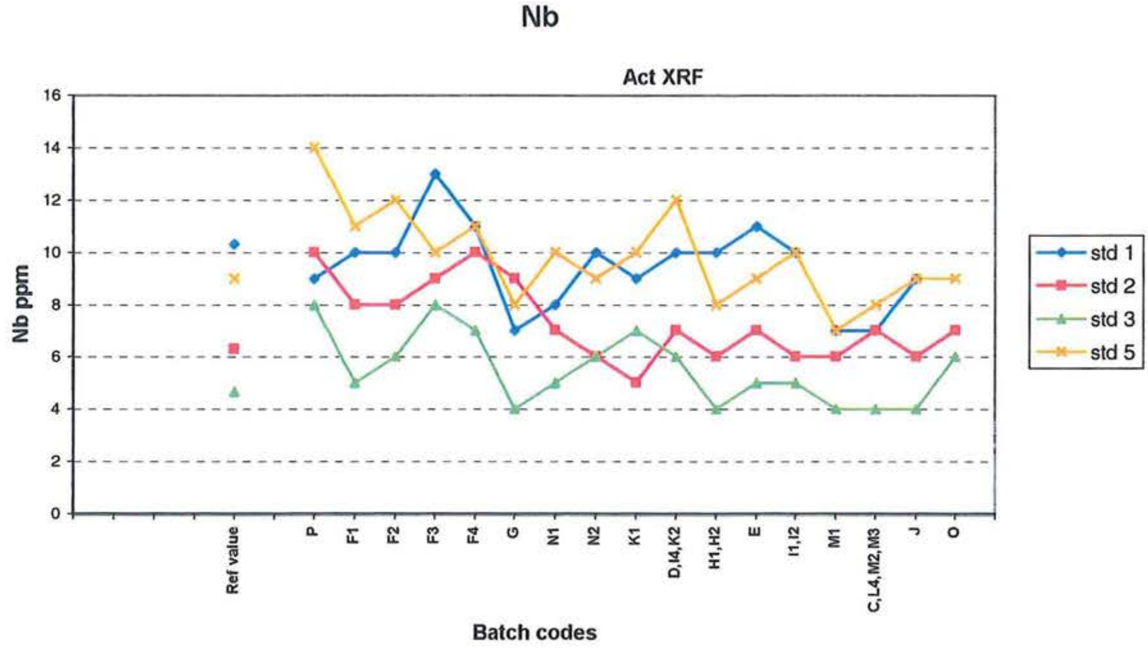


Figure 14e

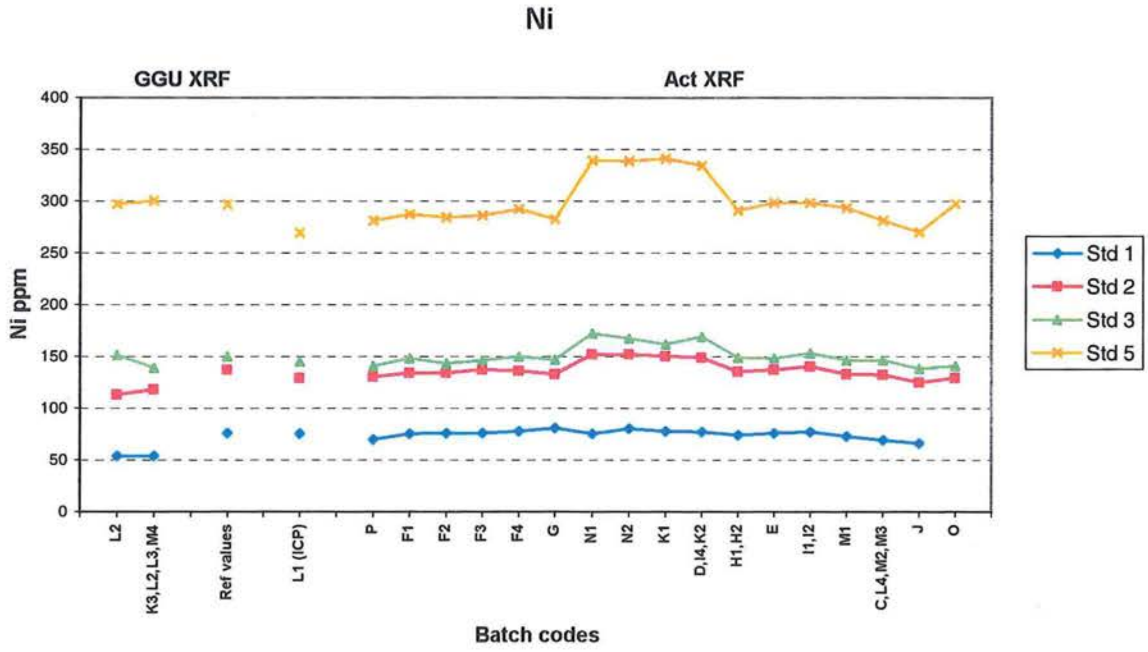


Figure 14f

Figure 14a-l. *Variability of trace element data selected for the atlas as monitored by standards.*

Laboratories: Act *(Activation Laboratories Ltd.);* GGU *(Geological Survey of Greenland).*

Methods: XRF *(X-ray Fluorescence Spectrometry);* AAS *(Atomic Absorption Spectrometry);* ICP *(Inductively Coupled Plasma Emission Spectrometry).*

Ref values: reference values (Table 6).

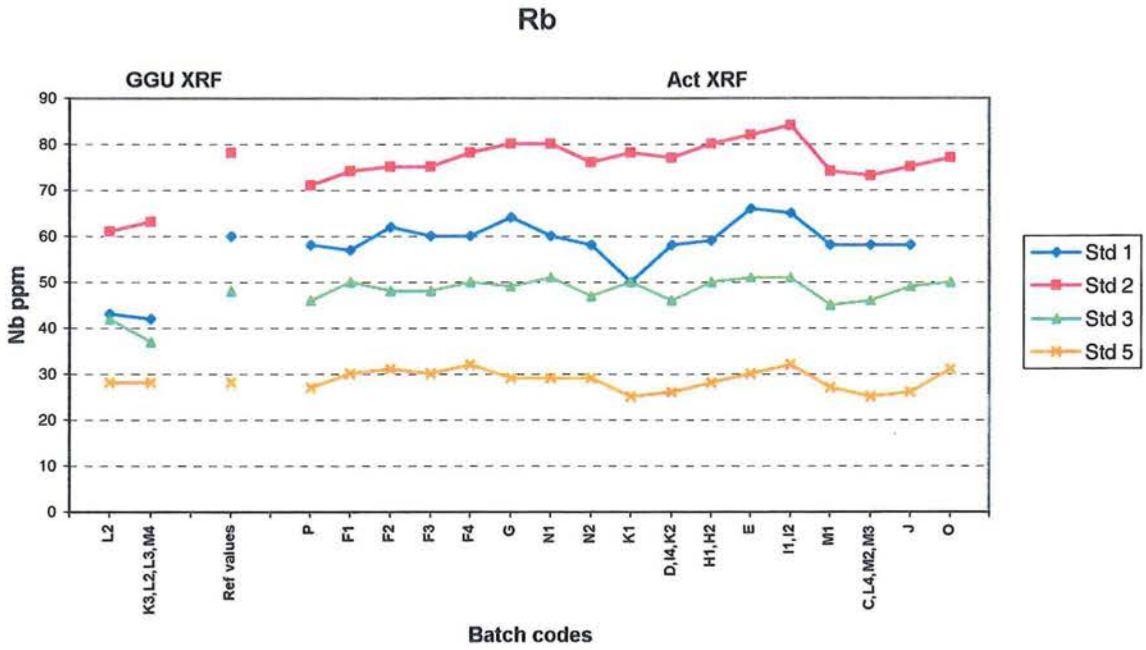


Figure 14g

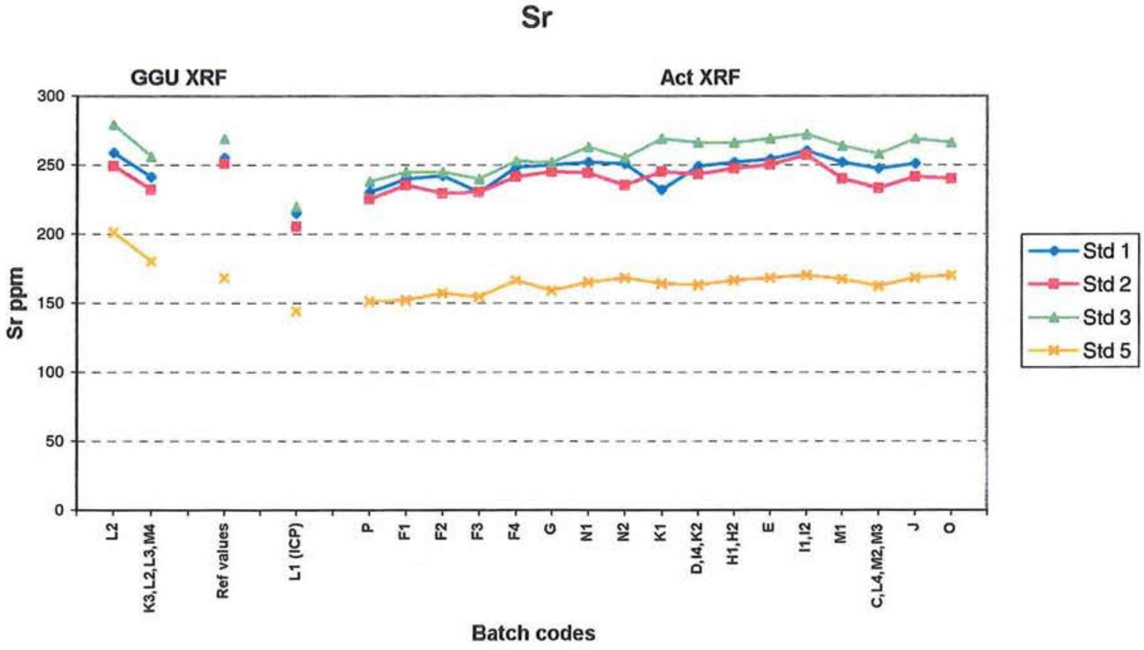


Figure 14h

Figure 14a-l. *Variability of trace element data selected for the atlas as monitored by standards.*
Laboratories: Act *(Activation Laboratories Ltd.);* GGU *(Geological Survey of Greenland).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* AAS *(Atomic Absorption Spectrometry);*
ICP *(Inductively Coupled Plasma Emission Spectrometry).*
Ref values: reference values (Table 6).

