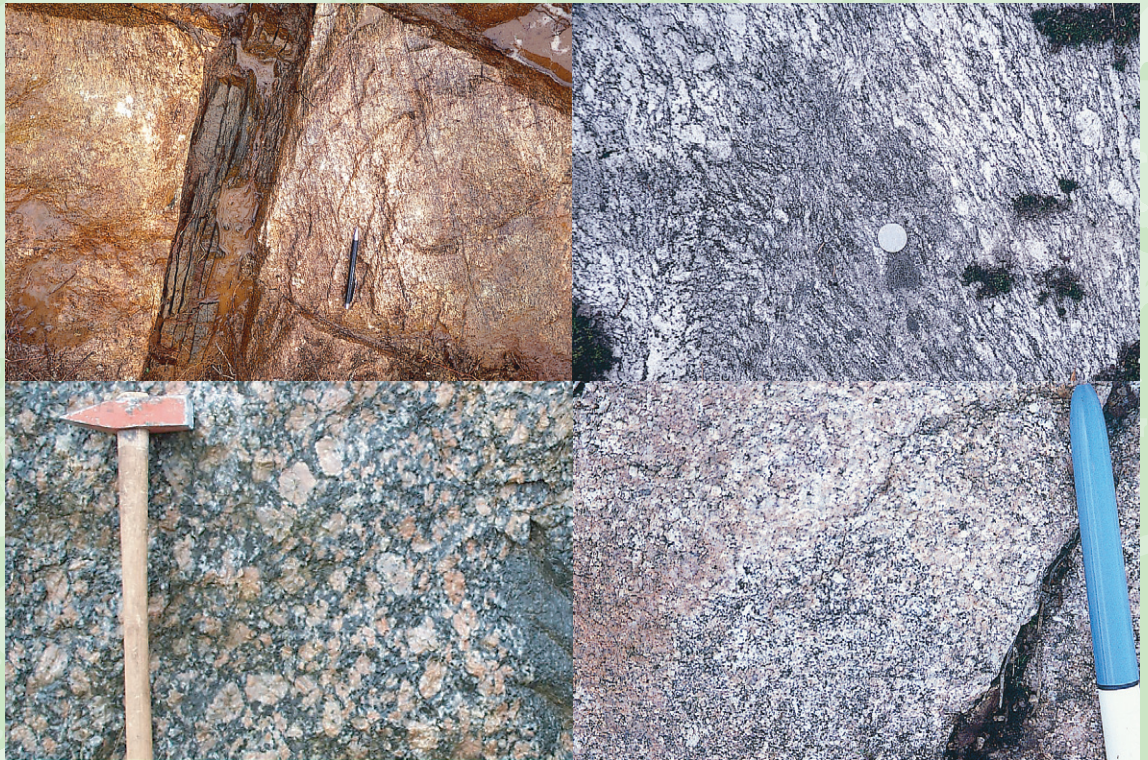


Geochemical classification of plutonic rocks in central and northern Sweden

Final report of research project 5172: "Geochemical classification
of Swedish granitoids" at the Geological Survey of Sweden

Martin Ahl, Stefan Bergman, Ulf Bergström,
Thomas Eliasson, Magnus Ripa & Pär Weiheid



SGU

Sveriges Geologiska Undersökning
Geological Survey of Sweden

Geochemical classification of plutonic rocks in central and northern Sweden

Martin Ahl, Stefan Bergman, Ulf Bergström,
Thomas Eliasson, Magnus Ripa & Pär Weihed

Final report of research project 5172: "Geochemical classification
of Swedish granitoids" at the Geological Survey of Sweden

ISSN 0349-2176
ISBN 91-7158-656-3

Cover picture:

Upper left: Archaean metagranitoid intruded by mafic dyke. 23 km NW of Övre Soppero (30K NO, 7586730/1733600).

Upper right: Strongly foliated and K-feldspar augen-bearing early-orogenic granitoid. Skattlösberget (12E SO, 6673840/1441360).

Lower left: Coarse K-feldspar porphyritic granitoid of Revsund-type with mafic schlieren. SE of Kälen (17F NV, 6949670/1453800).

Lower right: Syn- to late-orogenic granite with some mafic minerals. 1.5 km W of Lake Fläcksjön (11G NO, 6638340/1526000).

Layout: Agneta Ek, SGU
Print: Elanders Tofters, Östervåla 2001

CONTENTS

Abstract	4
Introduction	4
Compilation of data and definition of classes and groups	4
Previous geochemical work on plutonic rocks in the studied areas	6
Northern area (maps 25–32)	6
North central area (maps 19–24)	7
Central area (maps 14–18)	10
South central area (maps 9–13).....	11
Classification and petrogenesis of plutonic rocks	11
Results from individual areas	14
Northern area (25–32)	15
Characterisation of class 1 samples	15
Comparison between rock groups	25
Class 2 samples and summary of results from the northern area (25–32)	26
North central area (19–24)	37
Characterisation of class 1 samples	37
Comparison between rock groups	38
Class 2 samples and summary of results from the north central area (19–24)	55
Central (14–18) and south central (9–13) areas	55
Characterisation of class 1 samples	55
Comparison between rock groups	56
Class 2 samples and summary of results from the central (14–18) and the south central (9–13) areas	57
Regional similarities and variations	63
Conclusions	73
References	73
Appendix	80

Abstract

This study is a compilation and analysis of existing geochemical data from plutonic rocks in northern and central Sweden. The aim of the study is to establish a classification scheme for Swedish intrusive rocks, as a tool for classification of samples of uncertain affinity.

The analyses have been grouped into ten different intrusive groups based on their age and/or field appearance. The groups are Archaean rocks, three groups of early-orogenic intrusions, the Perthite monzonite suite, syn- to late orogenic granites, three groups of rocks from the Transscandinavian Magmatic Belt (TMB) and the Revsund granite (including unspecified TMB-rocks). In each of the ten groups the samples have been assigned to three different classes according to the certainty of classification, where class 1 samples come from dated plutons. Plotting and analysis of the data was done separately for different areas (an arbitrary division of Sweden into a northern, north-central, central and south central area).

A large number of diagrams are presented graphically, and useful discrimination diagrams are tabulated. These tables can be used for quick guidance of which diagrams to use in a particular case. In a majority of cases it is possible to classify an unknown sample (preferably a set of samples), or to detect samples that previously may have been misclassified. In some cases the available data is insufficient to permit definition of discrimination diagrams.

Key words: Litho-geochemistry, classification, plutonic rocks, Palaeoproterozoic, Fennoscandian Shield, Sweden.

Introduction

The plutonic rocks related to the Svecokarelian (or Svecofennian) orogen of Sweden have traditionally been subdivided into so-called primorogenic, serorogenic and postorogenic groups, with respect to the orogeny. With the increased knowledge, which has been obtained from regional mapping, isotopic, geochemical and structural studies, it has become clear that this subdivision needs modification. The oldest Proterozoic plutonic rocks are now known to have ages in the range 1.95–1.84 Ga, which overlaps with the ages of the postorogenic rocks, which are 1.85–1.65 Ga old (in some areas up to 1.88 Ga old). The postorogenic rocks, in turn, overlap in age with the serorogenic group at c. 1.8 Ga. In some cases field criteria are insufficient to determine to which group a specific pluton should be assigned. Geochronology may solve the problem, but more cost-efficient petrographical or geochemical analyses may be sufficient. The aim of this study is to compile and analyse existing geochemical data in order to create a geochemical classification scheme for Swedish plutonic rock suites by defining discriminating geochemical parameters.

The benefits from this study are:

- mapping projects at the Geological Survey may to some extent use relatively cheap geochemical analyses instead of expensive isotope analyses
- petrogenetic models may be tested and improved with a large amount of compiled data
- a better classification of plutonic suites will help the mineral industry to define exploration targets more efficiently

Compilation of data and definition of classes and group

The investigation was restricted to plutonic rocks (excluding dykes, except some Jörn-porphyrines) older than c. 1.65 Ga in the Precambrian bedrock of Sweden, excluding the areas represented by map numbers lower than 9 (i.e. southernmost Sweden) of the Swedish National Grid, southwestern Sweden and rocks in the Caledonian orogen (Fig. 1). Some analyses from rocks in the Rombak–Sjängeli area, which partly lies in Norway, were included. The investigated area was for practical reasons divided into four smaller areas (Fig. 1), which were studied separately. The somewhat arbitrary division follows the map sheet division of

the Swedish National Grid, numbered 1–32, from south to north. The northern area (25–32) was studied by S. Bergman, the north-central area (19–24) by M. Ahl, U. Bergström and T. Eliasson, and the central (14–18) and south central (9–13) areas by M. Ahl and M. Ripa (Figs. 2–7).

When the project started geochemical and isotope databases already existed at the Geological Survey of Sweden (SGU) from which screened data were extracted. A literature survey was performed in order to find additional data, which were added to the databases. Parts of this work were done by Johan Camitz and Carin Ivarsson. Unpublished data from SGU were also used. Map co-ordinates (Swedish National Grid RT 90) were assigned to all samples.

Geochemical samples that had been collected from plutons with isotopically determined ages of formation were assigned to class 1. Samples from dated batholiths or very large plutons, and taken a long distance from the dating locality, were also assigned to class 1 if it was reasonable to assume that they were co-magmatic with the dated pluton. Samples from plutons with an unknown age, but which had been classified by e.g. field evidence, were assigned to class 2. In cases where available information for classification was insufficient, samples were assigned to class 3.

In order to increase the number of samples in class 1, additional samples were collected from localities where age determinations had been made, but where no geochemical data was available. One new age determination was also carried out (Ripa & Persson 1997). Maps showing age determination and geochemical sample sites, are shown in Figs. 2–7.

All samples from classes 1 and 2 were classified into one of ten intrusive groups according to Table 1. The terms "early-orogenic" and "syn-late-orogenic" refer to the Svecokarelian orogeny (2.0–1.65 Ga) with peak deformation, metamorphism and anatexis at c. 1.9–1.8 Ga, in southern Sweden probably c. 1.85–1.8 Ga (Wahlgren et al. 1996). The number of analyses that were used are given in Table 2.

All data have been transformed into a file format suitable for Minpet 2.02" from Minpet Geological Software–Logiciel Géologique Minpet (Canada) by which all plots have been made.

TABLE 1. The ten intrusive groups into which all samples from classes 1 and 2 were classified.

Code	Group	Approximate age (Ga)
10	Transscandinavian Magmatic Belt 0 (TMB0)	1.85
20	Transscandinavian Magmatic Belt 1 (TMB1)	1.8
30	Transscandinavian Magmatic Belt 2 (TMB2)	1.7
50	Revsund granite and TMB unspecified	1.8
60	Perthite monzonite suite (PMS)	1.87
80	Syn-late-orogenic granite (SLOG)	1.8
90	Early-orogenic granitoid 2 (EOG2)	1.89–1.88
92	Early-orogenic granitoid 1 (EOG1)	1.95–1.90
95	Early-orogenic granitoid 3 (EOG3)	1.88–1.83
100	Archaean rocks	2.8–2.65

TABLE 2. Number of analyses that were used. Due to the low number of samples in the central and south central areas, these areas were combined. Figures denoted with * include groups 90, 92 and 95.

group/ class	10	20	30	50	60	80	90	92	95	100	Total
1		24	5		29	32	38		5	51	184
2		3	11		142	51	99		0	15	321
3		0	0		9	3	7		0	10	29
Sum northern area (25–32)		27	16		180	86	144		5	76	534
1				5	14	9	29	22	9	14	102
2				42	28	15	44	6	5	2	142
3							2		1		3
Sum north-central area (19–24)				47	42	24	75	28	15	16	247
1	34	22	12	0		37			18*		123
2	2	1	17	16		24			95*		155
Sum central and south-central areas (9–18)	36	23	29	16		61			113*		278
All areas	36	50	45	63	222	171	219	28	133	92	1059

Previous geochemical work on plutonic rocks in the studied areas

Northern area (maps 25–32)

Previously published geochemical analyses from the northern area (approximately the county of Norrbotten), that are used in this study, have been obtained from: Offerberg (1967), Witschard (1970, 1975), Padget (1970, 1977), Eriksson & Hallgren (1975), Lindroos & Henkel (1981), Öhlander (1984, 1985a), Öhlander et al. (1987a,b), Skiöld et al. (1988), Skiöld & Öhlander (1989), Romer et al. (1992), Wikström et al. (1996a), Mellqvist et al. (1997), Wikström & Persson (1997), and Martinsson et al. (1999). Results from some of these papers are given below. Previously unpublished analyses from the Geological Survey of Sweden have also been used.

Archaean rocks (100)

The largest area with Archaean rocks in Sweden is found north of Kiruna. Smaller areas with Archaean rocks are found at Kukkola north of Haparanda, near Luleå, Jokkmokk, and in the Rombak–Sjangeli basement culmination in the Caledonides. Age determinations of Archaean rocks have been presented by Matisto (1969), Welin et al. (1971), Skiöld (1979b), Öhlander et al. (1987a), Romer et al. (1992), Skiöld & Page (1998), Martinsson et al. (1999) and Mellqvist et al. (1999).

Öhlander et al. (1987a) studied the Archaean gneisses near Soppero and at Kukkola. They concluded that the gneisses have light rare earth element (LREE)-enrichment, low U contents and low K/Na ratios, which is typical for Archaean TTG (tonalite-trondhjemite-granodiorite) rocks. They suggested that the rocks were formed by partial melting of basic rocks, presumably amphibolites.

In the Rombak–Sjangeli basement culmination in the Caledonides at the Swedish–Norwegian border Archaean tonalitic gneisses (2.7 Ga old) are geochemically indistinguishable from early Proterozoic (1.94 Ga old) tonalites and trondhjemites in the same area (Romer et al. 1992). They have high Al_2O_3 contents and low K_2O and Rb contents and are geochemically similar to continental trondhjemites. According to Romer et al. (1992) they were formed by melting of a mafic precursor at medium to high pressures.

Early-orogenic granitoids and syenitoids, EOG (90, 92, 95)

The Haparanda suite (Ödman 1957) consists of granitoids, and to some extent also syenitoids, that were formed between 1.94 and 1.85 Ga ago. Age determinations of rocks from the Haparanda suite have been presented by Wilson et al. (1985), Skiöld et al. (1993), Skiöld (1979a, 1981a, b, 1988), Öhlander & Billström (1989), Romer et al. (1992), Wikström & Persson (1997), Lindroos & Henkel (1981), and Martinsson et al. (1999).

The rocks of the Haparanda suite have I-type characteristics such as a wide range of silica content, low K/Na ratios and low initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios (Wilson 1980). This was confirmed by Öhlander (1984) who suggested that they were formed in a compressional environment. He also found that the Sn content was higher than expected.

Skiöld et al. (1988, Vittangi area, including some PMS-rocks) and Mellqvist et al. (1997, Luleå area) found that the rocks of the Haparanda suite in these areas have pronounced calc-alkalic trends. Rare earth element (REE) patterns show variable Eu anomalies and straight to slightly concave-upward shapes of the middle REE and heavy REE (HREE). The low Nb, Y and Rb contents is similar to volcanic arc granitoids, and does not support the suggestion of a continental rift setting by Witschard (1984).

Perthite monzonite suite, PMS (60)

Age determinations of rocks assigned to the PMS have been presented by Skiöld (1981b), Skiöld & Öhlander (1989), Wikström et al. (1996b) and Martinsson et al. (1999). The PMS rocks at Koivu–Kuosanen and Masugnsbyn were found to define a diorite–quartz monzodiorite–quartz monzonite–adamellite trend (Skiöld & Öhlander 1989). The Masugnsbyn samples have higher Y, Nb and HREE contents than the Koivu–Kuosanen samples and the two groups are probably not co-magmatic.

Transscandinavian Magmatic Belt, TMB (20, 30)

Age determinations of rocks assigned to the TMB have been presented by Romer et al. (1992, 1994) and Skiöld et al. (1993), and some age figures are given by Öhlander & Skiöld (1994). The TMB granites in the Rombak-Sjangeli basement culmination are chemically different compared to the older tonalites and trondjemites in the area (Romer et al. 1992). The granites are characterised by higher contents of K_2O , Rb and Y+Nb and lower contents of Na_2O , CaO, and MgO. The two TMB groups are also different from each other. The younger 1.71 Ga old group (TMB2) has higher contents of Rb and lower Ba/Zr ratios than the 1.79 Ga old granites (TMB1). In discrimination diagrams (Rb vs. Y+Nb and Nb vs. Y) the younger granites predominantly fall in the field of within-plate granites, while the older granites mainly fall in the field of volcanic arc granites. In the R1–R2 diagram the younger granites fall in and close to the fields of syn-collision and post-orogenic granites, while the older granites plot as late-orogenic granites. Romer et al. (1992) concluded that the younger group has within-plate affinity and the older group has magmatic arc affinity.

Öhlander & Skiöld (1994) studied various plutonic rocks from Boden and Edefors and quartz monzonites from Larve. Most samples of the Edefors–Boden plutonic rocks form a well-defined syenite–quartz syenite-granite trend on the P–Q diagram. The Edefors–Boden rocks are rich in Zr and can clearly be separated from Lina-type granites (SLOG) using the Zr vs. $Mg/(Fe+Mg)$ diagram. They have some similar characteristics with A-type granites such as high contents of Na_2O+K_2O , Zr, high Fe/Mg ratios and low CaO contents. Features, which deviate from typical A-type granites, include rather low contents of REE, Y, Nb, Rb and Ta. They also have LREE enrichment and pronounced flattening of HREE.

Syn-late-orogenic granites, SLOG (80)

Age determinations of granites assigned to the SLOG (Lina type) have been presented by Skiöld (1988), Öhlander & Billström (1989), and Wikström & Persson (1997). Granites of this type in the Rappen area have low contents of Sn, Nb, Y, F, Cl, S (Öhlander 1985a), lower contents of U, Yb, Be, Sc, P, Zn, V, Cu and Cr and higher Rb content than an average granite (Vettasjärvi, Öhlander et al. 1987b). The Vettasjärvi granite was classified as a minimum melt I-type granite, and was suggested to have been generated by partial melting of Archaean TTG gneisses (Öhlander et al. 1987b).

Skiöld et al. (1988) showed that the Vettasjärvi–Tjärvetjarran granites have higher contents of Th and Pb than 1.89–1.87 plutonic rocks, and suggested that the granites were formed by fusion of these older rocks. The granites have highly fractionated LREE enriched patterns, marked negative Eu anomalies and a pronounced flattening in the HREE (cf. Öhlander & Skiöld 1994). This (and higher Rb content, Mellqvist et al. 1997) is distinctly different from the 1.89–1.87 plutonic rocks and suggests that they represent melts from a quartzofeldspathic source region and may have undergone additional feldspar fractionation. Granites of Lina type have higher U and Th contents, higher Th/U and lower Zr contents than Edefors plutonic rocks (Öhlander & Skiöld 1994).

North central area (maps 19–24)

This area is defined as the Precambrian rocks east of the Caledonides. The area is dominated by the mainly volcanic Skellefte and Arvidsjaur Districts and the northern part of the so called Bothnian Basin. Different granitoid suites exist in the area, mainly related to the Svecokarelian orogeny, but sparse Archaean rocks are also included in the northeasternmost part. Due to the important mining operations and exploration potential of the area, the rocks are relatively well studied and the geochemical database is fairly good. About 20 modern U–Pb datings with relevance for this project and a number of other isotope investigations exist from various parts of the area. The reasonably well-defined granitoid suites found in the area are described below.

Geochemical data have been compiled from the geological literature and results from the recent mapping programme by SGU in the area have been included. All analyses were made after 1980, and are considered high quality data. Complete trace element analyses including REE exist for at least 80 % of the samples.

Archaean rocks (100)

Archaean rocks are known from a N–NW trending heterogeneous belt of megaxenoliths in the Luleå area (e.g. the Vallen–Alhamn and Bälingsberget localities), mainly hosted by 1.89–1.87 Ga old volcanic and plutonic rocks (Wikström et al. 1996a, Lundqvist et al. 2000). The dominating rock type is a porphyritic adamellite–quartz monzodiorite, characterised by microcline megacrysts (Mellqvist 1997). Even-grained granodiorites to diorites are less common. An even-grained tonalite from the Vallen area has been dated at 2710 ± 3 Ma (Lundqvist et al. 1996), while porphyritic granodiorite clasts from Vallen and Bälingsberget (Wikström et al. 1996a) are dated at 2655 ± 4 Ma and 2638 ± 19 Ma respectively. The Archaean granitoids have distinctive low ϵ_{Nd} ($T=1890$ Ma) values, at around -10 (Mellqvist 1997).

Early-orogenic granitoids 1, EOG1 (92)

The Knaften suite: The Knaften area (Wasström 1990) is part of a well-preserved volcanic–sedimentary block, surrounded by postorogenic Revsund granitoids and veined gneisses, situated south of Lycksele. It is dominated by greywackes, basaltic lavas and volcanoclastic rocks. Two intrusive bodies with granodioritic to granitic compositions occur in the central part of the area. Quartz–feldspar porphyritic dykes are associated with the granitoid plutons. U–Pb datings of zircons gave ages of 1954 ± 6 Ma for the granite (Wasström 1993), and 1940 ± 14 Ma for the porphyry dykes (Wasström 1996). Wasström (1994) described the Knaften granitoids as peraluminous and weakly stanniferous.

The >1900 Ma suite: The rather obscure name "The >1900 Ma suite" is given to a suite of grey, foliated tonalites from various parts of the investigated area. The suite includes the Kattisavan pluton (Westerlund 1996) NW of Lycksele, dated at 1902 ± 3 Ma (Björk 1995), the small Barsele pluton situated east of Storuman, dated at 1907 Ma (Kjell Billström, Thomas Eliasson & Thomas Sträng, pers. com. 1999) and the larger Lankan pluton (Westerlund 1996) just north of Barsele. The Kristineberg pluton (Bergström et al. 1999), dated at 1907 ± 13 Ma and the Björkdal pluton, dated at c. 1905 Ma (cf. Billström & Weiheid 1996) are also included in this group. The two latter plutons are situated within the Skellefte District, and have a spatial relationship to rocks, which are supposedly younger (cf. Billström & Weiheid 1996). ϵ_{Nd} values are greater than $+3$ for all plutons (Westerlund 1996, Bergström et al. 1999, Thomas Eliasson, pers. com. 1999, Billström & Weiheid 1996). The $\delta^{18}\text{O}$ values for the Kattisavan pluton cluster around $+8$ ‰ (Westerlund 1996).

Early-orogenic granitoids 2, EOG2 (90)

The Jörn suite (90): The Jörn suite is the classical name for the "older granitoids" in the Skellefte District. The Jörn suite plutons have been suggested to be co-magmatic with rocks of the so called Skellefte Group (Weiheid 1992). The main Jörn pluton is situated in the north central part of the Skellefte District and is composed of several intrusive bodies with tonalitic to granitic compositions. A number of gabbroic intrusions occur along the margin of the pluton. The Jörn pluton was divided by Wilson et al. (1987b) into G1, the outer rim of grey tonalites–granodiorites, G2, a distinct phase around the town Jörn, G3, the core with red granite and G4, a specific phase within G3. The G1 phase is the only phase included into the Jörn suite as defined here. The other phases are included in other suites described below. A U–Pb dating of zircons by Wilson et al. (1987b) gave an age of 1888^{+20}_{-14} Ma. A possible Jörn suite granite from the Burträsk area was dated at 1895^{+14}_{-12} Ma (Nilsson 1995). The Jörn G1 phase has ϵ_{Nd} values from $+1.8$ to $+3.0$ (Wilson et al. 1987a) and $\delta^{18}\text{O}$ values from $+5.8$ to $+7.6$ ‰ (Wilson et al. 1987a). The Jörn G1 is calcic in character according to Weiheid (1992), who also emphasised the volcanic arc signature (low Rb, Y, and Nb).

Within the Jörn G1 granitoids, several intrusive quartz–feldspar porphyritic dykes and stocks occur. In at least two places, Tallberg and Granberg, there are porphyry copper mineralisations associated with these rocks (Weiheid 1992). They are distinguished texturally by large quartz and plagioclase phenocrysts, up to one cm in size. An age determination by Weiheid & Schöberg (1991) yielded 1886^{+15}_{-9} Ma for these rocks at Tallberg, with an ϵ_{Nd} value of $+4.0$ (Weiheid & Bergström, unpublished). Weiheid (1992) showed the strongly depleted HREE signature for the porphyries from the Tallberg area. The porphyries were interpreted by Weiheid (1992) as high level, possibly subvolcanic intrusions, which may constitute a link between the Jörn suite granitoids and the Skellefte Group volcanic rocks.

The Haparanda suite (90, 95): The term Haparanda suite was coined by Ödman (1957) for medium to coarse grained, moderately to strongly foliated, grey tonalites and granodiorites with associated gabbros, diorites and rare granites. A differentiated granitoid suite has its principal areal distribution further to the north around the city of Luleå. Three age determinations all give ages within 1868–1865 Ma for granodiorites–tonalites in the Piteå area (Persson & Lundqvist 1997, Wikström & Persson 1997). Further north, ages are somewhat higher, and show wider age span, 1892±14 Ma (Öhlander et al. 1987aa), 1879±4 Ma (Wikström et al. 1996) and 1883±6 Ma (Wikström & Persson 1997). A distinct gradient in ϵ_{Nd} values from slightly positive to the south-west to negative to the north-east in the Haparanda suite granitoids can be observed (Mellqvist 1997). This gradient coincides with the presence of the Archaean megaxenoliths described above and the occurrence of Bålinge type magmatic breccias, a subvolcanic feature of the Haparanda plutonic rocks (Wikström et al. 1996a). The geochemical composition of the Haparanda suite is typical for "volcanic arc granitoids" with low Rb, Y and Nb (Mellqvist 1997).

Early-orogenic granitoids 3, EOG3 (95)

The group "early-orogenic granitoids 3" includes the Stavaträsk suite and younger members of the Haparanda suite (see above). Recent investigations by Lundström et al. (1997, 1999) on the Boliden map sheet (23K) have indicated an older deformation phase in the vicinity of the Stavaträsk village. Structures related to this deformation are cut by gabbro–tonalite plutons of the Stavaträsk suite. The Stavaträsk pluton is composed of a gabbro–diorite core, with a tonalite–trondhjemite phase on the western rim. The diorite was dated (Lundström et al. 1997) at 1877±2 Ma and a tonalite dyke (apophyse), intruding foliated country rock conglomerate, at 1874±3 Ma. The age and Na-enriched geochemical character of the rock is almost identical to the Jörn G2 phase (mentioned above), imprecisely dated at 1874⁺⁴⁵₋₂₆ Ma by Wilson et al. (1987b). Antal & Lundström (1995) also distinguished the Blankforsen pluton c. 20 km north of Stavaträsk with similar characteristics. Wilson et al. (1987a) reported $\delta^{18}\text{O}$ values of +7.0 ‰ from the Jörn G2 suite. A small tonalite stock c. 5 km west of Stavaträsk at Pultarliden, which has similar characteristics as the Stavaträsk tonalite–trondhjemite, has an ϵ_{Nd} value of +4.4 (Bergström, unpublished results). Lundström et al. (1997) showed that the Stavaträsk suite has a fractionated REE pattern.

Perthite monzonite suite, PMS (60)

Granitoids of the Arvidsjaur suite occupy large parts of the Arvidsjaur District, which lies north of the Skellefte District and is distinguished by the presence of volcanic rocks of the Arvidsjaur Group. The Arvidsjaur suite is comparable to the PMS further north in the Norrbotten County and the two suites may be regarded as belonging to one unit.

The granitoids are mainly granites s.s. and adamellites with subordinate granodiorites and tonalites. Several plutons, for example the Arvidsjaur pluton (Muller 1980), are alkali feldspar granites, and may include minerals like riebeckite. Modern age determinations include an U-Pb zircon age of 1877⁺⁸₋₇ Ma for the Arvidsjaur pluton (Skiöld et al. 1993), and 1879⁺¹⁵₋₁₂ Ma for the Antak pluton (Kathol & Persson 1997). Older age determinations by Wilson et al. (1985) suggest similar ages, but are not accurate enough to be considered here. The age of the volcanic rocks of the Arvidsjaur Group is almost identical (Skiöld et al. 1993). The G3–G4 phases of the Jörn pluton, dated at 1873⁺¹⁸₋₁₄ Ma by Wilson et al. (1987b), are included into the PMS for compositional and textural reasons (cf. Lundström et al. 1999). Reported ϵ_{Nd} values are +1.1 to +3.4 (Wilson et al. 1985) and the $\delta^{18}\text{O}$ values cluster around +6 to +7 ‰ (Wilson et al. 1985). Wilson et al. (1987a) showed the chemical difference between the arc-type Arvidsjaur and Jörn suites, where Arvidsjaur samples showed much higher high field strength (HFS) element concentrations.

Syn–late-orogenic granites, SLOG (80)

A major intrusive component in the high-grade metamorphic terrains are grey, massive to weakly foliated, somewhat porphyritic granites s.s. They cross-cut older structures including migmatites, but are related to structures on a regional scale. In some cases they may form larger massifs like the Blaiken pluton, dated at 1809±8 Ma (Eliasson & Sträng 1997), but normally they form smaller intrusions surrounded by migmatites. ϵ_{Nd} values vary from –0.5 to +0.5, and the $\delta^{18}\text{O}$ values are around +10 ‰ (or even more positive for

fractionated ore-related phases), which may indicate a significant sedimentary component in the source (Wilson et al. 1985). The syn- to late orogenic granites are generally high in K, Rb, U and Th (Wilson et al. 1985).

The Revsund–Adak suite, (50)

The Revsund–Adak suite is the most voluminous and youngest of the described intrusive suites. Grey, massive and coarse microcline megacryst-bearing granites (Revsund type) occupy large areas in the southern and western parts of the investigated area. Further north within the Skellefte and Arvidsjaur Districts, the rocks partly grade into reddish, more even-grained granites (Adak type). Northwest of the town Sorsele, a quartz-poor Adak-like granite occurs (Sorsele type). The rocks often show quartz-poor monzonitic trends, and gabbroic-dioritic components are relatively common. Magma mixing/mingling textures are common. Age determinations on rocks within this suite include the ages 1772 ± 14 Ma for a shallow Adak granite porphyry type, 1778 ± 18 Ma for a Revsund type, and 1791 ± 22 Ma and 1766 ± 8 Ma for the Sorsele type (Skiöld 1988), 1802 ± 3 Ma for an Adak type (Bergström & Sträng 1999), and 1805 ± 9 Ma for a Revsund type (Eliasson & Sträng 1997). The age of the Ale massif in the Luleå area is 1802 ± 3 Ma and 1796 ± 2 Ma for the core and the rim of the massif, respectively (Öhlander & Schöberg 1991). The large areal extent and heterogeneous composition of this intrusive suite suggest a prolonged and complex emplacement history. This is further indicated by the large age interval. The Doublon Group (mainly ignimbrites) west of Sorsele, dated at 1803 ± 15 Ma by Skiöld (1988), is the only extrusive unit associated with the Revsund–Adak suite. Several mineralisations are related to this granitoid suite including Sn–W mineralisations in the Storuman area and U mineralisations in the Arvidsjaur area. ϵ_{Nd} values include +1.8 for the Adak type and +0.7 for the Joran pluton of the Revsund type (Kjell Billström pers. com. 1999). The Ale massif is strongly negative in this respect, ϵ_{Nd} is -5.2 and -3.7 for the core and the rim, respectively, of the intrusion. Reported $\delta^{18}O$ values (Wilson et al. 1985) are +9 to +10 ‰ for the fractionated, ore-related Joran and Grundfors plutons.

Central area (maps 14–18)

Previously published geochemical analyses from the central area that have been used in this study are taken from Lundqvist (1968), Lundqvist (1990), Claesson & Lundqvist (1995) and provided by Thomas Lundqvist (pers. com.). Unpublished analyses from SGU have also been used. The central area is dominated by the southern part of the Bothnian Basin, the Råtan granitoids and the Ljusdal batholith.

Early-orogenic granitoids, EOG3 (95)

Early-orogenic granitoids (s.c. "urgraniter") have been dated at 1843 ± 2 and 1858 ± 15 Ma (Delin 1996) and 1843 ± 3 , 1848 ± 4 , 1867 ± 7 , and 2030 ± 6 Ma (Welin et al. 1993). The granitoids constitute the felsic part of a calc-alkaline suite of ultramafic to granitic rocks (e.g. Claesson & Lundqvist 1995). Nd and Sr isotope data (Claesson & Lundqvist 1995) suggest an origin from a more or less depleted mantle source mixed with crustal material.

Syn–late-orogenic granites, SLOG (80)

Syn–late-orogenic granites of crustal origin have been dated at 1822 ± 5 Ma (Härnö granite, Claesson & Lundqvist 1995) and 1804 ± 7 Ma (Sam Sukotjo pers. com. 1996). The granites are granites s.s. and are associated with pegmatites. According to Claesson & Lundqvist (1995) the rocks formed by anatexis of the surrounding country rocks, which consist of metagreywackes and early-orogenic granitoids.

Transscandinavian Magmatic Belt, TMB (30, 50)

Dala-, Råtan- and Revsund-type plutonic rocks are included in the group of TMB rocks, which formed during two distinct time intervals at 1795–1783 and 1711–1693 Ma (Krogh 1987, Lee et al. 1988, Delin 1996, Lundqvist & Persson 1999). Age determinations with errors larger than 15 Ma have been excluded. The TMB-type plutonic rocks in this area are dominated by granites and show an alkali-calcic trend

(Claesson & Lundqvist 1995). Field observations combined with Nd and Sr isotopic data (Claesson & Lundqvist 1995) suggest that the rocks formed from mixing of mantle and lower crustal sources.

South central area (maps 9–13)

Previously published geochemical analyses from the south central area that have been used in this study are taken from Björk (1986), Billström et al. (1988), Öhlander & Zuber (1988), Bergman et al. (1995), Sundblad & Bergman (1997), Öhlander & Romer (1996), Ripa (1998) and provided by Ulf B. Andersson (pers. com.). Unpublished analyses from SGU have also been used. Major geological provinces in the south central area are the Bergslagen ore district and the Dala igneous complex.

Early-orogenic granitoids, EOG3 (95, 90)

The early-orogenic granitoids have been dated at between 1891 and 1850 Ma (Welin et al. 1980, Åberg et al. 1983a,b, Åberg & Strömberg 1984, Persson 1993, Persson & Persson 1997, 1999, Ripa & Persson 1997). The early-orogenic plutonic rocks are a differentiated suite of calcic and calc-alkaline, I-type intrusions ranging from ultramafic rocks, gabbros and diorites through dominant tonalites and granodiorites to granites s.s. (Wilson 1982, Gaal & Gorbatshev 1987). Isotopic and other geochemical data suggest that they were derived predominantly from material newly segregated from the mantle during the early Proterozoic (Patchett et al. 1987, Gaal & Gorbatshev 1987, Valbracht 1991).

Syn-late-orogenic granites, SLOG (80)

The syn-late-orogenic granites have been dated at between 1807 and 1748 Ma (Åberg & Bjurstedt 1986, Patchett et al. 1987, Billström et al. 1988, Stephens et al. 1993, Sundblad et al. 1993, Bergman et al. 1995, Ivarsson & Johansson 1995, Öhlander & Romer 1996, Persson & Persson 1997). The rocks represent crustal, anatectic, mostly S-type, undifferentiated granites associated with migmatites and large amounts of pegmatite (e.g. Gaal & Gorbatshev 1987).

Transscandinavian Magmatic Belt, TMB (10, 20, 30)

The TMB-type plutonic rocks have, according to available geochronological data, formed during three periods of igneous activity; i.e. at 1855 to 1829 Ma (Persson & Wikström 1993, Wikström 1996 and Carl-Henric Wahlgren pers. com.), at 1812 to 1763 Ma (Jarl & Johansson 1988, Persson & Ripa 1993, Stephens et al. 1993, Andersson 1997, Lundqvist & Persson 1999) and at 1699 to 1676 Ma (Stephens et al. 1993, Lindh et al. 1994, Ahl et al. 1997, 1999, Lundqvist & Persson 1999). The TMB rocks have Nd and Sr isotope signatures indicating derivation from the mantle or lower crust, and have a syenitic evolution trend (Wilson et al. 1985, Patchett et al. 1987, Gaal & Gorbatshev 1987).

Classification and petrogenesis of plutonic rocks

The main aim of this investigation is to distinguish different well-defined and precisely dated rock types from each other by geochemical parameters. A large number of elements or groups of elements have been plotted in Harker-type and ternary diagrams to find appropriate elements or combination of elements that can be used as discriminators. The symbols that have been used in the diagrams are shown in Fig. 8. In some diagrams colours have been added to make the diagrams more readable, note that the colours are not fully denoted to a specified rock group. Grey symbols denote class 2 and class 3 data. Another way to identify and separate intrusive rocks in this investigation has been to use established chemical classification and discrimination diagrams for the characterisation of different rock groups. The following classification/discrimination diagrams utilising major and trace elements have been used: Debon & Le Fort (1983) (nomenclature and magmatic association, Fig. 9), Debon & Le Fort (1983) and Maniar & Piccoli (1989) (alumina saturation, Figs. 9–10, the alumina saturation index was originally defined by Shand 1927), Irvine & Baragar (1971), Maniar & Piccoli (1989) and Sylvester (1989) (alkalinity,

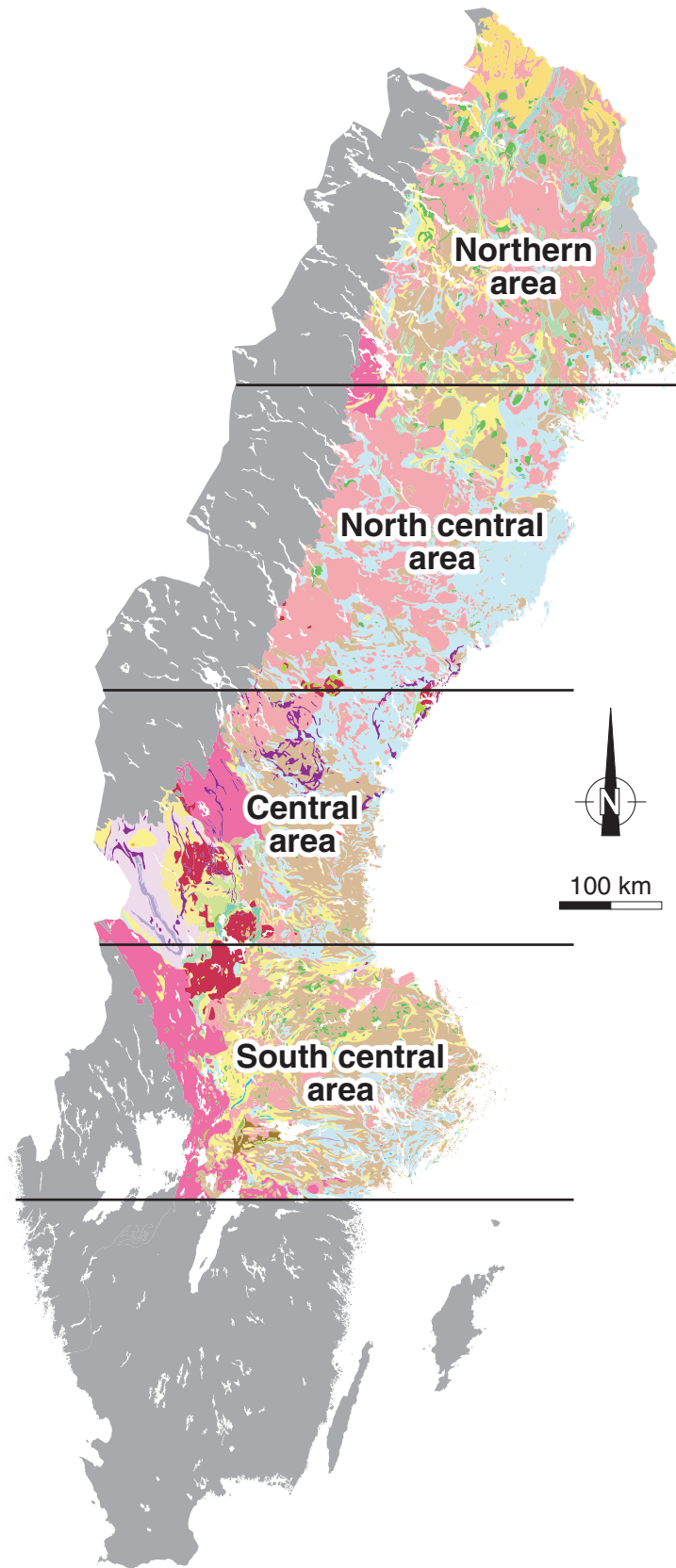


Fig. 1. Bedrock map of Sweden with studied areas indicated.

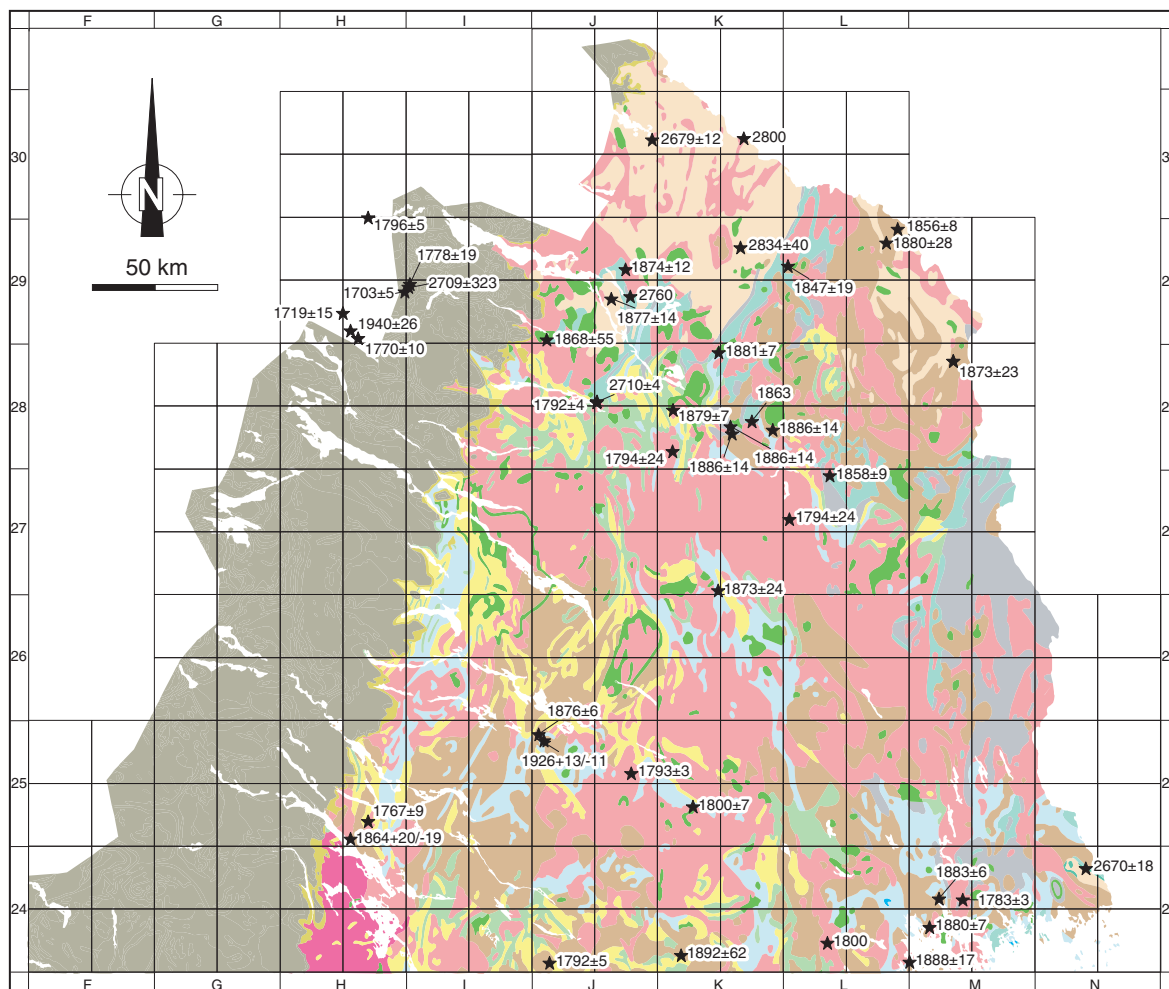


Fig. 2. Bedrock map of the northern area (maps 25–32) showing the distribution of age determination samples used in this study. Ages are given in million years. See APPENDIX A for references.