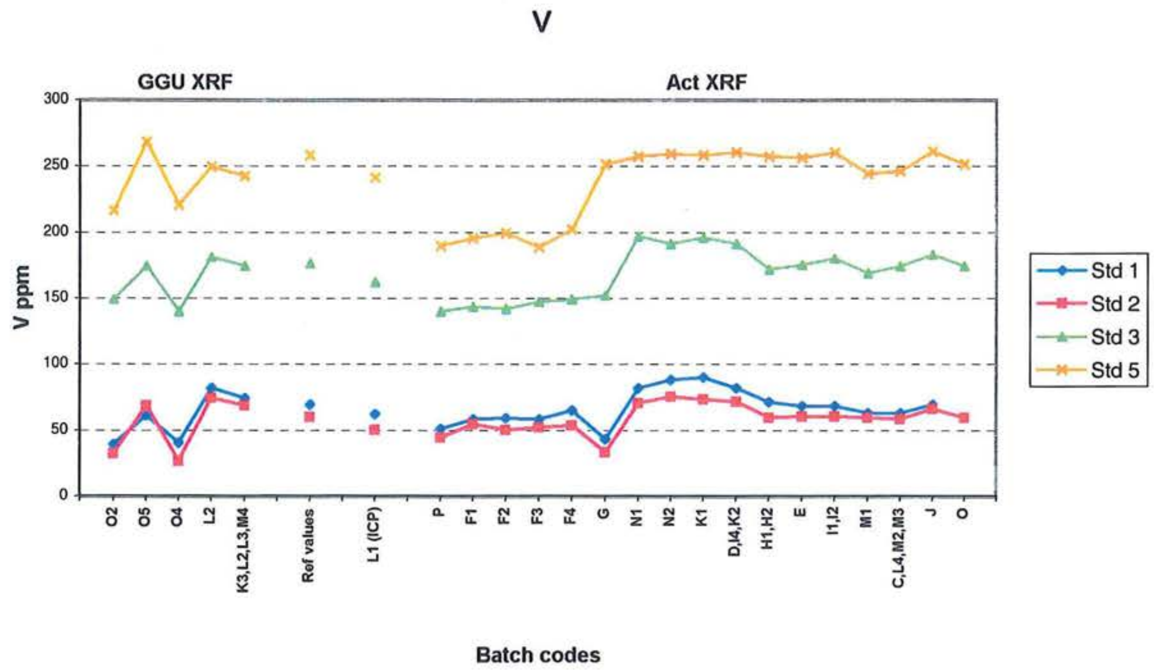


Figure 14i

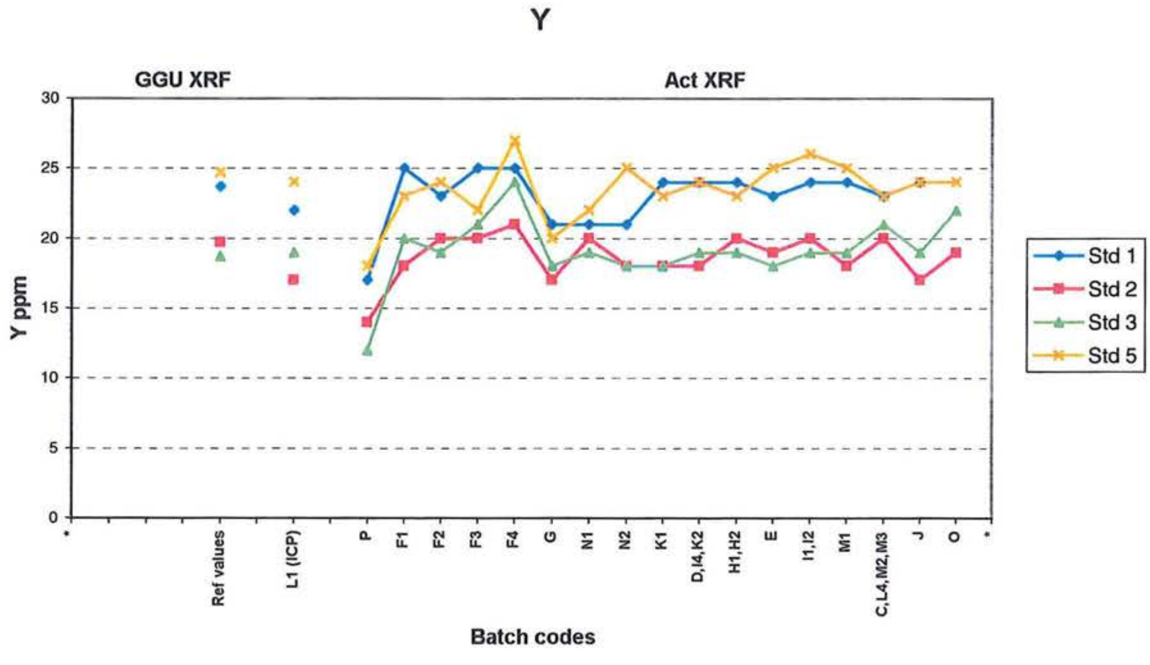


Figure 14j

Figure 14a-l. *Variability of trace element data selected for the atlas as monitored by standards.*
Laboratories: Act *(Activation Laboratories Ltd.);* GGU *(Geological Survey of Greenland).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* AAS *(Atomic Absorption Spectrometry);*
ICP *(Inductively Coupled Plasma Emission Spectrometry).*
Ref values: reference values (Table 6).

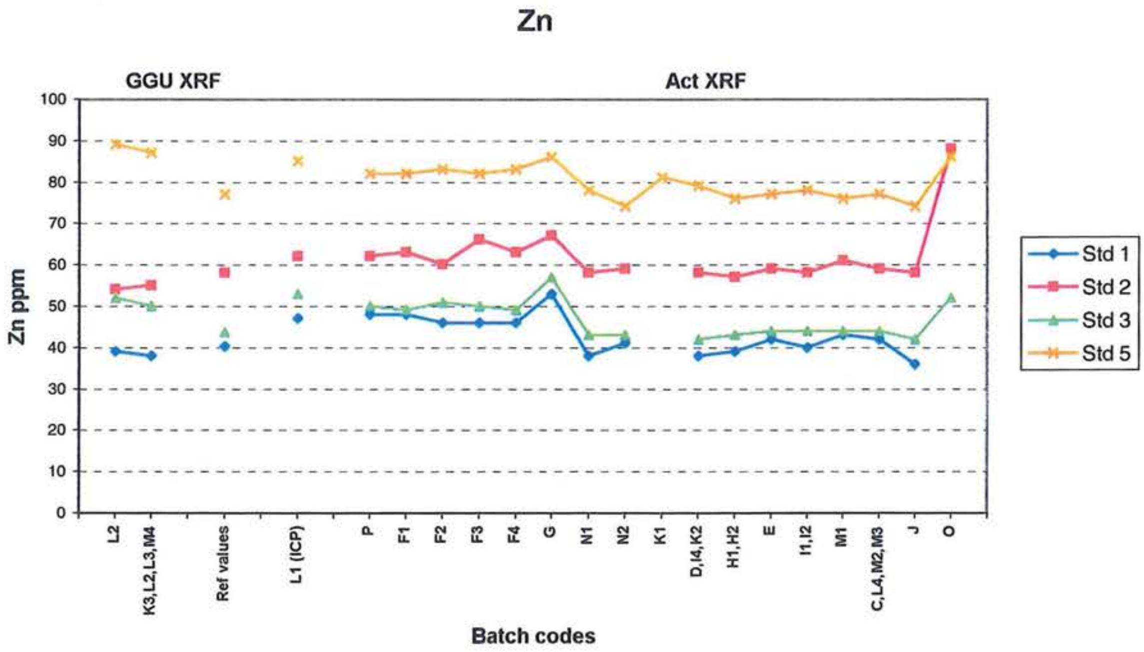


Figure 14k

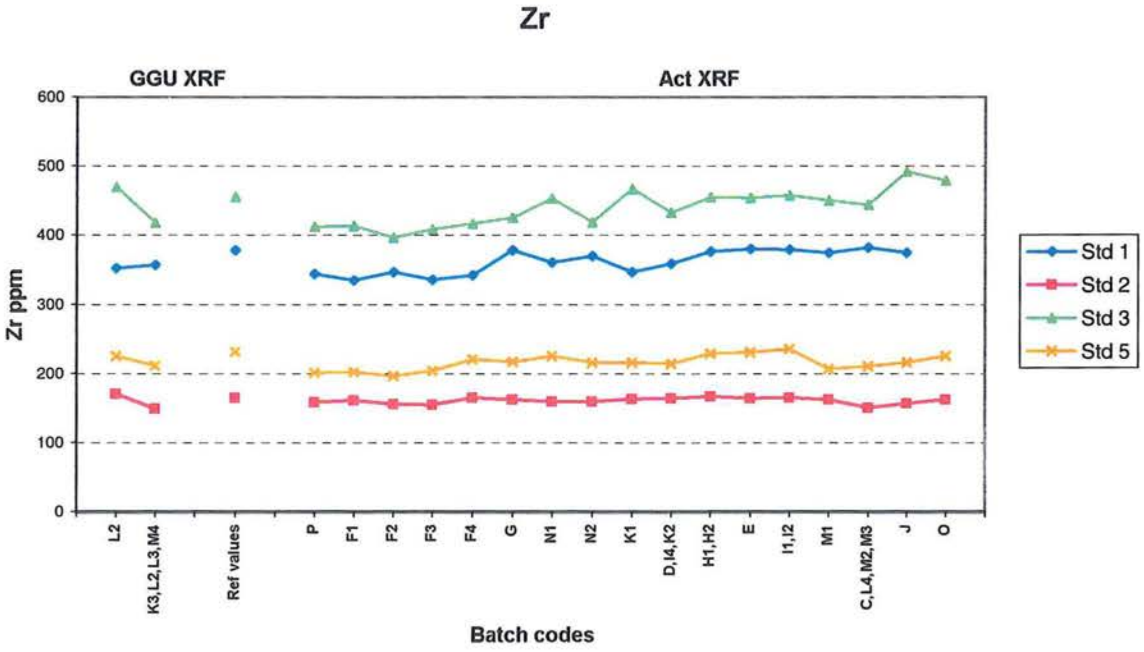


Figure 14l

Figure 14a-l. *Variability of trace element data selected for the atlas as monitored by standards.*
Laboratories: Act *(Activation Laboratories Ltd.);* GGU *(Geological Survey of Greenland).*
Methods: XRF *(X-ray Fluorescence Spectrometry);* AAS *(Atomic Absorption Spectrometry);* ICP *(Inductively Coupled Plasma Emission Spectrometry).*
Ref values: reference values (Table 6).

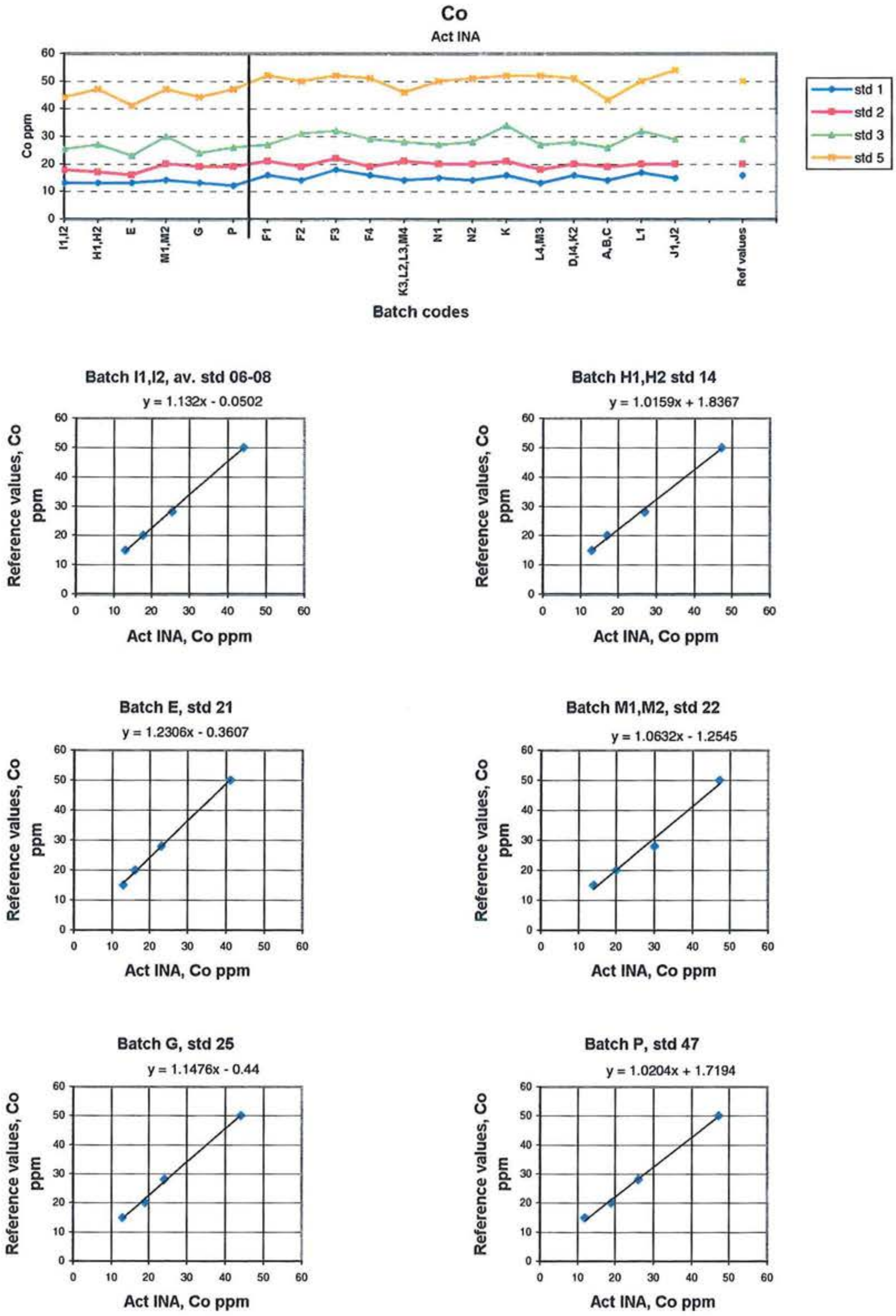
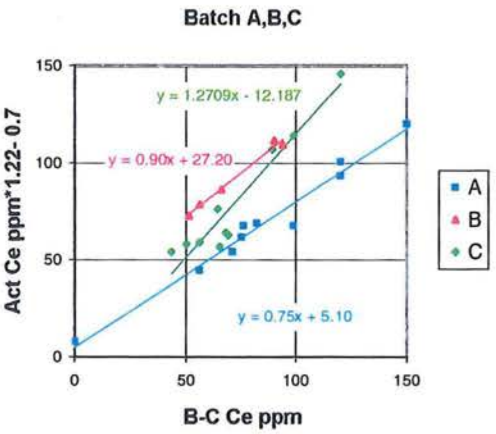
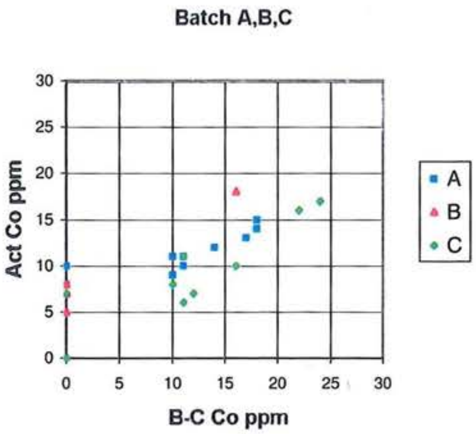


Figure 15

***Figure 15**. Determination of calibration parameters for Co determined by Act INA.*
Batches to the left of the vertical line in the top figure are corrected by means of regression of measured values for the standards accompanying these batches against reference values.
Parameters a and b of the equation for the regression lines are listed in Table 7b.
Correction is not considered necessary for the remaining batches (to the right of the line).
Laboratory: Act (Activation Laboratories Ltd.).
Method: INA (Instrumental Neutron Activation).

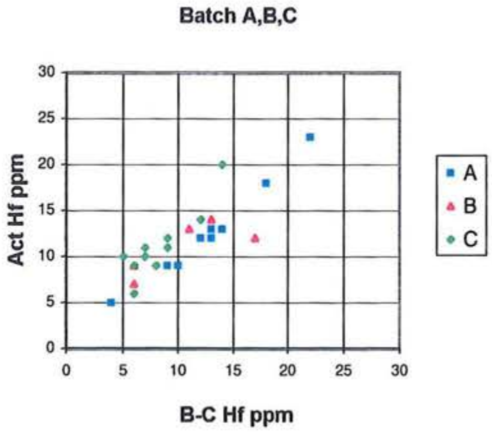


a

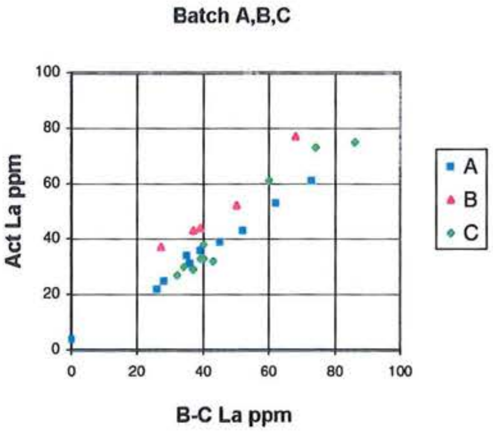


b

Figure 16a, b

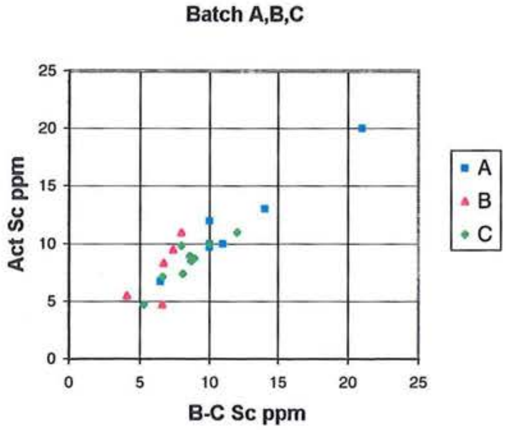


c

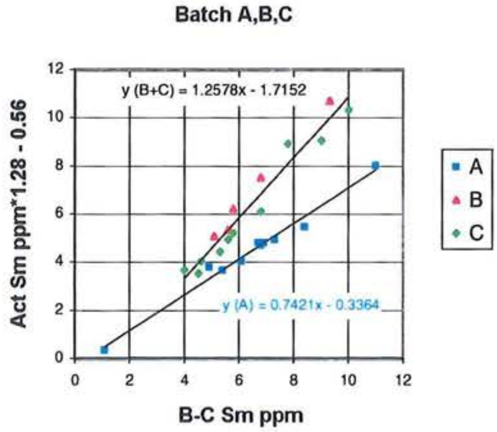


d

Figure 16c, d



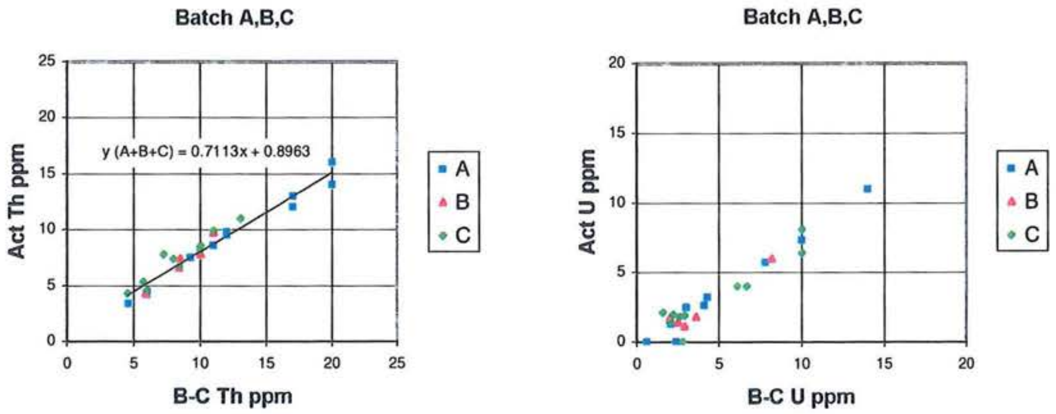
e



f

Figure 16e, f

Figure 16a-h. *Calibration of analytical values provided by B-C INA from batches A, B and C by means of calibrated Act INA data.*
Laboratories: B-C (Bondar-Clegg and Co. Ltd.); Act (Activation Laboratories Ltd.).
Method: INA *(Instrumental Neutron Activation).*



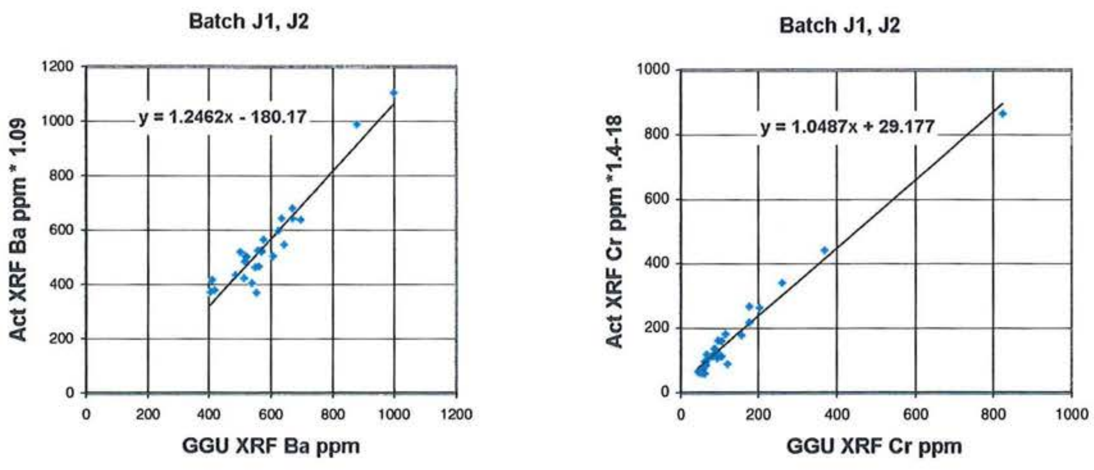
g h

Figure 16g, h

Figure 16a-h. *Calibration of analytical values provided by B-C INA from batches A, B and C by means of calibrated Act INA data.*

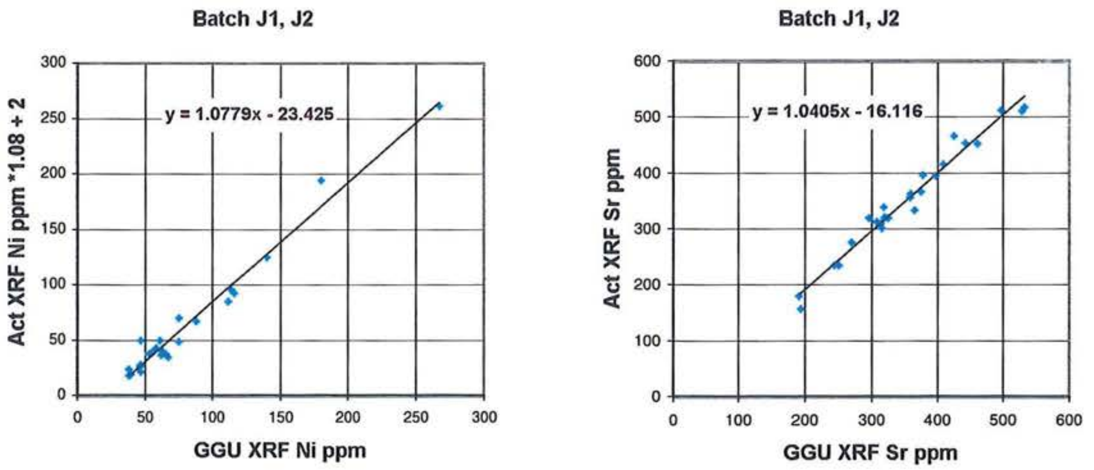
Laboratories: B-C (Bondar-Clegg and Co. Ltd.); Act (Activation Laboratories Ltd.).