Figs. 10–11), Peacock (1931) (alkali-lime index, Fig. 11), La Roche et al. (1980) (R1–R2 classification, Fig. 12), Batchelor & Bowden (1985), Pearce (1996) and Harris et al. (1986) (tectonic environment, Figs. 12–13). Other petrogenetic classification schemes which have been used are by Pearce et al. (1984), Chappell & White (1974), White & Chappell (1983; S-, I-, and M-types) and Collins et al. (1982; A-type).

The majority of samples are from intermediate to felsic rocks, while mafic rocks are "underrepresented". Although some of the diagrams were designed for mafic rocks, they are in this study used to differentiate groups of rocks.

Silica-rich samples from magmas of different origins may have evolved by fractional crystallisation/melting, mixing and assimilation, and converge towards rather similar end products in terms of major elements and mineralogy. In these cases trace element concentrations have been considered. Especially the contents of large-ion lithophile (LIL) elements such as K, Rb, Th, U and LREE, as well as those of high-field strength (HFS) elements such as Y, Hf, Zr, Ti, Nb and Ta have been studied. Different HFS/LIL ratios have been applied as tests for magmatic affinity, protolith and alteration style.

The C1 Chondrite values (Sun & McDonough 1989) have been used for normalisation in the REE diagrams (Fig. 14). In spidergrams the primitive mantle values given by Taylor & McLennan (1985) were used for normalisation.

Intrusive rocks do not usually show evident signs of having undergone metasomatism/alteration to the

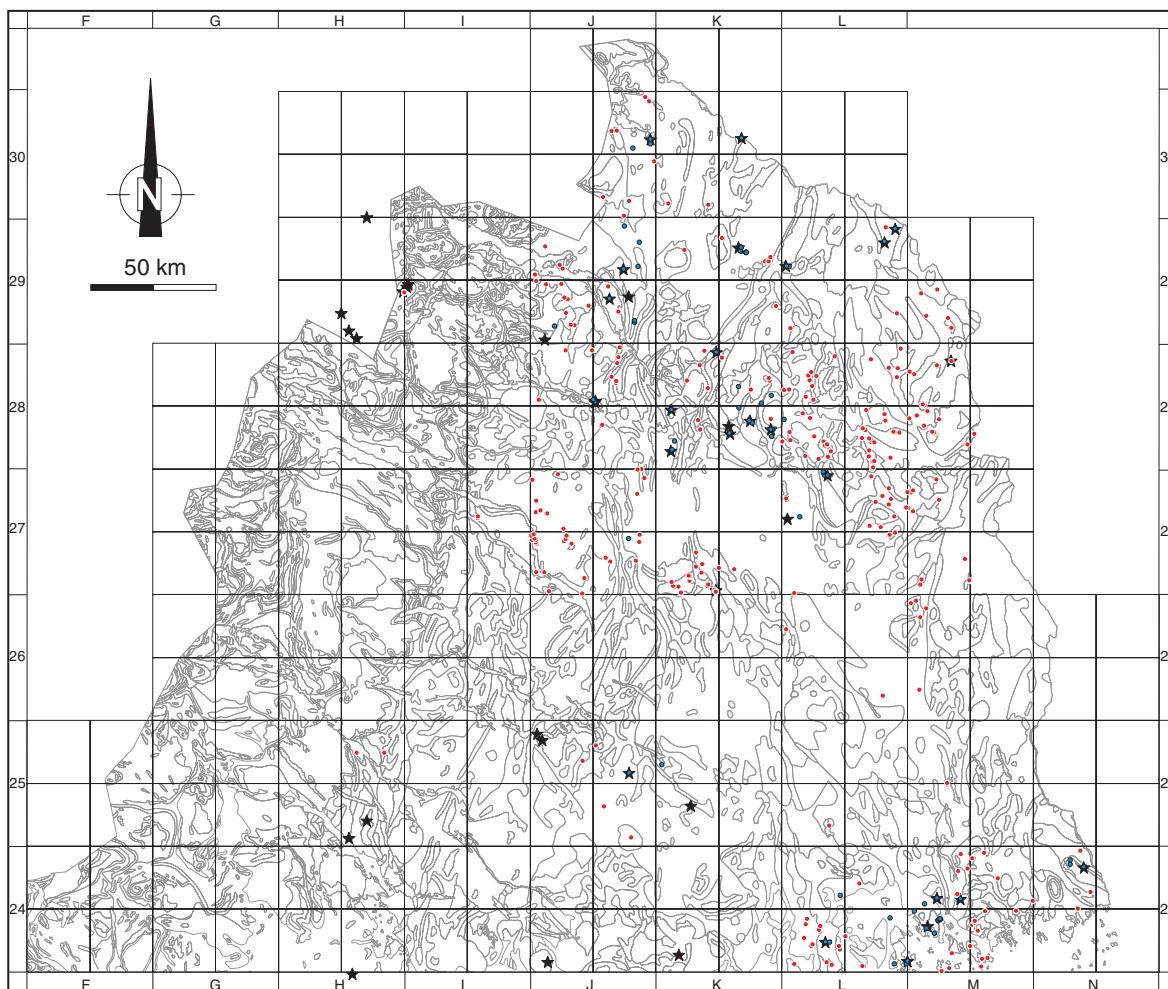


Fig. 3. Location of geochemical samples (blue dots=class 1, red dots=class 2–3) and age determinations (stars) that have been used in the northern area.

same extent as comparable extrusive rocks. The Hughes (1973) diagram, designed for extrusive rocks, has been used to show potential effects of alkali alteration (Fig. 13).

CIPW normative mineral abundance has been used to highlight characteristic normative minerals such as apatite, corundum and magnetite. The CIPW calculations were made by the software "Power Norm for Minpet 2.02" from Minpet Geological Software-Logiciel Géologique Minpet, Canada.

Other aspects, which of course have to be considered to account for the entire evolution of the plutonic systems are field relationships, petrography, mineralogy and isotope concentrations.

Results from individual areas

For each group in each area diagrams of major or trace elements vs. SiO_2 (Harker diagrams) and various classification diagrams have been plotted. The general characteristics of each suite and differences compared to other suites are presented below. Only diagrams, which can be used for discrimination, are presented here. For complete sets of data contact the first author or SGU, Uppsala.

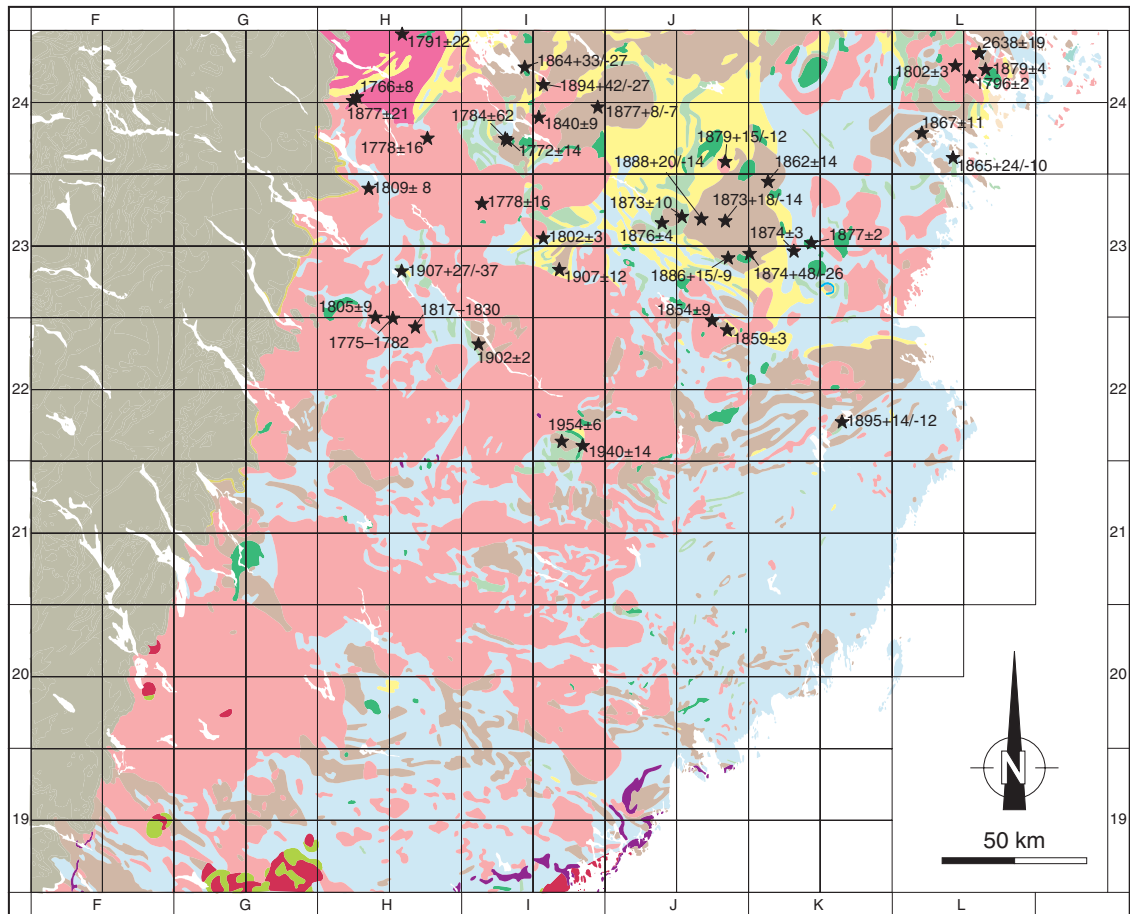


Fig. 4. Bedrock map of the north-central area (maps 19-24) showing the distribution of age determination samples used in this study. Ages are given in million years. See APPENDIX A for references.

Northern area (25-32)

Characterisation of class I samples

Archaean rocks (100)

Most of the studied Archaean rocks are classified as quartz diorites–tonalites–granodiorites–adamellites using the P–Q classification diagram (Fig. 9) of Debon & Le Fort (1983). They show a rather poorly defined alkali-calcic trend ($\text{CaO}/\text{alkali oxides}=1$ at $\text{SiO}_2=51.5$) on the modified Peacock (1931) diagram (Fig. 11) and they plot within the metaluminous and peraluminous fields (Fig. 10) of Maniar & Piccoli (1989). Nine samples plot outside the field of igneous rocks (Hughes 1973; Fig. 13).

EOG2 (90)

The studied rocks of the Haparanda suite are classified as gabbros–monzogabbros–quartz monzodiorites–quartz monzonites and tonalites–granodiorites–adamellites using the P–Q classification diagram of Debon & Le Fort (1983). They show an alkali-calcic trend ($\text{SiO}_2=52.9$) on the modified Peacock (1931) diagram (Fig. 11). Most samples plot within the metaluminous field (Fig. 10) of Maniar & Piccoli (1989), but some are peraluminous. Six samples plot outside the field of igneous rocks (Hughes 1973; Fig. 13).

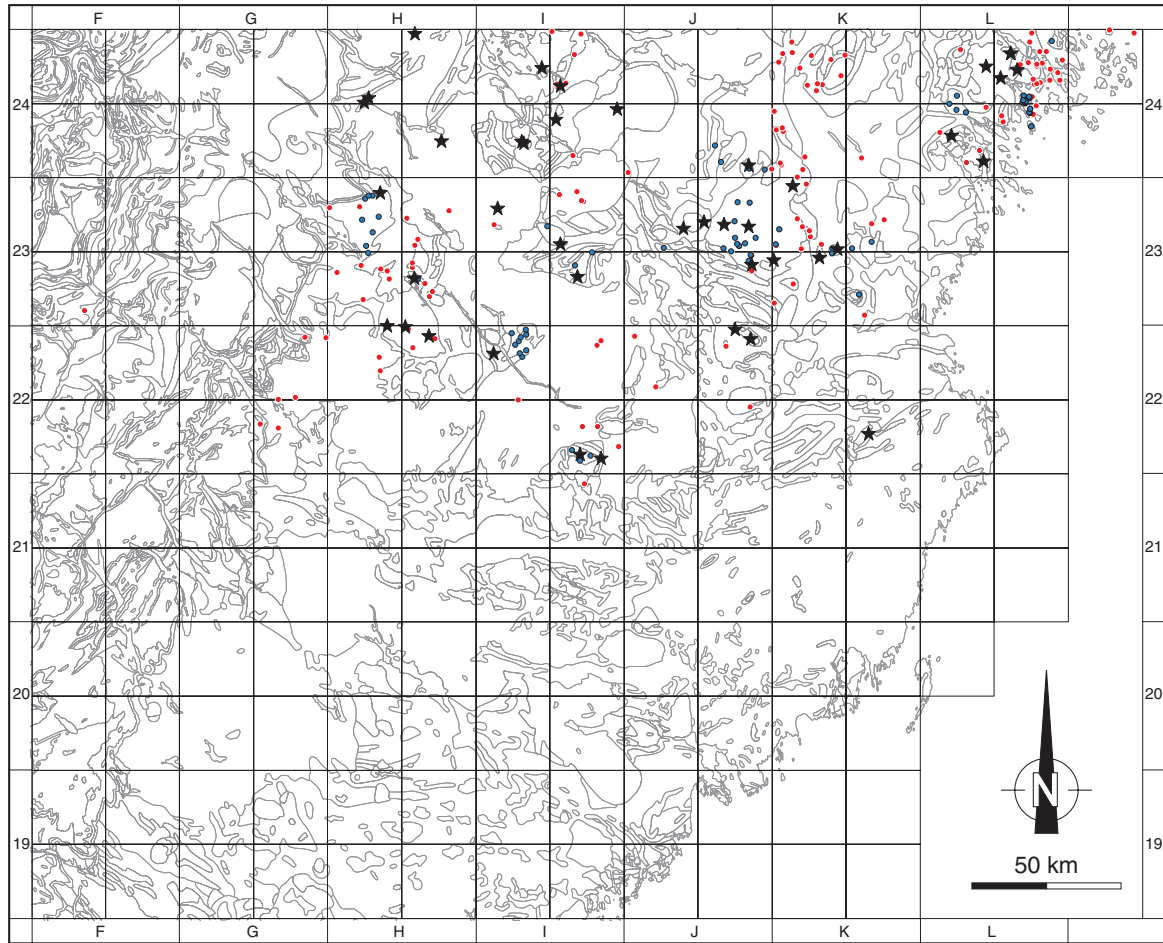


Fig. 5. Location of geochemical samples (blue dots=class 1, red dots=class 2-3) and age determinations (stars) that have been used in the north-central area.

PMS (60)

The studied rocks of the PMS are classified as monzogabbros–quartz monzodiorites–quartz monzonites–adamellites–granites using the P–Q classification diagram (Fig. 9) of Debon & Le Fort (1983). They show an alkalic trend ($\text{SiO}_2=46.2$) on the modified Peacock (1931) diagram (Fig. 11). They plot within the metaluminous and peraluminous fields (Fig. 10) of Maniar & Piccoli (1989), but near the boundary to the peralkaline field. Three samples plot outside the field of igneous rocks (Hughes 1973, Fig. 13).

SLOG (80)

Most of the studied rocks of the SLOG are classified as adamellites–granites using the P–Q classification diagram (Fig. 9) of Debon & Le Fort (1983). They have a narrow range of SiO_2 content and can therefore not be classified on the Peacock (1931) diagram (Fig. 11). Nearly all samples plot within the peraluminous field (Fig. 10) of Maniar & Piccoli (1989). Two samples plot outside the field of igneous rocks (Hughes 1973; Fig. 13).

TMBI (20)

The studied rocks of the TMB group are classified as syenites–quartz syenites–granites using the P–Q classification diagram (Fig. 9) of Debon & Le Fort (1983). Some samples also plot as monzonites–quartz monzonites. They have a much higher total alkali content than calcic content, which indicates an alkalic affinity on the Peacock (1931) diagram (Fig. 11). Most samples plot within the metaluminous field (Fig. 10) of Maniar & Piccoli (1989). Only one sample plots outside the field of igneous rocks (Hughes 1973; Fig. 13).

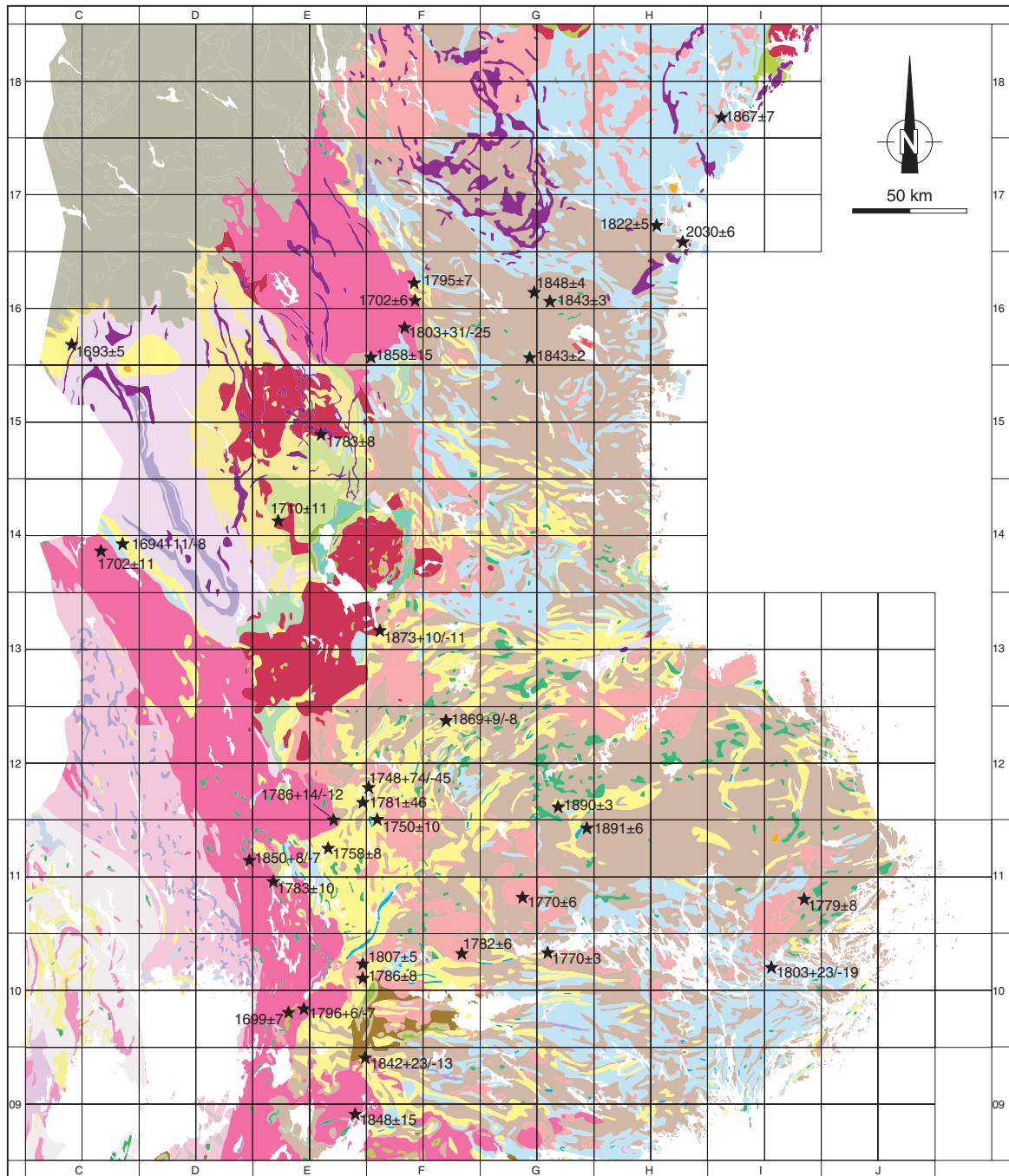


Fig. 6. Bedrock map of the central and south central areas (maps 9–18) showing the distribution of age determination samples used in this study. Ages are given in million years. See APPENDIX A for references.

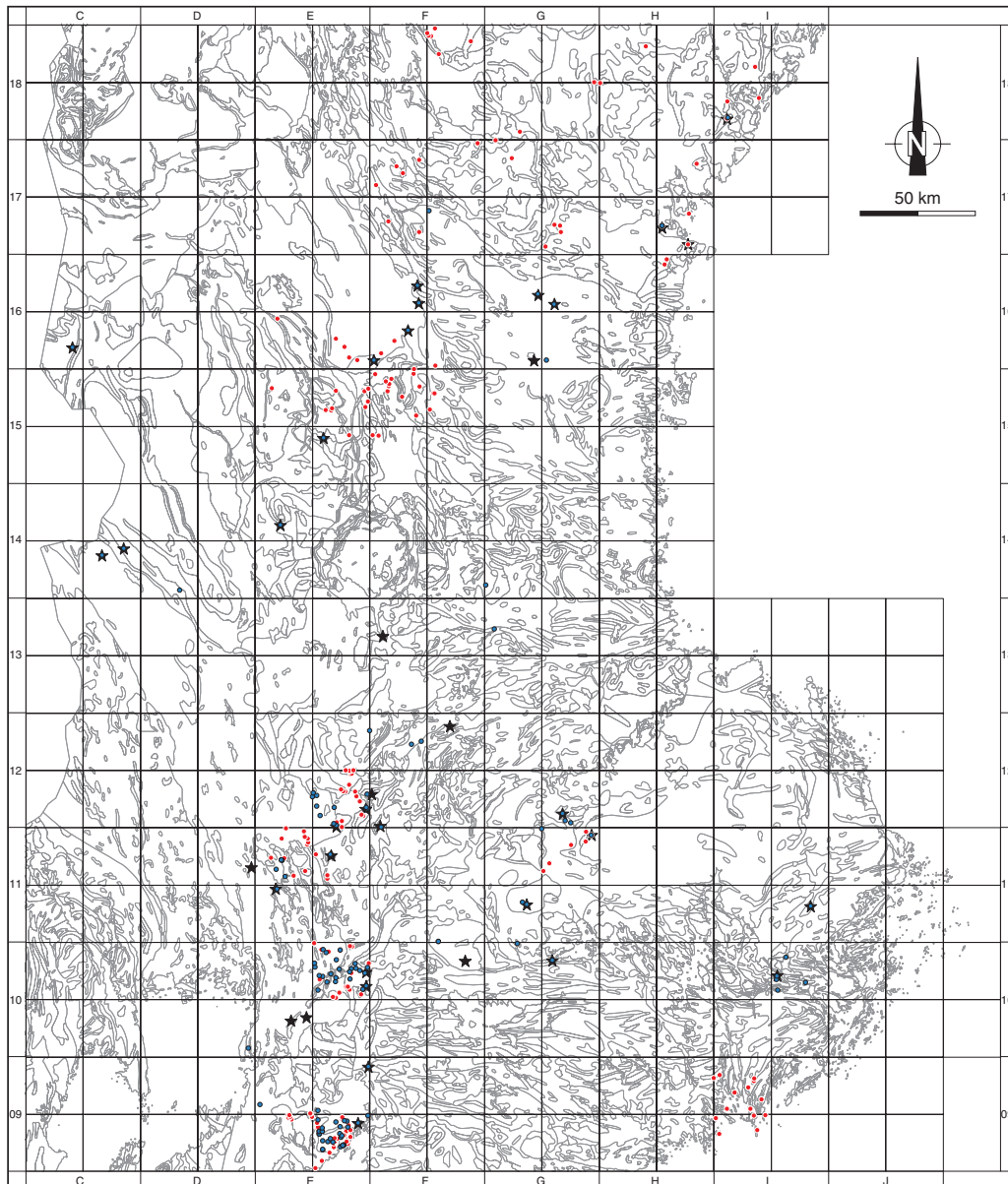


Fig. 7. Location of geochemical samples (blue dots=class 1, red dots=class 2–3) and age determinations (stars) that have been used in the central and south central areas.

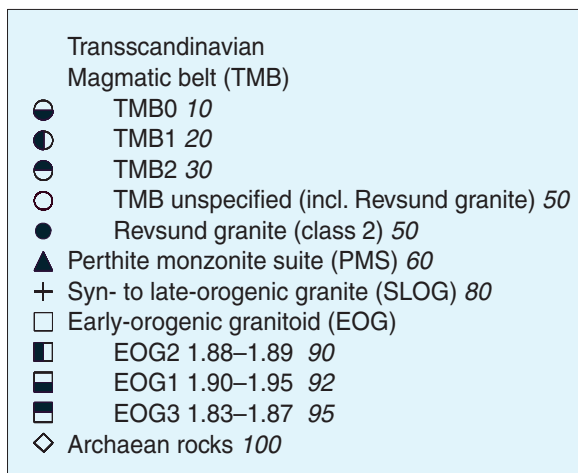


Fig. 8. Symbols that are used in the subsequent chemical diagrams. In some diagrams colours have been added to make the diagrams more readable; note that the colours are not fully denoted to a specified rock group. Grey symbols denote class 2 and class 3 data.

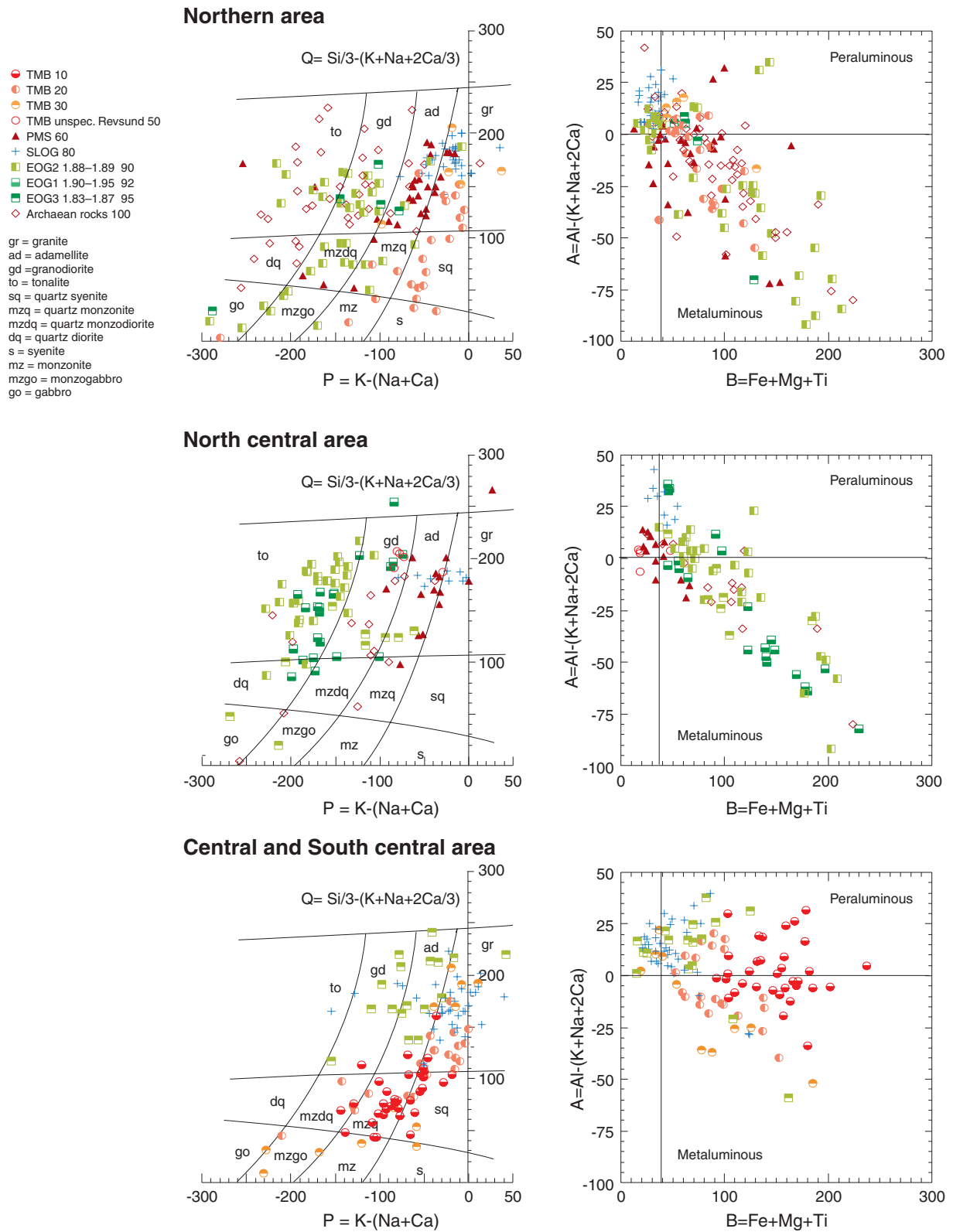
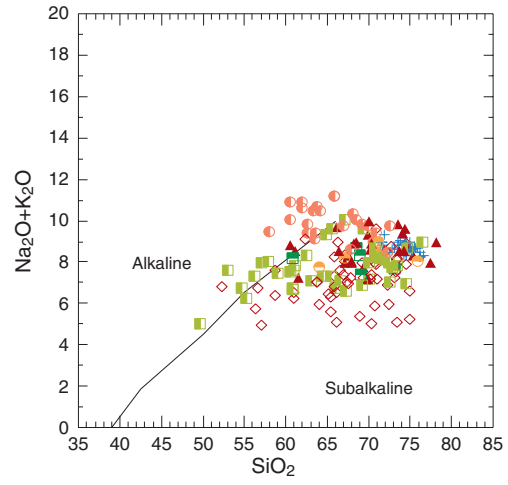
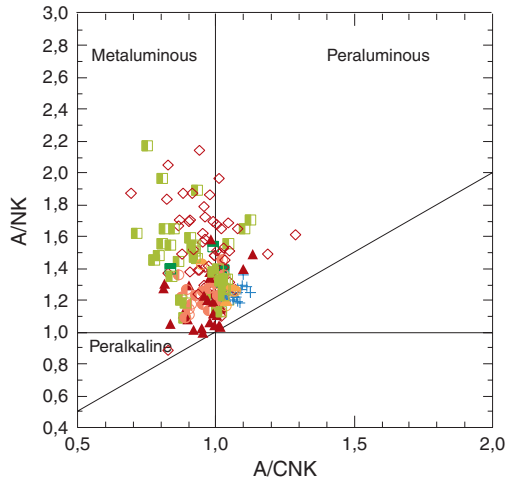
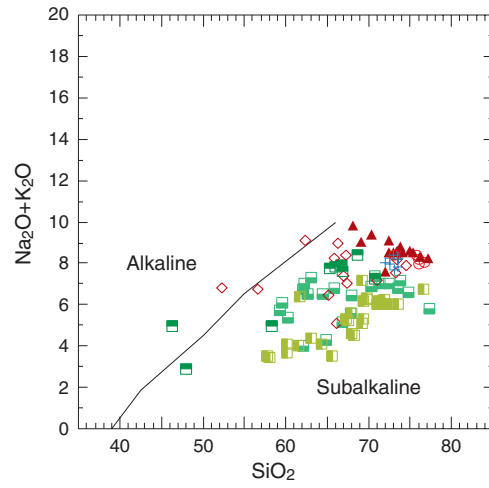
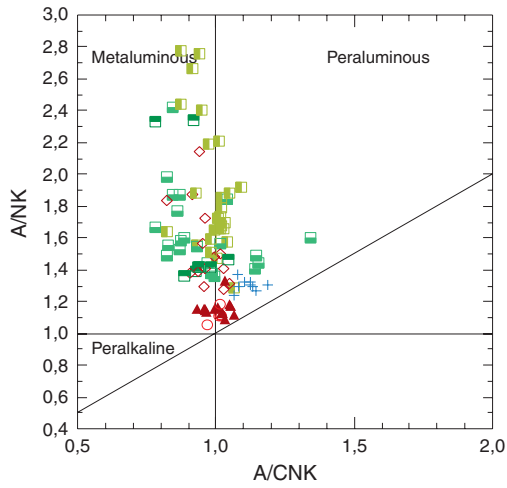


Fig. 9. All class 1 data, plotted in P–Q and B–A diagrams of Debon & Le Fort (1983).

Northern area



North central area



Central and South central area

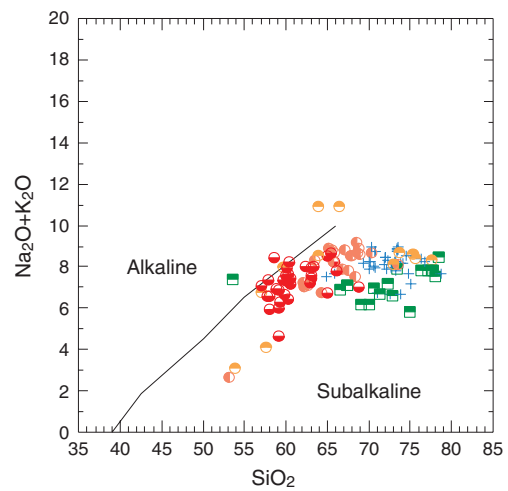
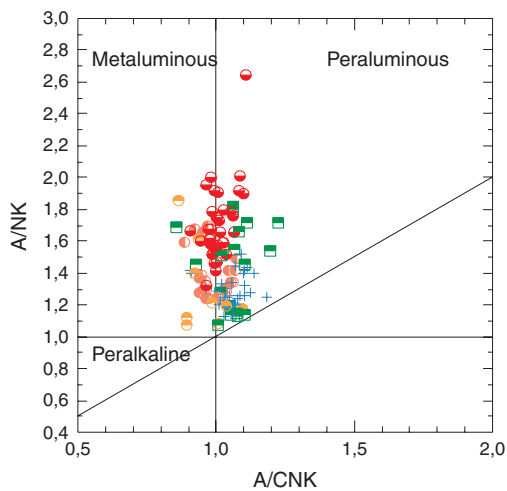


Fig. 10. All class 1 data, plotted in classification diagrams of Maniar & Piccoli (1989) and Irvine & Baragar (1971).

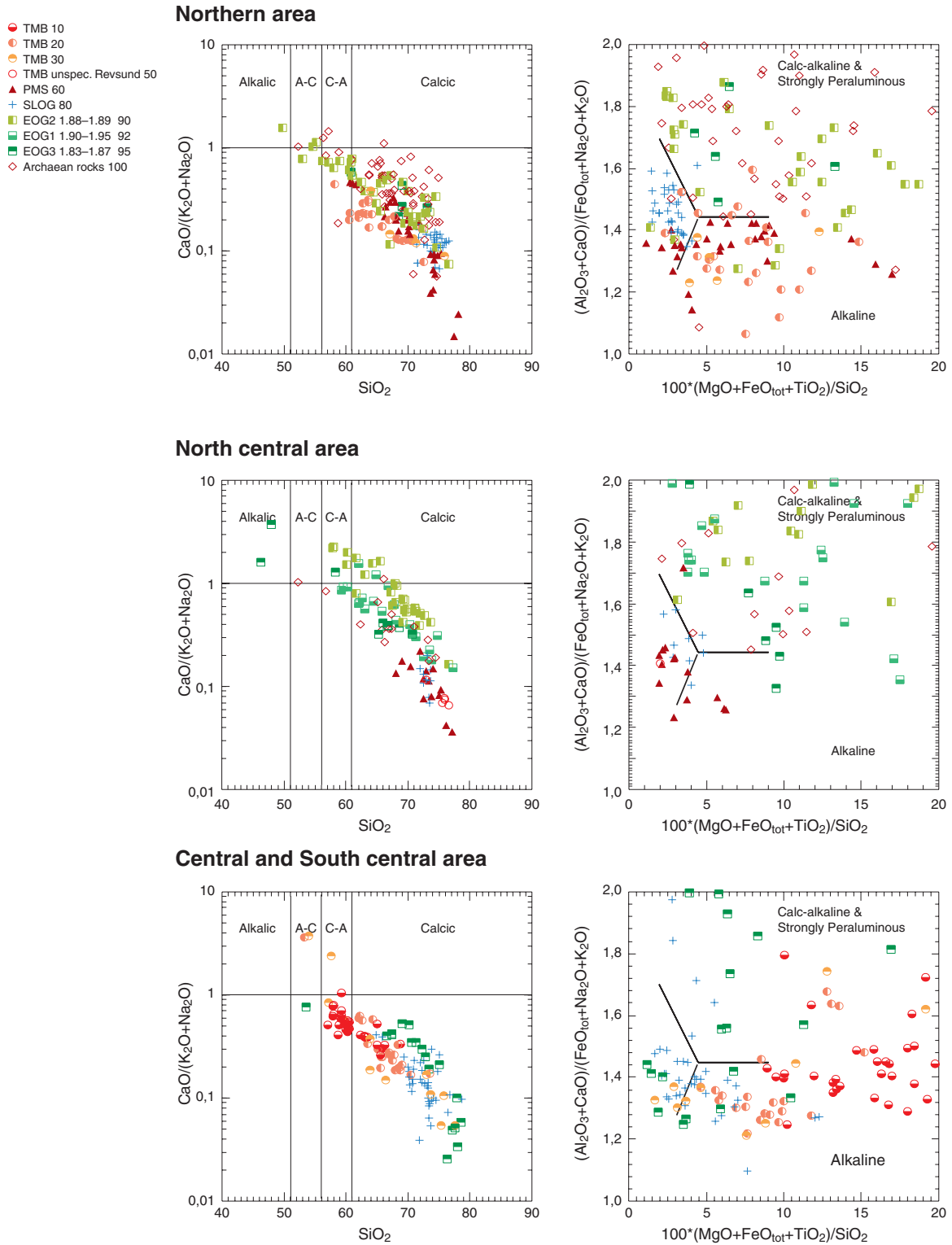


Fig. 11. All class 1 data, plotted in classification diagrams modified from Peacock (1931) and by Sylvester (1989).

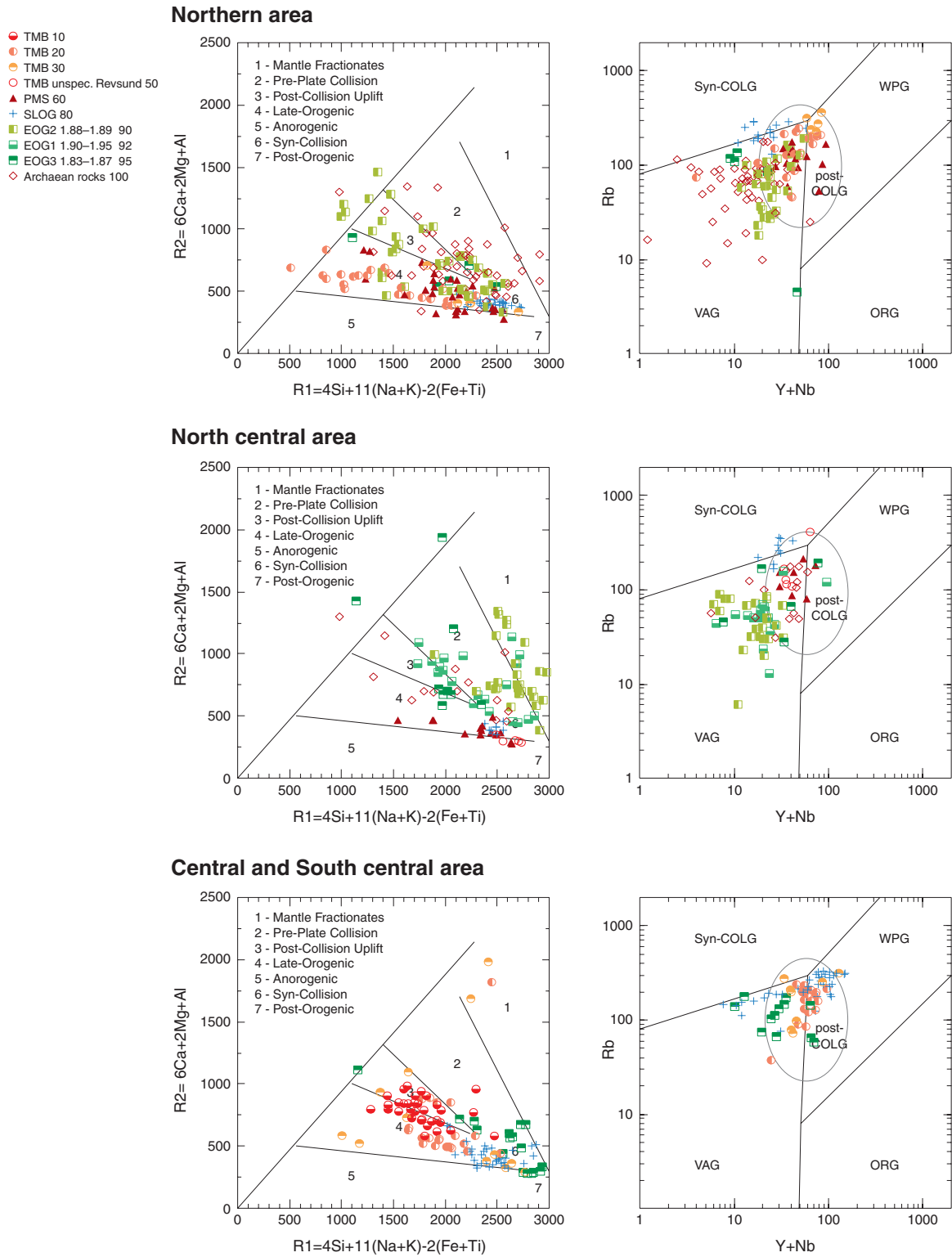
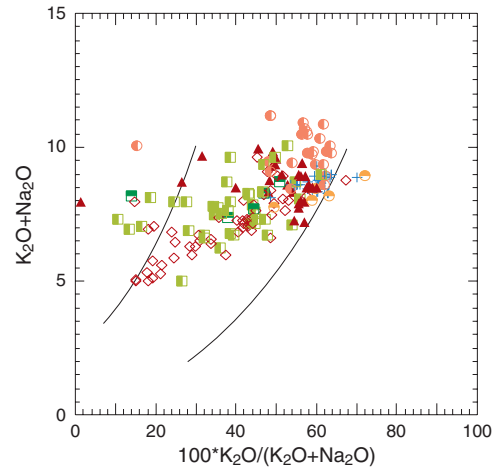
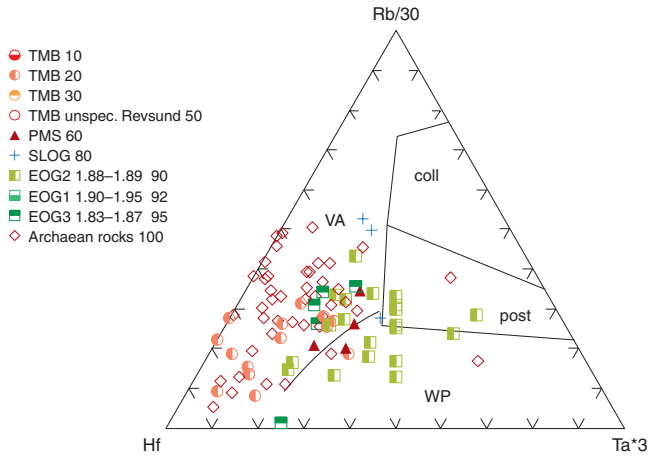
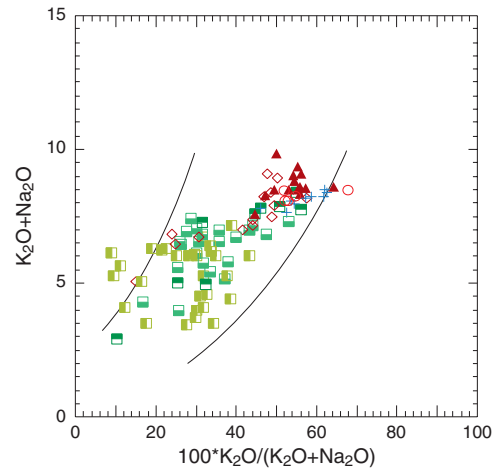
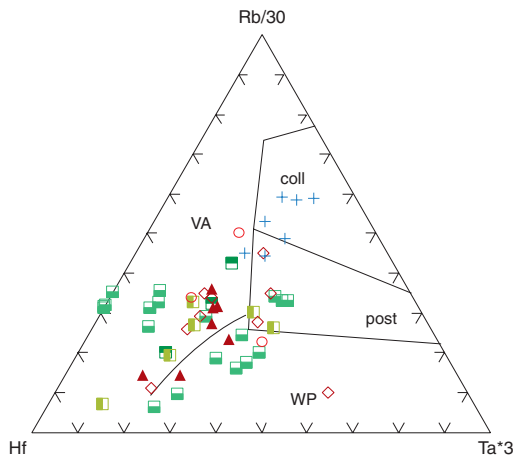


Fig. 12. All class 1 data, plotted in tectonomagmatic diagrams of Batchelor & Bowden (1985) and Pearce (1996). Syn-collision granites (syn-COLG), volcanic arc granites (VAG), post-collision granites (post-COLG), within plate granites (WPG) as well as normal and anomalous ocean ridge granites (ORG).