Method: INA *(Instrumental Neutron Activation).*



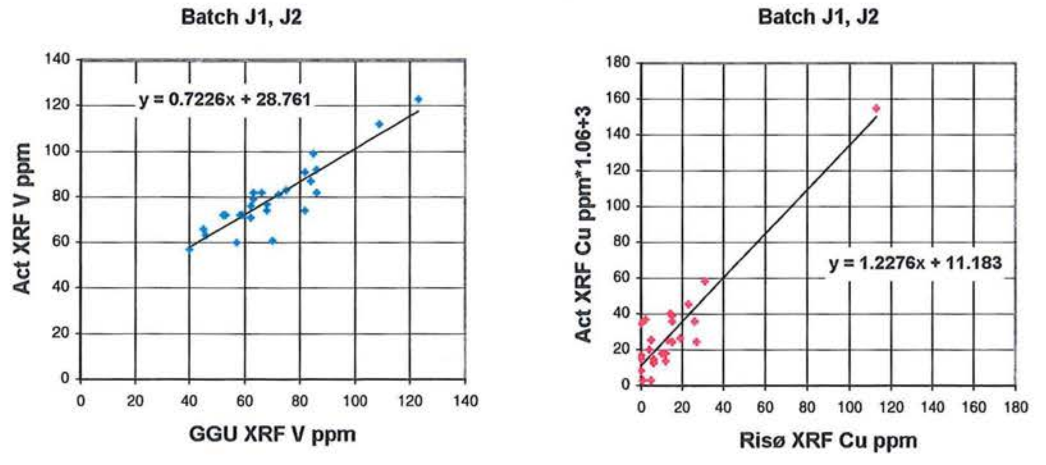
a **b**

Figure 17a, b



c **d**

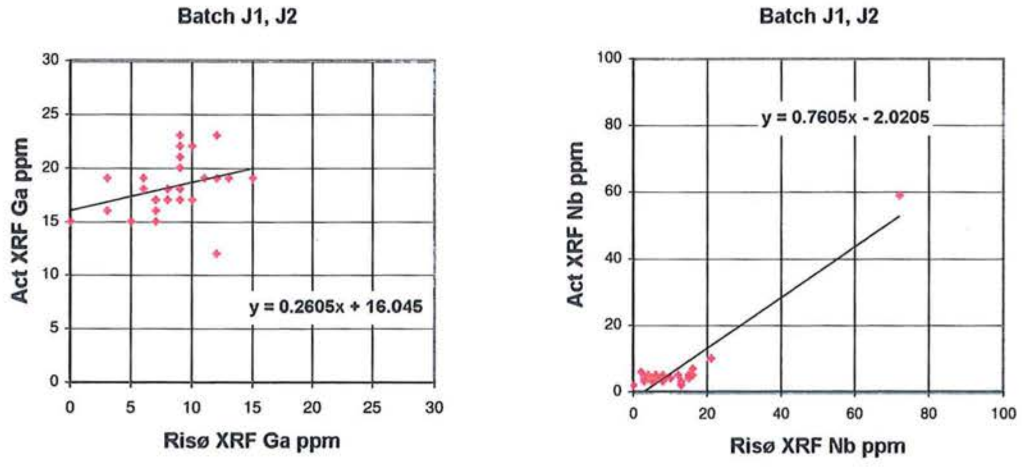
Figure 17c, d



e **f**

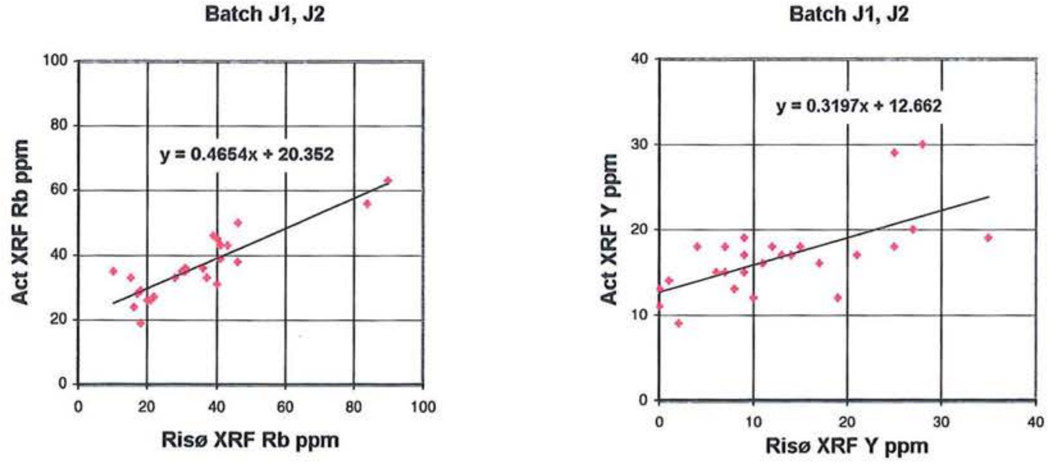
Figure 17e, f

Figure 17a-l. *Calibration of* GGU XRF *and* Risø XRF *values from area J by means of calibrated* Act XRF *data from 26 samples.*
Laboratories: Act *(Activation Laboratories Ldt.);* GGU *(Geological Survey of Greenland);* Risø *(Risø National Laboratory). Methods:* XRF *(X-ray Fluorescence Spectrometry).*



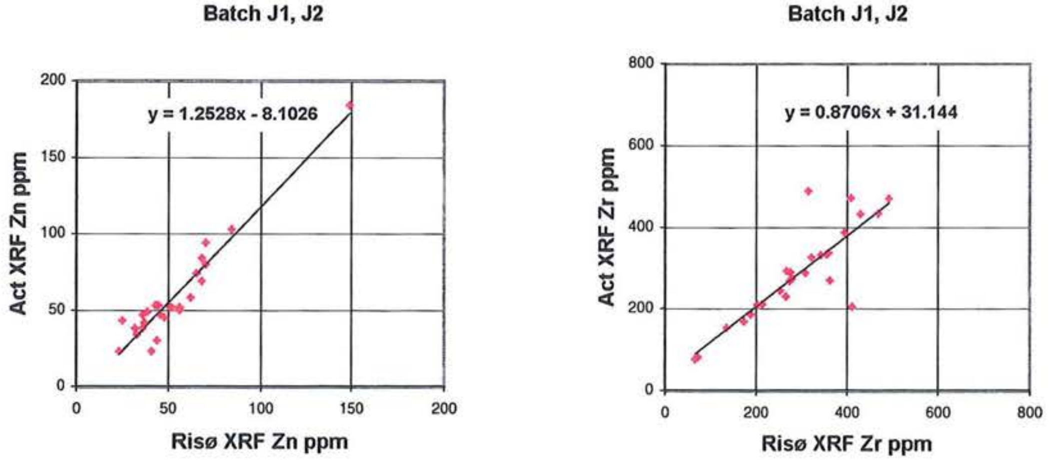
g **h**

Figure 17g, h



i **j**

Figure 17i, j



k **l**

Figure 17k, l

Figure 17a-l. *Calibration of* GGU XRF *and* Risø XRF *values from area J by means of calibrated* Act XRF *data from 26 samples.*
Laboratories: Act *(Activation Laboratories Ltd.);* GGU *(Geological Survey of Greenland);* Risø *(Risø National Laboratory). Methods:* XRF *(X-ray Fluorescence Spectrometry).*

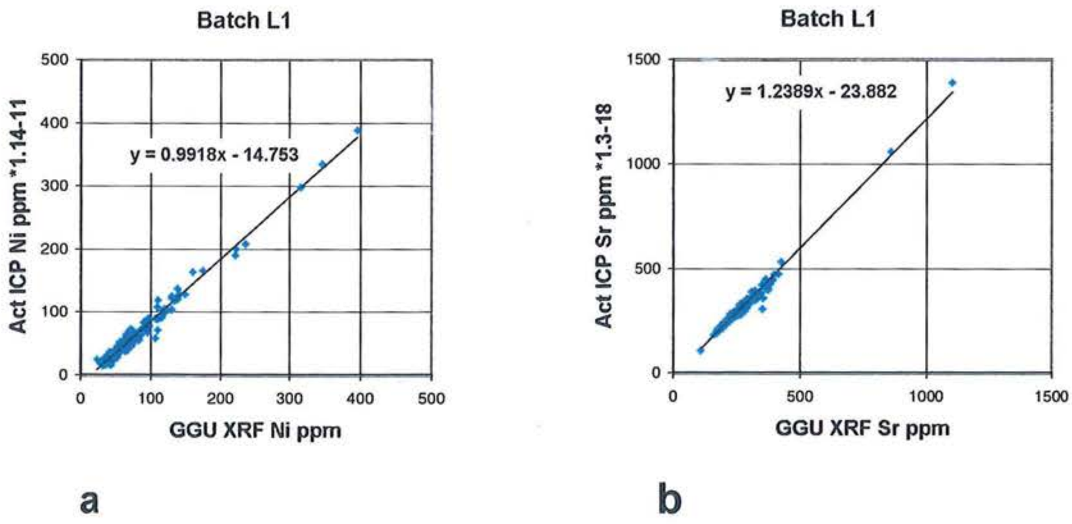


Figure 18a, b

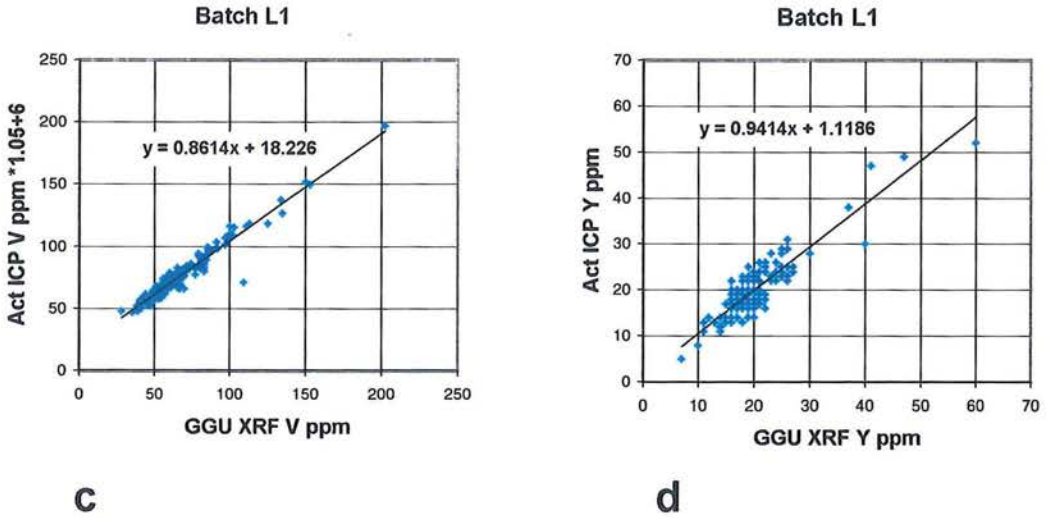


Figure 18c, d

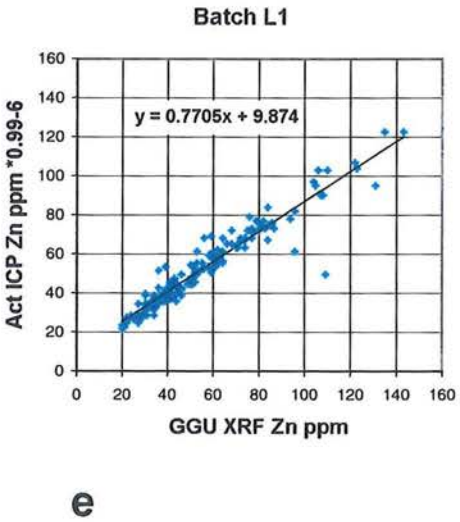


Figure 18e

Figure 18a-e. *Calibration of* GGU XRF *data from batch L1 by means of calibrated* Act ICP *analyses of 153 samples.*
Laboratories: Act *(Activation Laboratories Ltd.);* GGU *(Geological Survey of Greenland).*
Methods: ICP *(Inductively Coupled Plasma Emission Spectrometry);*
XRF *(X-ray Fluorescence Spectrometry).*

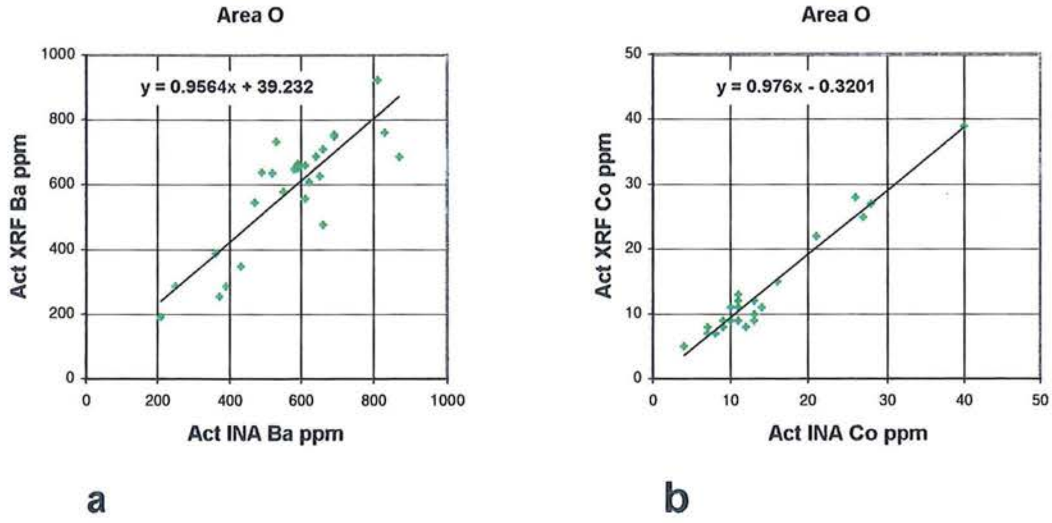


Figure 19a, b

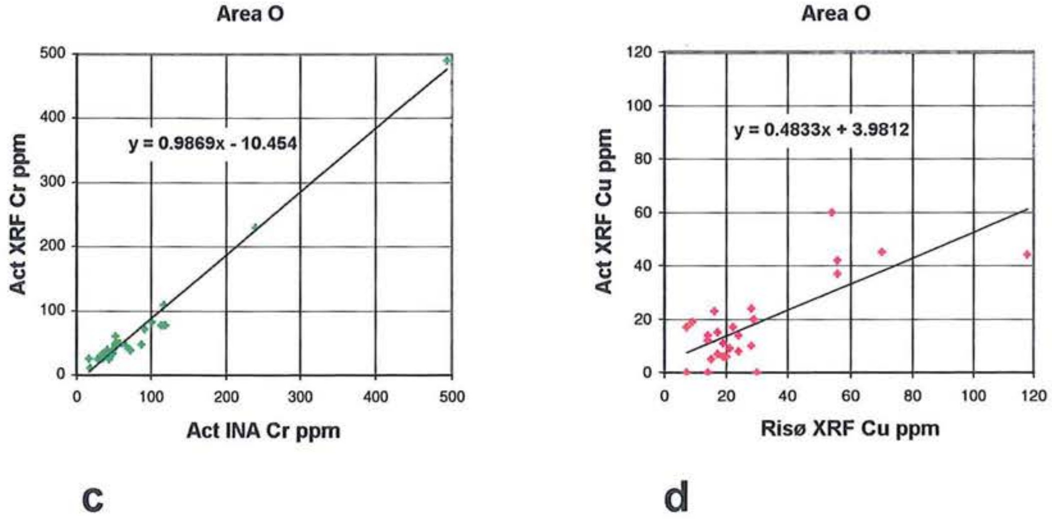


Figure 19c, d

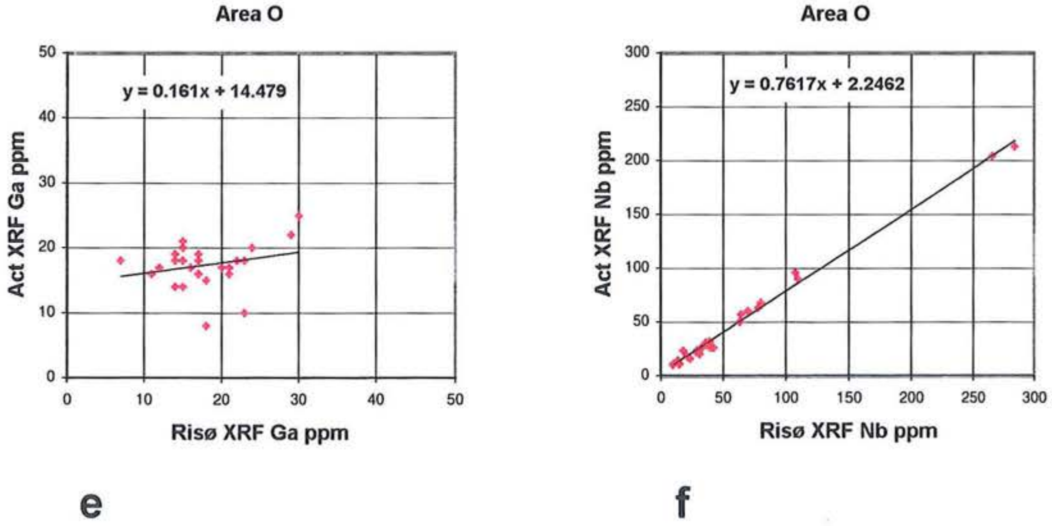
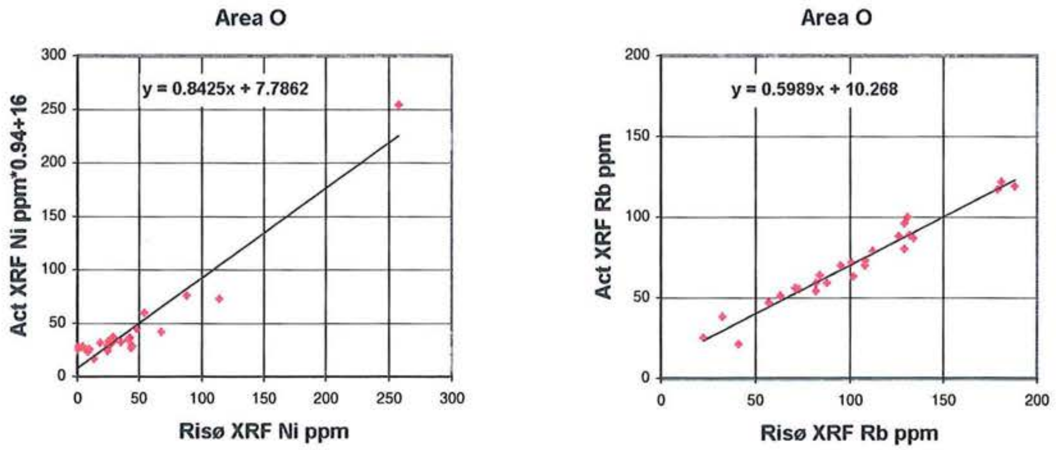


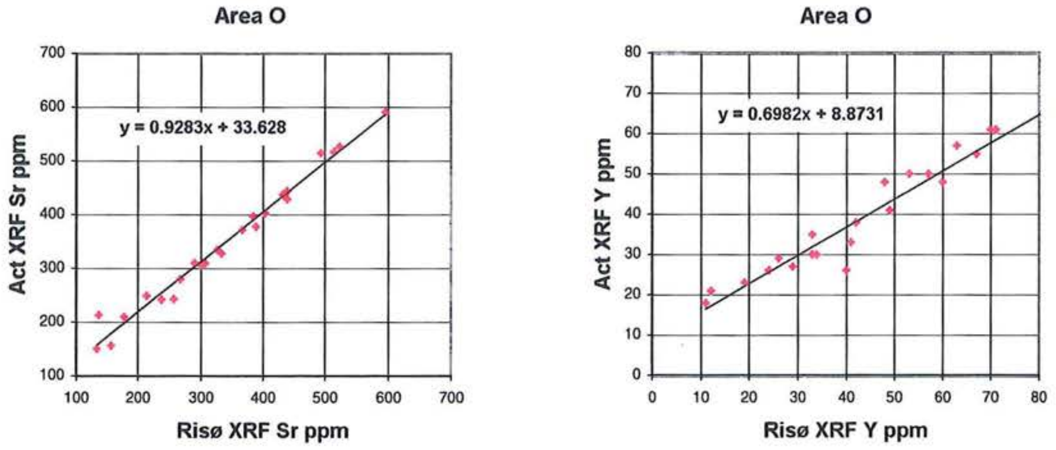
Figure 19e, f

Figure 19a-m. *Calibration of* Act INA, Risø XRF *and* GGU XRF *data from area O by means of calibrated* Act XRF *data from 27 samples.*
Laboratories: Act *(Activation Laboratories Ltd.);* GGU *(Geological Survey of Greenland);* Risø *(Risø National Laboratory). Methods:* XRF *(X-ray Fluorescence Spectrometry);* INA *(Instrumental Neutron Activation).*