Northern area



North central area



Central and South central area

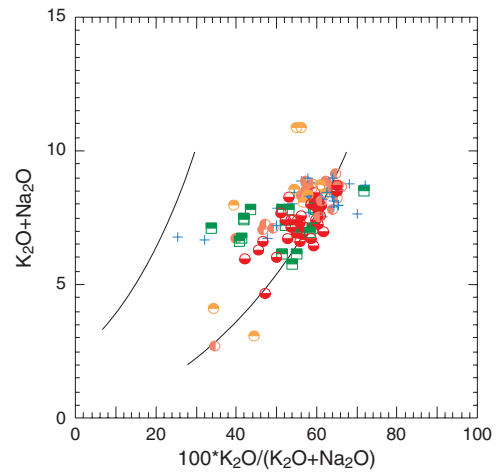
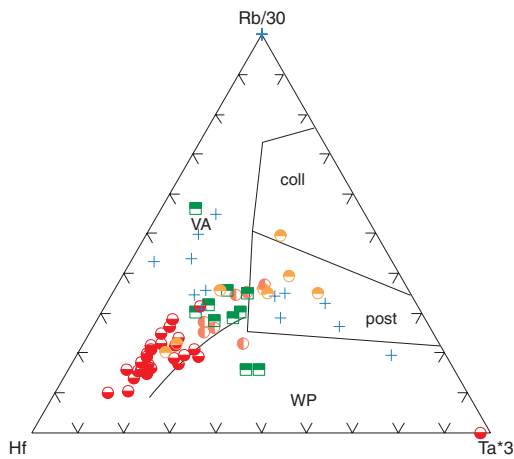
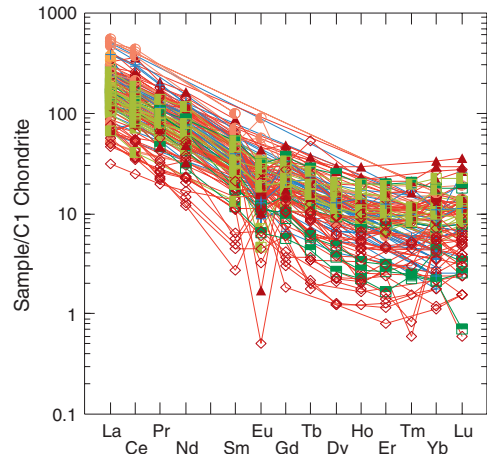
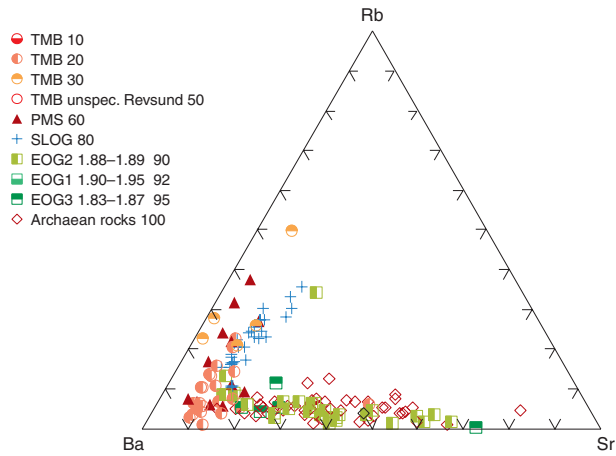
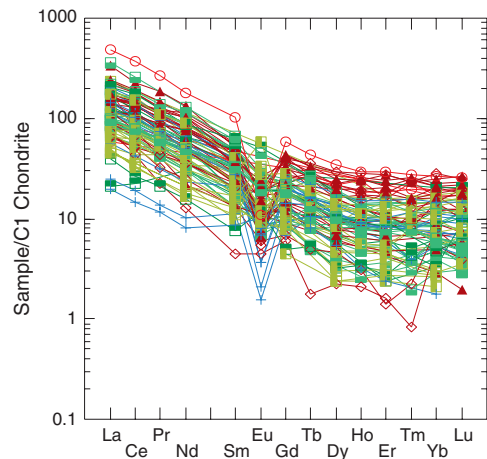
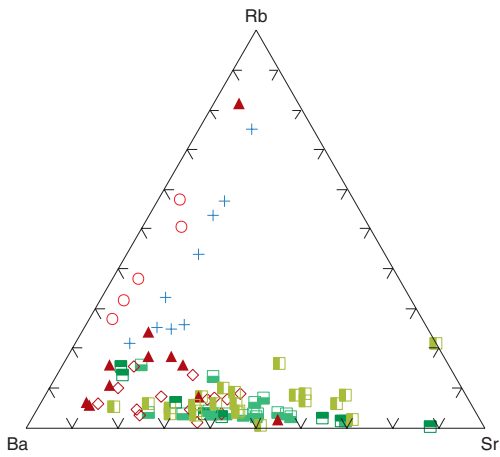


Fig. 13. All class 1 data, plotted in diagrams of Harris et al. (1986) and Hughes (1973). Volcanic-arc (VA), within-plate (WP), collision (coll) and post-collision (post).

Northern area



North central area



Central and South central area

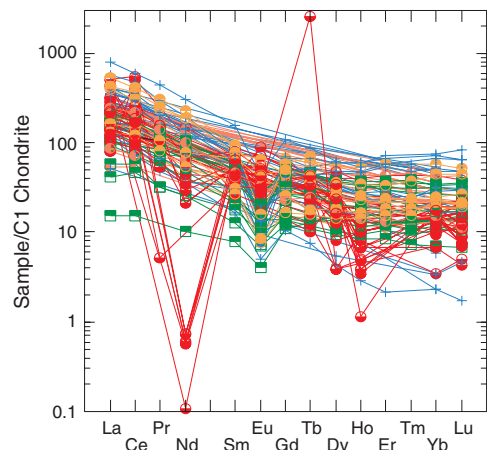
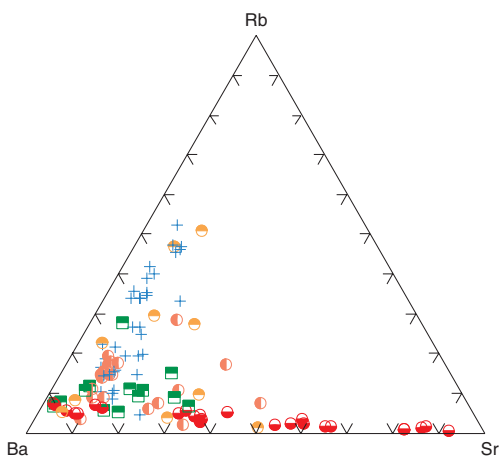


Fig. 14. All class 1 data, plotted in Sr - Ba - Rb - and in REE diagrams.

Comparison between rock groups

Archaean rocks vs. EOG: The Archaean rocks and the Haparanda suite have similar major and minor element contents. However, most Archaean rocks are depleted in U. They also generally have higher contents of Cr, Ni, Pb, Zn and Cu and lower contents of Y, Yb, Nb, Ta and Th at similar SiO₂ values, than the Haparanda suite. The two suites are best discriminated on the U vs. Pb diagram (Fig. 15). Unfortunately, not all class 1 samples have been analysed for Pb, so there is some uncertainty. A fairly good discrimination is also apparent on a diagram of U vs. SiO₂ (Fig. 15). U vs. Nb and U vs. Cr can also be used.

Archaean rocks vs. PMS: The Archaean rocks are richer in Al₂O₃ and CaO and poorer in MnO, TiO₂ and K₂O at similar SiO₂ values, than the PMS. A fairly good separation of the two suites is obtained on the Al₂O₃ vs. CaO/TiO₂ diagram (Fig. 16). Among trace elements, Sr contents are higher and Nb, Rb, U, Th, Y and Zr contents are generally lower in the Archaean rocks. The best discrimination between the two groups is obtained using the U vs. Y diagram (Fig. 16). Another useful diagram may be Sr vs. Y+Nb (Fig. 16).

Archaean rocks vs. SLOG: The Archaean rocks are richer in MgO, Na₂O and CaO and poorer in K₂O at similar SiO₂ values, than the SLOG. They are well separated on the K₂O vs. MgO diagram. The Archaean rocks are also generally richer in Cr, Cu, Sr, V and Zn and poorer in La, Rb, Nb, Th, U, V and Y. The two groups are well separated on the diagrams Th vs. V and Rb vs. Sr (Fig. 17).

Archaean rocks vs. TMB1: The Archaean rocks are richer in MgO, CaO and P₂O₅ and poorer in K₂O at similar SiO₂ values, than the TMB1 suite. They are well separated on the K₂O vs. CaO and K₂O vs. SiO₂/Al₂O₃ diagrams. The Archaean rocks are also generally richer in Cr, Sr and V and poorer in Ba, Hf, Nb, Pb, Rb, Ta, U, Y and Zr. Most samples from the two groups can be discriminated on a plot of Zr vs. Y (Fig. 18). The P–Q diagram can also be used.

EOG vs. PMS: At the same content of SiO₂ the Haparanda rocks generally have higher contents of Al₂O₃, Na₂O and CaO and lower contents of K₂O, P₂O₅ and TiO₂ than the PMS. On a major element plot of K₂O/(CaO + Na₂O) vs. Al₂O₃ these two suites can generally be separated (Fig. 19). The Haparanda suite generally has higher concentrations of Pb and Sr and lower concentrations of Hf, Rb, Th, Y, Zr than the PMS. The best separation of the two suites has been obtained by plotting Sr or Y vs. Th (Fig. 19). A plot of Sr/Th vs. Sr/Zr may also be used to separate the groups.

EOG vs. SLOG: The Haparanda suite is characterised by higher concentrations of Al₂O₃, Na₂O and CaO and lower concentrations of K₂O than the SLOG. Most samples can be discriminated by plotting K₂O/Na₂O vs. SiO₂/Al₂O₃ (Fig. 20). Among the trace elements, the most distinct differences are the high levels of Sr and the low levels of Pb, Rb and Th in the Haparanda suite in relation to the SLOG. Rb vs. Sr is a useful diagram to discriminate the two suites, but also Pb vs. Th (Fig. 20). Some samples in the SLOG have distinctly higher concentrations of e.g. La, V and Zr at similar values of SiO₂.

EOG vs. TMB1: At comparable levels of SiO₂ the Haparanda rocks generally have higher contents of Al₂O₃, MgO and CaO and lower contents of K₂O and P₂O₅ than the TMB1 suite. A fairly good separation of the two suites is obtained on a diagram of K₂O/(MgO+Na₂O) vs. SiO₂/Al₂O₃ (Fig. 21). Another diagram which may be used is K₂O vs. SiO₂/Al₂O₃ (Fig. 21). The Haparanda suite has high contents of Cr, Sr and V and low contents of Ba, Ga, Hf, Pb, Zn and Zr at similar SiO₂ values, compared to the TMB1 suite. A plot of Sr/Ba vs. Zr/V discriminates most samples of the two groups (Fig. 21). The diagram Zr vs. V may also be used.

PMS vs. SLOG: The PMS generally has higher contents of Fe₂O₃, MnO, TiO₂, Cu, Hf, Y, Yb and Zr and lower contents of Al₂O₃, CaO, Ba, Pb, Rb, Sr, Th and U than the SLOG, at similar SiO₂ values. Using major elements the plot Al₂O₃/TiO₂ vs. CaO/TiO₂ discriminates these two suites (Fig. 22). A little less

efficient are the plots $\text{Fe}_2\text{O}_3/\text{Al}_2\text{O}_3$ vs. CaO/TiO_2 and $\text{TiO}_2/\text{Al}_2\text{O}_3$ vs. $\text{Fe}_2\text{O}_3/\text{CaO}$. Generally high values of Nb, Y, Yb and Zr and low values of Ba, Pb, Rb, Sr, Th and U characterise the PMS in relation to the SLOG. The diagram Rb vs. Nb effectively separates the studied samples of the two groups (Fig. 22). Other plots that may work are Y vs. Th (Fig. 22) or Zr vs. Th.

PMS vs. TMB1: The PMS generally has higher contents of MgO, TiO_2 , P_2O_5 , Sc, Sn and Th and lower contents of Al_2O_3 , K_2O , Ga, Hf, Pb, Rb, Mo, Zn and Zr than the TMB1 suite, at similar SiO_2 values. The slopes of Al_2O_3 vs. SiO_2 are different, and using major elements the suites can be discriminated by plotting $\text{SiO}_2/\text{Al}_2\text{O}_3$ vs. K_2O (Fig. 23). The PMS has high contents of Sc, Sn, Th and V and low contents of Ga, Hf, Pb and Zr at similar SiO_2 values, compared to the TMB1 suite. A good discrimination is obtained on the Th vs. Zr diagram.

SLOG vs. TMB1: The SLOG generally has higher contents of Al_2O_3 , Na_2O , CaO, Rb, Sn and Th and lower contents of Cu, Cr, Ga, Hf, Y, Yb, Zn, Zr than the TMB1 suite, at similar (or extrapolated to similar) SiO_2 values. The major element A–B plot of Debon & Le Fort (1983) separates these two suites. Generally high values of Rb and Th and low values of Y, Zn and Zr characterise the SLOG in relation to the TMB1 suite. Plots of Th vs. Zr, or Y, effectively separate these suites (Fig. 24). All class 1 samples from the SLOG have Zr/Th ratios <10 and Y/Th ratios <2, in contrast to the samples of TMB1 suite, which have ratios higher than these values.

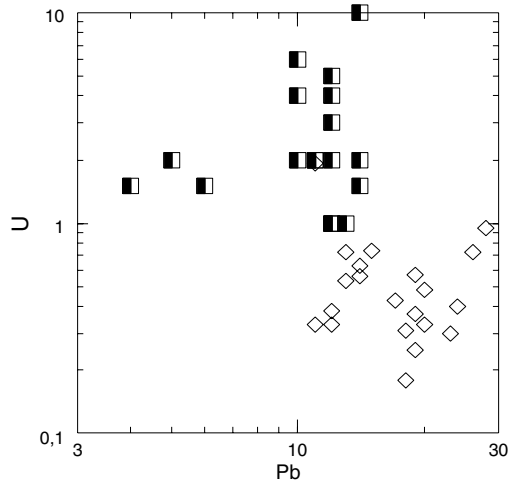
Class 2 samples and summary of results from the northern area (25–32)

The class 2 samples were tested with the plots that were most effective in discriminating class 1 samples from the different groups. The results are summarised in Table 3. It is apparent from this table that it is possible to geochemically separate all groups from each other, except for the PMS. However, in some cases the PMS may be discriminated from Archaean rocks, the SLOG and the TMB1 suite. The discrimination between the PMS and the EOG is problematic using the available database.

TABLE 3. Table summarising plots that may discriminate between different plutonic suites in the northern area. **Bold** text denotes plots that were effective using both class 1 and class 2 samples. Regular text denotes plots that were effective for class 1 samples and some, but not all class 2 samples. Text in *italics* denotes plots that were effective for class 1 samples only.

	TMB1 (20)	SLOG (80)	PMS (60)	EOG (90)
Archaean (100)	$\text{K}_2\text{O}-\text{CaO}$ $\text{K}_2\text{O}-\text{SiO}_2/\text{Al}_2\text{O}_3$ Zr-Y	$\text{K}_2\text{O}-\text{MgO}$ Rb-Sr Th-V	$\text{Al}_2\text{O}_3-\text{CaO}/\text{TiO}_2$ Sr-Y+Nb U-Y	U- SiO_2 U-Pb
EOG (90) (90)	$\text{K}_2\text{O}-\text{SiO}_2/\text{Al}_2\text{O}_3$ $\text{K}_2\text{O}/(\text{MgO}+\text{Na}_2\text{O})$ - $\text{SiO}_2/\text{Al}_2\text{O}_3$ Sr/Ba-Zr/V	$\text{K}_2\text{O}/\text{Na}_2\text{O}-\text{SiO}_2/\text{Al}_2\text{O}_3$ Rb-Sr Th-Pb	<i>$\text{K}_2\text{O}/(\text{CaO}+\text{Na}_2\text{O})-\text{Al}_2\text{O}_3$</i> Sr-Th Th-Y	
PMS (60)	$\text{K}_2\text{O}-\text{SiO}_2/\text{Al}_2\text{O}_3$ Th-Zr	$\text{Al}_2\text{O}_3/\text{TiO}_2-\text{CaO}/\text{TiO}_2$ Rb-Nb Th-Y		
SLOG (80)	A-B Th-Zr Th-Y			

Class 1



Class 1-3

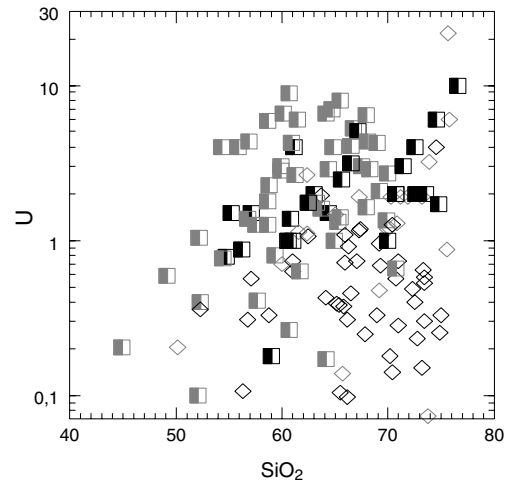
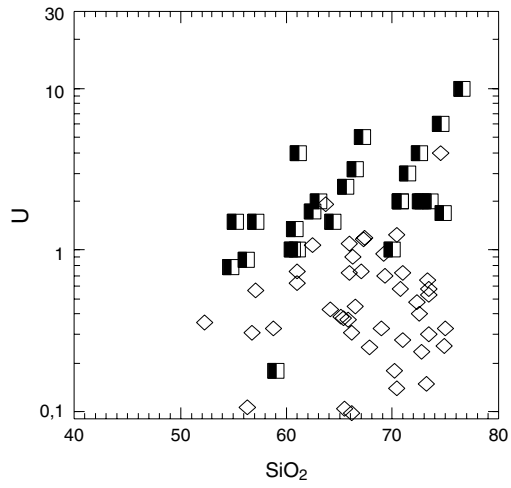
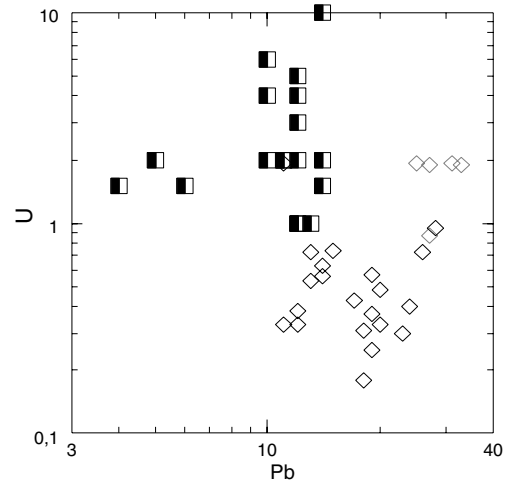
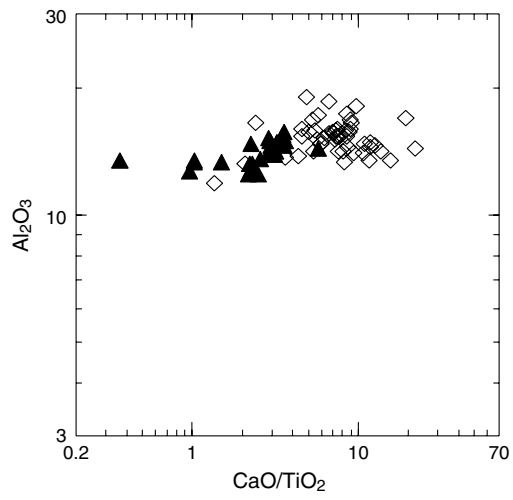


Fig. 15. Northern area, Archaean vs. EOG2.

Class 1



Class 1-3

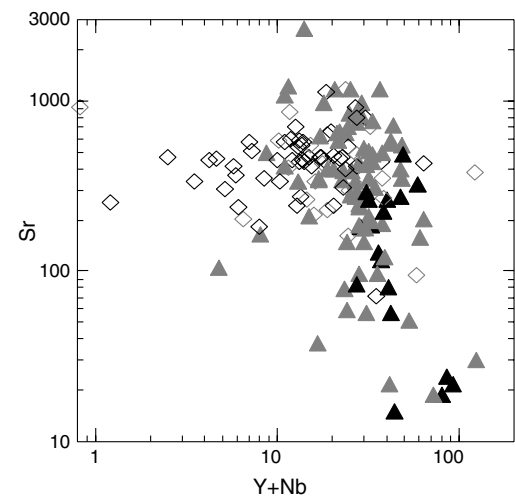
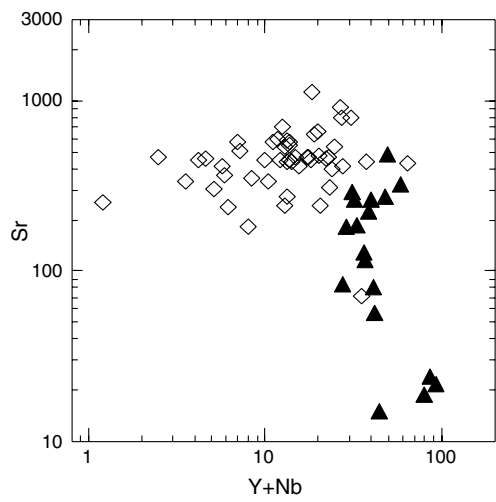
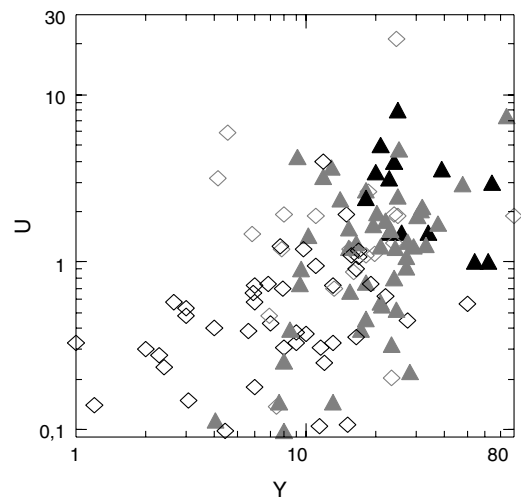
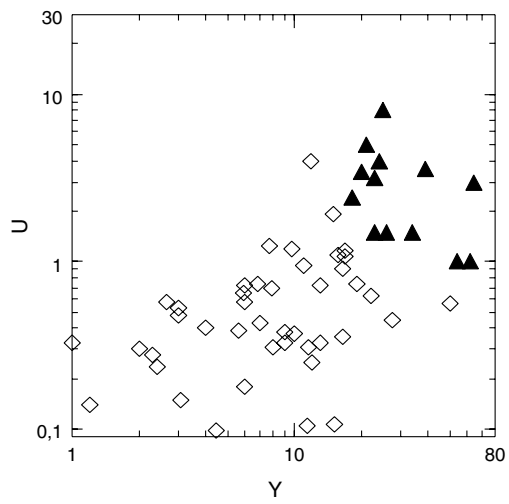
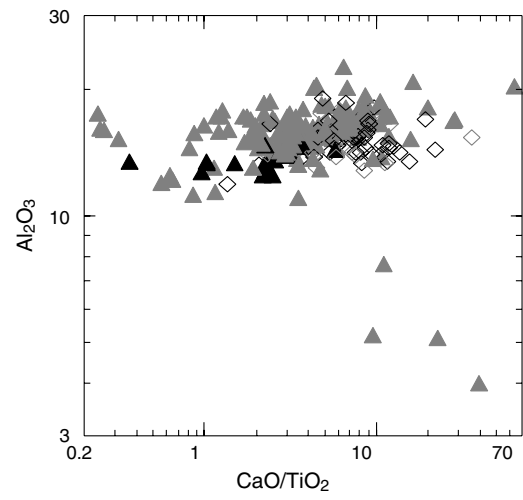
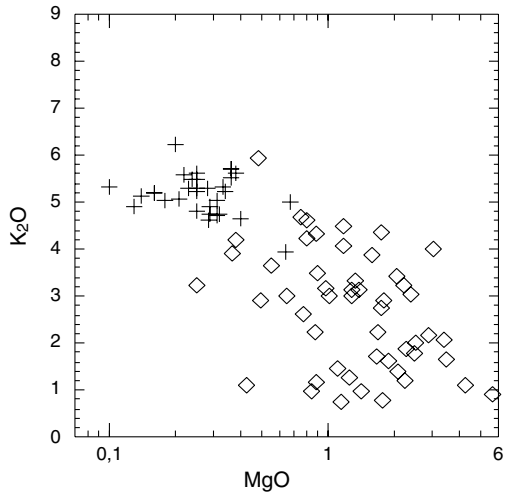


Fig. 16. Northern area, Archaean vs. PMS.

Class 1



Class 1-3

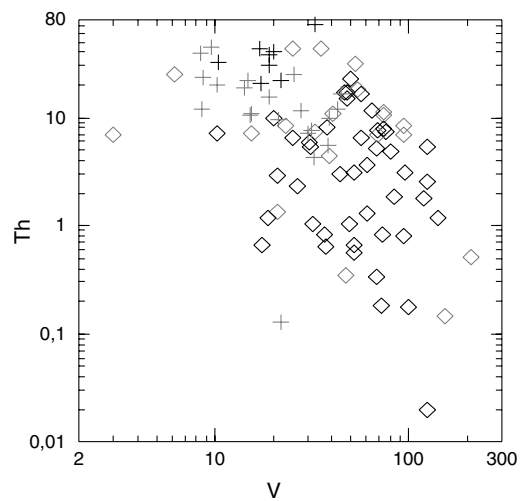
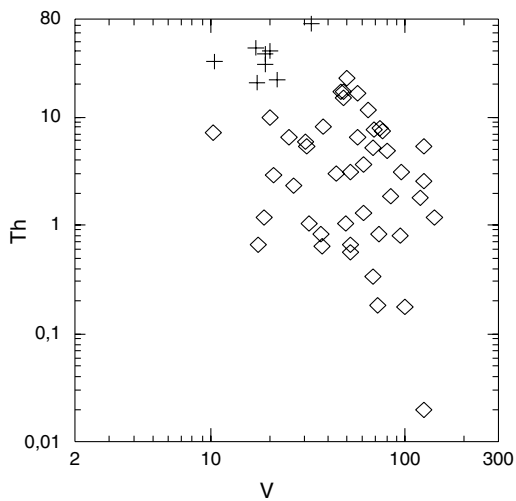
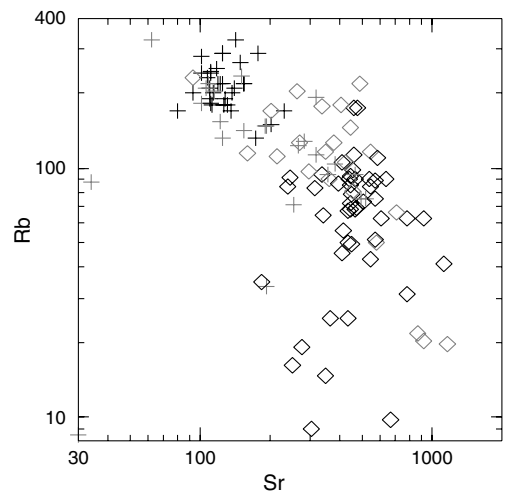
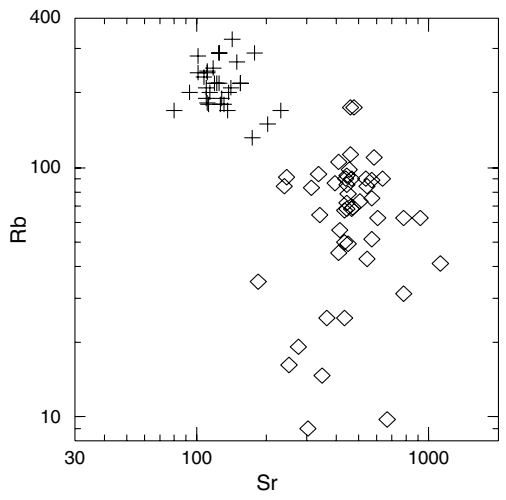
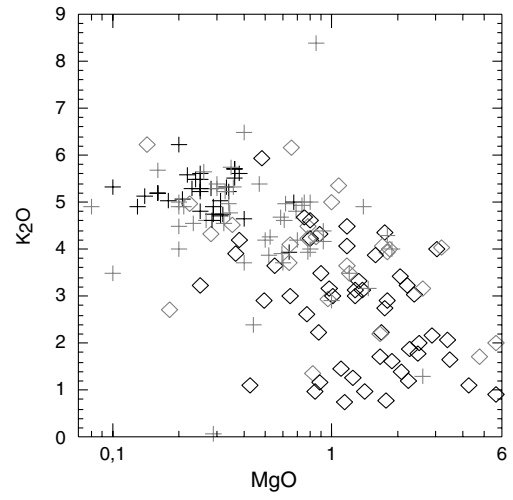
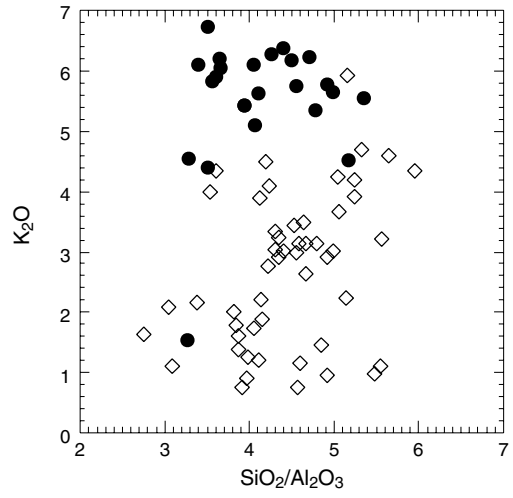


Fig. 17. Northern area, Archaean vs. SLOG.

Class 1



Class 1-3

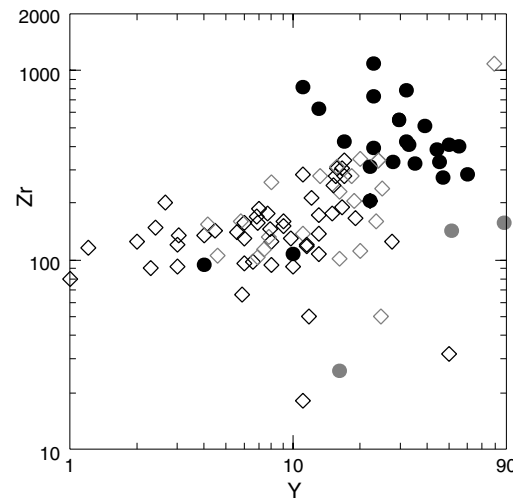
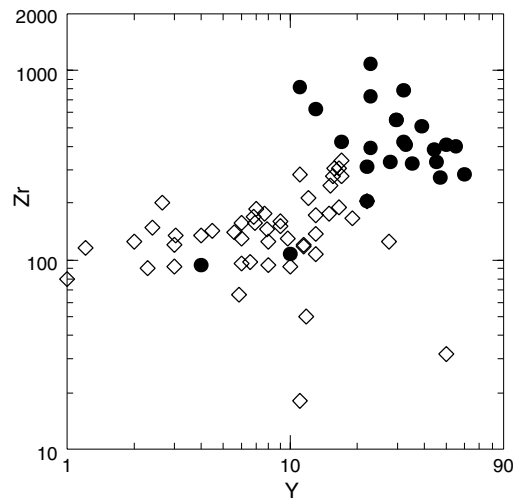
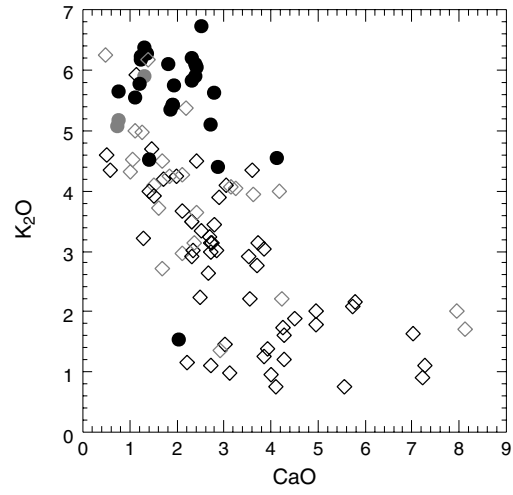
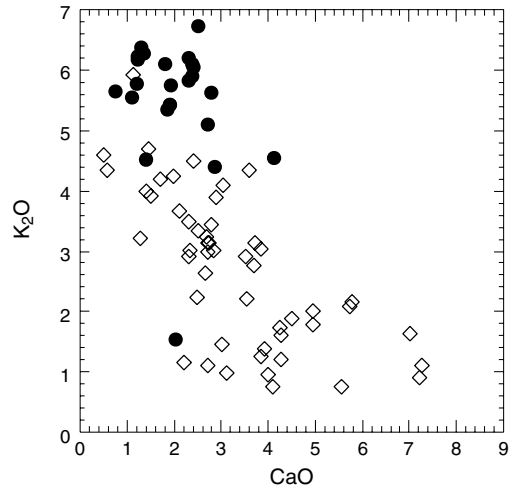
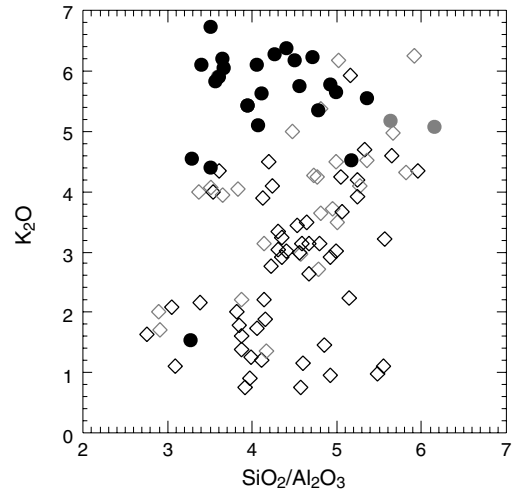
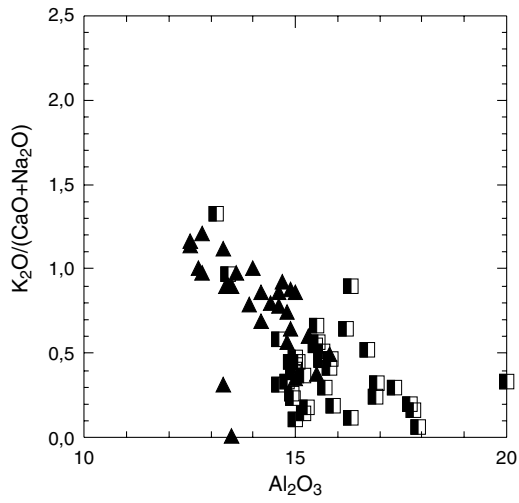


Fig. 18. Northern area, Archaean vs. TMB1.

Class 1



Class 1-3

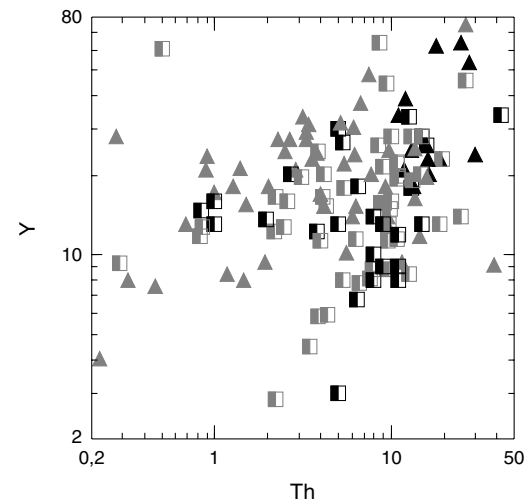
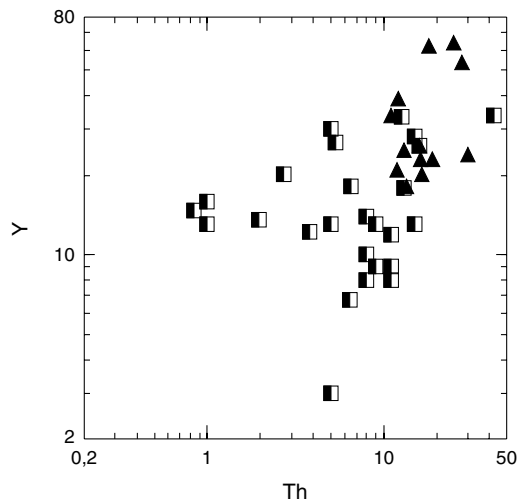
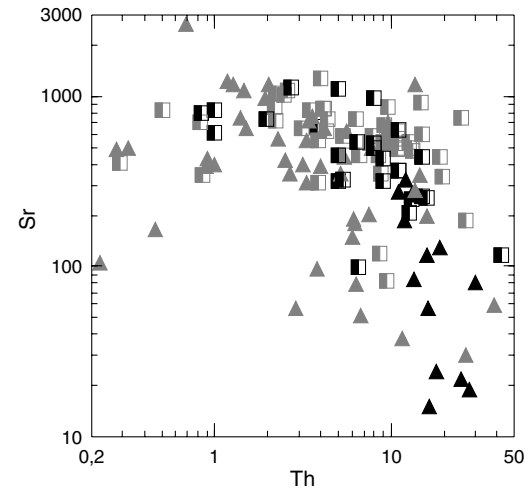
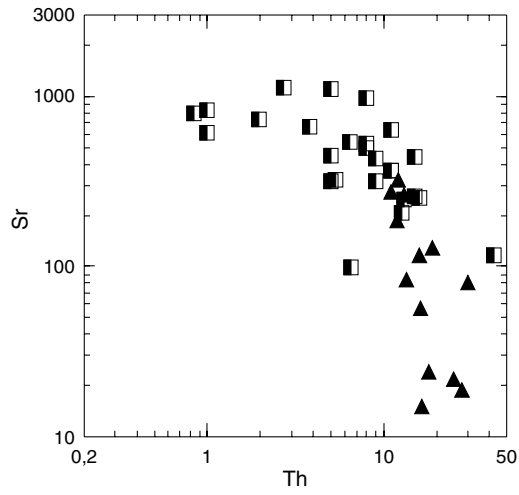
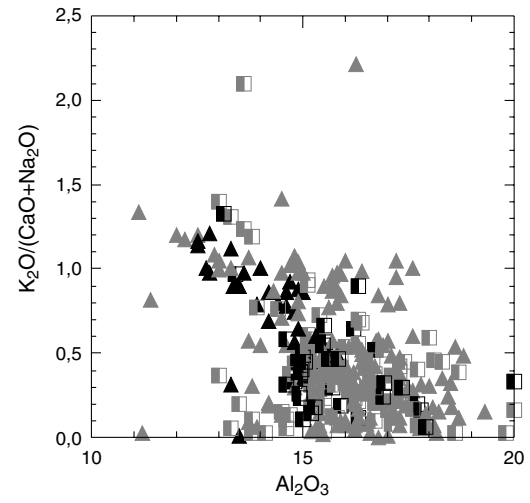
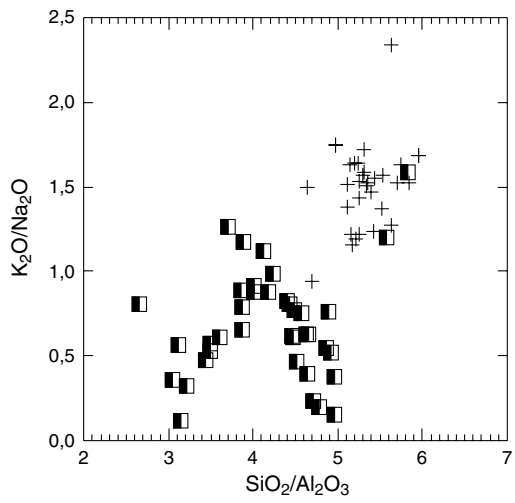


Fig. 19. Northern area, EOG2 vs. PMS.

Class 1



Class 1-3

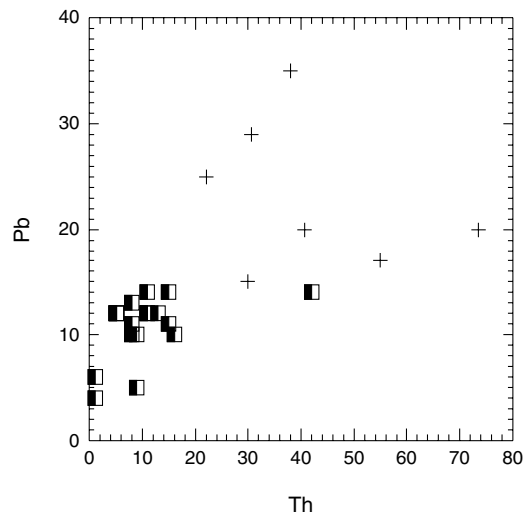
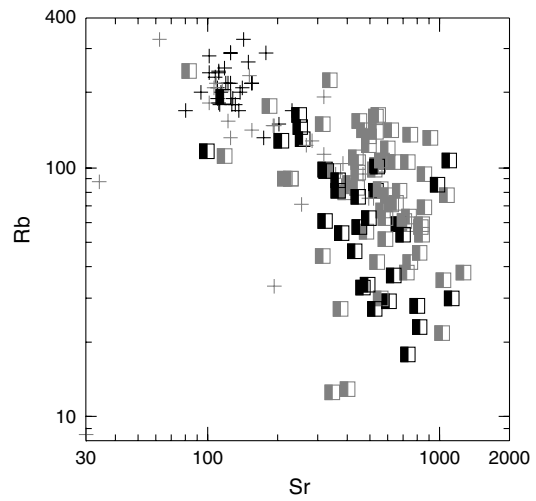
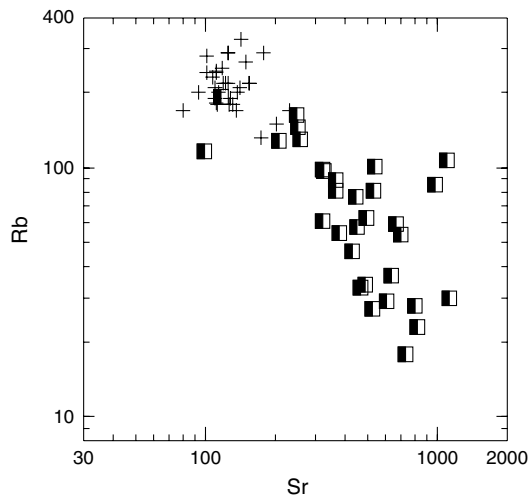
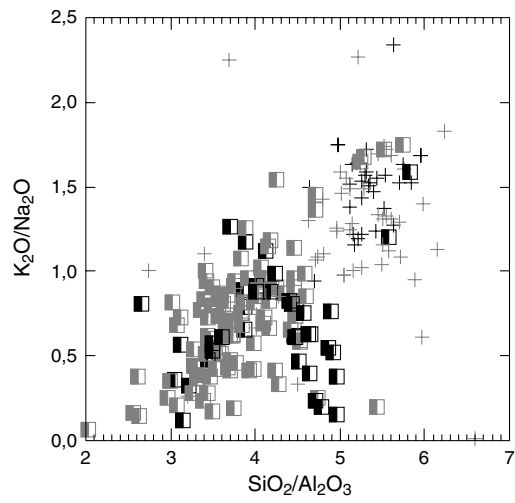
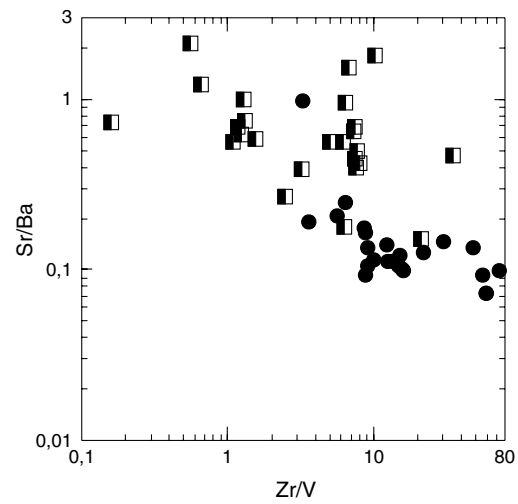
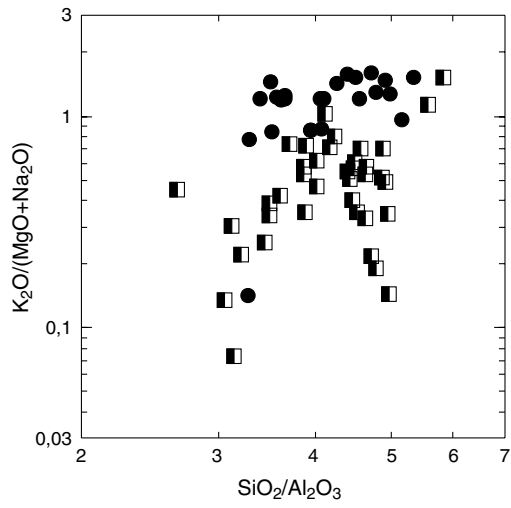
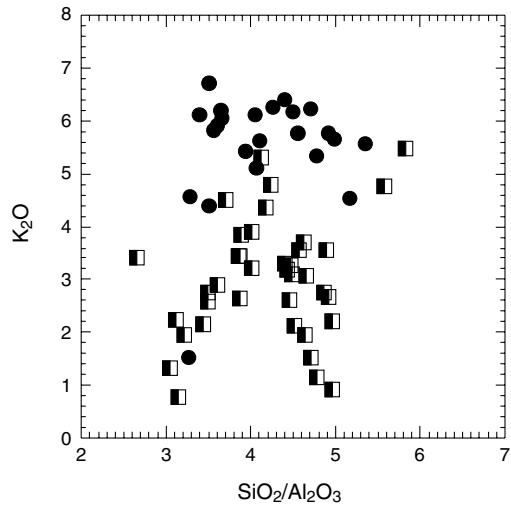


Fig. 20. Northern area, EOG2 vs. SLOG.

Class 1



Class 1-3

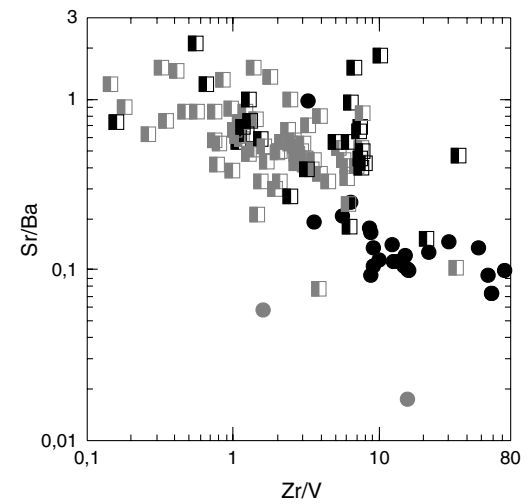
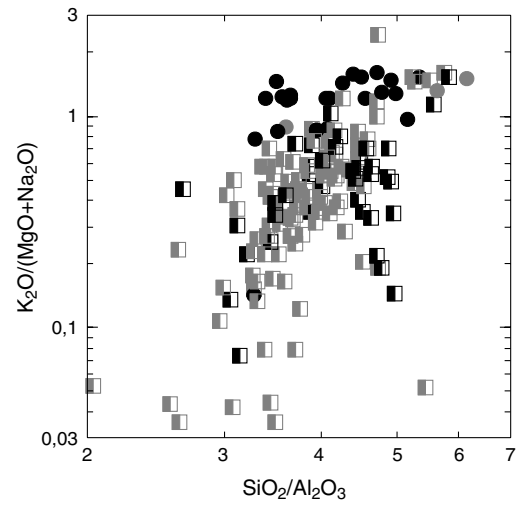
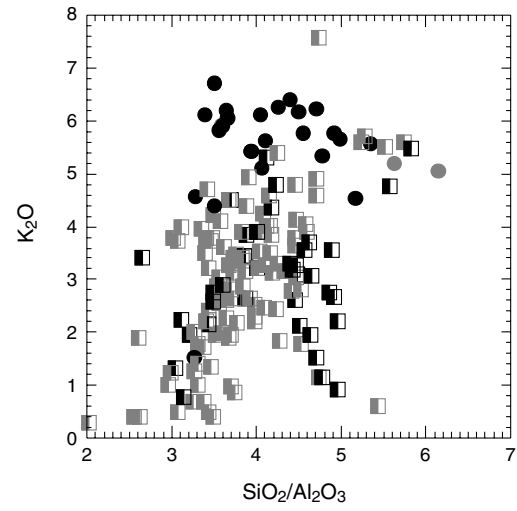
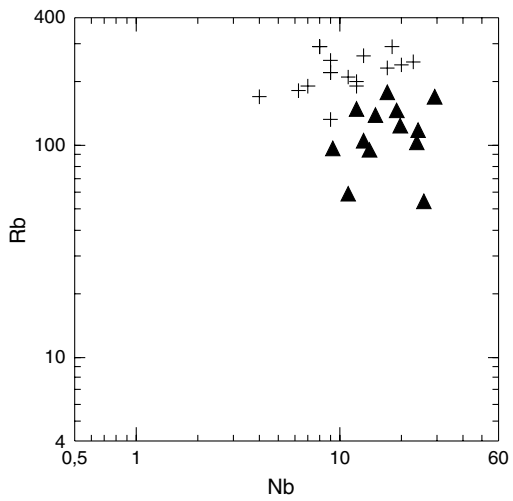
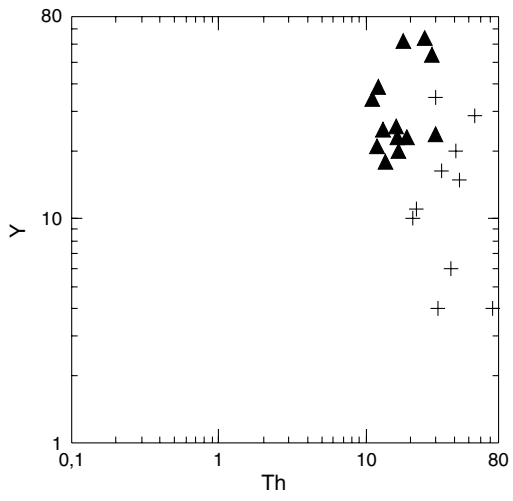
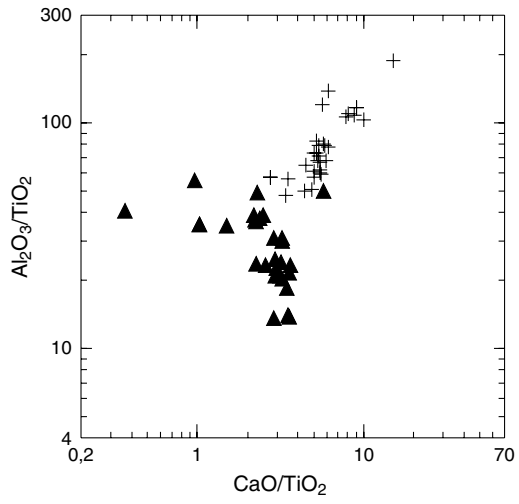


Fig. 21. Northern area, EOG2 vs. TMB1.

Class 1



Class 1-3

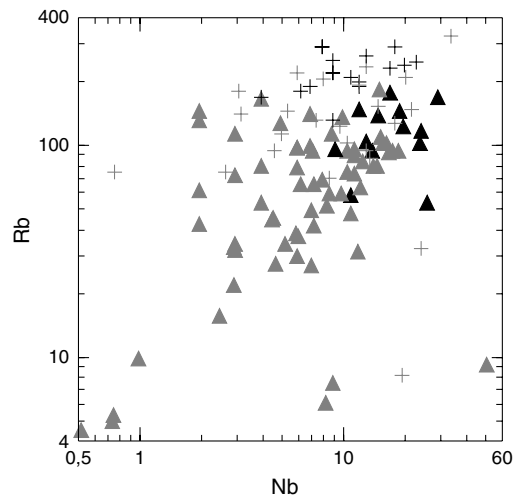
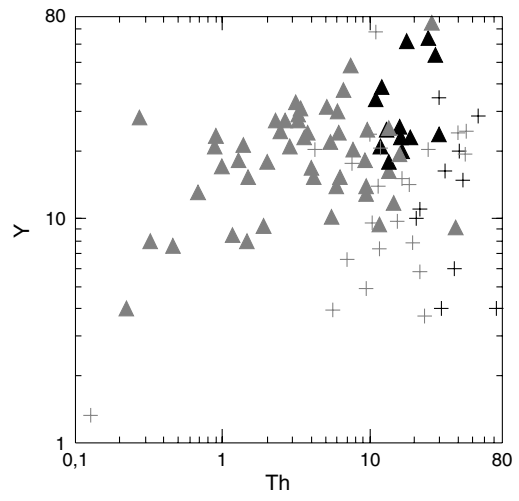
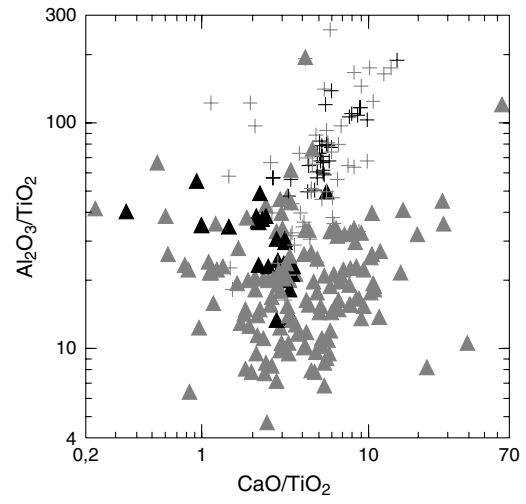
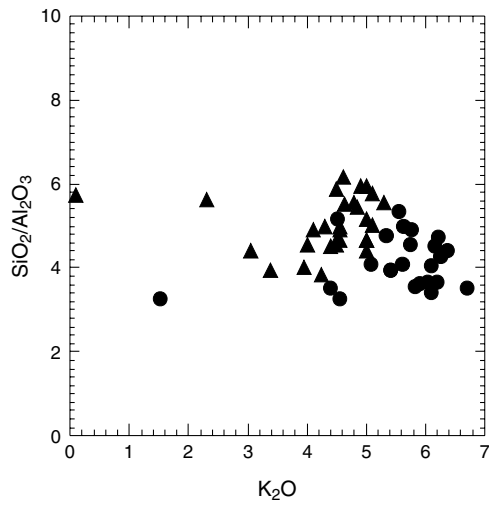


Fig. 22. Northern area, PMS vs. SLOG.

Class 1



Class 1-3

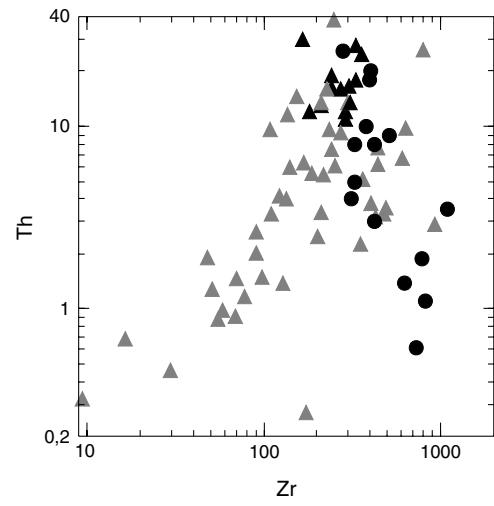
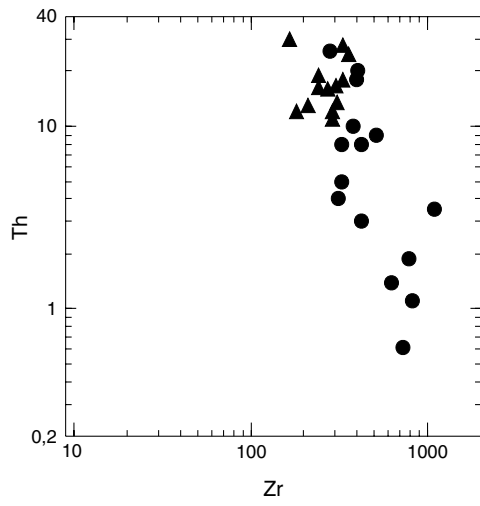
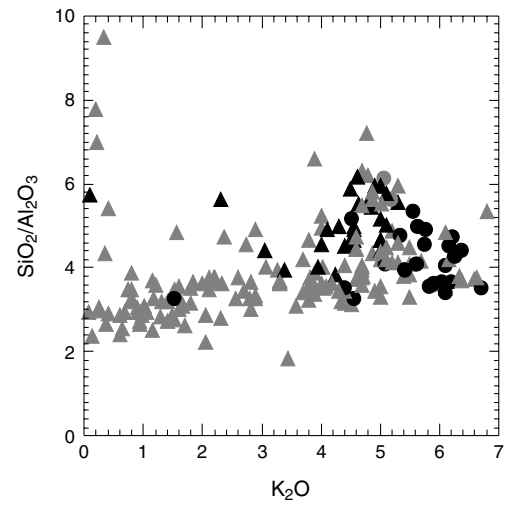
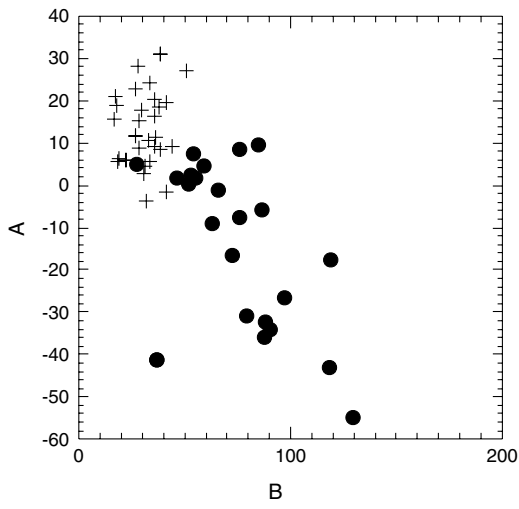


Fig. 23. Northern area, PMS vs. TMB1.

Class 1



Class 1-3

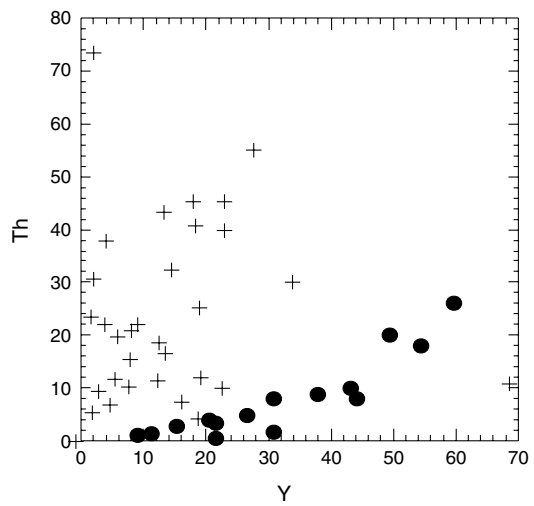
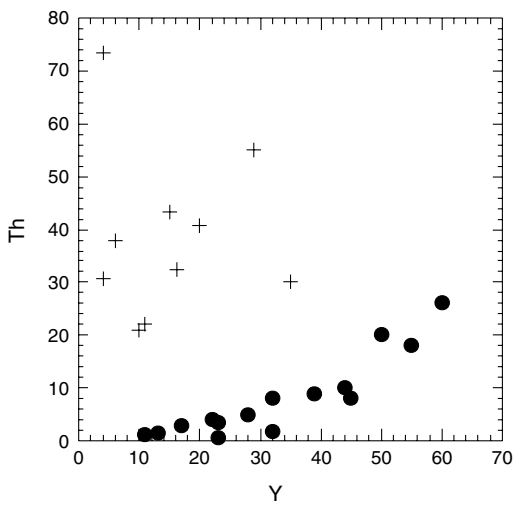
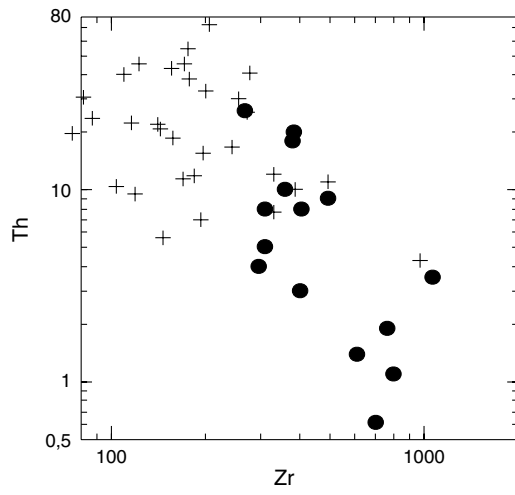
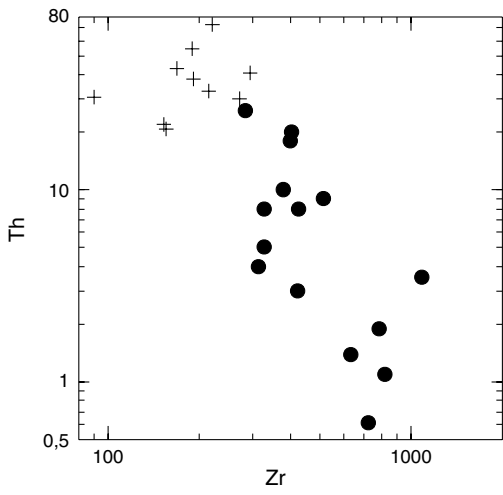
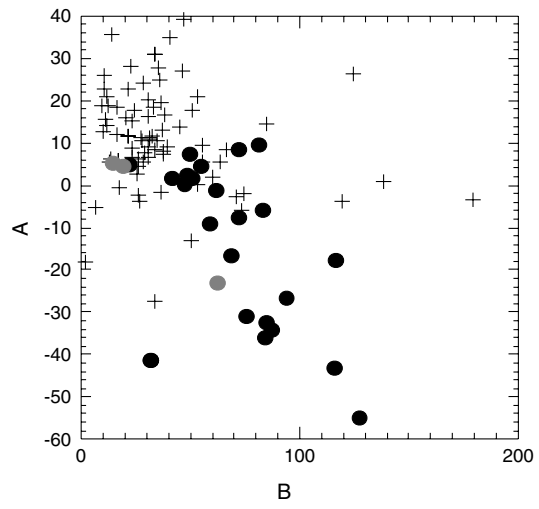


Fig. 24. Northern area, SLOG vs. TMB1.

North central area (19–24)

Characterisation of class I samples

Archaean rocks (100)

The Archaean rocks have a main tonalite–granodiorite–adamellite trend, and a less pronounced quartz monzonite–adamellite trend, using the P–Q classification diagram (Fig. 9) of Debon & Le Fort (1983). They are calc-alkaline to alkali-calcic according to Peacock (1931) and calc-alkaline using the Sylvester (1989) discrimination diagram (Fig. 11). In the Maniar & Piccoli (1989) diagram (Fig. 10) as well as in the Debon & Le Fort (1983) A–B diagram (Fig. 9) they show a metaluminous to peraluminous trend.

EOG3 (95)

The Haparanda (2) and Stavaträsk suites are classified as gabbro, monzogabbro, tonalite, granodiorite to adamellite in the Debon & Le Fort (1983) P–Q diagram (Fig. 9). They show a calc-alkaline trend in terms of Peacock (1931) and are mostly metaluminous in a Maniar & Piccoli (1989) A/NK–A/CNK diagram (Fig. 10). Five samples from this group have $\geq 1\%$ CIPW normative corundum.

EOG1 (92)

The Knaften and the “>1900 Ma” suite can be divided into subgroups where the Knaften is peraluminous and the rocks of the “>1900 Ma” suite are metaluminous. Some samples (e.g. 93001, 84133, 951001) display a more calc-alkaline affinity than the rest of the samples included in this group. While a majority of the samples have an alkali-calcic affinity according to Peacock (1931), almost all samples are calc-alkaline in the Sylvester (1989) diagram (Fig. 11). There are also other outliers, such as sample JPN 950031 which has extremely high contents of Zr, Rb, U, Th, Pb and Mo, and sample OIL 920055 which has high contents of Y, Nb, La, Ba, Rb, Sr and Th.

EOG2 (90)

Haparanda (1) and Jörn G1 suites are classified as tonalite to granodiorite in a Debon & Le Fort (1983) P–Q diagram (Fig. 9). They show a calc-alkaline trend in terms of Peacock (1931) and Sylvester (1989, Fig. 11) and are metaluminous to slightly peraluminous in a Maniar & Piccoli (1989) A/NK–A/CNK diagram (Fig. 10). A few samples from this group have $>1\%$ CIPW normative corundum (two samples) and apatite (two samples). Three samples plot in the Na-alteration field in Hughes (1973) igneous spectrum diagram (Fig. 13).

SLOG (80)

The “Late orogenic” suite is characterised by its restricted SiO₂ range between 72 and 74 wt. %, which complicates the comparison with the other groups. In the Batchelor & Bowden (1985) diagram (Fig. 12) this group plots in the field of monzo- and syeno-granites, and in a Debon & Le Fort (1983) plot in the fields for adamellite and granite (Fig. 9). The granites are peraluminous according to Shand’s index (Shand 1927) and in a Debon & Le Fort (1983) A–B diagram (Fig. 9). Their high content of Rb and depletion of Eu is characteristic. Seven samples from this group have $>1\%$ of CIPW normative corundum and six samples have normative magnetite and apatite $>1\%$.

PMS (60)

The PMS can be classified as a suite of quartz monzonite–adamellite–granite rocks according to the Debon & Le Fort (1983) P–Q diagram (Fig. 9). In the Maniar & Piccoli (1989) AN/K vs. A/CNK plot the suite is peraluminous to metaluminous (Fig. 10). An alkaline trend is apparent in the Peacock (1931), Sylvester (1989) and Batchelor & Bowden (1985) diagrams (Figs. 11–12).

Revsund suite (50)

As this group is very heterogeneous and the number of well defined class 1 samples are few, the class 2 samples have been included in order to be able to display the chemical trends for this group. Using both class 1 and class 2 samples, this suite can be classified as a quartz monzodiorite–quartz monzonite–adamel-

lite–granite suite in a Debon & Le Fort (1983) P–Q diagram (Fig. 9). This group shows a metaluminous to peraluminous trend and has an alkaline affinity shown in the Peacock (1931) and Sylvester (1989) diagrams (Fig. 11). Lithophile elements are enriched in this group and the Revsund suite displays a pronounced negative Eu anomaly in the chondrite-normalised REE-diagram. Three samples have >2 % normative magnetite.

Comparison between rock groups

Archaean rocks vs. EOG3 (100 vs. 95)

The Archaean and the EOG3 rocks have similar evolution trends for the major and trace elements vs. SiO_2 , with the exception for Na_2O . The Archaean rocks have a negative slope in the diagram Na_2O vs. SiO_2 , whereas the EOG3 rocks have a positive slope (Fig. 25). Small compositional differences appear for some trace elements. The Archaean rocks show slightly higher contents of Ta and Hf and lower contents of Sr, Sc, Zr and Co.

Archaean rocks vs. EOG1 (100 vs. 92)

The Archaean and EOG1 rocks show, if two samples from group 92 are excluded from the population (e.g. OIL 920055 and JPN 950031), different behaviour of both major and trace elements. The Knaften suite displays a unique chemical character for its silica rich part, which shows high content of MnO, K_2O , Rb, Th and Co for a given SiO_2 content. The Archaean rocks have a higher content of major oxides such as Al_2O_3 , K_2O and P_2O_5 while the “>1900 Ma” suite is enriched in elements such as Zr, Y, and Nb. A fairly good discrimination is obtained by using Zr vs. Ga and K_2O vs. SiO_2 (Fig. 26).

Archaean rocks vs. EOG2 (100 vs. 90)

The Archaean and EOG2 rocks display a divergence in major oxides as well as in some HFS elements. The Al_2O_3 , K_2O and P_2O_5 contents are higher in the Archaean rocks while the Fe_2O_3 , MnO, MgO and CaO are lower. The Na_2O slope for the Archaean rocks is negative and for the EOG2 rocks it is positive. Trace elements such as Zr, Nb and Rb are higher in the Archaean rocks. The two groups are separated in the diagrams K_2O vs. SiO_2 , Al_2O_3 vs. CaO, Ba vs. Rb (Fig. 27) and Nb vs. Zr (Fig. 28).

Archaean rocks vs. SLOG (100 vs. 80)

The Archaean rocks and the “Late orogenic” (Homogeneous granite) suite are compared at a restricted silica interval around 73 wt. %, in which the SLOG has higher P_2O_5 and Rb content and lower CaO, Ba, Sr, Cu and Ni content. Fairly good discriminators are CaO vs. MgO and Rb vs. Sr (Fig. 29). Other diagrams that can be used are K_2O and $\text{K}_2\text{O}/(\text{Na}_2\text{O}+\text{CaO})$ vs. MgO, Th vs. V and the two ternary diagrams Ba-Sr-Rb and $\text{Hf-Ta} \cdot 3\text{-Rb}/30$. The Eu anomaly is more negative for the SLOG than for the Archaean rocks.

Archaean rocks vs. PMS (100 vs. 60)

Archaean rocks have higher contents of major oxides such as Al_2O_3 , MgO and CaO, and lower K_2O . The Sr, V and Sc contents in the Archaean rocks are in general higher. Plots of Al_2O_3 vs. CaO/TiO_2 , K_2O vs. SiO_2 and Sr vs. Y+Nb are fairly good discriminators for these rocks (Fig. 30).

Archaean rocks vs. Revsund (100 vs. 50)

The Archaean rocks and the Revsund suite are difficult to discriminate because of the small number of class 1 samples. The only discriminators that work fairly well are the Al_2O_3 vs. SiO_2 diagram and the ternary Ba-Sr-Rb diagram (Fig. 31). Another discriminator is the normalised REE plot, which displays a pronounced negative Eu anomaly for the Revsund suite.

EOG3 vs. EOG1 (95 vs. 92)

The EOG3 rocks display similar geochemical features for major and trace elements as the EOG1 rocks. There is no simple way to separate the two groups using discrimination diagrams.

EOG3 vs. EOG2 (95 vs. 90)

The EOG3 rocks are also geochemically similar to the EOG2 rocks. The EOG3 rocks are slightly more evolved and have an alkaline affinity, which is seen in Batchelor & Bowden (1985), and modified Peacock (1931) diagrams (Fig. 32).

EOG3 vs. SLOG (95 vs. 80)

It is difficult to compare the EOG3 with the SLOG rocks as the latter have higher and restricted silica contents. One diagram which works is the Ba-Sr-Rb ternary plot (Fig. 33) in which the SLOG rocks plot in and close to the field of "Strongly differentiated granites" of El Bouseily & El Sökkary (1975). The SLOG rocks also have a pronounced negative Eu anomaly.

EOG3 vs. PMS (95 vs. 60)

The PMS shows a more pronounced alkaline trend than the EOG3 rocks, i.e. higher K_2O and Na_2O and lower contents of Al_2O_3 , MgO and CaO . This alkaline trend is apparent in Batchelor & Bowden (1985) R1–R2 and Sylvester (1989) diagrams, and is also shown on a major element plot of $K_2O/(CaO + Na_2O)$ vs. Al_2O_3 (Fig. 34). The EOG3 rocks have lower contents of trace elements such as Ta, Hf, Y, U and Th than the PMS.

EOG3 vs. Revsund (95 vs. 50)

The Haparanda (2) and the Stavaträsk suites are less evolved than the Revsund suite according to the contents of lithophile elements such as Rb, Hf, Ta and Th (Fig. 35). The number of class one samples is too small for a meaningful comparison of the two groups.

EOG1 vs. EOG2 (92 vs. 90)

The Knaften and the ">1900 Ma" suites show similar geochemical characteristics, even if the scatter in major, minor and trace element Harker diagrams is large, within the Haparanda (1) and the Jörn G1 suites. The only diagram that separates the two groups is the R1–R2 diagram of Batchelor & Bowden (1985, Fig. 36).

EOG1 vs. SLOG (92 vs. 80)

The EOG1 rocks are compared with the SLOG rocks at a restricted silica interval around 73 wt. %. The EOG1 rocks have higher K_2O , P_2O_5 and Rb, and lower TiO_2 , MnO , MgO , CaO , Ba, Sr, Cu and Ni content. Fairly good discriminators are K_2O vs. MnO , Rb vs. Nb, and the ternary diagram Ba-Sr-Rb (Fig. 37). The diagram $Hf-Ta*3-Rb/30$ can also be used.

EOG1 vs. PMS (92 vs. 60)

The EOG1 rocks have higher contents of Al_2O_3 , MnO , MgO , CaO and Sr, and lower K_2O , Zr, Hf, Rb and Th than the PMS, at comparable contents of SiO_2 . The two groups (92 respectively 60) can be separated by using K_2O vs. MgO and $Hf+Y$ vs. V. Also in Batchelor & Bowden (1985) R1–R2 and Debon & Le Fort (1983) P–Q diagrams it is possible to discriminate the two groups (Fig. 38).

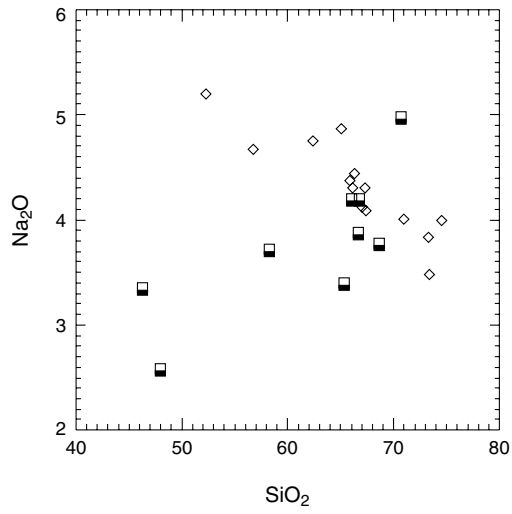
EOG1 vs. Revsund (92 vs. 50)

If class two of the Revsund group is included it is separated by a number of major and trace element plots. The EOG1 rocks are less evolved as they have higher contents of Na_2O , MgO , V, Sr, Ni and Cu and have lower contents of lithophile elements such as Rb, Hf, Ta and Th than the Revsund rocks. Good discrimination diagrams are Na_2O vs. K_2O , $Zr+Y+Nb+Hf$ vs. V, and the ternary diagram Ba-Sr-Rb (Fig. 39).

EOG2 vs. SLOG (90 vs. 80)

If the EOG2 rocks are compared to the SLOG rocks at similar SiO_2 values, the older suite has higher contents of major elements, such as Fe_2O_3 tot, TiO_2 , MnO , MgO , Na_2O and trace elements such as Sr, Sc and V. The two groups are well separated by using CaO vs. K_2O and the ternary diagram Ba-Sr-Rb (Fig. 40). The Sylvester (1989) diagram is also useful to discriminate the two groups (Fig. 40). The $Hf-Ta*3-Rb/30$ diagram can also be used.

Class 1



Class 1 & 2

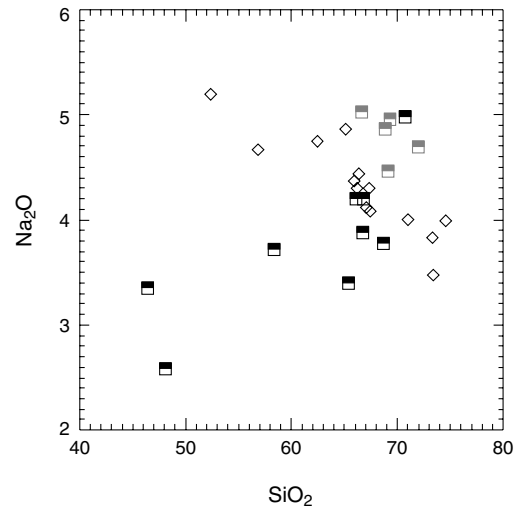
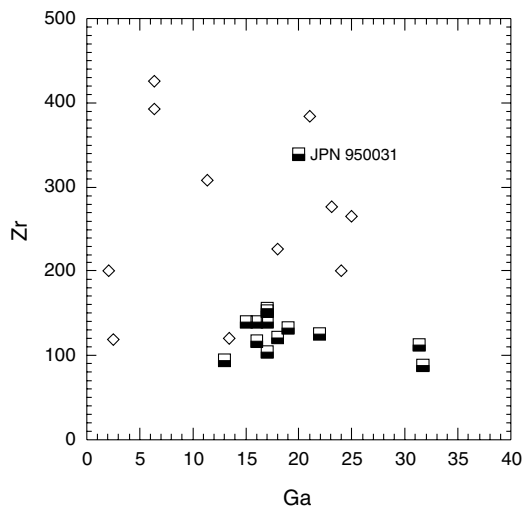


Fig. 25. North central area, Archaean vs. EOG3.

Class 1



Class 1 & 2

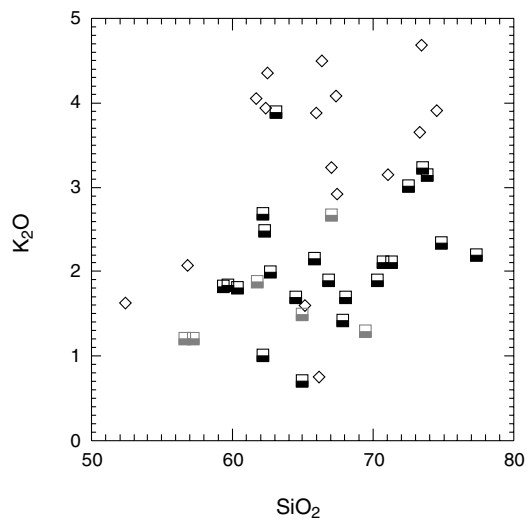
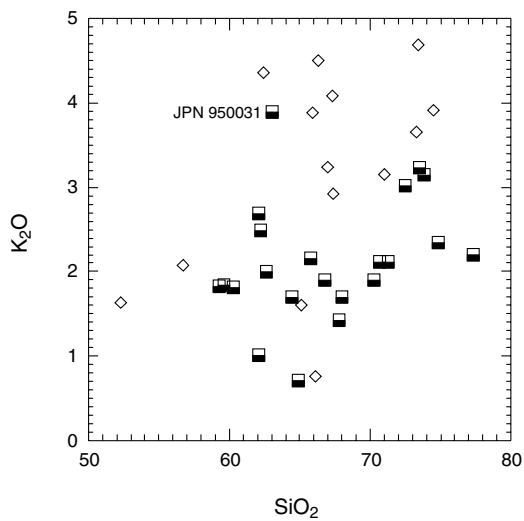
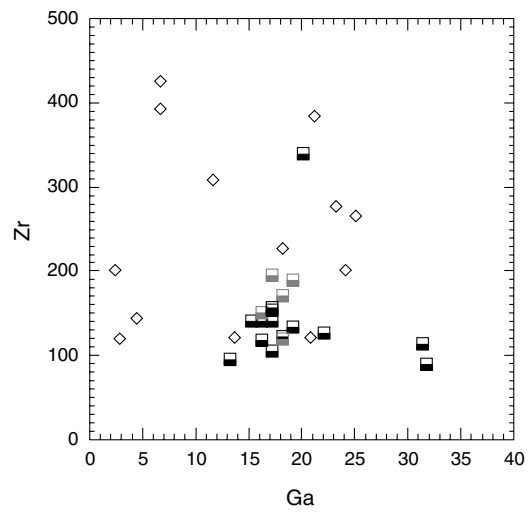
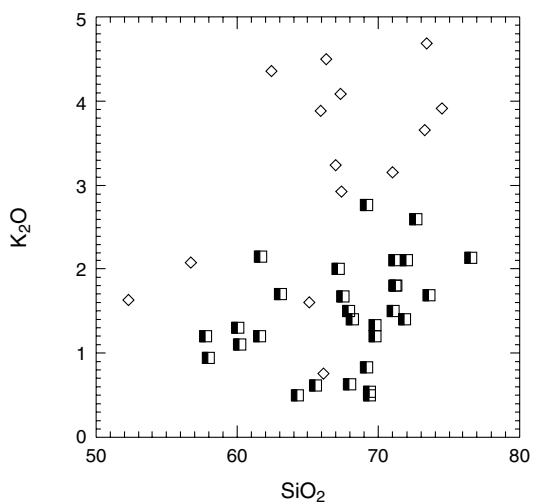


Fig. 26. North central area, Archaean vs. EOG1.