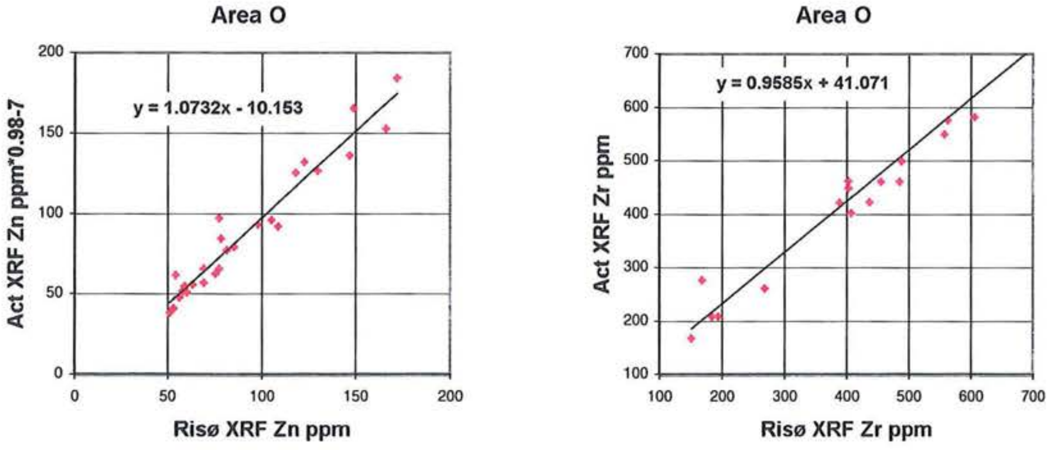
g **h**

Figure 19g, h



i **j**

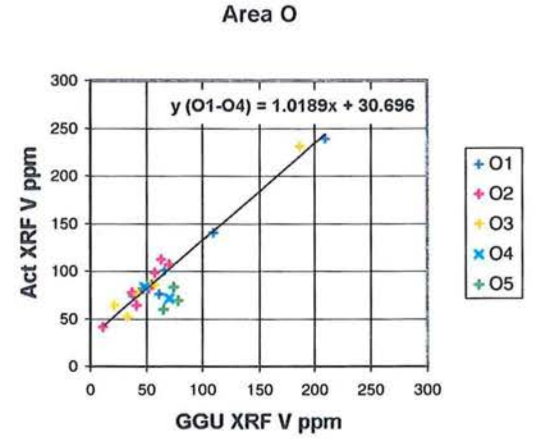
Figure 19i, j



k **l**

Figure 19k, l

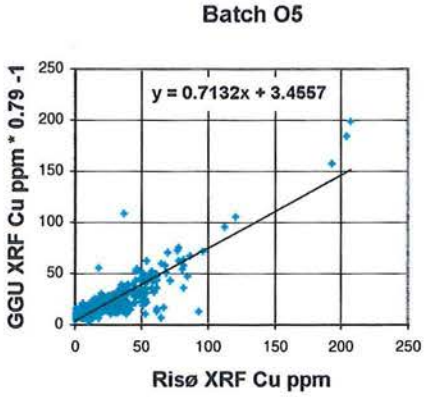
Figure 19a-m. *Calibration of* Act INA, Risø XRF *and* GGU XRF *data from area O by means of calibrated* Act XRF *data from 27 samples.*
Laboratories: Act *(Activation Laboratories Ltd.);* GGU *(Geological Survey of Greenland);* Risø *(Risø National Laboratory). Methods:* XRF *(X-ray Fluorescence Spectrometry);* INA *(Instrumental Neutron Activation).*



m

Figure 19m

Figure 19m. *Calibration of* GGU XRF *data for V from area O by means of calibrated* Act XRF *data from 27 samples. Samples are divided into batches as analysed at* GGU XRF. *Samples from batches O2 and O4 plot along a line above y=x while samples from O5 differ from the other batches and plot closer to y=x, in accordance with the variations displayed by the standards analysed together with batches O2, O4 and O5, see Figure 6j.*



n

Figure 19n

Figure 19n. *Calibration of* Risø XRF *Cu values from area O by means of calibrated* GGU AAS *Cu values from batch O5.*

Figure 19m-n. *Calibration of* Act INA, Risø XRF *and* GGU XRF *data from area O. Laboratories:* Act *(Activation Laboratories Ltd.);* GGU *(Geological Survey of Greenland);* Risø *(Risø National Laboratory). Methods:* XRF *(X-ray Fluorescence Spectrometry);*

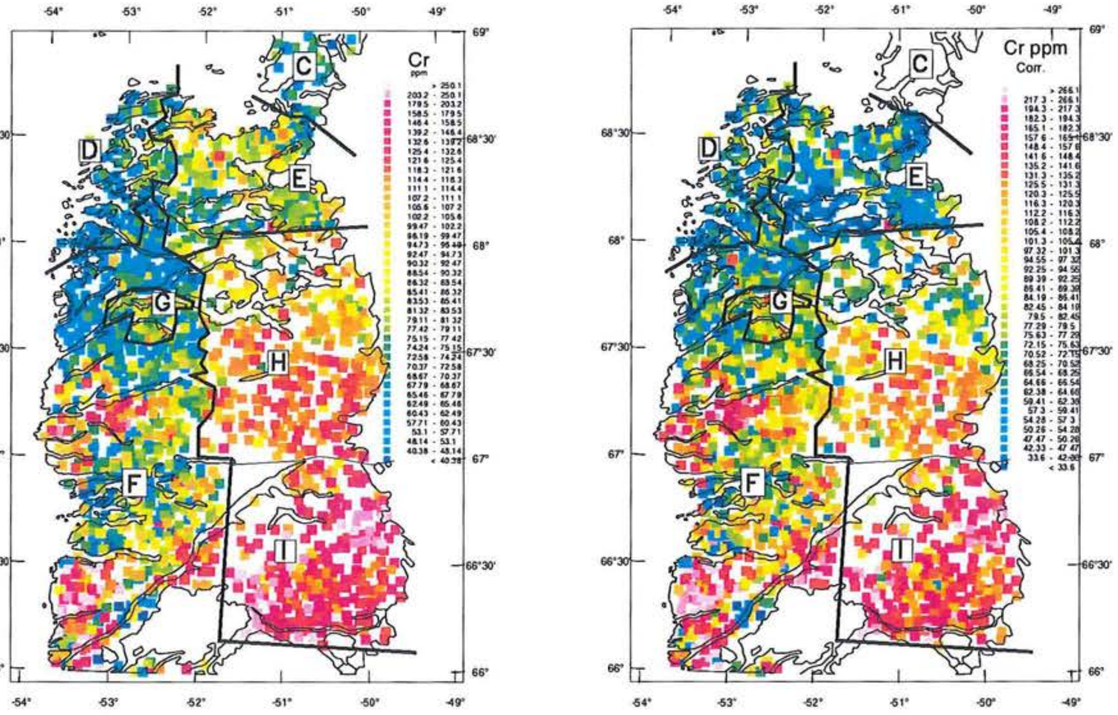


Figure 20. *The effect of calibration. Geochemical maps of Cr by Act XRF for a part of the atlas area. The map of uncalibrated data (left) shows the effect of the analytical bias influencing the batches from the areas E, H and I in the range around 200 ppm and below, see Fig. 14b. The false geochemical boundaries coinciding with the boundaries between surveys (heavy lines) have been eliminated in the map of calibrated data (right).*
Laboratory: Act (Activation Laboratories Ltd.).
Method: XRF (X-ray Fluorescence Spectrometry).

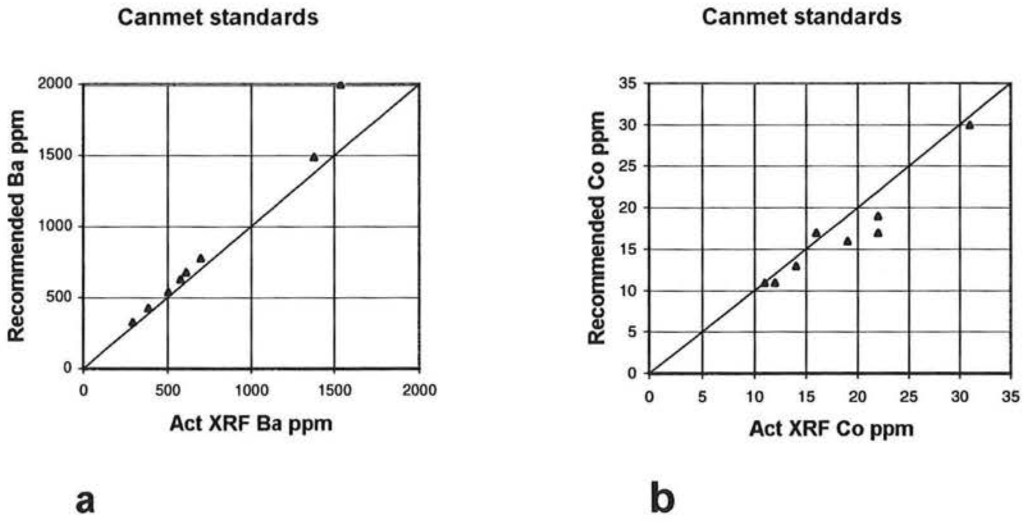


Figure 21a, b

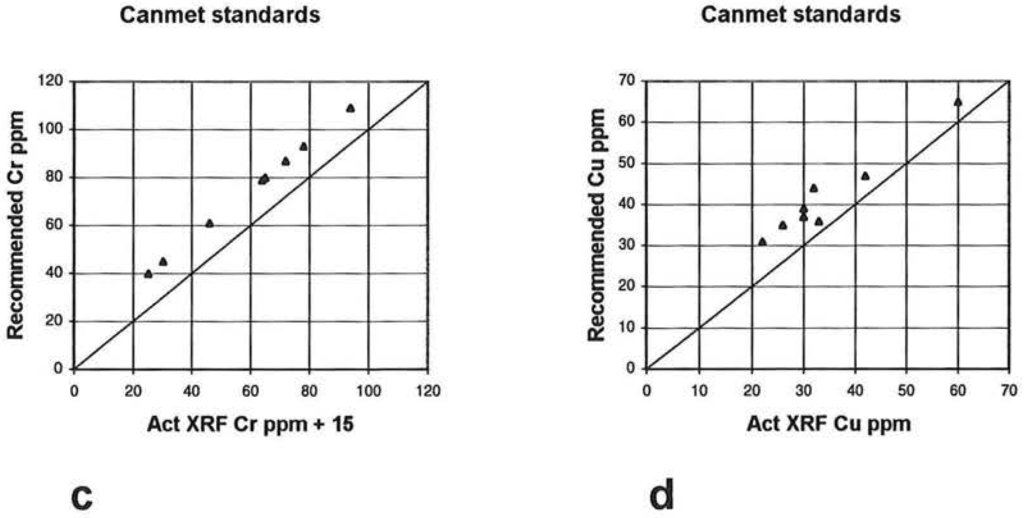


Figure 21c, d

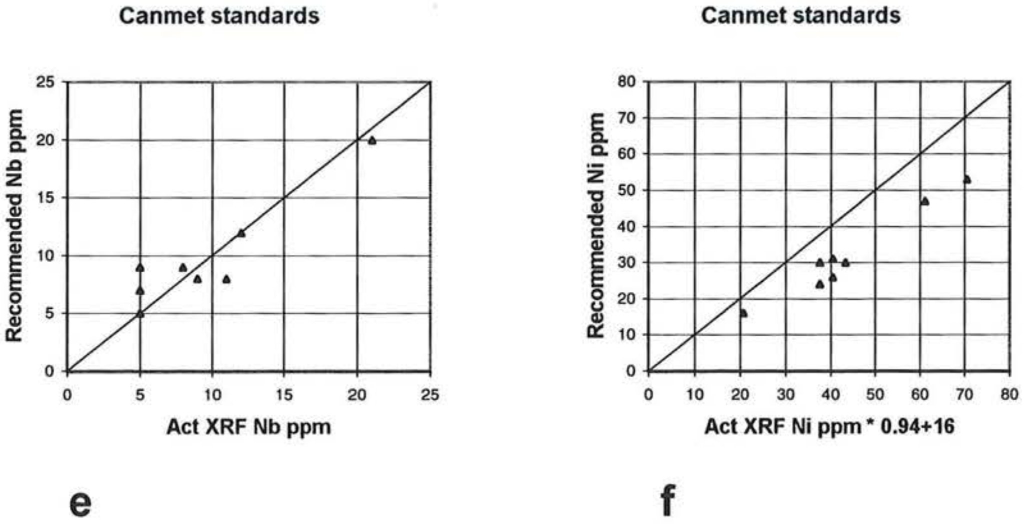


Figure 21e, f

Figure 21a-l. *Accuracy of analyses performed by X-ray Fluorescence Spectrometry (XRF) at Activation Laboratories Ltd. (Act) as monitored by eight standards from CANMET (STSD-1, STSD-2, STSD-3, STSD-4, LKSD-1, LKSD-2, LKSD-3, LKSD-4).*