Class 1



Class 1 & 2

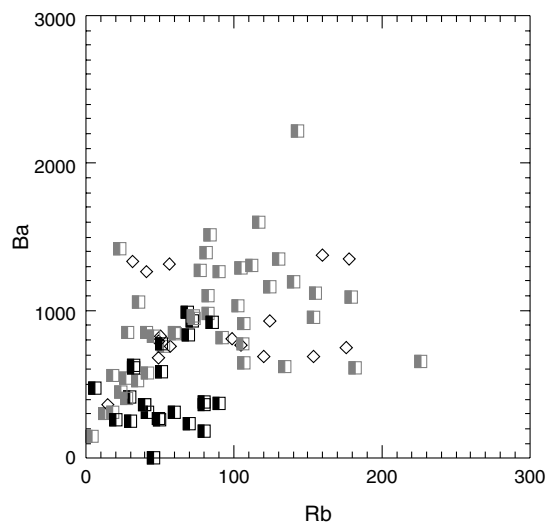
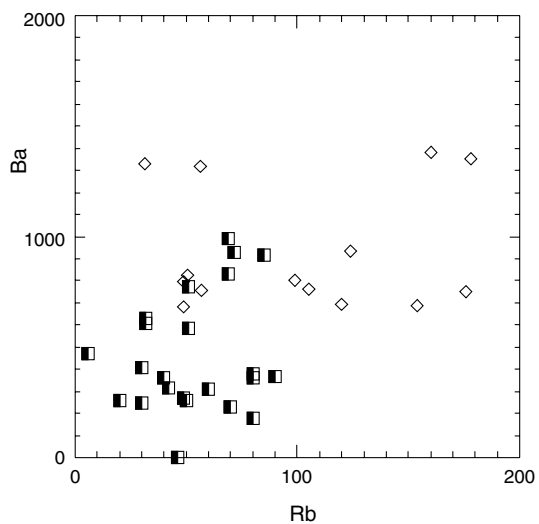
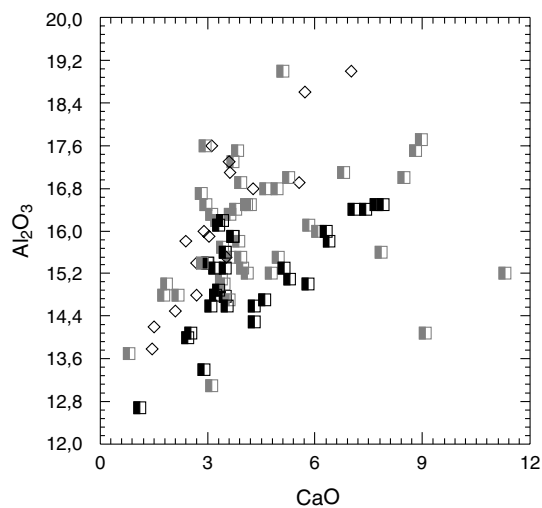
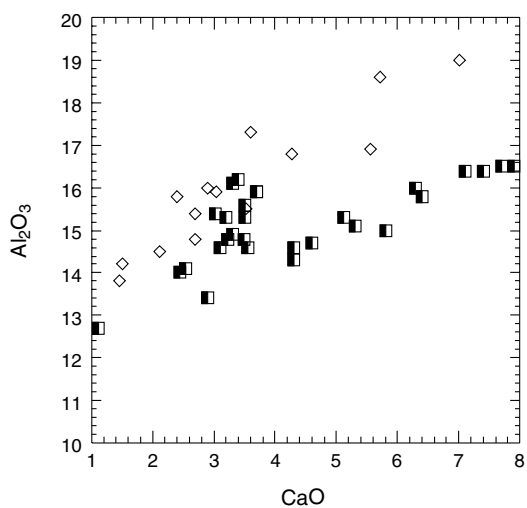
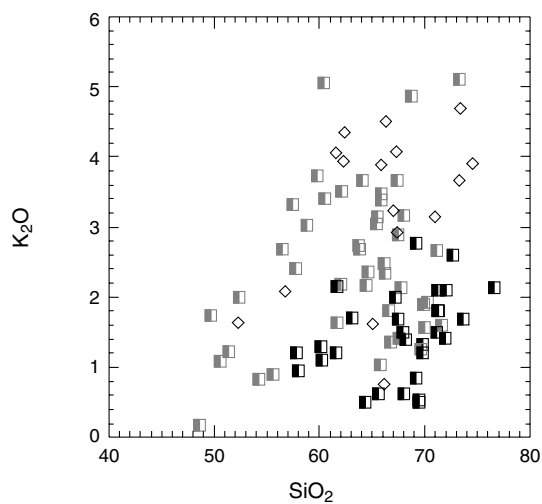
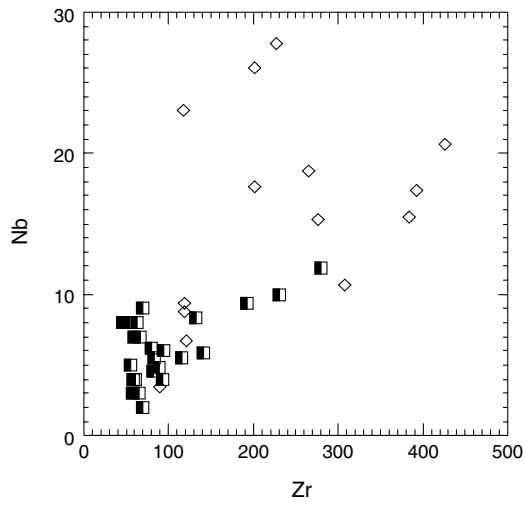


Fig. 27. North central area, Archaean vs. EOG2.

Class 1



Class 1 & 2

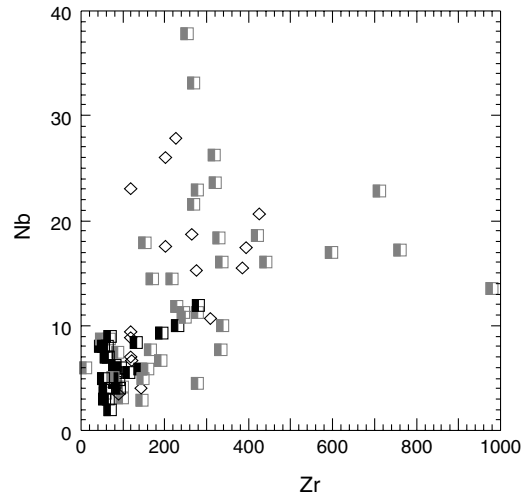
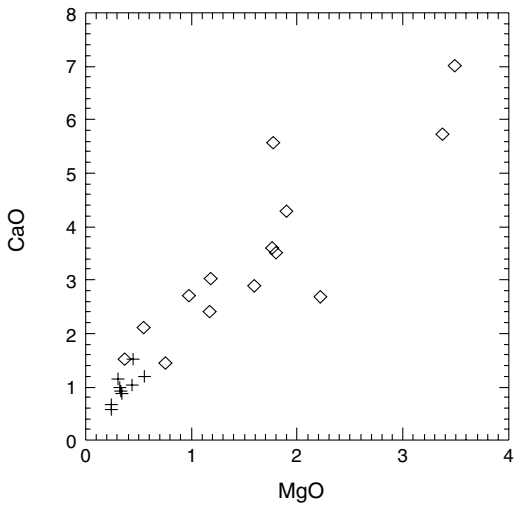


Fig. 28. North central area, Archaean vs. EOG2.

Class 1



Class 1 & 2

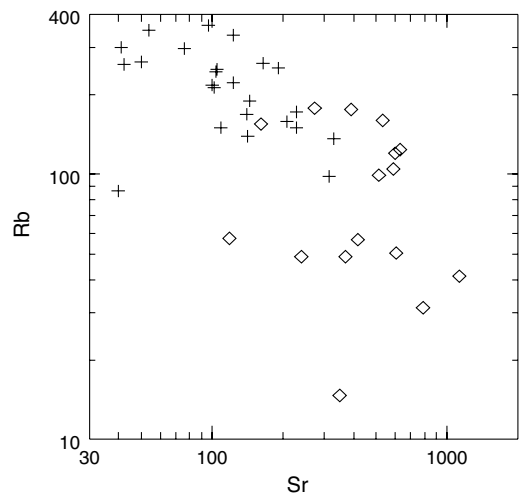
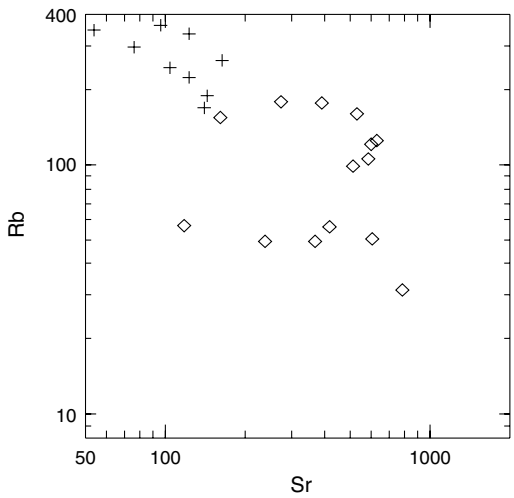
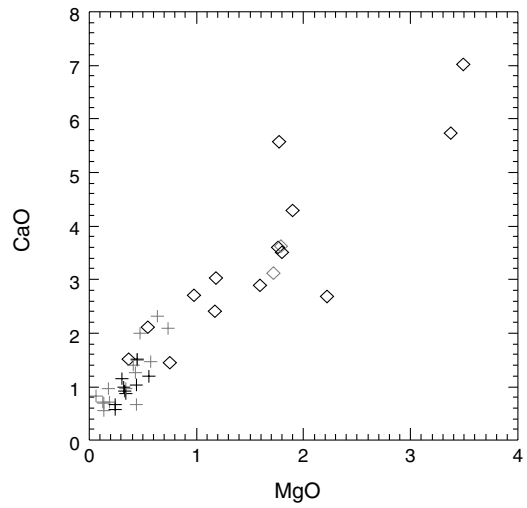
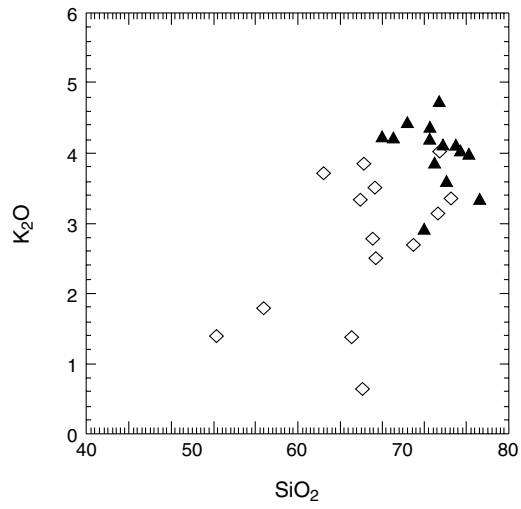


Fig. 29. North central area, Archaean vs. SLOG.

Class 1



Class 1 & 2

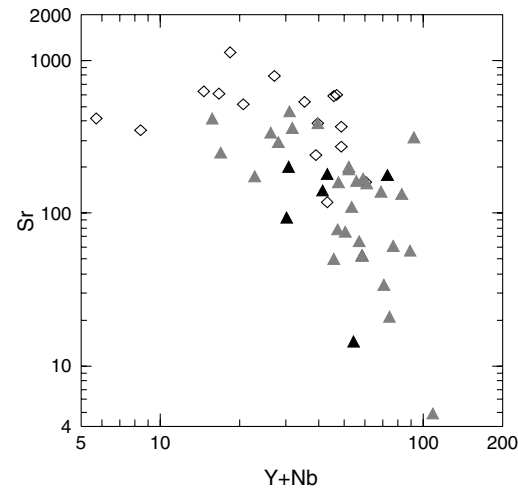
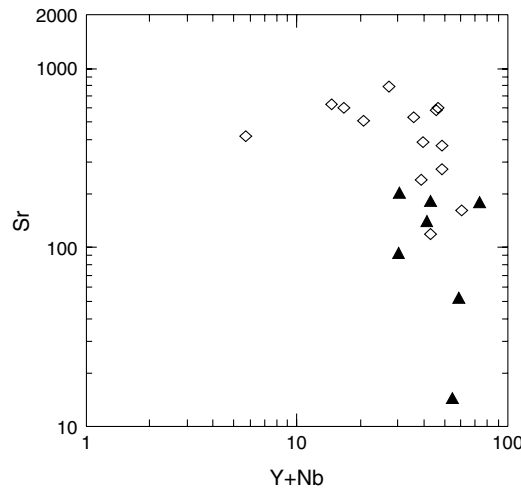
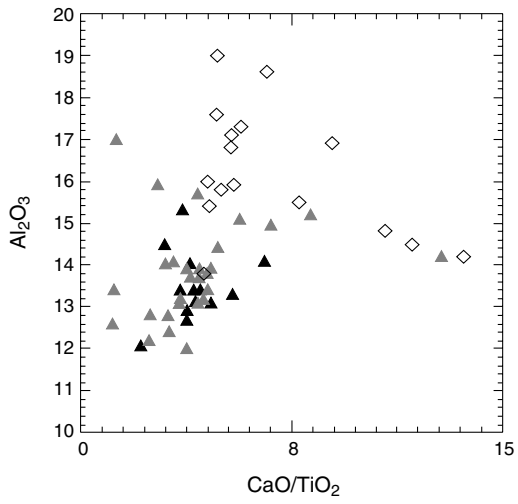
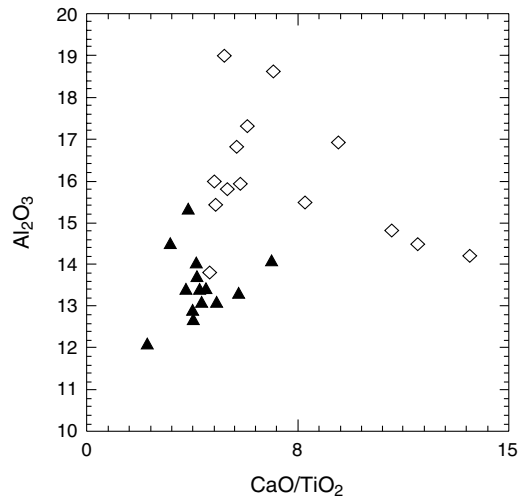
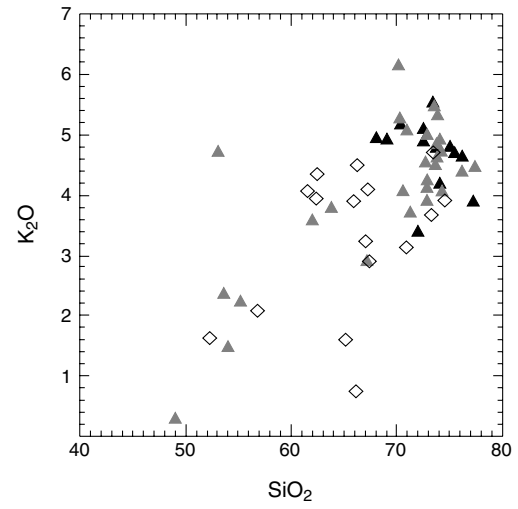


Fig. 30. North central area, Archaean vs. PMS.

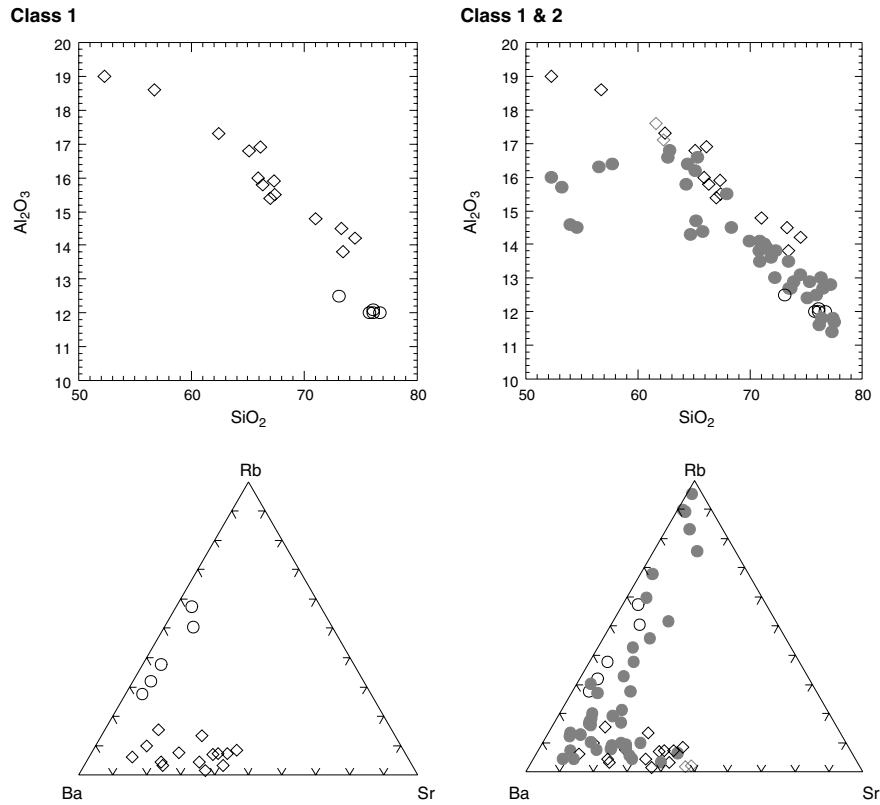


Fig. 31. North central area, Archaean vs. Revsund.

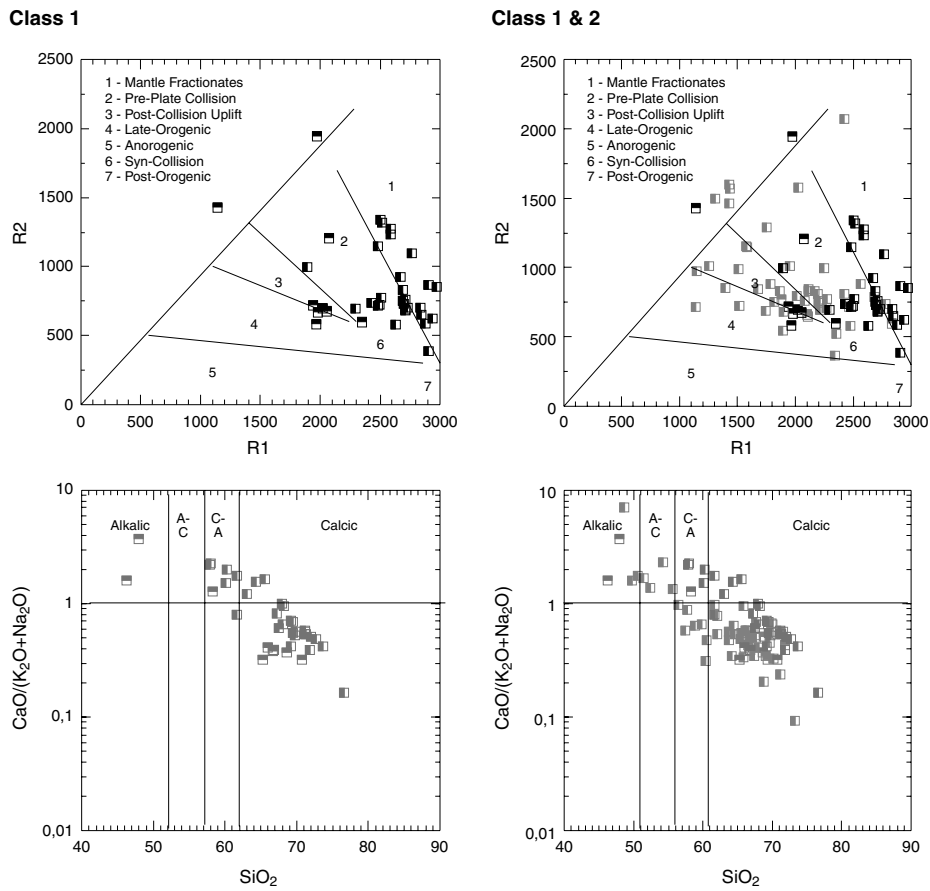


Fig. 32. North central area, EOG3 vs. EOG2.

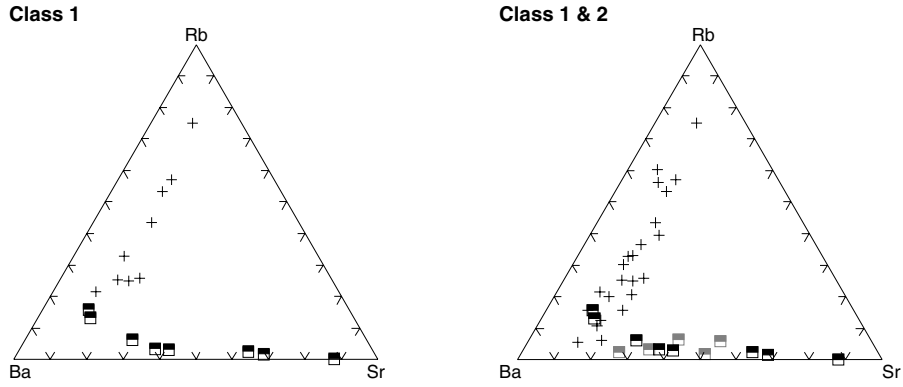


Fig. 33. North central area, EOG3 vs. SLOG.

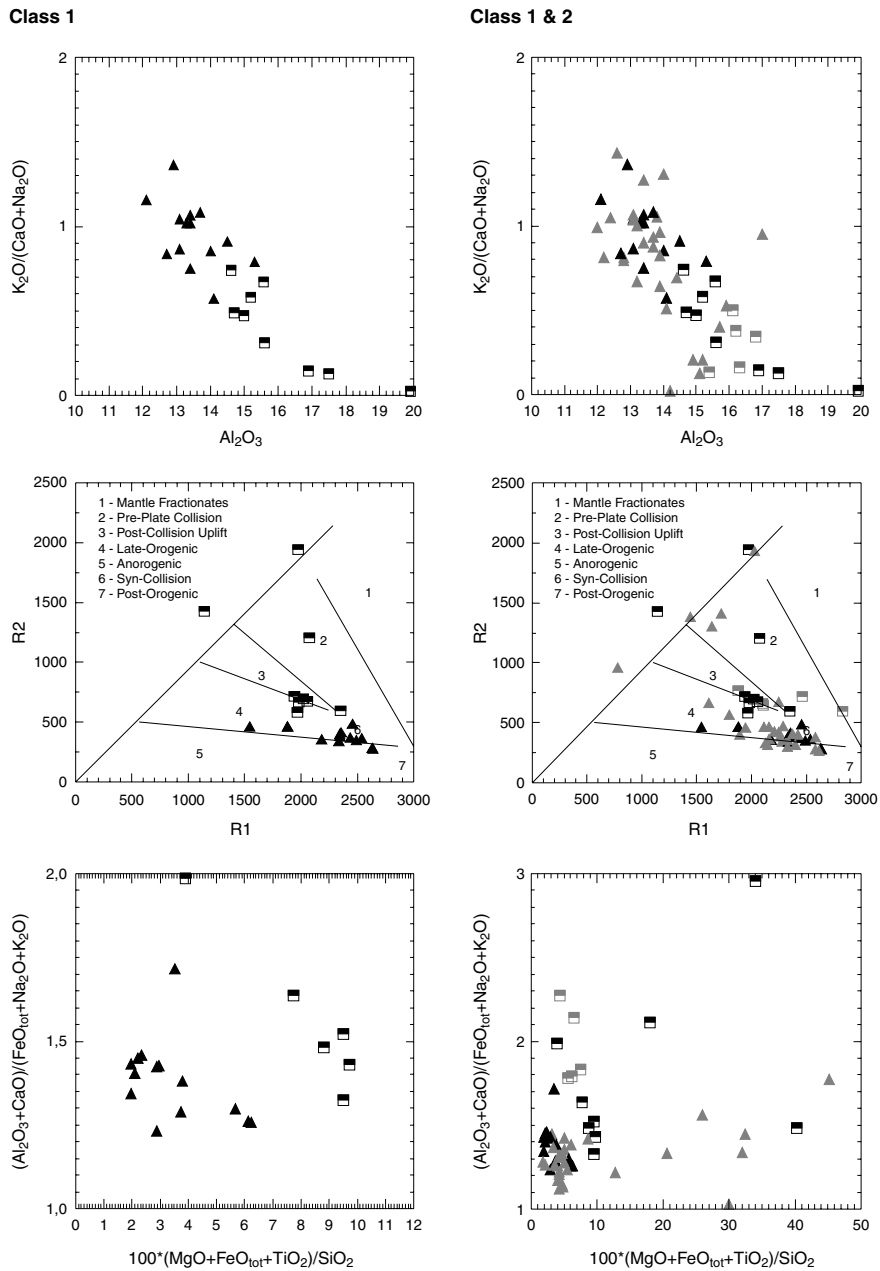


Fig. 34. North central area, EOG3 vs. PMS.

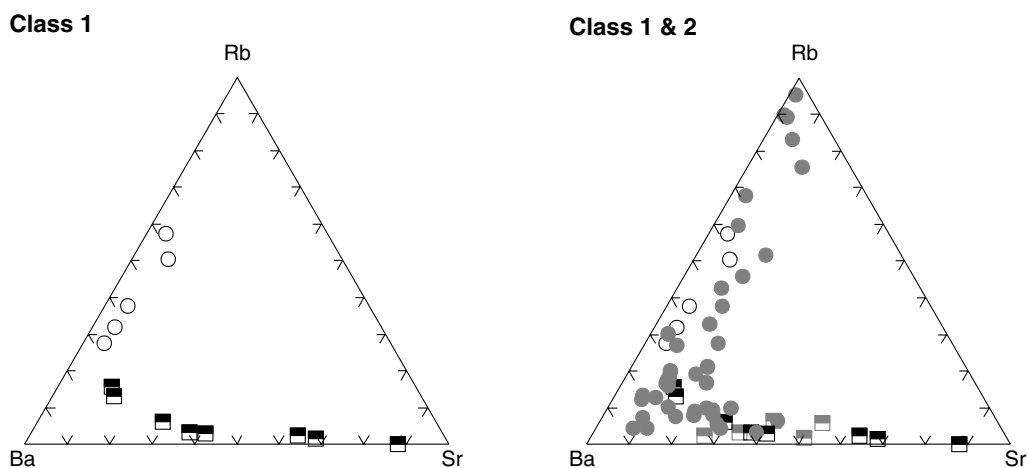


Fig. 35. North central area, EOG3 vs. Revsund.

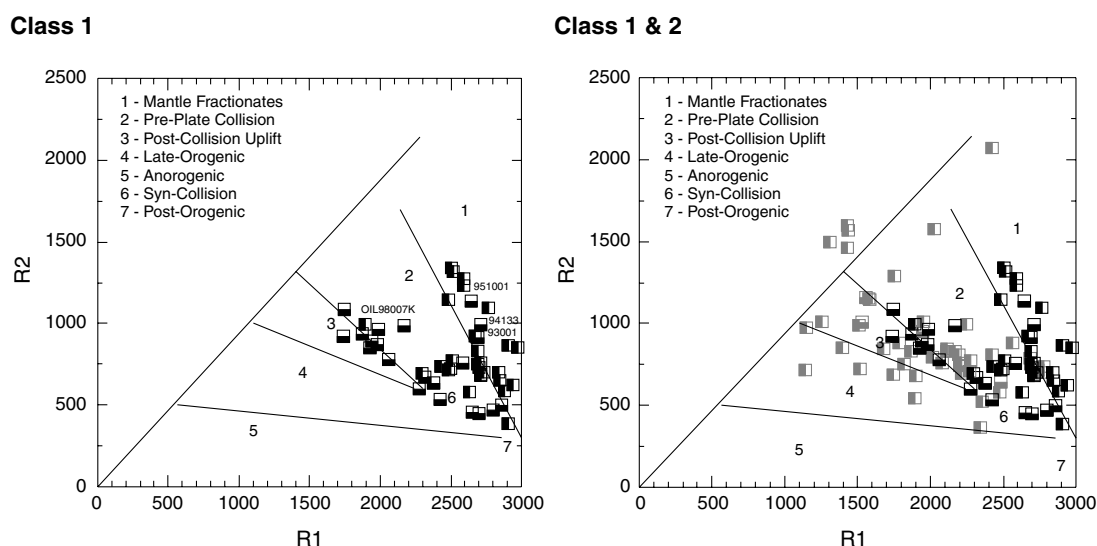


Fig. 36. North central area, EOG1 vs. EOG2.

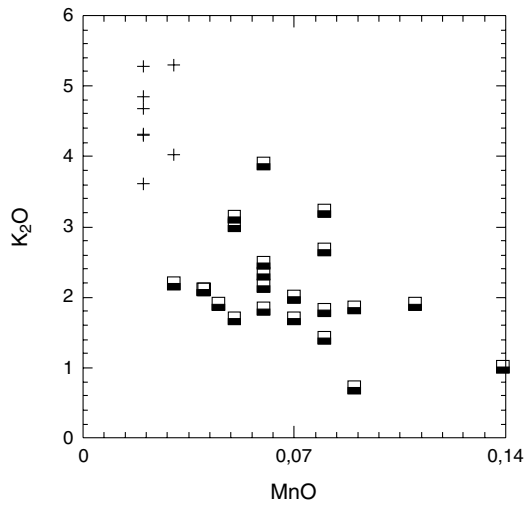
EOG2 vs. PMS (90 vs. 60)

The EOG2 rocks are well separated from the PMS by their calc-alkaline affinity and less evolved characteristics which are shown in Batchelor & Bowden (1985) R1–R2, Debon & Le Fort (1983), and Sylvester (1989) diagrams (Fig. 41). The EOG2 rocks have higher contents of oxides such as MgO, CaO, and trace elements such as Sr, Sc and V, as well as lower contents of trace and light REE such as Zr, Nb, Ta, Rb, La, Ce, Nd, Sm and Dy. Good discrimination diagrams are CaO vs. K₂O and Rb vs. Sr (Fig. 41).

EOG2 vs. Revsund (90 vs. 50)

The EOG2 rocks display more primitive features than the Revsund rocks (class two samples included) which is obvious in Batchelor & Bowden (1985) R1–R2 and Debon & Le Fort (1983) diagrams (Fig. 42). A good discrimination diagram is CaO vs. K₂O, and fairly good is the ternary diagram Ba-Sr-Rb (Fig. 42).

Class 1



Class 1 & 2

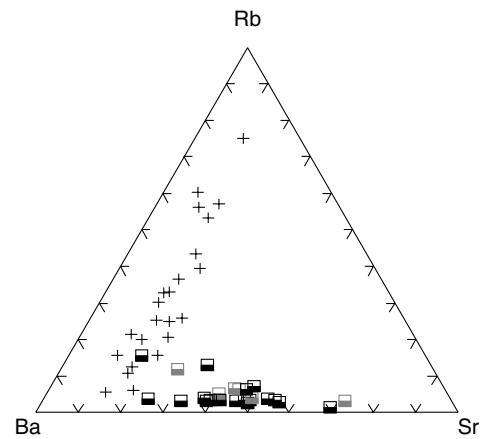
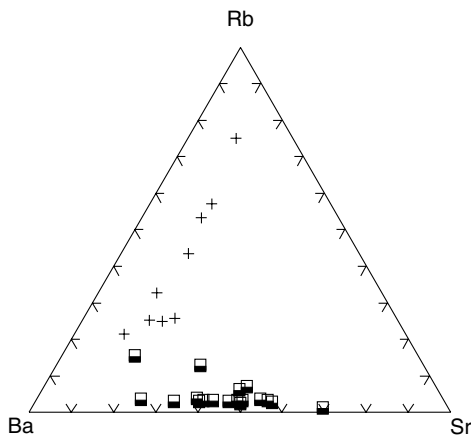
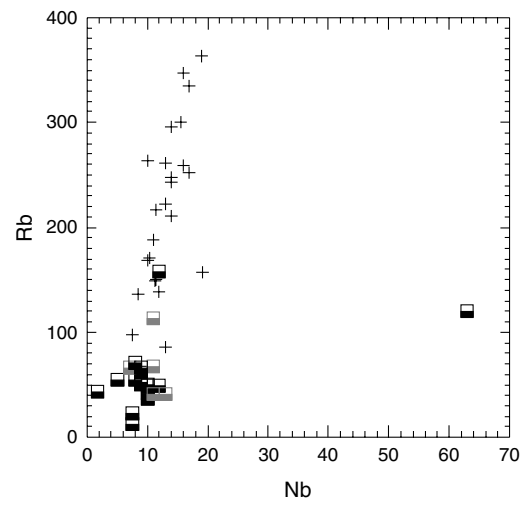
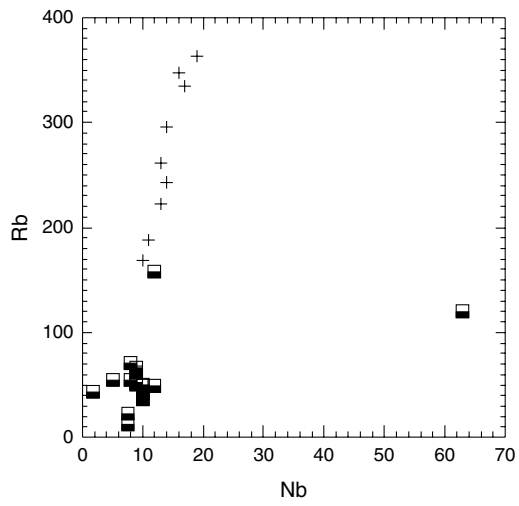
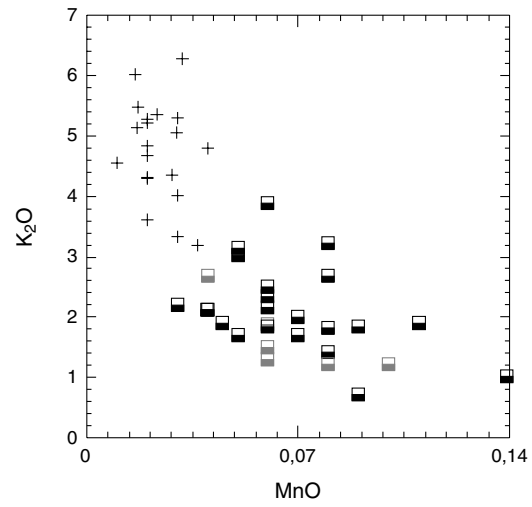
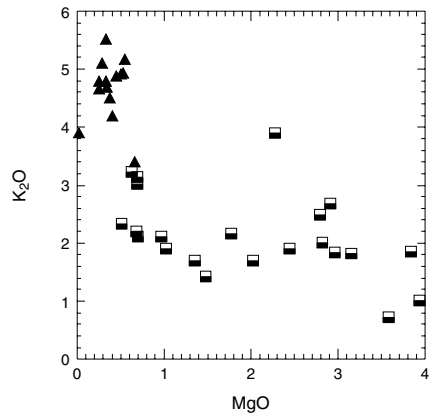


Fig. 37. North central area, EOG1 vs. SLOG.

SLOG vs. PMS (80 vs. 60)

The SLOG and the PMS show quite similar geochemical characteristics. Two elements that behave differently at comparable silica contents are Rb and Hf. This can be shown in ternary diagrams such as Ba-Sr-Rb and Hf-Ta*3-Rb/30 (Fig. 43). The A-B diagram is also useful (Fig. 43).

Class 1



Class 1 & 2

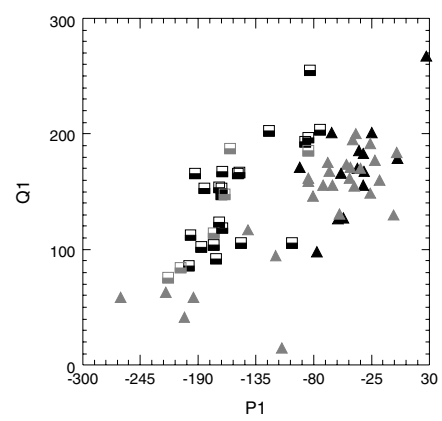
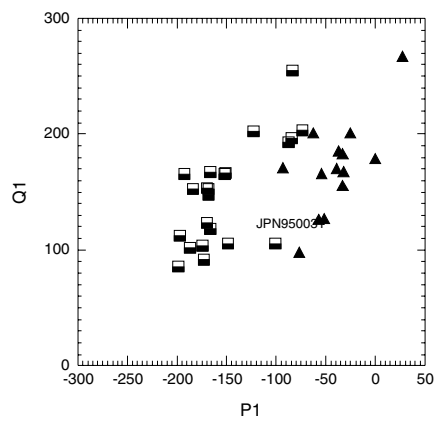
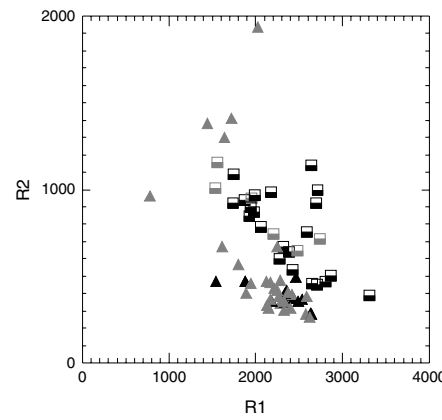
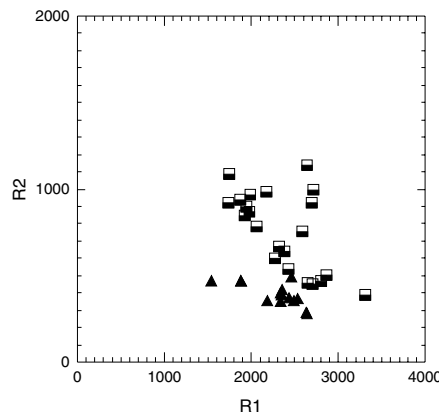
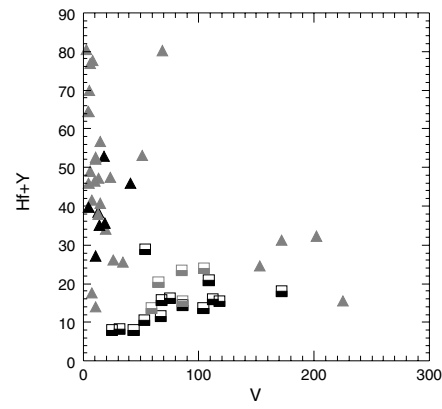
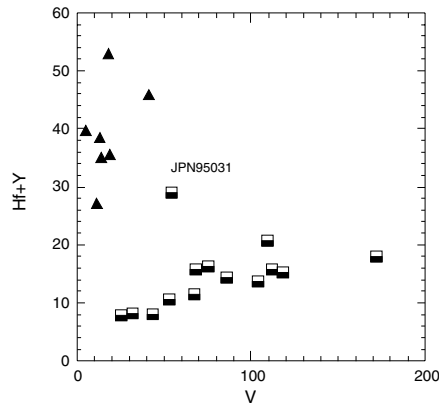
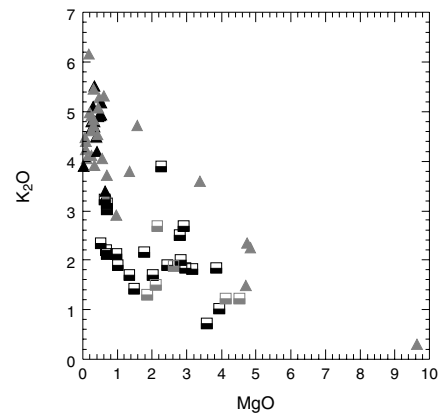
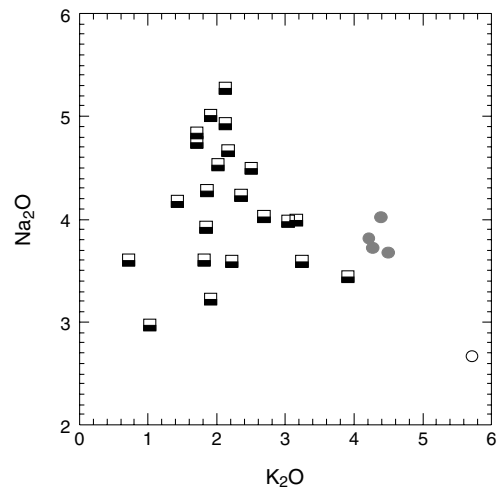
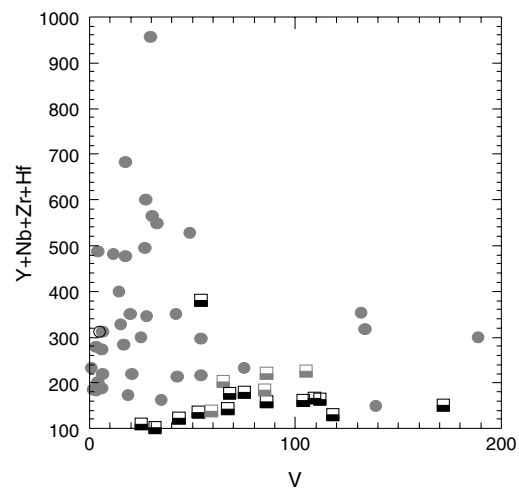
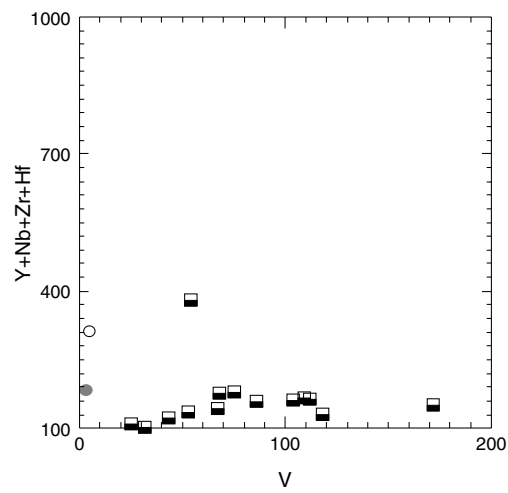
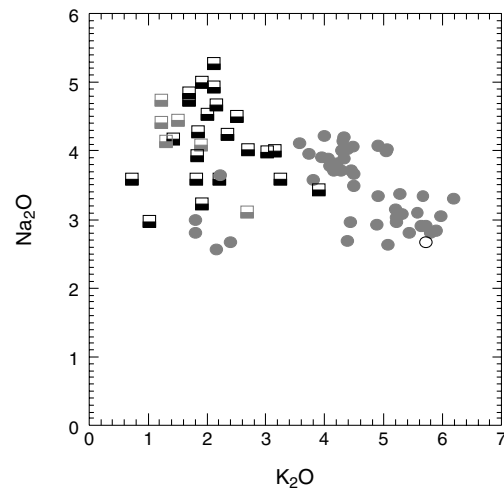


Fig. 38. North central area, EOG1 vs. PMS.

Class 1



Class 1 & 2



Class 1 & 2

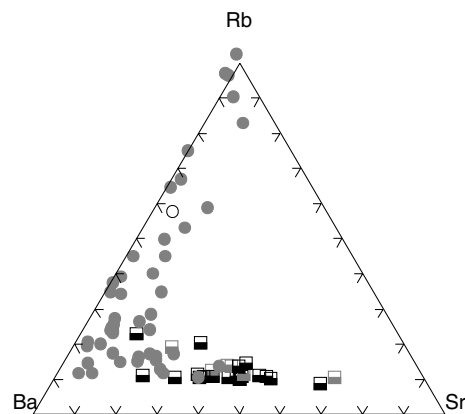
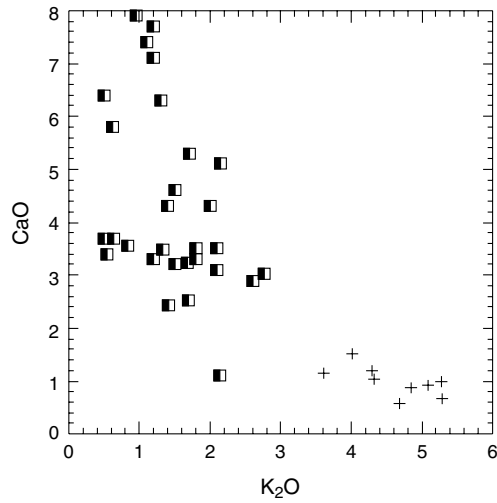


Fig. 39. North central area, EOG1 vs. Revsund.

SLOG vs. Revsund (80 vs. 50)

The SLOG and the Revsund/TMB suites display many similar geochemical features. Two factors make the discrimination ambiguous; the restricted silica content for the SLOG and the small number of class one samples for the Revsund. For the SLOG slightly higher contents of Al_2O_3 can be recognised, and slightly lower contents for trace elements such as Zr, Y and Hf. A poor discriminator is CaO vs. Al_2O_3 (Fig. 44).

Class 1



Class 1 & 2

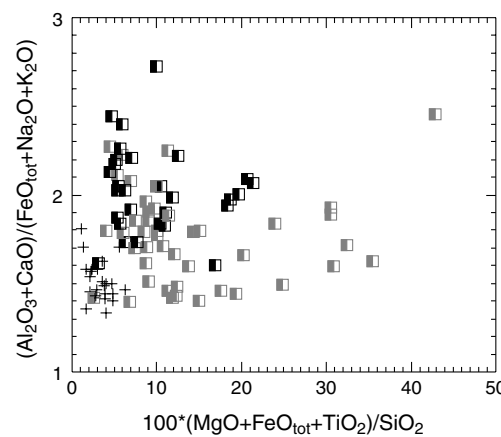
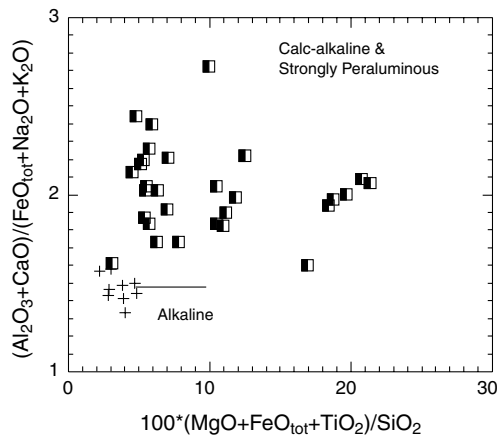
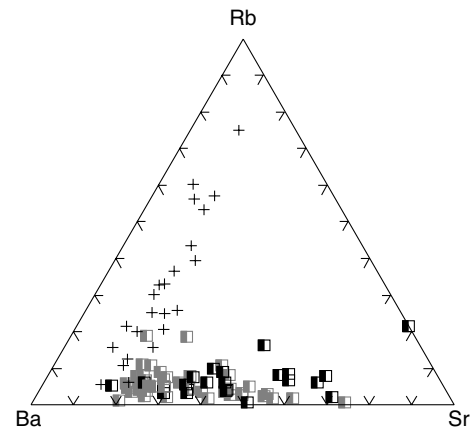
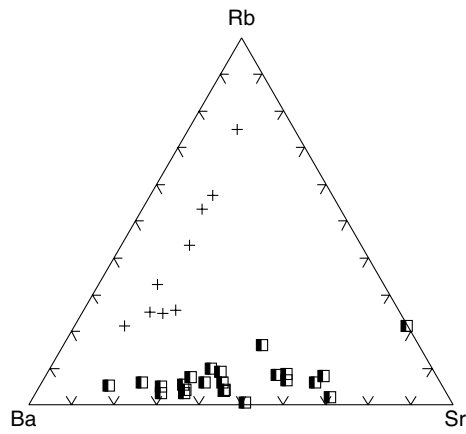
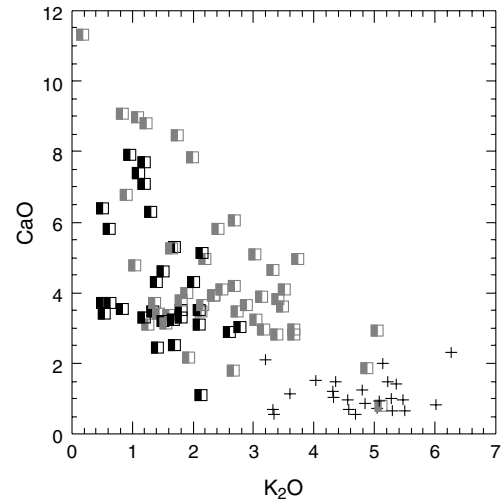
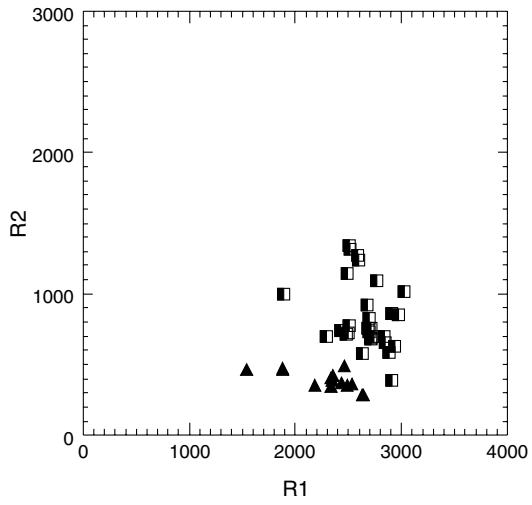


Fig. 40. North central area, EOG2 vs. SLOG.

PMS vs. Revsund (60 vs. 50)

The PMS and the Revsund suites overlap each other in almost all elements. There is a group of samples of the Revsund group, which in the K_2O vs. Na_2O diagram (not shown) plot in the field of S-type granites according to White & Chappell (1983), while all the other samples plot in the field for I-type granites.

Class 1



Class 1 & 2

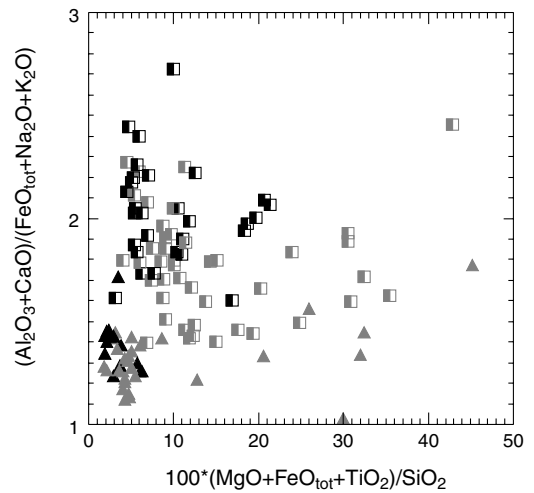
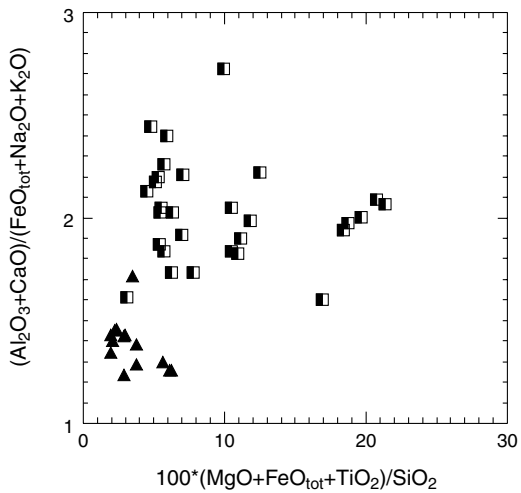
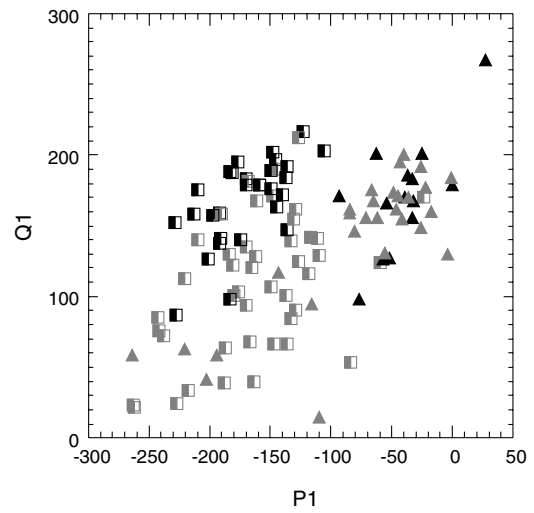
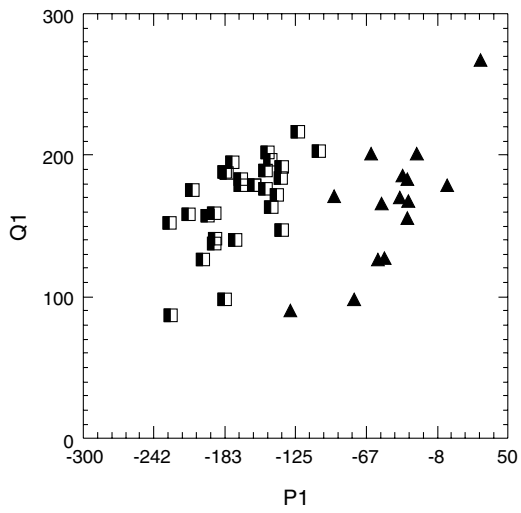
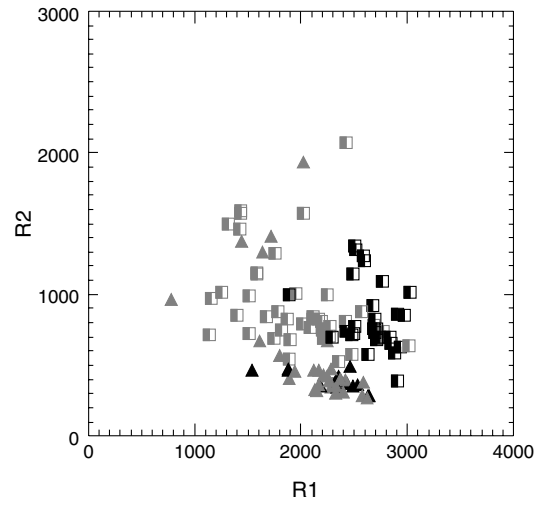
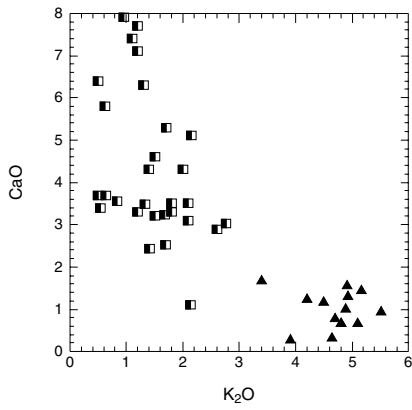


Fig. 41. North central area, EOG2 vs. PMS.

Class 1



Class 1 & 2

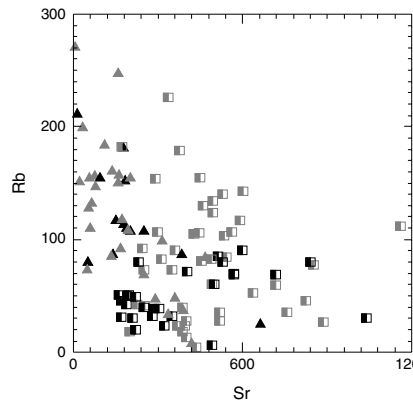
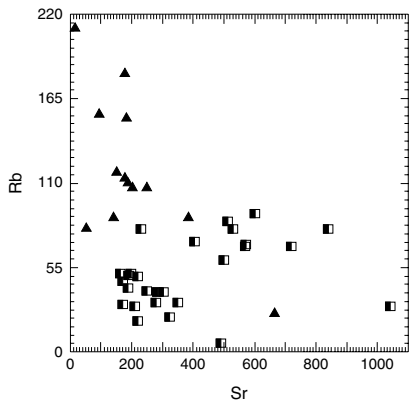
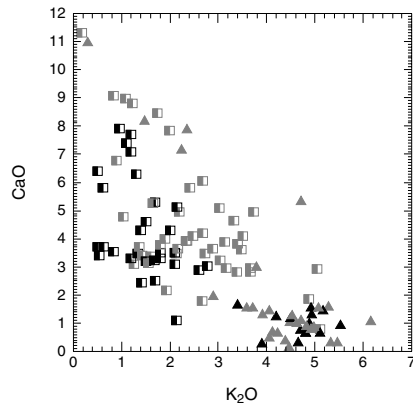


Fig. 41 cont. North central area, EOG2 vs. PMS.

Class 1 & 2

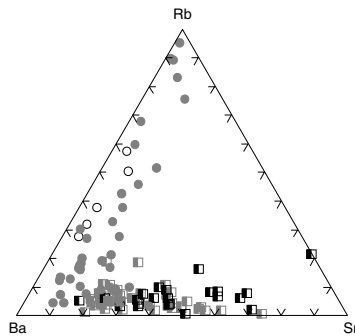
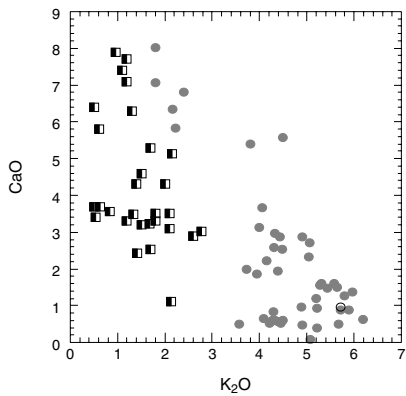
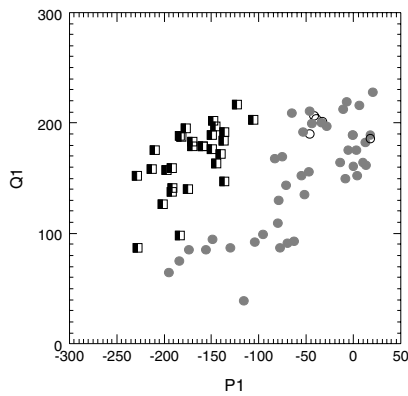
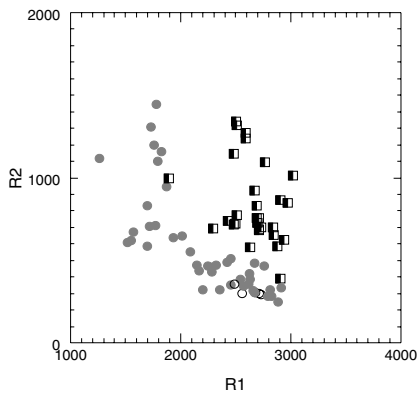
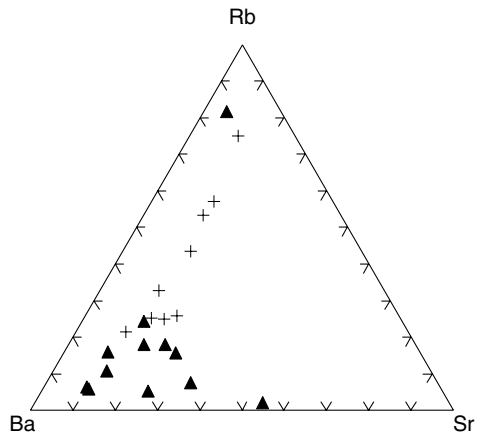


Fig. 42. North central area, EOG2 vs. Revsund.

Class 1



Class 1 & 2

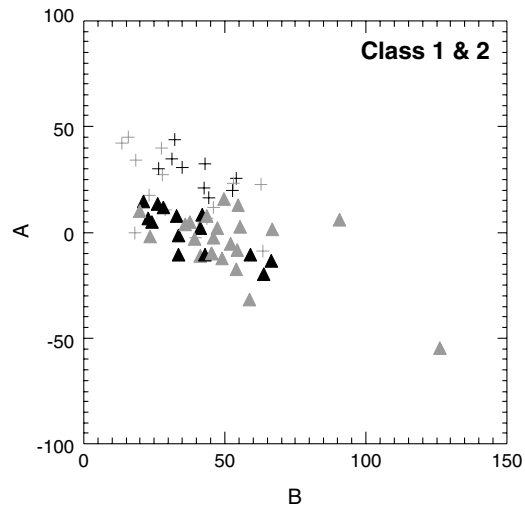
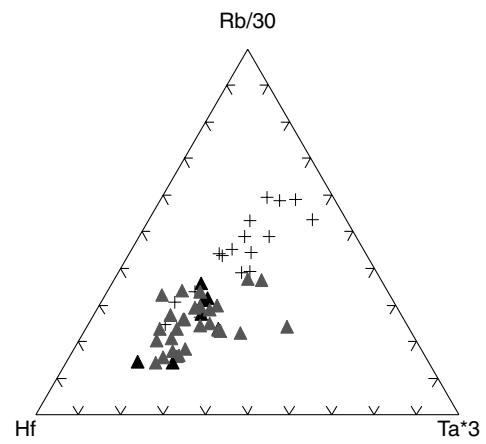
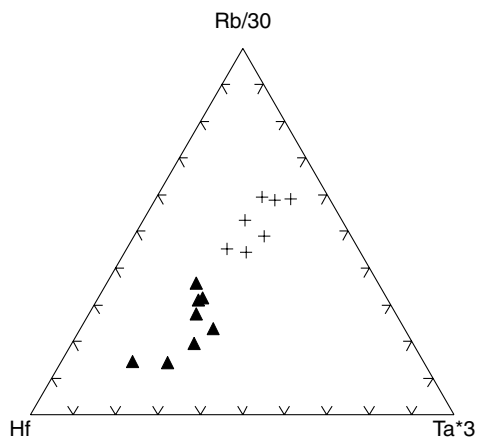
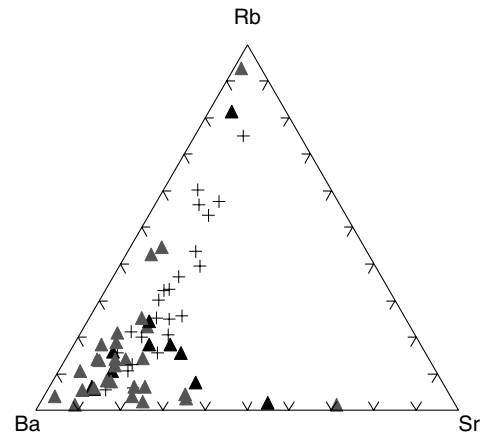
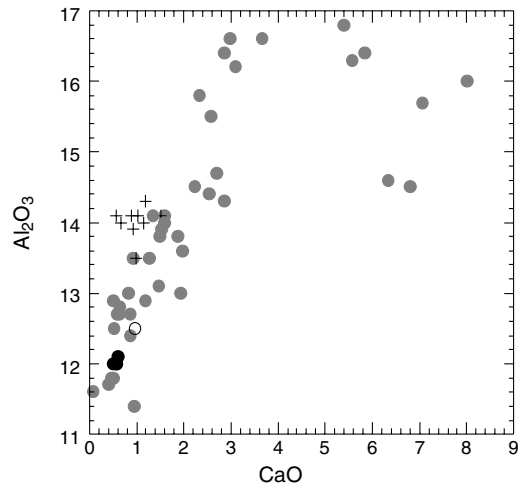


Fig. 43. North central area, SLOG vs. PMS.

Class 1 & (2 for group 50)



Class 1 & 2

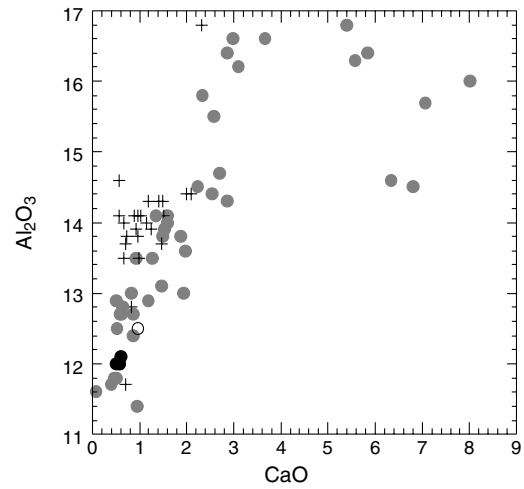


Fig. 44. North central area, SLOG vs. Revsund.

TABLE 4. Table summarising plots that may discriminate between different suites in the north central area. **Bold** text denotes plots that were effective using both class 1 and 2 samples. Regular text denotes plots that were effective for class 1 samples and some, but not all class 2 samples. Text in *italics* denotes plots that were effective for class 1 samples only.

	Revsund (50)	PMS (60)	SLOG (80)	EOG2 (90)	EOG1 (92)	EOG3 (95)
Archaean (100)	$Al_2O_3-SiO_2$ <i>Ba-Sr-Rb</i>	Al_2O_3-CaO/TiO_2 K_2O-SiO_2 <i>Sr-Y+Nb</i>	CaO-MgO <i>Rb-Sr</i>	K_2O-SiO_2 Al_2O_3-CaO <i>Ba-Rb</i> <i>Nb-Zr</i>	Zr-Ga K_2O-SiO_2	Na_2O-SiO_2
EOG3 (92)	Ba-Sr-Rb	$K_2O/(CaO + Na_2O) - Al_2O_3$ R1-R2 Sylvester 1989	Ba-Sr-Rb	$Na_2O+K_2O-SiO_2$ <i>R1-R2</i>	not found	
EOG1 (92)	Na_2O-K_2O Y+Nb+Zr+Hf-V Ba-Sr-Rb	K_2O-MgO Hf+Y-V R1-R2 P-Q	K_2O-MnO Rb-Nb Ba-Sr-Rb	<i>R1-R2</i>		
EOG2 (90)	$CaO-K_2O$ Ba-Sr-Rb <i>R1-R2</i> P-Q	$CaO-K_2O$ Rb-Sr Sylvester 1989 <i>R1-R2</i> P-Q	$CaO-K_2O$ Ba-Sr-Rb Sylvester 1989			
SLOG (80)	<i>CaO-Al_2O_3</i>	Hf-Ta*3-Rb/30 <i>Ba-Sr-Rb</i> A-B				
PMS (60)	not found					

Class 2 samples and summary of results from the north central area (19–24)

The class 2 samples were plotted in the diagrams that were most effective in discriminating class 1 samples from the different groups. The results are summarised in Table 4 on p. 54.

Central (14–18) and south central (9–13) areas

Characterisation of class 1 samples

EOG3 (95)

The early-orogenic granitoids here include intrusions with local names such as Njurunda, Svärdsjö, Sala, Vänge, Rullbo, Horrsjö, Skaga and Ljusdal. These granitoids show a granodioritic to adamellitic trend in the Debon & Le Fort (1983) P–Q diagram (Fig. 9). They are calc-alkaline in terms of Peacock (1931) and are dominantly peraluminous in the Maniar & Piccoli (1989) A/NK–A/CNK diagram (Fig. 9). This peraluminous trend is also shown in a Sylvester (1989) diagram and a Debon & Le Fort (1983) A–B diagram (Figs. 9–10). The granitoids display a normal granitic chondrite-normalised pattern for the REE with an enrichment of LREE and a weak negative Eu anomaly. Three samples plot slightly to the right (K_2O enriched) of the igneous spectrum in a Hughes (1973) diagram (Fig. 13).

SLOG (80)

Syn- to late-orogenic granites are locally called Härnö, Fellingsbro, Lisjö, Skålhöjden, Högberget, Stockholm, Örebro, Vallentuna, Fjällberg, Pingstaberget, Köping, and Bispbergsklack intrusions. These granitoids show a granodioritic, adamellitic to granitic trend in a Debon & Le Fort (1983) P–Q diagram (Fig. 9). The silica content is high with an average of 72.4 wt. %. They are dominantly peraluminous in a Maniar & Piccoli (1989) A/NK–A/CNK diagram (Fig. 10) and Debon & Le Fort (1983) A–B diagram (Fig. 9). In the Sylvester (1989) diagram (Fig. 11) they exhibit an alkaline trend. In the Pearce (1996) Nb+Y vs. Rb diagram, there are two groups, one with higher Nb content which plots in the field of "Within plate granites" (WPG), while the other group plots entirely within the field for "Volcanic arc granites" (Fig. 12).

Revsund//TMB unsp. (50, only class 2 data)

This group includes Revsund granite and rocks of TMB type with unknown age. The rocks are here classified as monzodiorite, quartz monzonite, quartz syenite, adamellite to granite using the P–Q classification diagram of Debon & Le Fort (1983, Fig. 9). The group is rather heterogeneous ranging from calc-alkaline to alkali-calcic in a modified Peacock (1931) diagram (Fig. 11). This is also shown in a Sylvester (1989) diagram (Fig. 11). They are peraluminous to metaluminous in the diagrams of Maniar & Piccoli (1989) and Debon & Le Fort (1983, Figs. 9–10).

TMB2 (30)

The younger granitoids of the TMB include the granitoids with local names such as Roteds, Råtan and Siljan. These plutonic rocks have a clear monzonitic trend. Classified in accordance with Debon & Le Fort (1983) they are monzogabbro, monzonite, syenite, quartz monzonite, quartz syenite and granite in composition (Fig. 9). There are three exceptions, represented by the mafic samples Annertz -52 %, Annertz >52% and A 91:1, which do not follow the common trends for this group. An alkaline trend is also apparent in Peacock (1931) and Sylvester (1989) diagrams as well as a transition from metaluminous to peraluminous features (Fig. 11).

TMB1 (20)

The Järna and Filipstad types are included in the group of TMB1 rocks (Larson & Berglund 1992). The majority of this group can be classified as quartz syenite to granite according to the Debon & Le Fort (1983) P–Q diagram (Fig. 9). A smaller group (Järna) with lower SiO_2 content displays a monzodiorite,

quartz monzodiorite to monzonite trend. The whole group is calc-alkaline in a Peacock (1931) diagram (Fig. 11) but displays an alkaline trend in a Sylvester (1989) diagram (Fig. 11) with the exception of the Järna group. They are metaluminous to peraluminous, especially some charnockitic rocks show a pronounced peraluminosity in the Debon & Le Fort (1983) A–B diagram (Fig. 9).

TMB0 (10)

This group is entirely represented by rocks from the Askersund batholith. Classified in the Debon & Le Fort (1983) P–Q diagram (Fig. 9) these rocks are quartz monzonites, quartz syenites, adamellites and granites. They display a mean of 61.1 % SiO₂ and show an alkali-calcic trend in the Peacock (1931) diagram (Fig. 11). In the Debon & Le Fort (1983) A–B diagram (Fig. 9) the group plots in the peraluminous and the metaluminous fields. The majority of class two samples plot in the tholeiitic field of the Miyashiro (1974) FeO_{tot}/MgO versus SiO₂ diagram (not shown) and in the AFM ternary diagram of Irvine & Baragar (1971) (not shown). Some samples from this group have extremely high contents of Sr (up to 1 wt. %) and Sn (up to 1000 ppm). Some display a depletion in Nd. Other extremes are sample UBA9362 and JAW 9327, with a Tb content of 98 ppm and a Ta content of 101 ppm for the former and a Rb content of 9000 ppm for the latter. In this group, 12 out of 36 samples have CIPW normative corundum, ranging from 0.8 to 2.53 %.

Comparison between rock groups

EOG3 vs. SLOG (95 vs. 80)

The early-orogenic granitoids and the syn- to late-orogenic granites show differences in major elements at similar silica content. The latter have higher contents of K₂O and lower contents of CaO. Large ion lithophile elements (LILE) such as Rb is higher in the SLOG group (Fig. 45) as well as large highly charged cations such as Nb, Y, Ga and other high field strength (HFS) elements such as Mo, U and Th (Fig. 45). Odd high contents are recorded for Co in the SLOG group, an element that is compatible and siderophile, for which this environment is erroneous; it may point at an analytic problem.

EOG3 vs. Revsund/TMB unsp. (95 vs. 50 only cl. 2 samples)

The EOG and the Revsund/TMB are slightly different in their peraluminosity and alkalinity. The former shows calc-alkaline and peraluminous trends while the latter has a more alkali-calcic and metaluminous affinity (Fig. 46). The latter also shows slightly higher contents of K₂O and Rb.

EOG3 vs. TMB2 (95 vs. 30)

These two groups display slightly different alkalinity trends. The former is more calc-alkaline while the latter is alkali-calcic (Fig. 47).

EOG3 vs. TMB1 (95 vs. 20)

When comparing the EOG and TMB1 suites, differences are shown in the major elements CaO, Na₂O and K₂O. Higher content of K₂O and lower of CaO in the TMB1 makes these rocks more alkaline and it is possible to discriminate by using CaO vs. K₂O. This is also apparent in the P–Q diagram (Fig. 48).

EOG3 vs. TMB0 (95 vs. 10)

The EOG and the TMB0 suites have different ranges of silica content, which makes it difficult to separate these two groups from each other. TMB0 has a slight tendency to be syenitic (Fig. 49). It is also possible to use Cu vs. SiO₂ as TMB0 seems to have overall high contents of siderophile elements such as Cu, Cr and Ni (Fig. 49).

SLOG vs. Revsund/TMB unsp. (80 vs. 50 only cl. 2 samples)

The syn- to late-orogenic Svecokarelian granites and the Revsund/TMB groups are impossible to separate from each other, as they are too heterogeneous as groups. The number of high silica samples are too few in the younger group to make any comparison possible.

SLOG vs. TMB2 (80 vs. 30)

The SLOG and TMB2 are impossible to separate from each other, as they are too heterogeneous as groups, with different silica range.

SLOG vs. TMB1 (80 vs. 20)

The SLOG and TMB1 are impossible to separate from each other, as the number of high silica samples are too few in the TMB1 group.

SLOG vs. TMB0 (80 vs. 10)

The SLOG and TMB0 are impossible to separate from each other, as the number of high silica samples are too few in the TMB0 group.

Revsund/TMB unspec. vs. TMB2 (50 vs. 30)

It is not possible with this small number of data to discriminate the Revsund/TMB and the TMB2.

Revsund/TMB unspec. vs. TMB1 (50 vs. 20)

It is not possible with this small number of data to discriminate the Revsund/TMB rocks and the TMB1.

Revsund/TMB unspec. vs. TMB0 (50 vs. 10)

By using MnO vs. Fe₂O_{3,tot} (Fig. 50) it is possible to separate the Revsund/TMB rocks and TMB0. The former is also slightly more evolved with lower Sr and higher Rb values (Fig. 50). Both are metaluminous to peraluminous, the peraluminosity is more pronounced in TMB0 granitoids.

TMB2 vs. TMB1 (30 vs. 20)

It is not possible with available data to discriminate TMB2 and TMB1 with certainty. There is, however, a tendency for an enrichment of Rb in TMB2 rocks, exemplified in Fig. 51.

TMB2 vs. TMB0 (30 vs. 10)

At similar values of SiO₂, TMB2 has a slightly lower content of Na₂O than TMB0, which makes it possible to separate these two groups. As the samples are so different in their content of SiO₂, it is only possible to recognise tendencies for the groups. With this in mind, the TMB2 shows a more evolved character with higher content of Rb and a slightly more developed alkaline trend (Fig. 52)

TMB1 vs. TMB0 (20 vs. 10)

Using Na₂O vs. SiO₂ and MnO vs. Fe₂O_{3,tot} can separate the rocks of TMB1 and TMB0. Another discriminator is Cu vs. Co (Fig 53).

Class 2 samples and summary of results from the central (14–18) and the south central (9–13) areas

The class 2 samples were plotted in diagrams that were most effective in discriminating class 1 samples from the different groups. The results are summarised in Table 5 on p. 63.

Class 1

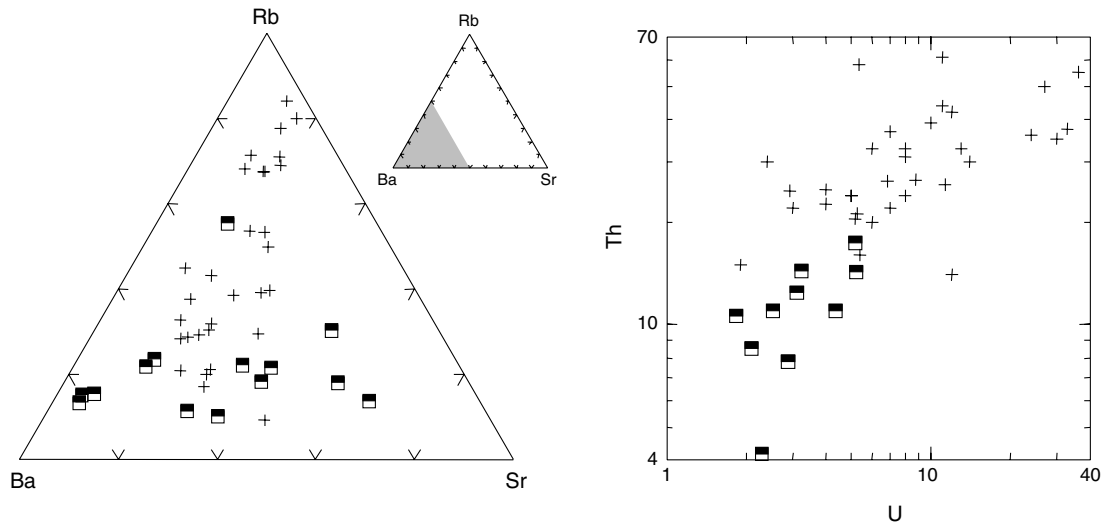


Fig. 45. Central and south central areas, EOG vs. SLOG.

Class 1 & (2 for group 50)

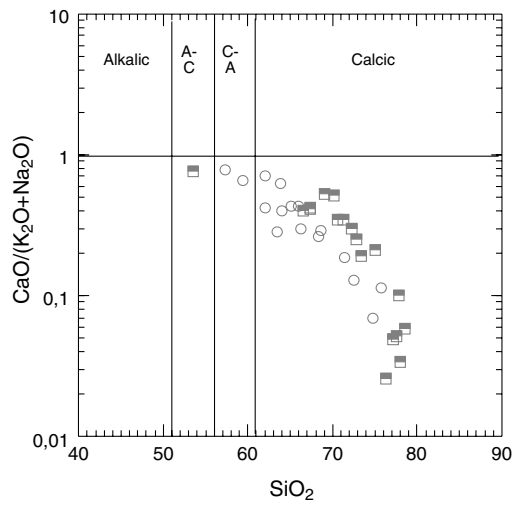


Fig. 46. Central and south central areas, EOG vs. Revsund/TMB.

Class 1 & 2

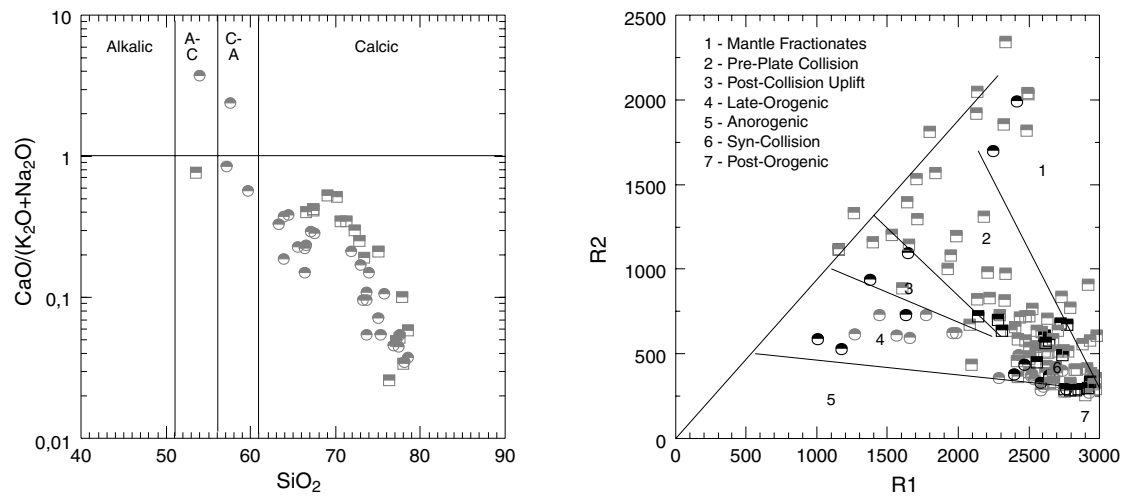


Fig. 47. Central and south central areas, EOG vs. TMB2.

Class 1

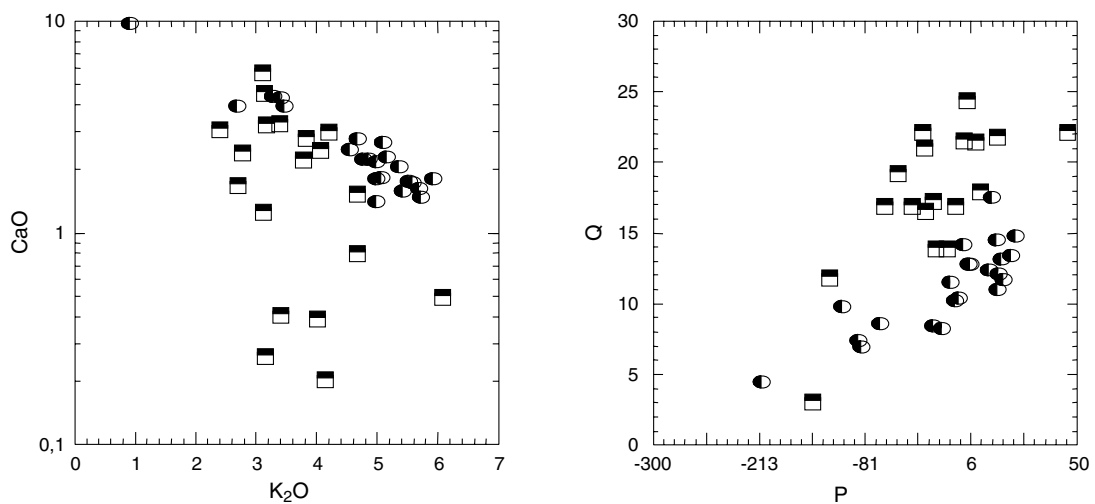


Fig. 48. Central and south central areas, EOG vs. TMB1.

Class 1

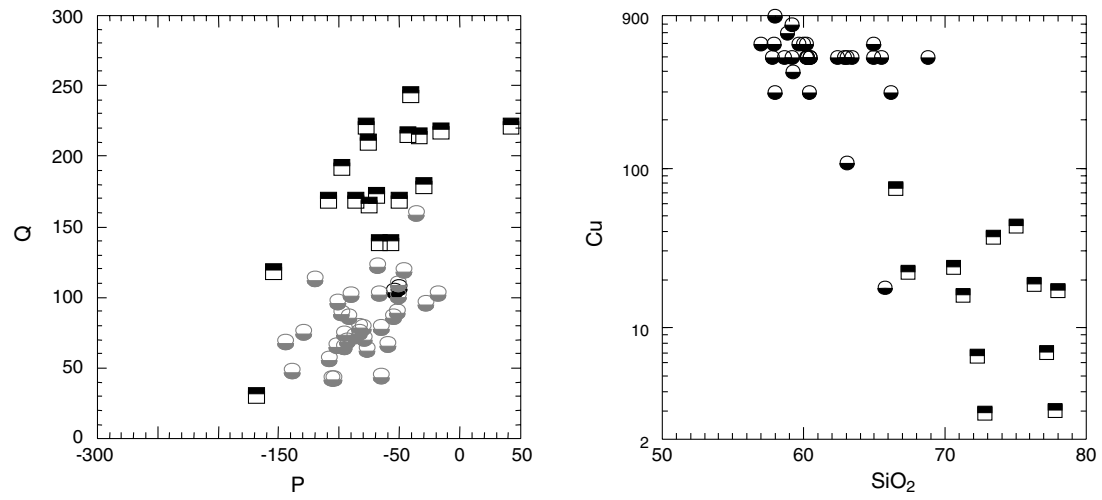


Fig. 49. Central and south central areas, EOG vs. TMB0.

Class 1 (& 2 for group 50)

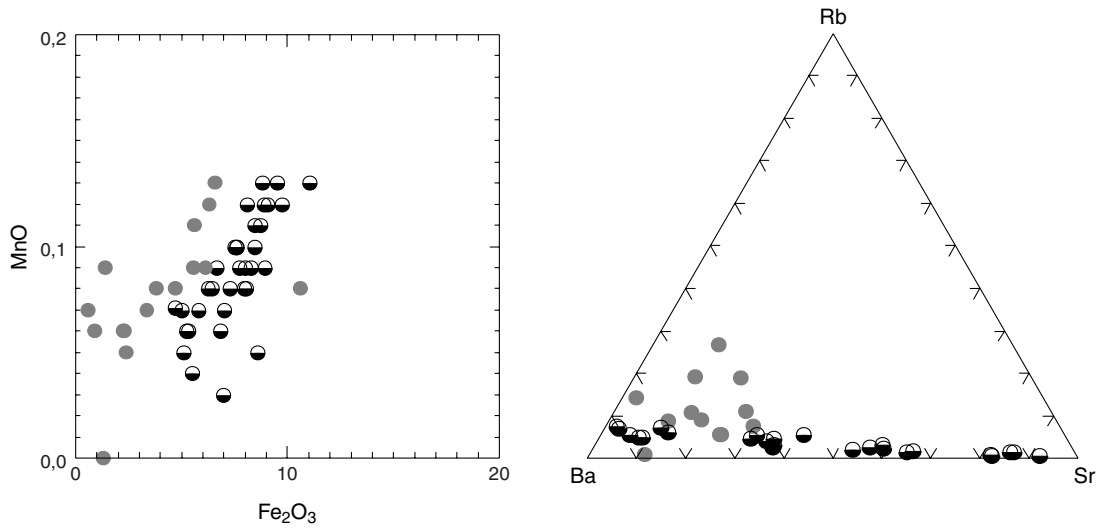


Fig. 50. Central and south central areas, Revsund/TMB vs. TMB0.

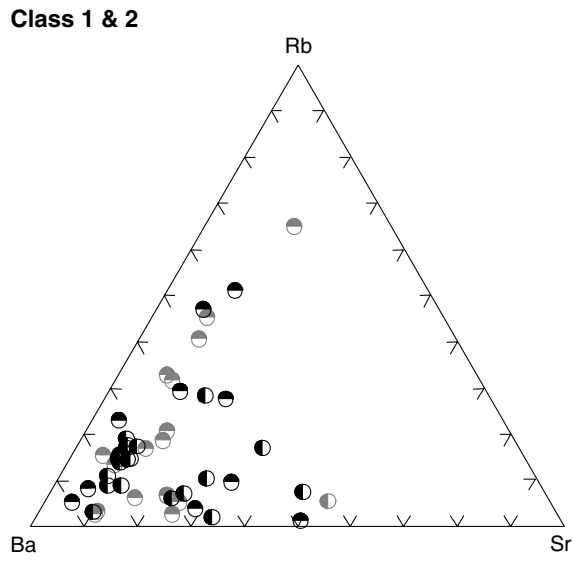


Fig. 51. Central and south central areas, TMB2 vs. TMB1.

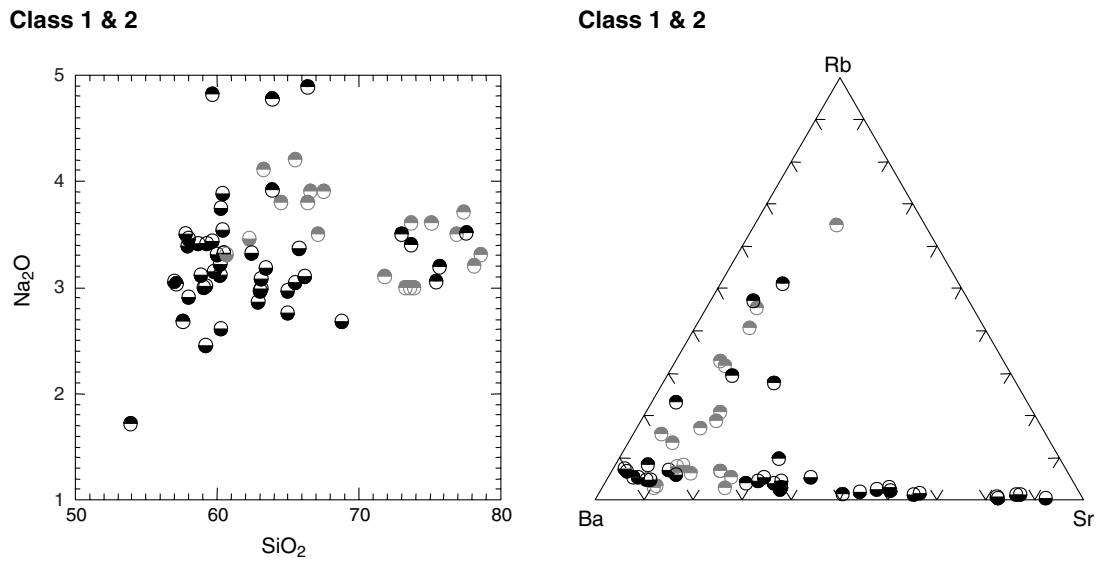


Fig. 52. Central and south central areas, TMB2 vs. TMB0.