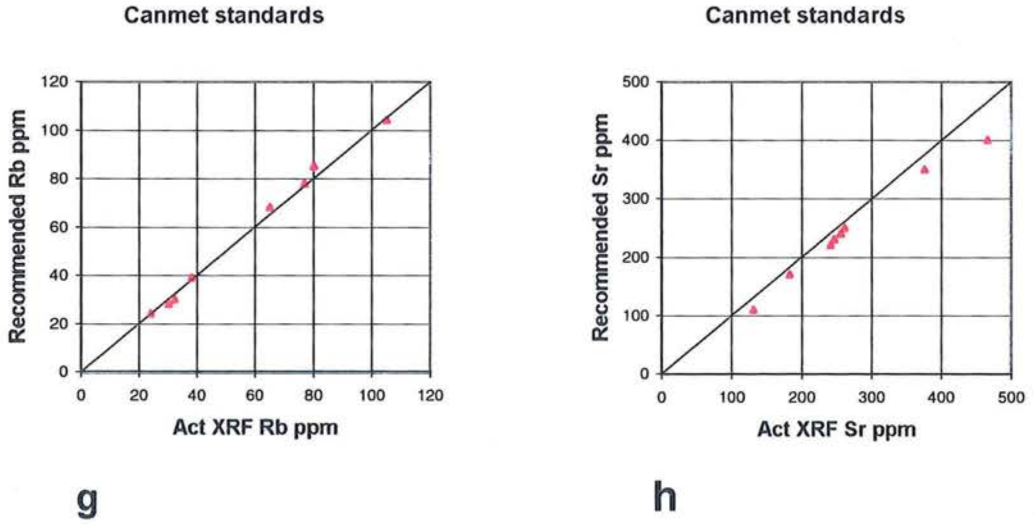


Figure 21g, h

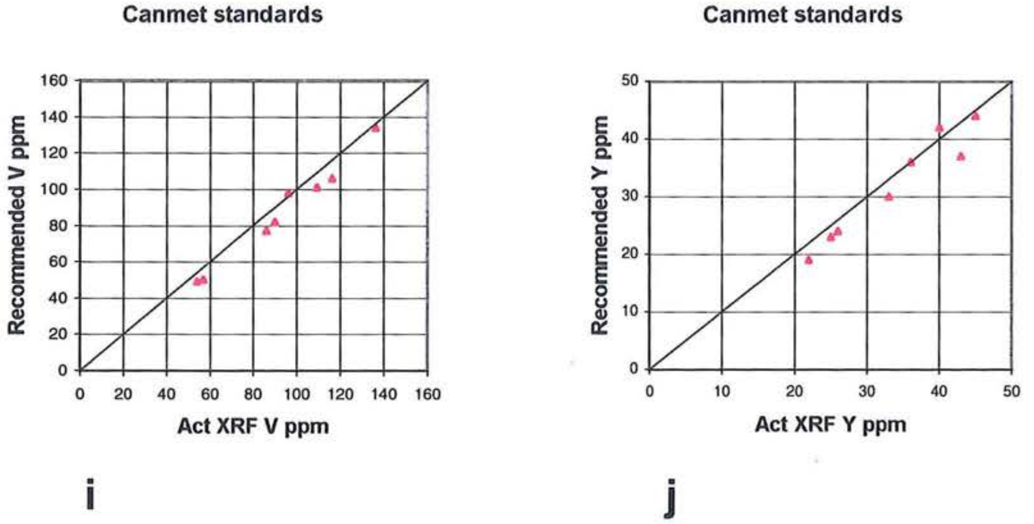


Figure 21i, j

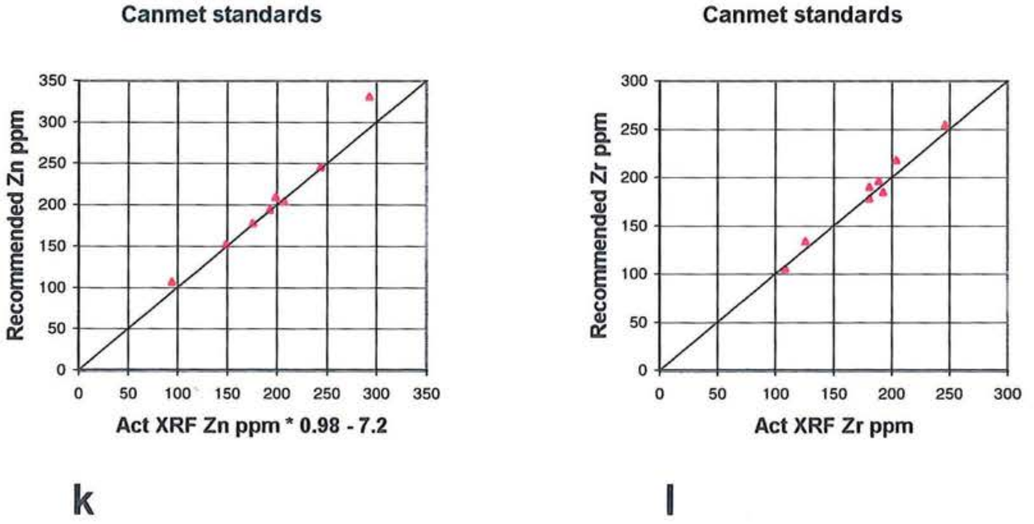
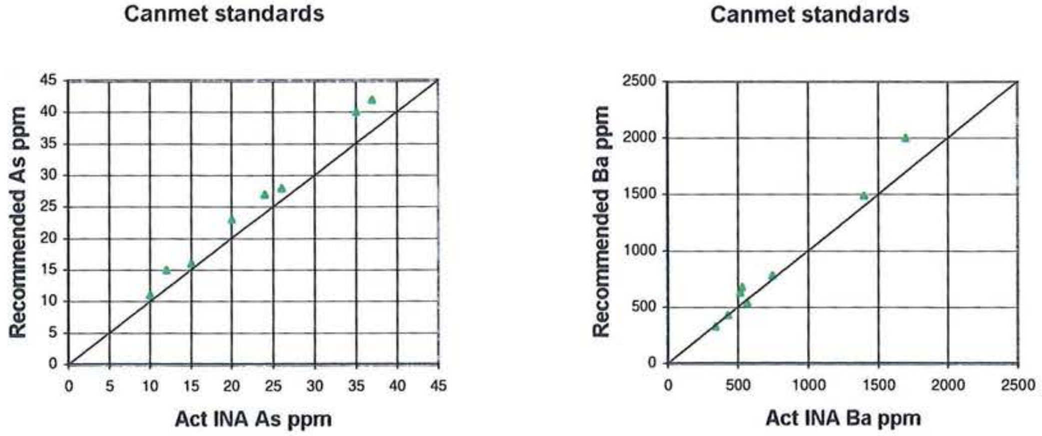


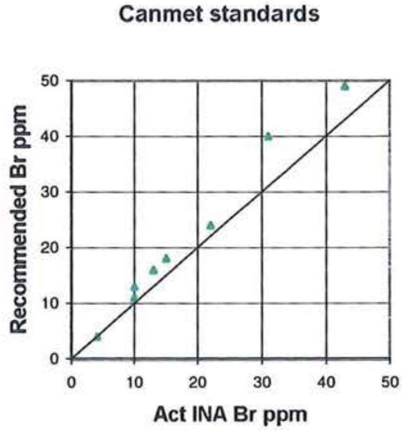
Figure 21k, l

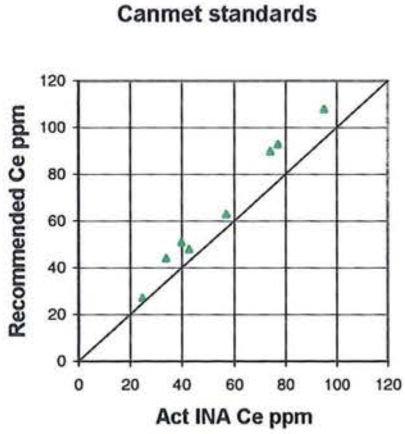
Figure 21a-l. *Accuracy of analyses performed by X-ray Fluorescence Spectrometry (XRF) at Activation Laboratories Ltd. (Act) as monitored by eight standards from CANMET (STSD-1, STSD-2, STSD-3, STSD-4, LKSD-1, LKSD-2, LKSD-3, LKSD-4).*