Class 1 & 2

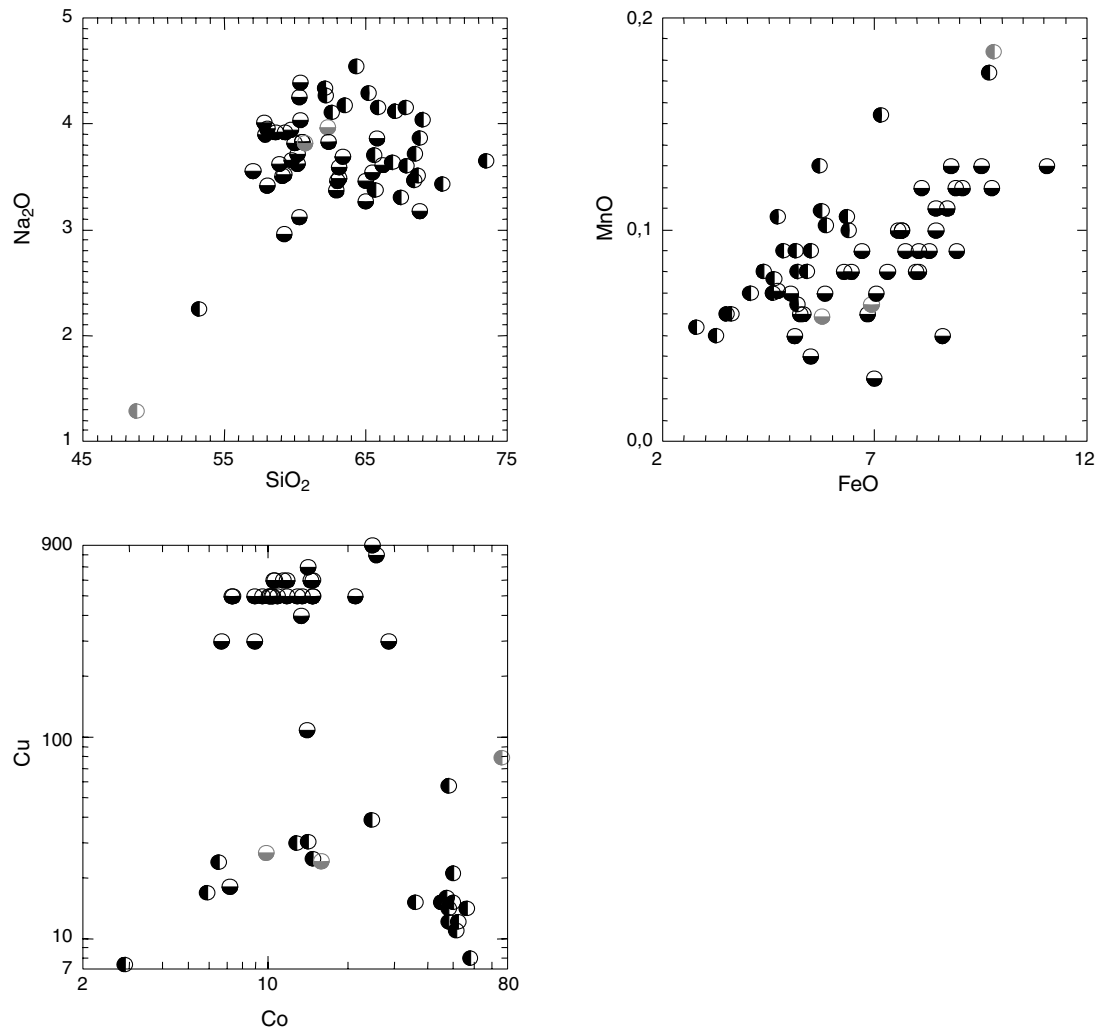


Fig. 53. Central and south central areas, TMB1 vs. TMB0.

TABLE 5. Table summarising plots that may discriminate between different suites in the central and south central areas. **Bold** text denotes plots that were effective using both class 1 and 2 samples. Regular text denotes plots that were effective for class 1 samples and some, but not all class 2 samples. Text in *italics* denotes plots that were effective for class 1 samples only.

	TMB0 (10)	TMB1 (20)	TMB2 (30)	Revsund/TMB (50)	SLOG (80)
EOG3 (95)	Q-P Cu-SiO₂	CaO-K ₂ O Q-P	Na ₂ O+K ₂ O-SiO ₂ R1-R2	Na ₂ O+K ₂ O-SiO ₂	U-Th Ba-Sr-Rb
SLOG (80)	Not found	Not found	Not found	Not found	
Revsund/TMB (50)	MnO-Fe ₂ O ₃ tot. Ba-Sr-Rb	Not found	Not found		
TMB 2 (30)	Na ₂ O-SiO ₂ Ba-Sr-Rb	Ba-Sr-Rb			
TMB 1 (20)	Na ₂ O-SiO ₂ MnO-Fe ₂ O ₃ tot. Cu-Co				

Regional similarities and variations

In order to make a regional comparison of the geochemical characteristics, class 1 samples from all areas are plotted together, group by group, in Figures 54–61.

Archaean rocks (100) from the northern and the north central area have in the previous description been grouped together as they belong to a geological complex that occurs in both areas. The results from this investigation confirm that they exhibit similar geochemical characteristics. The Archaean rocks from the north central area are slightly more evolved, with higher contents of Y and Nb. The Archaean rocks form a tonalite to granite, calc-alkaline suite, dominated by rocks of a metaluminous affinity, which plot in the fields of volcanic arc granitoids (Figs. 60 and 61).

The early-orogenic intrusive rocks, EOG1–3 (90, 92, 95) are very heterogeneous. Some regional trends may be outlined, the majority of samples from the northern area show an alkali-calcic affinity and a monzonitic trend, while the EOG1–3 from the north central area are calcic and display a tonalitic to granitic trend. Rocks from both areas are metaluminous. This is in contrast to the EOG3 rocks from the central and south central area which are calc-alkaline, peraluminous, and display a narrow range of silica contents and an adamellitic to granitic trend.

The Perthite monzonite suite, PMS (60) has a quite uniform monzonitic to granitic geochemical composition in the two northernmost areas. The number of samples from the north central area is low and they have a high and narrow range of SiO₂ contents. They are also more peraluminous in character than the samples from the northern area.

The syn-late-orogenic granites, SLOG (80), are in general granites s.s., with a SiO₂ content between 70 to 80 wt.%. They all show highly fractionated features (Figs. 58–61). SLOG from different areas have slightly variable characteristics. The granites from the northern and north central areas are somewhat variable in LREE and HFS element contents (Fig. 60), but SLOG from the north central area plot in the field of collision granites, maybe due to sedimentary precursors. In the central and south central area one population of samples plots as samples from the northern and north central areas, while another population shows an alkaline trend with within-plate characteristics (Figs. 58 and 61).

The Transscandinavian Magmatic Belt, comprising TMB0–2 and the Revsund–Adak suite, TMB un-spec. (10, 20, 30 and 50) constitutes a large, heterogeneous group, which was emplaced over a time span of

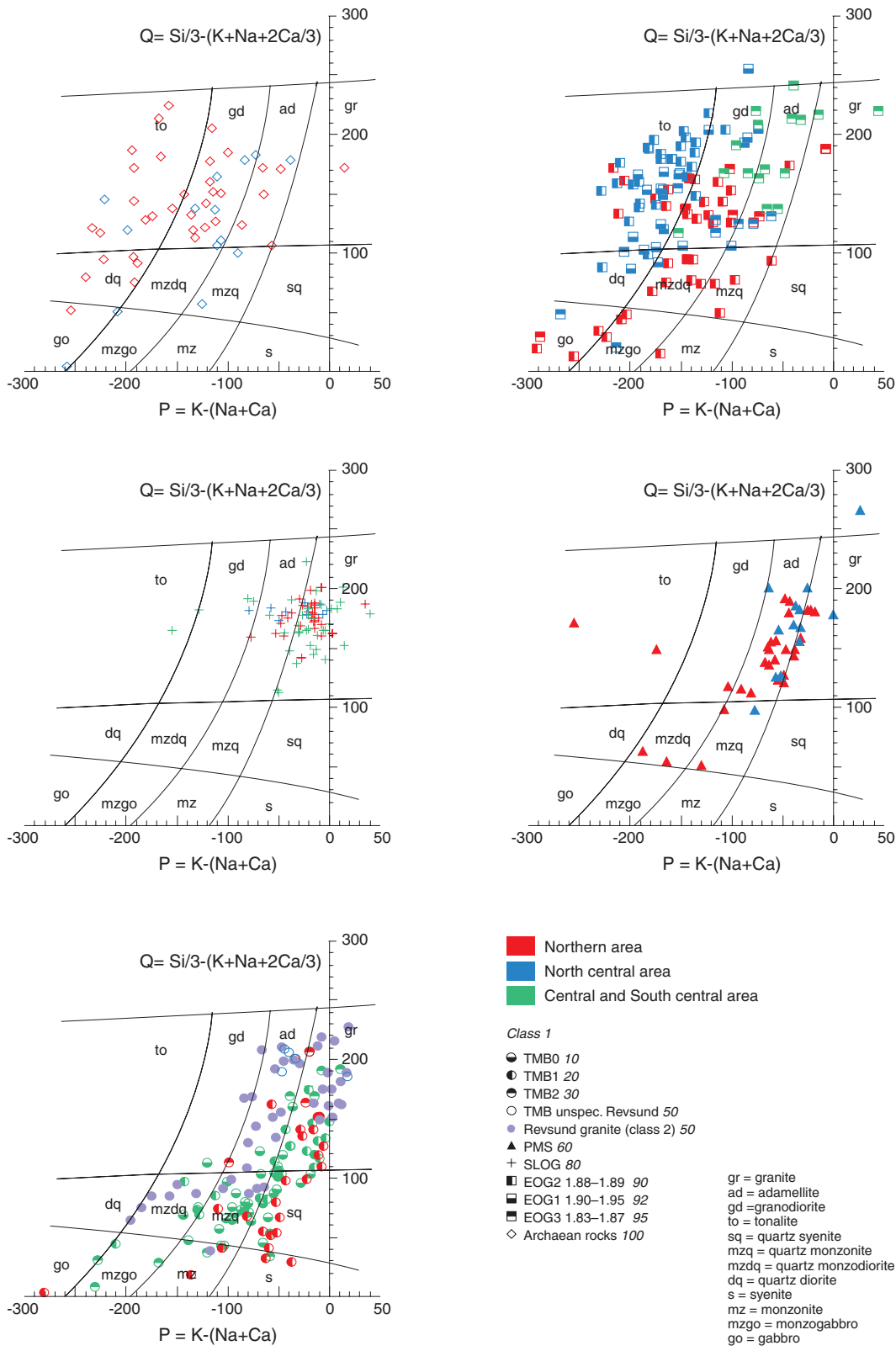


Fig. 54. All class 1 data, plotted in classification diagrams after Debon & Le Fort (1983).

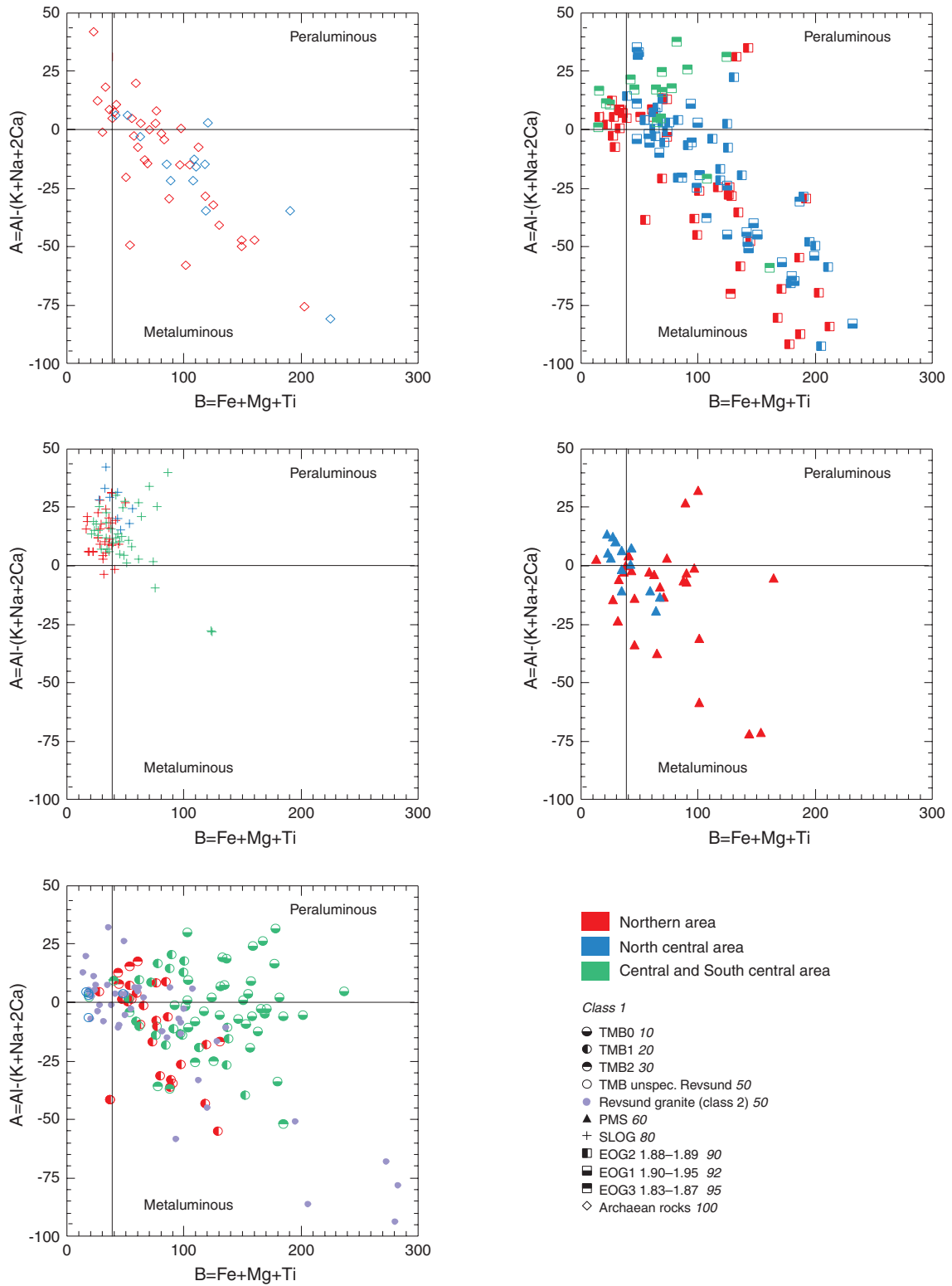


Fig. 55. All class 1 data, plotted in classification diagrams after Debon & Le Fort (1983).

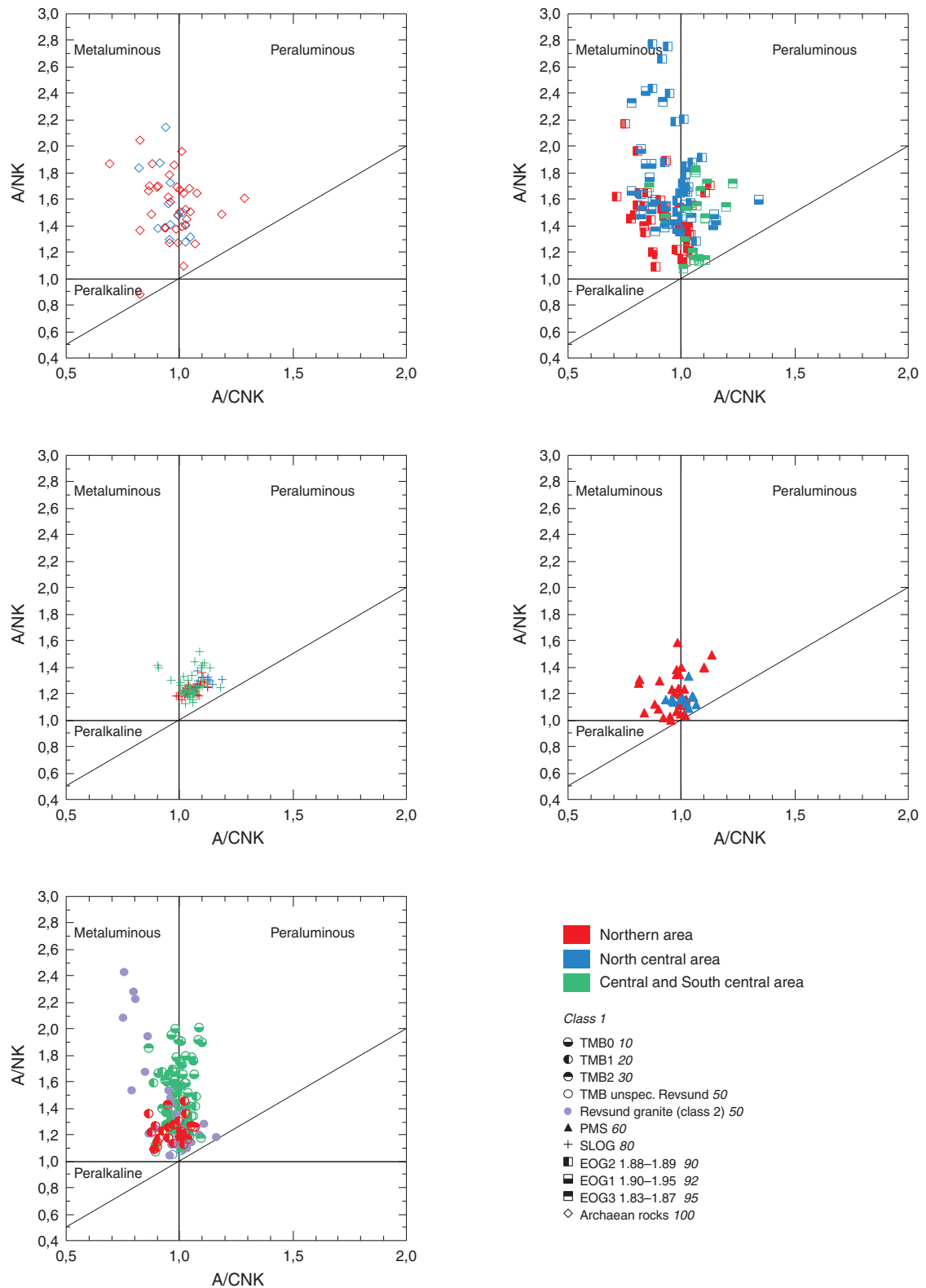


Fig. 56. All class 1 data, plotted in classification diagrams by Maniar & Piccoli (1989).

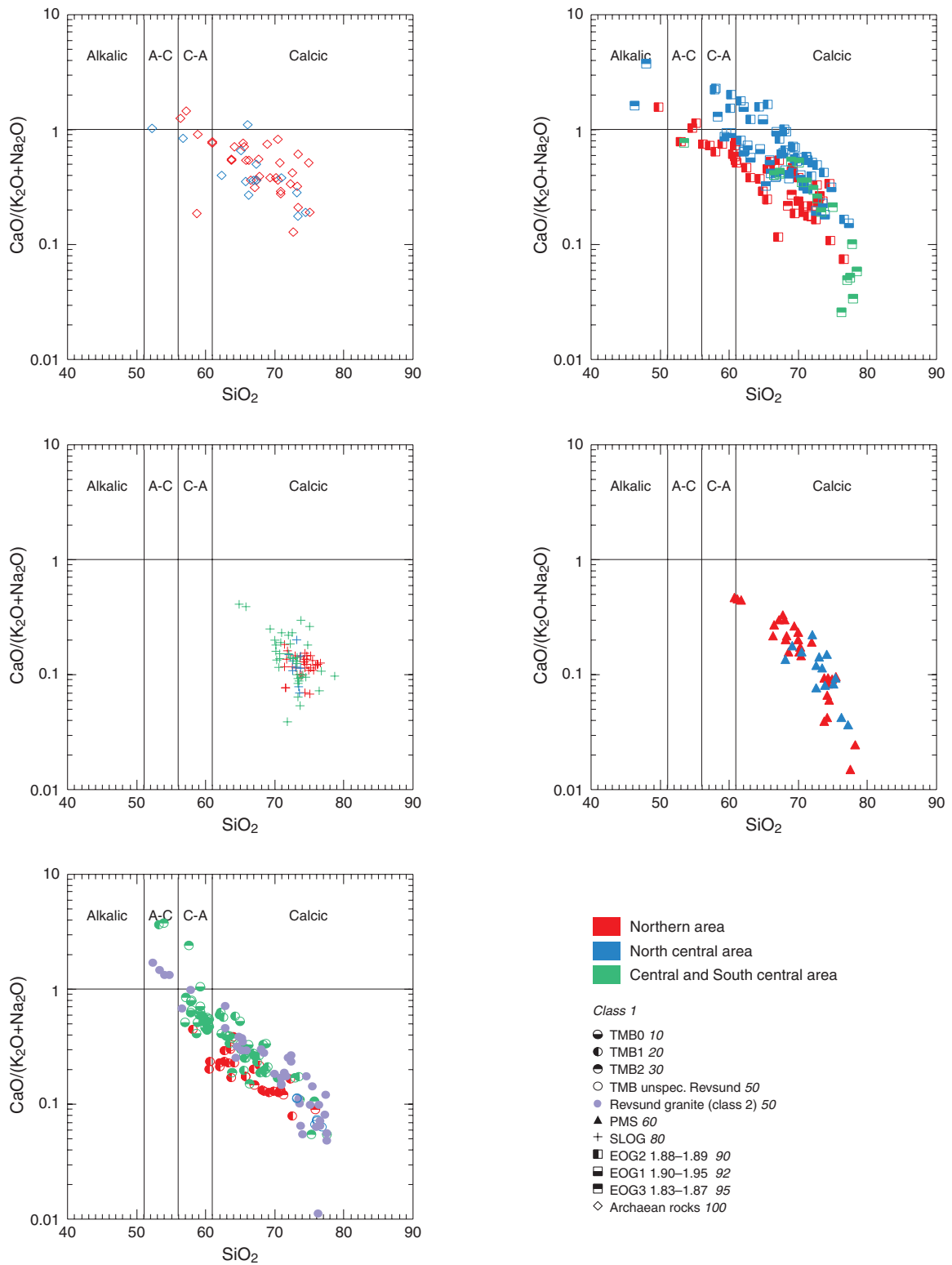


Fig. 57. All class 1 data, plotted in classification diagrams after Peacock (1931).

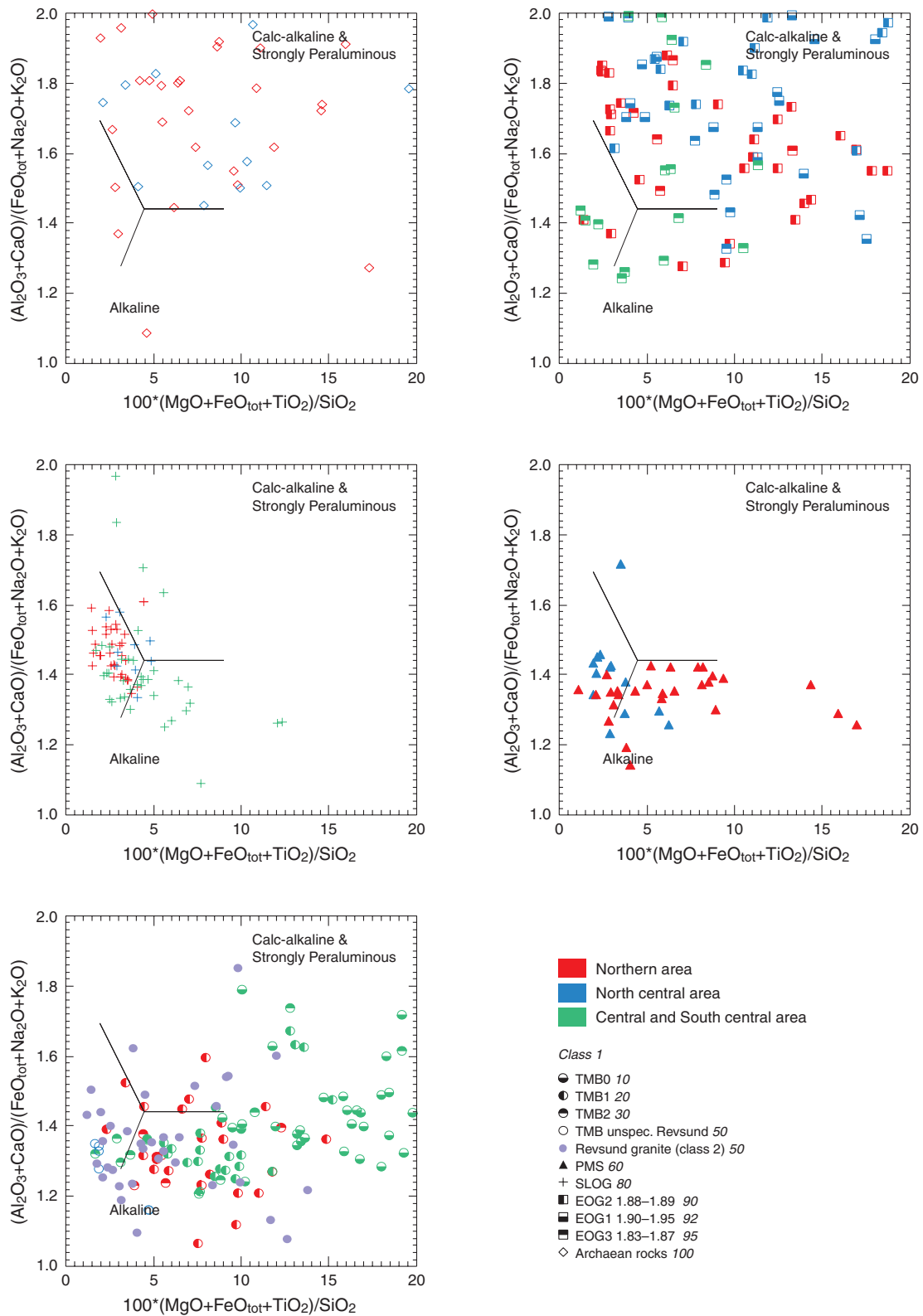


Fig. 58. All class 1 data, plotted in classification diagrams by Sylvester (1989).

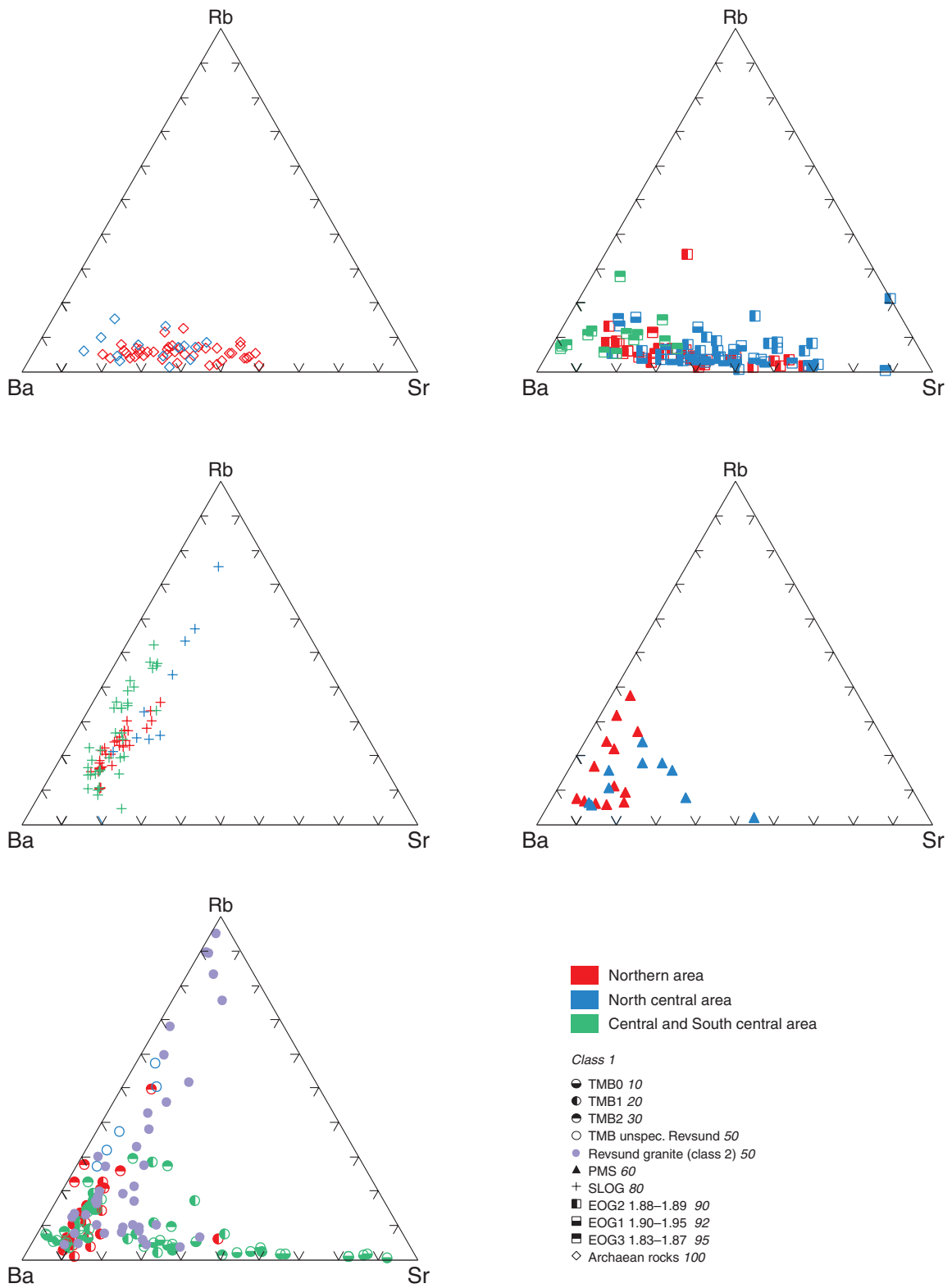


Fig. 59. All class 1 data, plotted in Sr - Ba - Rb diagrams.

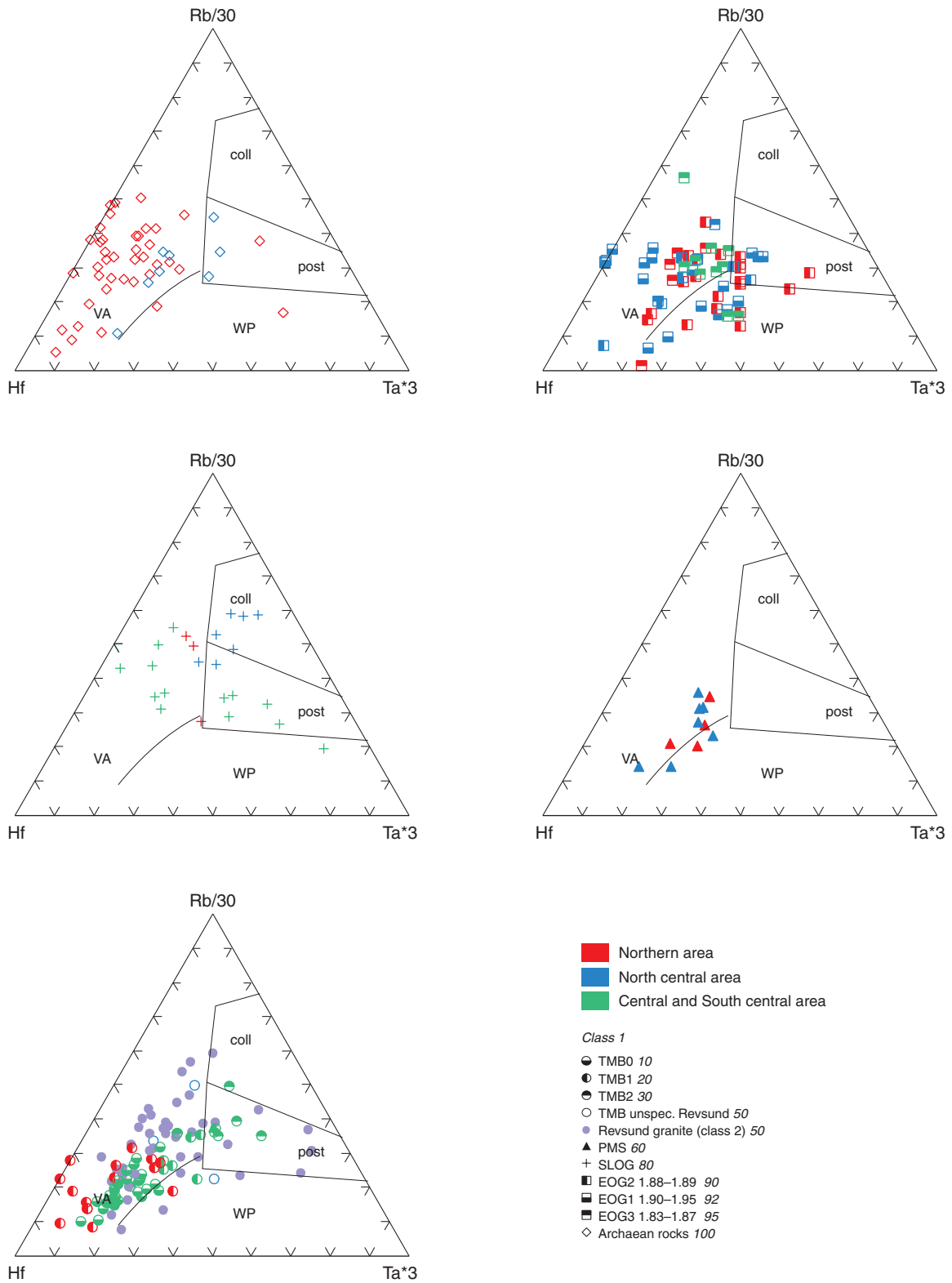


Fig. 60. All class 1 data, plotted in classification diagrams of Harris et al. (1986). Volcanic-arc (VA), within-plate (WP), collision (coll) and post-collision (post).

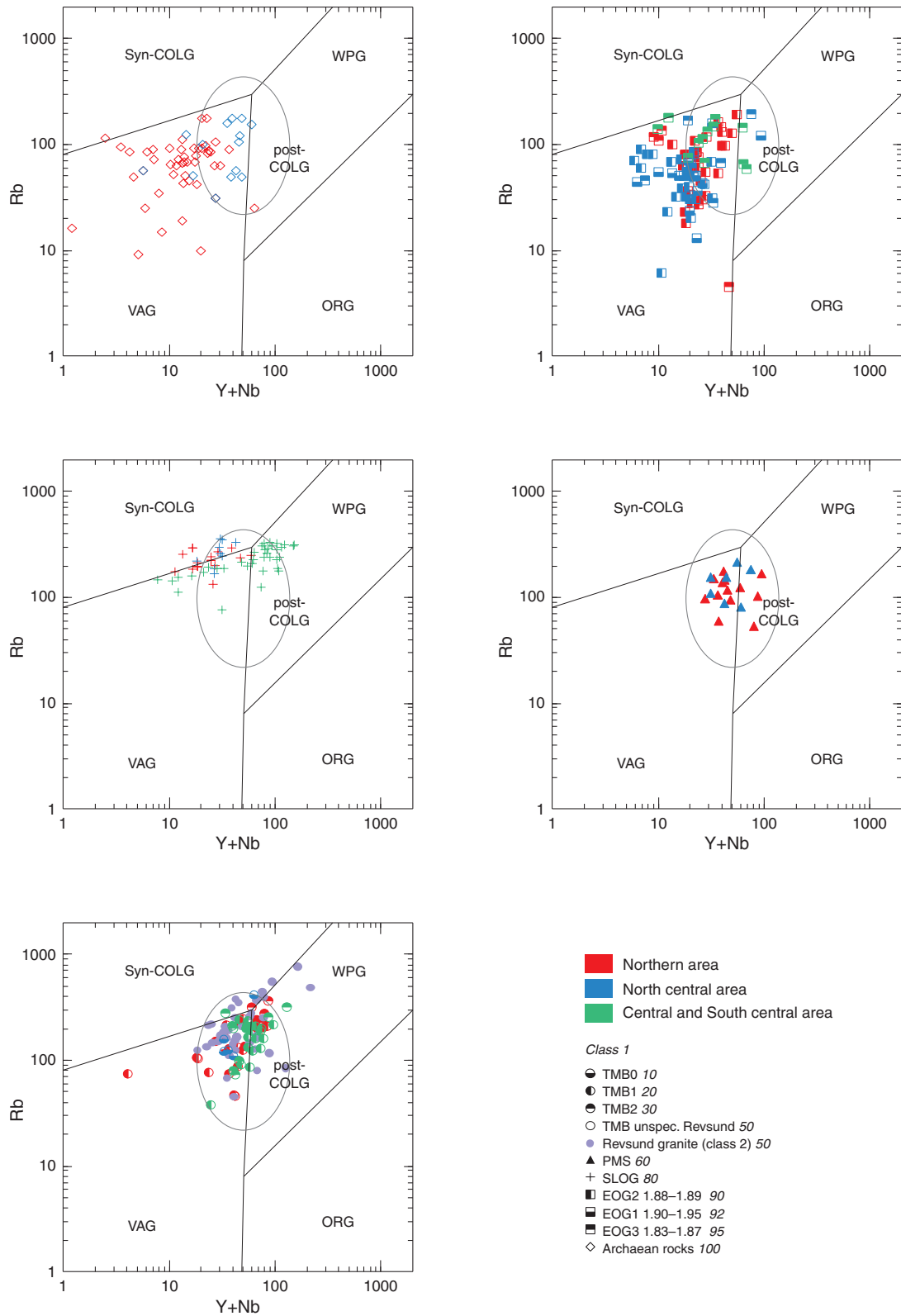


Fig. 61. All class 1 data, plotted in classification diagrams of Pearce (1996). Syn-collision granites (syn-COLG), volcanic arc granites (VAG), post-collision granites (post-COLG), within plate granites (WPG) as well as normal and anomalous ocean ridge granites (ORG).

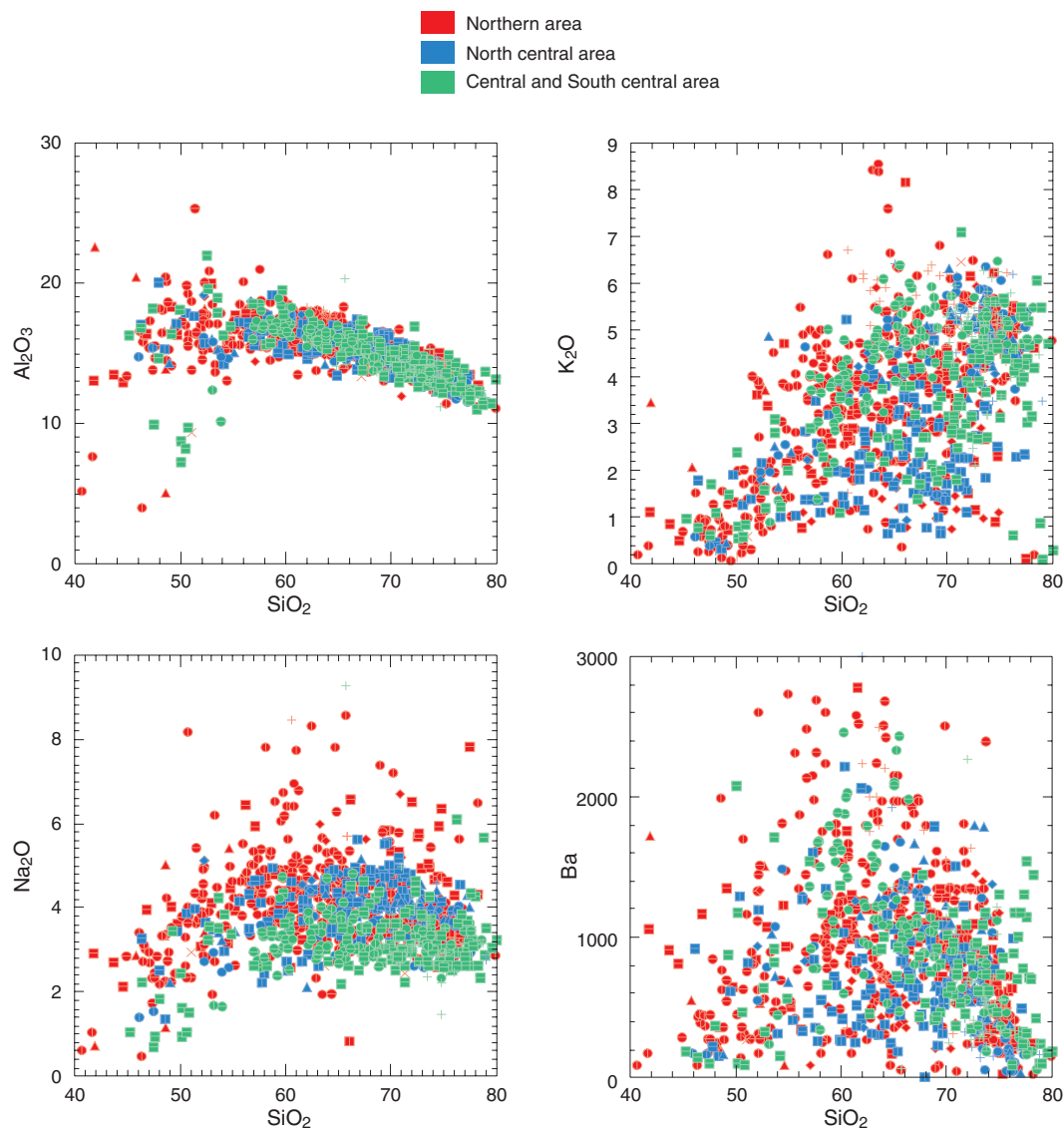


Fig. 62. All class 1 and 2 data, plotted in various Harker diagrams.

nearly 200 Ma. There is a large overlap in chemical composition between the different groups. In general they show an alkaline affinity. In the northern area, both TMB1 and TMB2 are represented. They exhibit a pronounced syenitic trend, while the TMB unsp. (Revsund–Adak suite) represents a poorly defined quartz monzodioritic trend (class 2 data). TMB0–2 rocks from the central and south central area are intermediate and show a quartz monzonitic trend. The TMB0 rocks display a unique geochemical feature (see p. 63), while TMB1 and TMB2 are similar to each other.

In general, the chemical composition of each group is similar in the three areas, even if there are exceptions. This is illustrated for some elements in Figure 62. In this figure all class 1 and 2 data are included (a total of 1027 samples). The class 2 data make the plots more scattered. For Al₂O₃, there is a very good correlation for SiO₂ content of 55 wt.% and higher. Also K₂O shows a good correlation with SiO₂, even if there is a somewhat higher K₂O content in silica rich rocks from the central and south central area. The most significant difference in element contents between different areas is recognised for Na₂O. Samples from the northern area show the highest Na₂O content at a given SiO₂ content.

Conclusions

This study shows that it is possible to discriminate the majority of rock groups by geochemistry. This indicates that it is possible to classify an unknown sample using the discrimination diagrams listed in Tables 3–5. It is, however, recommended to use a set of samples, preferably with a wide range of compositions. The diagrams may also be used as a check of field-classified samples and may serve as a basis for re-classification. Examples of this has been given where class 1 samples plot as a homogeneous group, whereas there is a wide scatter if class 2 samples are included. It is clear that the degree of certainty of classification of an unknown sample varies from case to case.

The database is quite reliable for the northern area, but possibly too small for the north central, the central, and south central areas and has to be extended in these areas. The number of class 1 samples must reach a level, where they constitute an obvious homogeneous group. Serious care has to be taken, when choosing samples that shall be included into class 1. These class 1 reference samples should be examined using petrography, mineralogy (fO_2 etc.), metallogeny, stable and radiogenic isotopes such as $\delta^{18}O$, δD , $^{87}Sr/^{86}Sr$, U-Pb, Pb-Pb, Sm-Nd, and ϵ_{Nd} . It is important to sample the whole range of plutonic rocks from ultramafic to the most felsic compositions to identify evolution and mixing trends for a group or suite.

The scheme of useful discrimination diagrams will most likely be modified in the future, as more data become available. The presence of subgroups also indicates that there is need for a more detailed definition of rock groups in some areas.

References

- Åberg, G. & Bjurstedt, S., 1986: Radiometric dating of the serorogenic Svecokarelian Enkullen and Fjällberget granites, south central Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 108, 73–77.
- Åberg, G. & Strömberg, A.G.B., 1984: Radiometric dating of Svecokarelian metarhyolites and pre-kinematic granitoids from Bergslagen, south central Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 106, 209–213.
- Åberg, G., Bollmark, B., Björk, L. & Wiklander, U., 1983a: Radiometric dating of the Horrsjö granite, south central Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 105, 78–81.
- Åberg, G., Levi, B. & Fredriksson, G., 1983b: Zircon ages of metavolcanic and synorogenic granitic rocks from the Svärdsjö and Yxsjöberg areas, south central Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 105, 199–203.
- Ahl, M., Andersson, U.-B., Lundqvist, T. & Sundblad, K. (eds.), 1997: Rapakivi granites and related rocks in central Sweden. *Sveriges geologiska undersökning C* 87, 99 pp.
- Ahl, M., Sundblad, K. & Schöberg, H., 1999: Geology, geochemistry, age and geotectonic evolution of the Dala granites, central Sweden. *Precambrian Research* 95, 147–166.
- Andersson, U.B., 1997: Petrogenesis of some Proterozoic granitoid suites and associated basic rocks in Sweden (geochemistry and isotope geology). *Sveriges geologiska undersökning Rapporter och meddelanden* 91, 216 pp.
- Antal, I. & Lundström, I., 1995: Berggrunden på kartbladen 23K Boliden. In C.-H. Wahlgren (ed.): *Regional berggrundsgeologisk undersökning – Sammanfattning av pågående undersökningar 1994. Sveriges geologiska undersökning Rapporter och meddelanden* 79, 102–114.
- Batchelor, R.A. & Bowden, P., 1985: Petrogenetic interpretation of granitoid rock series using multicationic parameters. *Chemical Geology* 48, 43–55.
- Bergman, T., Schöberg, H. & Sundblad, K., 1995: Geochemistry, age, and origin of the Högberget granite, western Bergslagen, Sweden. *GFF* 117, 87–95.
- Bergström, U. & Sträng, T., 1999: Kartbladen 23I Malå. In C.-H. Wahlgren (ed.): *Regional berggrundsgeologisk undersökning -- Sammanfattning av pågående undersökningar 1998. Sveriges geologiska undersökning Rapporter och meddelanden* 99, 48–54.
- Bergström, U., Billström, K. & Sträng, T., 1999: Age of the Kristneberg pluton, western Skellefte District,

- northern Sweden. In S. Bergman, (ed.): *Radiometric dating results 4. Sveriges geologiska undersökning C 831*, 7–19.
- Billström, K. & Öhlander, B., 1989: U-Pb zircon age of the Rostberget W-occurrence, northern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar 111*, 121–126.
- Billström, K. & Weihed, P., 1996: Age and provenance of host rocks and ores in the Paleoproterozoic Skellefte District, northern Sweden. *Economic Geology 91*, 1054–1072.
- Billström, K., Åberg, G. & Öhlander, B., 1988: Isotopic and geochemical data of the Pingstabergr Mo-bearing granite in Bergslagen, south central Sweden. *Geologie en Mijnbouw 67*, 255–263.
- Björk, L., 1986: Beskrivning till berggrundskartan Filipstad NV. *Sveriges geologiska undersökning Af 147*, 110 pp.
- Björk, L., 1995: Berggrunden på kartbladen 22G Vilhelmina NO och SO, 22H Järvsjö och 22I Lycksele. In C.-H. Wahlgren (ed.): *Regional berggrundsgeologisk undersökning – Sammanfattning av pågående undersökningar 1994. Sveriges geologiska undersökning Rapporten och meddelanden 79*, 63–66.
- Björk, L. & Kero, L., 1996: Kartbladen 22H Järvsjö NO och 22I Lycksele. In C.-H. Wahlgren (ed.): *Regional berggrundsgeologisk undersökning – sammanfattning av pågående undersökningar 1995. Sveriges geologiska undersökning Rapporten och meddelanden 84*, 72–75.
- Chappel, B.W. & White, A.J.R., 1974: Two contrasting granite types. *Pacific Geology 8*, 173–174.
- Claesson, S. & Lundqvist, T., 1995: Origins and ages of Proterozoic granitoids in the Bothnian Basin, central Sweden; isotopic and geochemical constraints. *Lithos 36*, 115–140.
- Collins, W.J., Beams, S.D., White, A.J.R. & Chappell, B.W., 1982: Nature and origin of A-type granites with particular reference to south-eastern Australia. *Contribution to Mineralogy and Petrology 80*, 189–200.
- Debon, F. & Le Fort, P., 1983: A chemical-mineralogical classification of common plutonic rocks and associations. *Transactions of Royal Society of Edinburgh, Earth Sciences 73*, 135–149.
- Delin, H., 1993: The radiometric age of the Ljusdal granodiorite of central Sweden. In T. Lundqvist (ed.): *Radiometric dating results. Sveriges geologiska undersökning C 823*, 13–16.
- Delin, H., 1996: U-Pb zircon ages of granitoids in the Kårböle region, central Sweden. In T. Lundqvist (ed.): *Radiometric dating results 2. Sveriges geologiska undersökning C 828*, 6–14.
- El Bouseily, A.M. & El Sokkary, A.A., 1975: The relation between Rb, Ba and Sr in granitic rocks. *Chemical Geology 16*, 207–219.
- Eliasson, T. & Sträng, T., 1997: Berggrunden på kartbladen 22H Stensele. In C.-H. Wahlgren (ed.): *Regional berggrundsgeologisk undersökning – Sammanfattning av pågående undersökningar 1996. Sveriges geologiska undersökning Rapporten och meddelanden 89*, 41–46.
- Eriksson, B. & Hallgren, U., 1975: Beskrivning till berggrundskartbladen Vittangi NV, NO, SV, SO. *Sveriges geologiska undersökning Af 13–16*, 1–203.
- Gaal, G. & Gorbatshev, R., 1987: An outline of the Precambrian evolution of the Baltic Shield. *Precambrian Research 35*, 15–52.
- Harris N.B.W., Pearce, J.A. & Tindle, A.G., 1986: Geochemical characteristics of collision-zone magmatism. In M.P. Coward & A.C. Ries (eds.): *Collision Tectonics. Geological Society Special Publication 19*, 67–81.
- Hughes, C.J., 1973: Spilites, keratophyres, and the igneous spectrum. *Geological Magazine 109*, 513–527.
- Irvine, T.N. & Baragar, W.R.A., 1971: A guide to the chemical classification of the common volcanic rocks. *Canadian Journal of Earth Sciences 8*, 523–548.
- Ivarsson, C. & Johansson, Å., 1995: U-Pb zircon dating of Stockholm granite at Frescati. *GFF 117*, 67–68.
- Jarl, J.-G. & Johansson, Å., 1988: U-Pb zircon ages of granitoids from the Småland–Värmland granite-porphyrity belt, southern and central Sweden. *Geologiska Föreningens i Stockholm Förhandlingar 110*, 21–28.
- Kathol, B. & Persson, P.-O., 1997: U-Pb zircon dating of the Antak granite, northeastern Västerbotten County, northern Sweden. In T. Lundqvist (ed.): *Radiometric dating results 3, Sveriges geologiska undersökning C 830*, 6–13.

- Krogh, T.G., 1987: Zircon and titanite U-Pb isotopic age studies at Vattenfall, Sweden. *Report to Vattenfall*.
- La Roche, H. de, Leterrier, J., Grandclaude, P. & Marchal, M., 1980: A classification of volcanic and plutonic rocks using R1-R2 diagram and major element analyses; its relationships with current nomenclature. *Chemical Geology* 29, 183–210.
- Larson, S.-Å. & Berglund, L., 1992: A chronological subdivision of the Transscandinavian Igneous Belt – three magmatic episodes? *Geologiska Föreningens i Stockholm Förhandlingar* 114, 459–461.
- Lee, J.K.W., Onstott, T.C., Henne, R., Krough, T.E. & Castano, J.R., 1988: $^{40}\text{Ar}/^{39}\text{Ar}$ laser microprobe and U-Pb geochronology of Siljanring samples. *100th Annual Geological Society of America meeting, Denver, Colorado, A24*.
- Lindh, A., Schöberg, H. & Annertz, K., 1994: Disturbed radiometric ages and their bearing on inter-regional correlations in the SW Baltic Shield. *Lithos* 31, 65–79.
- Lindroos, H. & Henkel, H., 1981: Beskrivning till berggrundskartorna och geofysiska kartorna Huuki NV/NO, SV, SO och Muonionalusta NV, SV/SO. *Sveriges geologiska undersökning Af* 35–39.
- Lundqvist, T., 1968: Precambrian geology of the Los–Hamra region central Sweden. *Sveriges geologiska undersökning Ba* 23, 255 pp.
- Lundqvist, T., 1990: Beskrivning till berggrundskartan över Västernorrlands län. *Sveriges geologiska undersökning Ba* 31, 429 pp.
- Lundqvist, T. & Persson, P.-O., 1999: Geochronology of porphyries and related rocks in northern and western Dalarna, south-central Sweden. *GFF* 121, 307–322.
- Lundqvist, T., Vaasjoki, M. & Skiöld, T., 1996: Preliminary note on the occurrence of Archaean rocks in the Vallen-Alhamn area, northern Sweden. In T. Lundqvist (ed.): *Radiometric dating results 2. Sveriges geologiska undersökning C* 828, 32–33.
- Lundqvist, T., Skiöld, T. & Vaasjoki, M., 2000: Archaean-Proterozoic geochronology of the Vallen-Alhamn area, northern Sweden. *GFF* 122, 273–280.
- Lundström, I., Vaasjoki, M., Bergström, U., Antal, I. & Strandman, F., 1997: Radiometric age determinations of plutonic rocks in the Boliden area: the Hobergsliden granite and the Stavaträsk diorite. In T. Lundqvist (ed.): *Radiometric dating results 3. Sveriges geologiska undersökning C* 830, 20–30.
- Lundström, I., Persson, P.-O. & Bergström, U., 1999: Indications of early deformational events in the northeastern part of the Skellefte field. Indirect evidence from geological and radiometric data from the Stavaträsk–Klintån area, Boliden map-sheet. In S. Bergman (ed.): *Radiometric dating results 4. Sveriges geologiska undersökning C* 831, 52–69.
- Maniar, P.D. & Piccoli, P.M., 1989: Tectonic discrimination of granitoids. *Geological Society of America Bulletin* 101, 635–643.
- Martinsson, O., Vaasjoki, M. & Persson, P.-O., 1999: U-Pb ages of Archaean to Palaeoproterozoic granitoids in the Torneträsk–Råstojaure area, northern Sweden. In S. Bergman (ed.): *Radiometric dating results 4. Sveriges Geologiska Undersökning C* 831, 70–90.
- Matisto, A., 1969: Kivilajikartan selitys. Lehti B8, Enontekiö. *Geological Survey of Finland, General Geological Map of Finland, 1:400 000*, 1–78.
- Mellqvist, C., 1997: *Proterozoic crustal growth along the Archaean continental margin in the Luleå area, northern Sweden*. Licentiate thesis 1997:40, Luleå University.
- Mellqvist, C., Öhlander, B., Skiöld, T. & Wikström, A., 1997: The Archaean-Proterozoic boundary in the Luleå area, northern Sweden: Field and isotope geochemical evidence for a sharp terrane boundary. In C. Mellqvist: *Proterozoic crustal growth along the Archaean continental margin in the Luleå area, northern Sweden. Licentiate thesis 1997:40, Luleå University of Technology, Paper I*, 1–29.
- Mellqvist, C., Öhlander, B. & Skiöld, T., 1999: Traces of Archaean crust in the Jokkmokk area, northern Sweden: a way of defining the Archaean-Proterozoic boundary. In C. Mellqvist: *Proterozoic crustal growth along the Archaean continental margin in the Luleå and Jokkmokk areas, northern Sweden. Doctoral thesis 1999:24, Luleå University of Technology, Paper I*, 1–23.
- Miyashiro, A., 1974: Volcanic rock series in island arcs and active continental margins. *American Journal of Science* 274, 321–355.
- Muller, J.P.E., 1980: *Geochemical and petrophysical study of the Arvidsjaur granitic intrusion, Swedish Lap-*

- land. Doctoral thesis No 1965, Universite de Geneve.
- Nilsson, G., 1995: Berggrunden på kartbladen 22K Skellefteå och 22L Rönnskär. In C.-H. Wahlgren (ed.): *Regional berggrundsgeologisk undersökning – Sammanfattning av pågående undersökningar 1994. Sveriges geologiska undersökning Rapporter och meddelanden 79*, 67–72.
- Nironen, M., 1997: The Svecofennian Orogen: a tectonic model. *Precambrian Research* 86, 21–44.
- Ödman, O.H., 1957: Beskrivning till berggrundskarta över urberget i Norrbottens län. *Sveriges geologiska undersökning Ca 41*.
- Offerberg, J., 1967: Beskrivning till berggrundskartbladen Kiruna NV, NO, SV, SO. *Sveriges geologiska undersökning Af 1–4*, 1–147.
- Öhlander, B., 1984: Geochemical analyses of rocks of the Haparanda suite, northern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 106, 167–169.
- Öhlander, B., 1985a: Geochemistry of Proterozoic molybdenite-mineralized aplites in northern Sweden. *Mineralium Deposita* 20, 241–248.
- Öhlander, B., 1985b: Geochemical characteristics of granites associated with Proterozoic molybdenite mineralization in northern Sweden. *Chemical Geology* 51, 247–263.
- Öhlander, B. & Billström, K., 1989: Regional implications of U-Pb dating of two Proterozoic granites associated with molybdenite mineralized aplites in northern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 111, 229–238.
- Öhlander, B. & Romer, R.L., 1996: Zircon ages of granites occurring along the Central Swedish Gravity Low. *GFF* 118, 217–225.
- Öhlander, B. & Schöberg, H., 1991: Character and U-Pb zircon age of the Proterozoic Ale granite, northern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 113, 105–112.
- Öhlander, B. & Skiöld, T., 1994: Diversity of 1.8 Ga potassic granitoids along the edge of the Archaean craton in northern Scandinavia: a result of melt formation at various depths and from various sources. *Lithos* 33, 265–283.
- Öhlander, B. & Zuber, J., 1988: Genesis of the Fellingsbro-type granites: evidence from gravity measurements and geochemistry. *Geologiska Föreningens i Stockholm Förhandlingar* 110, 39–54.
- Öhlander, B., Skiöld, T., Hamilton, P.J. & Claesson, L.-Å., 1987a: The western border of the Archaean province of the Baltic Shield: evidence from northern Sweden. *Contributions to Mineralogy and Petrology* 95, 437–450.
- Öhlander, B., Hamilton, P.J., Fallick, A.E. & Wilson, M.R., 1987b: Crustal reactivation in northern Sweden: the Vettajärvi granite. *Precambrian Research* 35, 277–293.
- Padget, P., 1970: Beskrivning till berggrundskartbladen Tärendö NV, NO, SV, SO. *Sveriges geologiska undersökning Af 5–8*, 95 pp.
- Padget, P., 1977: Beskrivning till berggrundskartbladen Pajala NV, NO, SV, SO. *Sveriges geologiska undersökning Af 21–24*, 73 pp.
- Patchett, P.J., Todt, W. & Gorbatshev, R., 1987: Origin of continental crust of 1.9–1.7 Ga age: Nd isotopes in the Svecofennian orogenic terrains of Sweden. *Precambrian Research* 35, 145–160.
- Peacock, M. A., 1931: Classification of igneous rock series. *Journal of Geology* 39, 65–67.
- Pearce, J.A., 1996: Source and settings of granitic rocks. *Episodes* 19, 120–125.
- Pearce, J.A., Harris, N.B.W. & Tindle, A.G., 1984: Trace element discrimination diagrams for the tectonic interpretation of granitic rocks: *Journal of Petrology* 25, 956–983.
- Persson, L., 1993: The U-Pb zircon age of the Sala "granite" of south-central Sweden. In T. Lundqvist (ed.): *Radiometric dating results. Sveriges geologiska undersökning C 823*, 32–35.
- Persson, L. & Persson, P.-O., 1997: U-Pb datings of the Hedesunda and Åkersberga granites of south-central Sweden. *GFF* 119, 91–95.
- Persson, L. & Persson, P.-O., 1999: U-Pb zircon age of the Vätö granite, south central Sweden. In S. Bergman (ed.): *Radiometric dating results 4. Sveriges geologiska undersökning C 831*, 91–99.
- Persson, P.-O. & Lundqvist, T., 1997: Radiometric dating of the Paleoproterozoic Pite conglomerate in northern Sweden. In T. Lundqvist (ed.): *Radiometric dating results 3, Sveriges geologiska undersökning C 830*, 41–49.
- Persson, P.-O. & Ripa, M., 1993: U-Pb zircon dating of a Järna-type granite in western Bergslagen, south-

- central Sweden. In T. Lundqvist (ed.): *Radiometric dating results. Sveriges geologiska undersökning C 823*, 41–44.
- Persson, P.-O. & Wikström, A., 1993: A U-Pb dating of the Askersund granite and its marginal augen gneiss. *Geologiska Föreningens i Stockholm Förhandlingar 115*, 321–329.
- Ripa, M., 1998: Beskrivning till berggrundskartan Säfsnäs SO. *Sveriges geologiska undersökning Af 190*, 77 pp.
- Ripa, M. & Persson, P.-O., 1997: The U-Pb age of the Sala-Vänge granite at Sala, south central Sweden. In T. Lundqvist (ed.): *Radiometric dating results 3. Sveriges geologiska undersökning C 830*, 57–62.
- Romer, R.L., Kjørnes, B., Korneliussen, A., Lindahl, I., Skyseth, T., Stendal, M. & Sundvoll, B., 1992: The Archaean-Proterozoic boundary beneath the Caledonides of northern Norway and Sweden: U-Pb, Rb-Sr and ϵ_{Nd} isotope data from the Rombak-Tysfjord area. *Norges Geologiske Undersøgelse Rapport 91.225*, 1–67.
- Romer, R.L., Martinsson, O. & Perdahl, J.-A., 1994: Geochronology of the Kiruna iron ores and hydrothermal alterations. *Economic Geology 89*, 1249–1261.
- Shand, S.J., 1927: *Eruptive rocks. Their genesis, composition, classification and their relation to ore-deposits*. London: Murby.
- Skiöld, T., 1979a: U-Pb zircon and Rb-Sr whole-rock and mineral ages of Proterozoic intrusives on mapsheet Lannavaara, north-eastern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar 101*, 131–137.
- Skiöld, T., 1979b: Zircon ages from an Archean gneiss province in northern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar 101*, 169–171.
- Skiöld, T., 1981a: U-Pb isotope analyses of zircons from a Precambrian gneiss area in northern Sweden and their chronostratigraphic implications. *Geologiska Föreningens i Stockholm Förhandlingar 103*, 17–25.
- Skiöld, T., 1981b: Radiometric ages of plutonic and hypabyssal rocks from the Vittangi-Karesuando area, northern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar 103*, 317–329.
- Skiöld, T., 1988: Implications of new U-Pb zircon chronology to early Proterozoic crustal accretion in northern Sweden. *Precambrian Research 38*, 147–164.
- Skiöld, T. & Öhlander, B., 1989: Chronology and geochemistry of late Svecofennian processes in northern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar 111*, 347–354.
- Skiöld, T. & Page, R.W., 1998: SHRIMP and isotope dilution zircon ages on Archaean basement-cover rocks in north Sweden. 23. *Nordiske Geologiske Vintermøde, Abstract volume Århus 1998*, 273 pp.
- Skiöld, T., Öhlander, B., Vocke, Jr., R.D. & Hamilton, P.J., 1988: Chemistry of Proterozoic orogenic processes at a continental margin in northern Sweden. *Chemical Geology 69*, 193–207.
- Skiöld, T., Öhlander, B., Markkula, H., Widenfalk, L. & Claesson, L.-Å., 1993: Chronology of Proterozoic orogenic processes at the Archaean continental margin in northern Sweden. *Precambrian Research 64*, 225–238.
- Stephens, M.B., Wahlgren, C.-H. & Annertz, K., 1993: U-Pb zircon dates in two younger suites of Palaeoproterozoic intrusions, Karlskoga area, south-central Sweden. In T. Lundqvist (ed.): *Radiometric dating results. Sveriges geologiska undersökning C 823*, 46–59.
- Sun, S.S. & McDonough, W.F., 1989: Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. In A.D. Saunders & M.J. Norry (eds.): *Magmatism in the ocean basins. Geological Society, Special Publication, 42*, 313–345.
- Sundblad, K. & Bergman, T., 1997: Late Svecofennian granitoids. In M. Ahl, U.B. Andersson, T. Lundqvist & K. Sundblad (eds.): *Rapakivi granites and related rocks in central Sweden. Sveriges geologiska undersökning Ca 87*, 7–15.
- Sundblad, K., Ahl, M. & Schöberg, H., 1993: Age and geochemistry of granites associated with Mo-mineralizations in western Bergslagen, Sweden. *Precambrian Research 64*, 319–335.
- Sylvester, P.J., 1989: Post-collisional alkaline granites. *Journal of Geology 97*, 261–280.
- Taylor, S.R. & McLennan, S.M., 1985: *The continental crust: its composition and evolution*. Blackwell, Oxford, 312 pp.
- Valbracht, P.J., 1991: Early Proterozoic continental tholeiites from western Bergslagen, central Sweden, II. Nd and Sr isotopic variations and implications from Sm-Nd systematics for the Svecofennian sub-

- continental mantle. *Precambrian Research* 52, 215–230.
- Wahlgren, C.-H., Bergman, S., Lundström, I. & Stephens, M.B., 1996: Terminologi. In C.-H. Wahlgren (ed.), *Regional berggrundsgeologisk undersökning. Sammanfattning av pågående undersökningar 1995. Sveriges geologiska undersökning Rapporter och Meddelanden 84*, 152–154 (Appendix).
- Wasström, A., 1990: *Knaftenområdet – en primitiv tidig Proterozoisk vulkanisk öbåge söder om Skelleftefältet, norra Sverige*. Unpublished M.Sc. thesis, Åbo Akademi, Finland. 128 pp.
- Wasström, A., 1993: The Knaften granitoids of the Västerbotten county, northern Sweden. In T. Lundqvist (ed.): *Radiometric dating results. Sveriges geologiska undersökning C 823*, 59–63.
- Wasström, A., 1994: The felsic intrusive and extrusive rocks in the Knaften area. Unpublished FoU report, *Sveriges geologiska undersökning*, 32 pp.
- Wasström, A., 1996: U-Pb zircon dating of a quartz-feldspar porphyritic dyke in the Knaften area, Västerbotten county, northern Sweden. In T. Lundqvist (ed.): *Radiometric dating results 2. Sveriges geologiska undersökning C 828*, 34–40.
- Weihed, P., 1992: *Geology and genesis of the Early Proterozoic Tallberg porphyry-type deposit, Skellefte District, northern Sweden*. Dissertation *Geologiska Institutionen Publication A 72*, Chalmers Tekniska Högskolan/Göteborgs Universitet, 147 pp.
- Weihed, P. & Schöberg, H., 1991: Age of porphyry-type deposits in the Skellefte District, northern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 113, 289–294.
- Welin, E., Christiansson, K. & Nilsson, Ö., 1971: Rb-Sr radiometric ages of extrusive and intrusive rocks in northern Sweden. *Sveriges geologiska undersökning C 666*, 1–38.
- Welin, E., Kähr, A.M. & Lundegårdh, P.H., 1980: Rb-Sr isotope systematics at amphibolite facies conditions, Uppsala region, eastern Sweden. *Precambrian Research* 13, 87–101.
- Welin, E., Christiansson, K. & Kähr, A.M., 1993: Isotopic investigations of metasedimentary and igneous rocks in the Palaeoproterozoic Bothnian Basin, central Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 115, 285–296.
- Westerlund, K.J., 1996: *S- and I-type granitoids from Vasterbotten county, northern Sweden; petrography, geochemistry and isotope characteristics*. Unpublished B.Sc thesis. University of Cape Town.
- White, A.J.R. & Chappell, B.W., 1983: Granitoid types and their distribution in the Lachlan fold belt, southeastern Australia. *Geological Society of America Memoir* 159, 21–34.
- Wikström, A., 1996: U-Pb zircon dating of a coarse porphyritic quartz monzonite and an even grained, grey tonalitic gneiss from the Tiveden area, south central Sweden. In T. Lundqvist (ed.): *Radiometric dating results 2. Sveriges geologiska undersökning C 828*, 41–47.
- Wikström, A. & Persson, P.-O., 1997: Two Haparanda type granodiorites with contrasting ages in the southeastern part of Norrbotten County, northern Sweden. In T. Lundqvist (ed.): *Radiometric dating results 3. Sveriges geologiska undersökning C 830*, 73–80.
- Wikström, A., Mellqvist, C. & Persson, P.-O., 1996a: An Archaean megaxenolith and a Proterozoic fragment within the Bälunge magmatic breccia, Luleå, northern Sweden. In T. Lundqvist (ed.): *Radiometric dating results 2. Sveriges geologiska undersökning C 828*, 48–56.
- Wikström, A., Skiöld, T. & Öhlander, B., 1996b: The relationship between 1.88 Ga old magmatism and the Baltic-Bothnian shear zone in northern Sweden. In T.S. Brewer (ed.): *Precambrian crustal Evolution in the North Atlantic Region. Geological Society Special Publication* 112, 249–259.
- Wilson, M.R., 1980: Granite types in Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 102, 167–176.
- Wilson, M.R., 1982: Magma types and the tectonic evolution of the Swedish Proterozoic. *Geologische Rundschau* 71, 120–129.
- Wilson, M.R., Hamilton, P.J., Fallick, A.E., Aftalion, M. & Michard, A., 1985: Granites and early Proterozoic crustal evolution in Sweden: evidence from Sm-Nd, U-Pb and O isotope systematics. *Earth and Planetary Science Letters* 72, 376–388.
- Wilson, M.R., Öhlander, B., Cuney, M. & Hamilton, P.J., 1987a: Geodynamic significance of contrasting granite types in northern Sweden. In A. Kröner (ed.): *Proterozoic Lithospheric Evolution. American Geophysical Union, Geodynamic Series* 17, 161–173.
- Wilson, M.R., Claesson, L.-Å., Sehlstedt, S., Smellie, J.A.T., Aftalion, M., Hamilton, P.J. & Fallick,

- A.E., 1987b: Jörn: An early Proterozoic intrusive complex in a volcanic arc environment. *Precambrian Research* 36, 201–225.
- Witschard, F., 1970: Description of the geological maps Lainio NV, NO, SV, SO. *Sveriges geologiska undersökning Af* 9–12.
- Witschard, F., 1975: Description of the geological maps Fjällåsen NV, NO, SV, SO. *Sveriges geologiska undersökning Af* 17–20, 1–125.
- Witschard, F., 1984: The geological and tectonic evolution of the Precambrian of northern Sweden – a case for basement reactivation. *Precambrian Research* 23, 273–315.

APPENDIX A. Age determinations that have been used in this study.

ID	Grp	N-S	E-W	Map	Object	Age	Year	Reference
918	10	6520850	1444950	09E	Askersundgranite, Kerstintorp	1848±15	1993	Persson & Wikström
920	10	6545500	1449450	09E	Askersundgranite, Karlberg	1842±23/13	1993	Persson & Wikström
862	20	6567100	1422400	10E	Charnockitic Granite	1796±6/7	1993	Stephens et al.
677	20	6623050	1409100	11E	Filipstadgranite	1783±10	1988	Jarl & Johansson
1064	20	6637700	1433240	11E	Granite, Skälhögden	1758±8	1993	Sundblad et al.
698	20	6650320	1435580	12E	Järnagranite	1786±14/12	1993	Persson & Ripa
1104	20	6650500	1454750	12F	Granite, Högberget	1750±10	1995	Bergman et al.
1167	20	6819800	1429950	15E	Dalagranite, Sotbo	1783±8	1999	Lundqvist & Persson
1149	20	6866800	1466900	16F	Granodiorite, Borrberget	1803±31/25	1996	Delin
1148	20	6886400	1470900	16F	Granodiorite, Björnberget	1795±7	1996	Delin
20		7303800	1657100	25J	Granite, Storliden	1792±5	1993	Skiöld et al.
20		7311750	1767500	25L	Syenite, Boden	1800	1994	"Pers. comm. E. Welin 1993" in Öhlander & Skiöld
20		7365950	1714000	26K	Granite-quartzsyenite, Edefors	1800±7	1994	Ref "submitted to GFF" in Öhlander & Skiöld
20		7379000	1689500	26J	Quartzmonzonite, Larve	1793±3	1994	Ref "submitted to GFF" in Öhlander & Skiöld
20		7527000	1676000	29J	Syenite, Saarijervi	1792±4	1994	Romer et al.
20		7552000	1581000		Granite, Gautells, Norge	1770±10	1992	Romer et al.
20		7573500	1601500	30I	Granite, Sjangeli	1778±19	1992	Romer et al.
20		7600000	1585000		Granite, Svartdal, Norge	1796±5	1992	Romer et al.
834	30	6565550	1415850	10E	Diorite-nonzodiorite, Roledsmassivet	1699±7	1993	Stephens et al.
1176	30	6768650	1333200	14C	Värmlandsgranite, Girå-Larsknipen	1702±11	1999	Lundqvist & Persson
1177	30	6771650	1342750	14C	Fältspatporphyry, Stor-Kallberget	1694±11/-8	1999	Lundqvist & Persson
1169	30	6781800	1411160	14E	Garbergranite, Oxberg	1710±11	1999	Lundqvist & Persson
1179	30	6859350	1320400	16C	Quartz-feldsparporphyry, Flickerbäcken	1693±5	1999	Lundqvist & Persson
1150	30	6878700	1471400	16F	Rätangranite, Öjeforsen, Kårböle	1702±6	1996	Delin
1315	30	6725550	1408250	13F	Siljansgranite, Van	1681±16	1999	Ahl et al.
30		7562000	1575000		Granite, Sördal, Norge	1719±15	1992	Romer et al.
30		7570500	1599500	30H	Granite, Sjangeli	1703±5	1992	Romer et al.
52		7197000	1584000	22H	Revsundgranite, Björnberget	1817-1830		SGU (unpublished)
52		7200440	1570000	23H	Revsund, Joran	1805±9	1991	Eliasson & Sträng
1010	52	7284000	1777000	24L	Aleggranite, randfacies	1796±2	1991	Öhlander & Schöberg
1011	52	7288000	1772000	24L	Aleggranite, center	1802±3 (1803±3)	1991	Öhlander & Schöberg
699	54	7200000	1576200	22H	Granite, greisenvein, Fostberget	1775-1782	1989	Billström & Öhlander
734	54	7240000	1607200	23I	Revsundgranite, Holmörs	1778±16	1988	Skiöld
734	54	7262750	1588250	24H	Revsundgranite, Holmörs	1778±16	1988	Skiöld
56		7227950	1628510	23I	Adakgranite, Sörberget	1802±3	1988	SGU (unpublished)
743	56	7262000	1616000	24I	Ledfatsgranite, Gråberget	1772±14	1988	Skiöld
742	56	7262600	1615400	24I	Ledfatsgranite, Gråberget	1784±62	1988	Skiöld
738	58	7277200	1563700	24H	Sorselegranite	1766±8	1988	Skiöld
739	58	7299000	1579400	24H	Sorselegranite	1791±22	1988	Skiöld
1063	60	7233300	1669900	23J	Gallejaurgabbro	1876±4	1993	Skiöld et al.
730	60	7233890	1691940	23J	Jörn G3	1873±18/-14	1987b	Wilson et al.
744	60	7235500	1676900	23J	Gallejaurmonzonite, Bredträskliden	1873±10	1988	Skiöld
1127	60	7254650	1691940	24J	Antakgranite, 1.5 km SE Kåtaelet	1879±15/-12	1997	Kathol & Persson
889	60	7269950	1626950	24I	Avaviken qzdiorite-gabbro, Gjelesiden	1840±9	1985	Wilson et al.
1062	60	7273500	1647550	24I	Arvidsjaurgranite, Vittfjäll, skidbacken	1877±8/7	1993	Skiöld et al.
892	60	7281300	1628500	24I	Storavan/ISM, Jan-Svensamössan	1894±42/-27	1985	Wilson et al.
893	60	7287500	1622100	24I	Renviken, Långberget	1864±33/-27	1985	Wilson et al.
60		7304100	1800250		Granite, Degeberget	1888±17	1996b	Wikström et al.
60		7318000	1808100		Granite, Bläsberget	1880±7	1996b	Wikström et al.

ID	Grp	N-S	E-W	Map	Object	Age	Year	Reference
60	60	7497450	1768400	29L	Granite, Masugnbyn	1858±9	1989	Skiöld & Öhlander
60	60	7519000	1737500	29K	Granite, Aijälvi	1863 (1826)	1981b	Skiöld
60	60	7523550	1706250	29K	Syenite, Koivo-Kuosanen	1879±7	1989	Skiöld & Öhlander
60	60	7551460	1655920	30J	Monzonite, Runkanjumme	1868±55	1999	Martinsson et al.
857	80	7579440	1687260	30J	Granite, Rakisvare	1874±12	1999	Martinsson et al.
1102	80	6580560	1448480	10E	Even grained granite	1786±8	1993	Stephens et al.
1115	80	6585300	1627950	10I	Stockholmsgranite, Frescati	1803±23/-19	1995	Ivarsson & Johansson
753	80	6586640	1448480	10E	Porphyritic granite	1807±5	1993	Stephens et al.
760	80	6591529	1491867	10F	Fellingsbrogranite	1782±6	1987	Patchett et al.
1115	80	6591800	1529800	10G	Granite, Lisjö	1770±3	1996	Öhlander & Romer
80	80	6615400	1642500	11I	Granite, Vallentuna (IHLD)	1779±8	1996	Öhlander & Romer
1116	80	6616250	1518650	11G	Granite, Lisjö	1770±6	1996	Öhlander & Romer
766	80	6657910	1448360	12E	Pingstabergranite	1781±46	1988	Billström et al.
657	80	6664500	1451000	12F	Serogenic intrusion, Fjällberg	1748±74/45	1986	Aberg & Bjurstedt
951	80	6911700	1577650	17H	Härmögranite, Kvissleby	1822±5	1995	Claesson & Lundqvist
	80	7245220	1567730	23H	Granite, Blaken	1809±8	1997	Eliasson & Sträng
	80	7328800	1821300	25M	Granite, Klinten	1783±3	1997	Wikström & Persson
	80	7360000	1585000	26H	Granite, Alleluoda	1767±9	1989	Öhlander & Billström
	80	7480070	1752500	28L	Granite, Vettasjärvi	1794±24	1988	Skiöld
	80	7507000	1706000	29K	Granite, Tjärveljarram	1794±24	1988	Skiöld
	80	7164000	1732500	22K	Tonalite, Kvarnberget	1895±14/-12	1995	Nilsson
933	90	7221000	1693000	23J	Quartz-feldsparporphyry, Tallberg	1886±15/-9	1991	Weihed & Schöberg
727	90	7234560	1683680	23J	Jörn G1	1888±20/-14	1987b	Wilson et al.
	90	7306700	1709300	25K	Granite, Kåtaberget	1892±62	1989	Öhlander & Billström
	90	7329200	1811900	25M	Granodiorite, Tore	1883±6	1997	Wikström & Persson
	90	7353000	1578000	26H	Granite, Guorbavare	1864±20/19	1985	Wilson et al.
	90	7392050	1654800	26J	Tonalitic gneiss, Norvijaaur	1926±13/11	1993	Skiöld et al.
	90	7394550	1652800	26J	Granite, Juoksokko	1876±6	1993	Skiöld et al.
	90	7451700	1724040	28K	Metadiorite, Aitiik	1873±24	1988	SGU (unpublished)
	90	7514000	1729500	29K	Granodiorite, Hopukka	1886±14	1988	Skiöld
	90	7515620	1745900	29K	Granodiorite, Lehtovaara	1886±14	1988	Skiöld
	90	7517000	1729000	29K	Granodiorite, Jänkkijärvi	1886±14	1988	Skiöld
	90	7543000	1817500	29M	Granodiorite, Puristakero	1873±23 (1858)	1981	Skiöld
	90	7543000	1817500	29M	Granodiorite, Puristakero	1880	1981	Lindroos & Henkel
	90	7546300	1724200	29K	Metadiorite, Maattavaara	1881±7	1981	SGU (unpublished)
	90	7555000	1578000	Tonalite,	Gautelis, Norge	1940±26	1992	Romer et al.
	90	7567640	1681640	30J	Granite, Lulep Patsajäkel	1877±14	1999	Martinsson et al.
	90	7580700	1751800	30L	Granodiorite, Juolovanjärvet	1847±19 (1864±17)	1981	Skiöld
	90	7590000	1791000	30L	Granodiorite, Paittasjärvi	1880±28	1979a	Skiöld
927	92	7196000	1692600	22J	Ortogneiss, Sikträsk	1856±8	1993	SGU (unpublished)
	92	7196000	1692600	22J	Sikträsk granodiorite	1859±3	1993	Weihed & Vaasjoki
729	92	7222590	1687300	23J	Jörn G2, Skidbacken, Jörn	1854±8.9	1996	Billström & Weihed
	92	7222590	1687300	23J	Jörn G2, Skidbacken, Jörn	1874±48/-26	1987b	Wilson et al.
	92	7223500	1715820	23K	Tonalite vein, Stavaträsk	1874±3	1999	Lundström et al.
1133	92	7226380	1721900	23K	Diorite, Stavaträsk	1877±2	1997	Lundström et al.
1132	92	7247600	1706800	23K	Granite (G3), Hobergsleden	1862±14	1997	Lundström et al.
1137	92	7256000	1771250	24L	Tonalite vein, Degerberget	1865±24/-10	1997	Persson & Lundqvist
1145	92	7264550	1760400	24H	Haparandagrä, Karlberg	1867±11	1997	Wikström & Persson
736	92	7275800	1562300	24H	Older Granite, Doubblon	1877±21	1988	Skiöld
1163	92	7286700	1782600	24L	Tonalite breccia, Måttsundsberget	1879±4	1996b	Wikström et al.
602	95	6632481	1398511	11E	Horrsjögranite	1850±87	1983a	Aberg et al.

ID	Grp	N-S	E-W	Map	Object	Age	Year	Reference
1140	95	6646600	1546980	11G	Sala-Vängegranite, Sala	1891±6	1997	Ripa & Petsson
765	95	6655920	1534350	12G	Salagranite	1890±3	1993	Persson
627	95	6694000	1485000	12F	Primorogenic granite, NNO Ludvika	1869±9/8	1984	Åberg & Strömberg:
609	95	6733488	1455883	13F	Synorogenic granite, Svärdsjö	1873±10/11	1983b	Åberg et al.
685	95	6853700	1521800	16G	Granodiorite foliated, Ljusdalsgranite	1843±2 (1852±25/8)	1993	Delin
1147	95	6853800	1451900	16F	Granite, Rullbo	1858±15	1996	Delin
902	95	6878300	1530700	16G	Granite, evengrained, foliated, Norrnjupen	1843±3	1993	Welin et al.
900	95	6882300	1523700	16G	Ljusdalsgranite, Tvårforsen	1848±4	1993	Welin et al.
897	95	6904500	1589000	17H	Granite, Njurunda	2030±6	1993	Welin et al.
894	95	6959300	1606000	18I	Granitoid, Oringen	1867±7	1993	Welin et al.
1159	95	7155730	1642200	22I	Qz-fsp porphyryvein, Knafthen	1940±14	1996	Wassström
692	95	7157120	1634980	22I	Granite, Knafthen	1954±6	1993	Wassström
	95	7191000	1606000	22H	Kattisavantonalite, Klodden	1902±2	1996	Biörk & Kero
	95	7216450	1579220	23H	Granodiorite, Barselse	1907±27/37		SGU (unpublished)
	95	7216930	1634140	23I	Kribergstonalite, Norra Svanaberget	1907±12	1999	Bergström et al.
1162	100	7292350	1780350	24L	Porphyritic Archean granite, Bällingsberget	2639±19	1996b	Wikström et al.
	100	7292350	1780350	24L	Granitoid, Bällingsberget	2638±19	1996b	Wikström et al.
	100	7341355	1870300	25N	Gneiss, Kukkola	2670±18	1987a	Ohlander et al.
	100	7526520	1675800	29J	Granite, Saarijärvi	2710±4	1998	Skiöld & Page
	100	7568600	1689250	30J	Gneissgranite, Vuollosjärvi	2760	1971	Welin et al.
	100	7572500	1601000	30I	Tonalite, Sjangeli	2709±323	1992	Romer et al.
	100	7588000	1733000	30K	Gneissgranite, NV Soppero	2834±40	1979b	Skiöld
	100	7631020	1697840	31J	Metatonalite, Rastojaure	2679±12	1999	Martinson et al.
	100	7631500	1734200	Granodiorite, NV Karesuando, Finland	2800	1969	Mattisto	



Geological Survey of Sweden
Box 670
SE-751 28 Uppsala
Phone: +46 18 17 90 00
Fax: +46 18 17 92 10
www.sgu.se

Uppsala 2001
ISSN 0349-2176
ISBN 91-7158-656-3
Print: Elanders Tofters AB