a **b**

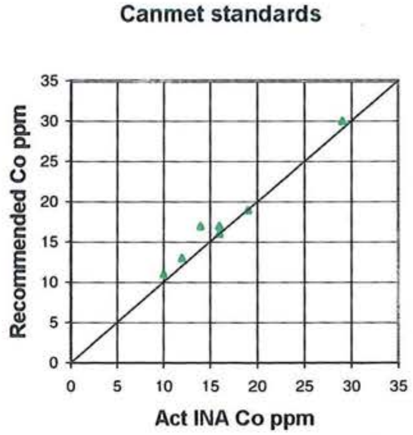
Figure 22a, b

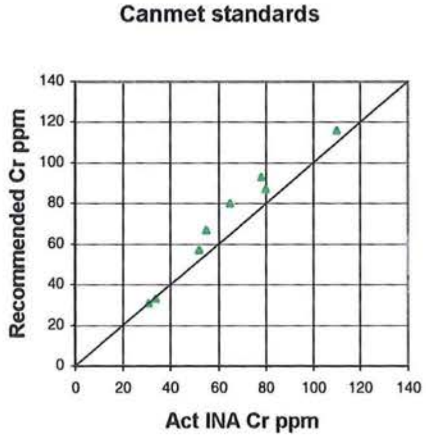




c **d**

Figure 22c, d

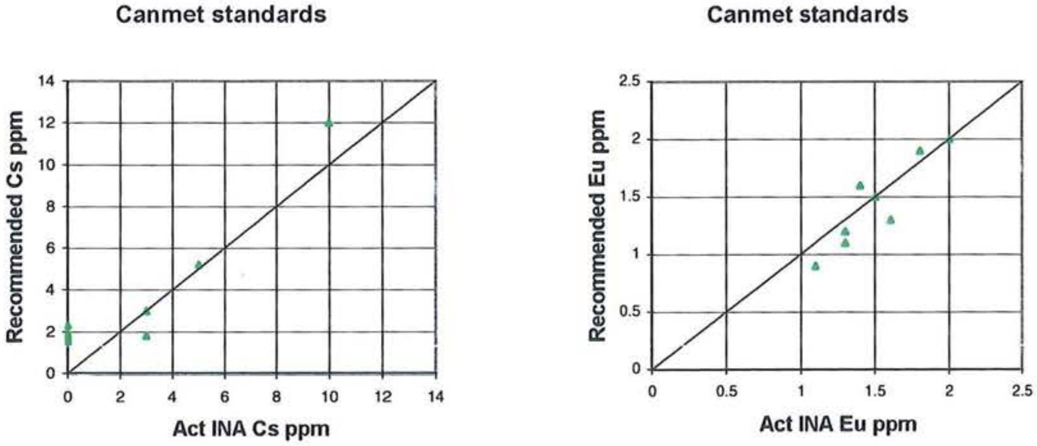




e **f**

Figure 22e, f

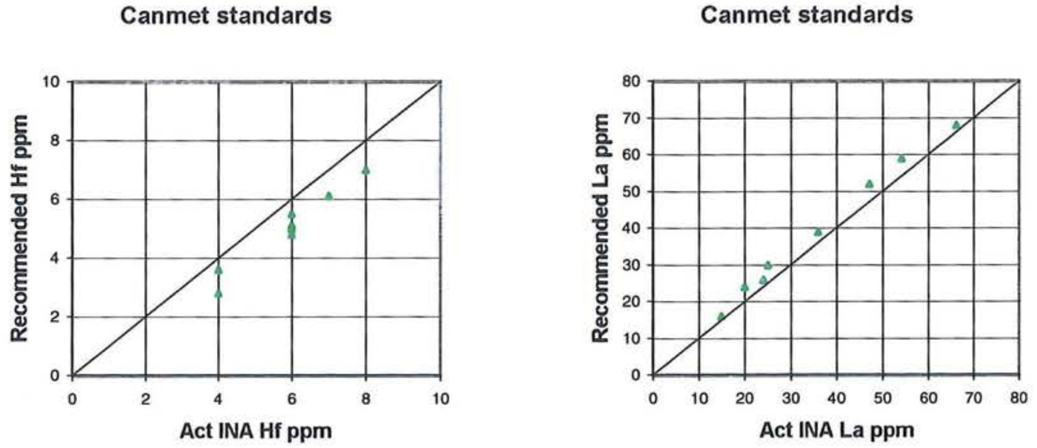
Figure 22a-t. *Accuracy of analyses performed by Instrumental Neutron Activation Analysis (INA) at Activation Laboratories Ltd. (Act) as monitored by eight standards from CANMET (STSD-1, STSD-2, STSD-3, STSD-4, LKSD-1, LKSD-2, LKSD-3, LKSD-4).*



g

h

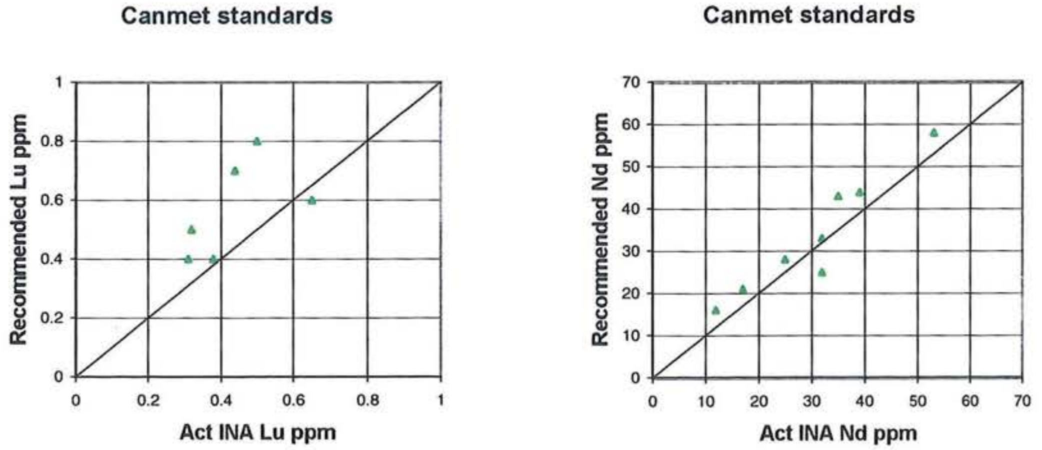
Figure 22g, h



i

j

Figure 22i, j

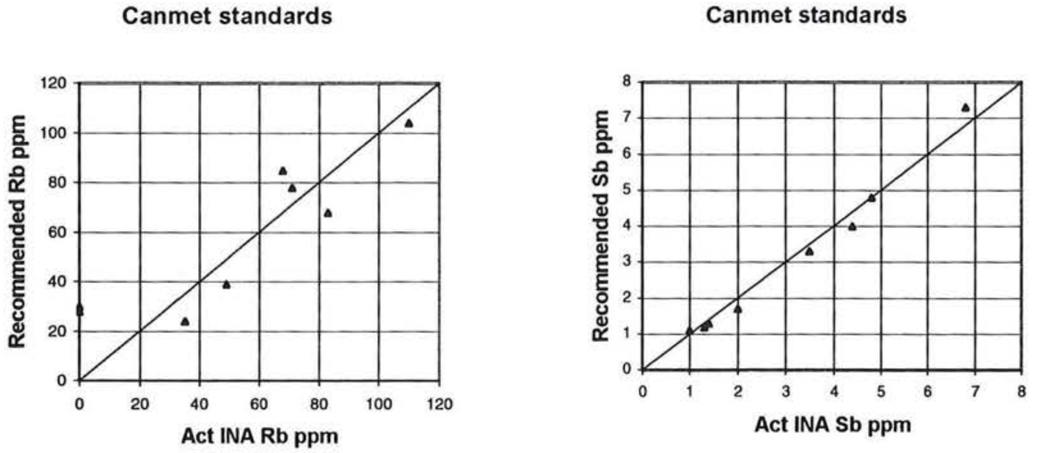


k

l

Figure 22k, l

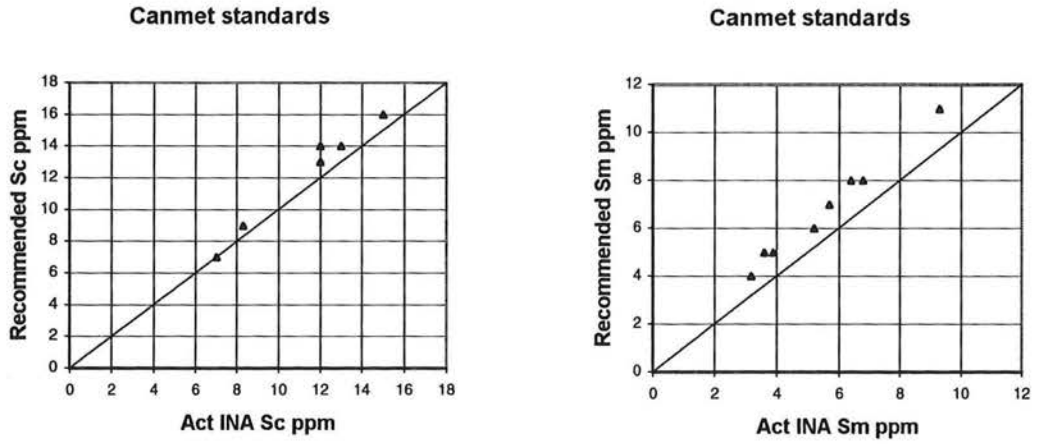
Figure 22a-t. *Accuracy of analyses performed by Instrumental Neutron Activation Analysis (INA) at Activation Laboratories Ltd. (Act) as monitored by eight standards from CANMET (STSD-1, STSD-2, STSD-3, STSD-4, LKSD-1, LKSD-2, LKSD-3, LKSD-4).*



m

n

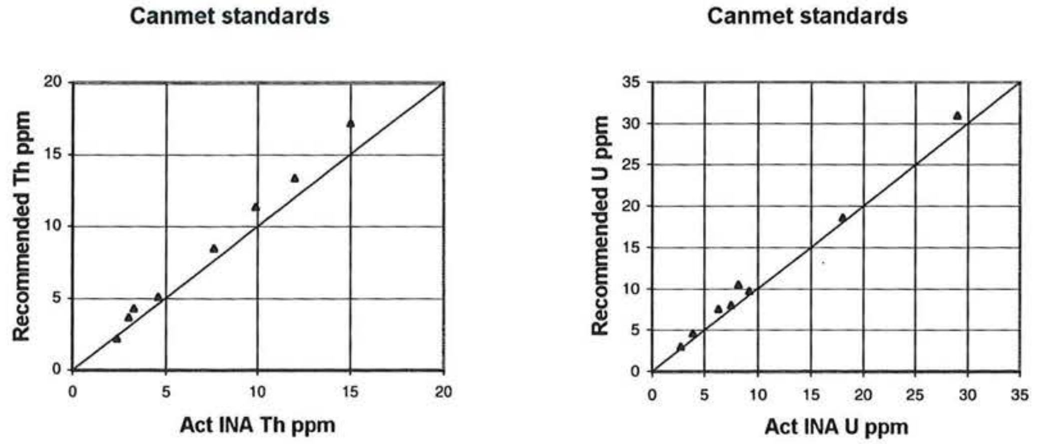
Figure 22m, n



o

p

Figure 22o, p

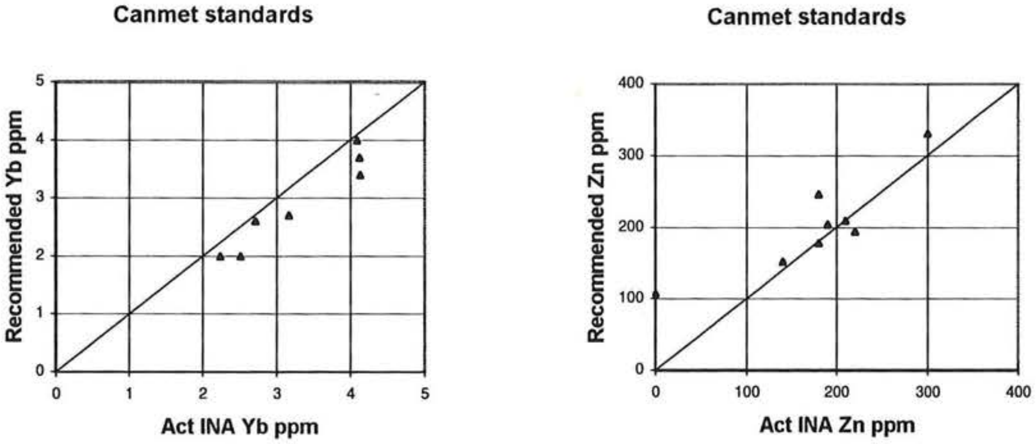


q

r

Figure 22q, r

Figure 22a-t. *Accuracy of analyses performed by Instrumental Neutron Activation Analysis (INA) at Activation Laboratories Ltd. (Act) as monitored by eight standards from CANMET (STSD-1, STSD-2, STSD-3, STSD-4, LKSD-1, LKSD-2, LKSD-3, LKSD-4).*



s **t** **Figure 22s, t**

Figure 22a-t. *Accuracy of analyses performed by Instrumental Neutron Activation Analysis (INA) at Activation Laboratories Ltd. (Act) as monitored by eight standards from CANMET (STSD-1, STSD-2, STSD-3, STSD-4, LKSD-1, LKSD-2, LKSD-3, LKSD-4).*