SVERIGES GEOLOGISKA UNDERSÖKNING

SER C NR 666 AVHANDLINGAR OCH UPPSATSER ÅRSBOK 65 NR 12

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Rb – Sr RADIOMETRIC AGES OF EXTRUSIVE AND INTRUSIVE ROCKS IN NORTHERN SWEDEN. I.

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C. DAVIDSONS BOKTRYCKERI AB, VÄXJÖ 1972

CONTENTS

Abstract

Rocks and minerals from northern Sweden have been analyzed for Rb, Sr and Sr isotopic composition. The following radiometric ages have been calculated:

Revsund granite	1785 ±40 m.y.
Sorsele granite	1625 ±45 m.y.
Lina granites	1565 ±25 m.y. and
	1820 ±50 m.y.
Acid volcanics, Duobblon	1725 ±75 m.y.
Acid volcanics, Kaska Tjåurek	1635 ±90 m.y.
Acid volcanics, Kiruna	1605 ±65 m.y.

Gneissic granites from the Vuolosjärvi-Vakkojärvi area north of Kiruna indicate an age of 1750 m. y. which is not in accordance with meagre geological observations and with zircon and sphene dating. Possibly the rocks have been downdated by a metamorphic event 1800–1700 m.y. ago. Owing to this event the rocks were presumably chemically opened and new material added, resulting in an initial Sr^{87}/Sr^{86} of 0.716.

Introduction

The radiometric dating presented in this paper has been carried out at the Geochronological Laboratory in Stockholm during the years 1966–1969. The laboratory was founded 1966 on a grant from Malmfonden (Foundation for scientific research and industrial development) and is presently operated with support of grants from STU (Swedish board for technical development). The field work and the collecting of samples has been carried out in co-operation with geologists at the Geological Survey of Sweden and the mining company Luossavaara-Kiirunavaara AB.

The present work does not involve a detailed discussion of the geological evolution of northern Sweden based on the submitted radiometric ages but is confined to the interpretation of the analytical results and the significance of calculated ages. The petrogenetic implications of the results will be discussed to a limited extent. In a separate paper the stratigraphic conclusions drawn from the calculated ages will be discussed in detail (Welin 1970). For a description of the geological evolution of northern Sweden the reader is referred to that paper. A summary of this paper is given here in the last chapter. The chemical preparation of the investigated samples has been carried out by Mr. Knut Christiansson and the mass spectrometric analyses by Mr. Östen Nilsson.

Results of the present study

Petrographic descriptions and the geographic locations of the samples are given in the Appendix. The location of the samples is also marked on the maps, Figures 1, 4, 6, 8, 11 and 13. The geological mapsheets of Norrbotten and Västerbotten counties have served as a base for these maps (Ödman 1957, Gavelin 1955), whereas Figure 13 is based on the geological mapsheet SGU Ser Af nr 3 (Offerberg 1967). The detailed map, Figure 9, of the Gällivare area is based on the topographical map 1:50 000.

The content of rubidium and strontium in the investigated samples has been determined by isotope dilution analyses after a preliminary determination by X-ray fluorescence spectrography. Six detailed XRF-analyses on pressed briquettes of rock powder have been carried out according to a technique described by Norrish and Chappell (1967) and by Pankhurst (1968). These analyses have been used in the calculation of the age of the rocks in Table 7. Sr^{87}/Sr^{86} has been measured in unspiked samples and normalized to $Sr^{86}/Sr^{88} = 0.1194$. Results of these analyses are given in Tables 1, 2, 4, 6, 8, 10 and 11. A detailed description of the laboratory treatment of the samples is the subject of a future publication. The percent standard deviation of a single analysis for the measured Sr^{87}/Sr^{86} is 0.20 and 1.5 for the Rb^{87}/Sr^{86} as calculated from replicate analyses. The value of the normalized Sr^{87}/Sr^{86} of the Eimer and Amend $SrCO_3$ Lot 492327 is 0.707 ± 0.001. All results are quoted to an arbitrary value of 0.708 for this ratio by adding 0.001. Repeated blank analyses show a contamination of less than 0.05 μg rubidium per analysis and 0.1 μg strontium per analysis. The Sr^{87}/Sr^{86} and Rb^{87}/Sr^{86} ratios have been plotted on isochron diagrams (Figures 2, 5, 7, 10, 12, 14 and 15). The calculation of the ages using $\lambda = 1.39 \cdot 10^{-11} yr^{-1}$ has been made according to a statistical method of McIntyre et al (1966) and the results are given in Tables 3, 5, 7, and 9.

The statistical assessment of Rb-Sr isochrons by McIntyre et al (1966) is based on a least squares regression which takes into account errors in the Rb^{87}/Sr^{86} values as well as variations in the Sr^{87}/Sr^{86} ratio. The regression treatment of the data is made in four different models. The computer program has been made available for the present calculations through the courtesy of Dr. G. A. McIntyre, Canberra. The first model treats all cases where the scatter about the isochron can be assigned to experimental errors only. This means geologically that all analyzed samples had the same initial Sr^{87}/Sr^{86} and that the chemical system of the samples became closed to Rb and Sr loss or gain in a time span which was short compared to the experimental precision of the measurements (Heier and Compston 1969). If these geological conditions are not present and if the analytical precision has been sufficient to resolve the data, the mean square for weighted deviates (MSWD) of the regression will exceed unity. An F-test is customarily applied on the MSDW-value and if the tabulated F-value at 0.05 probability level is larger than the calculated MSWD, the samples are referred to model 1. In the present investigation only this model is considered.

A. GNEISSIC GRANITES FROM THE VUOLOSJÄRVI-VAKKOJÄRVI AREA

The samples 65027 and 65028 from the Vuolosjärvi-Vakkojärvi area north of Kiruna (Fig. 1) were collected in co-operation with Mr. B. Ericsson, Geological Survey of Sweden (SGU). Since the area is not easily accessible the

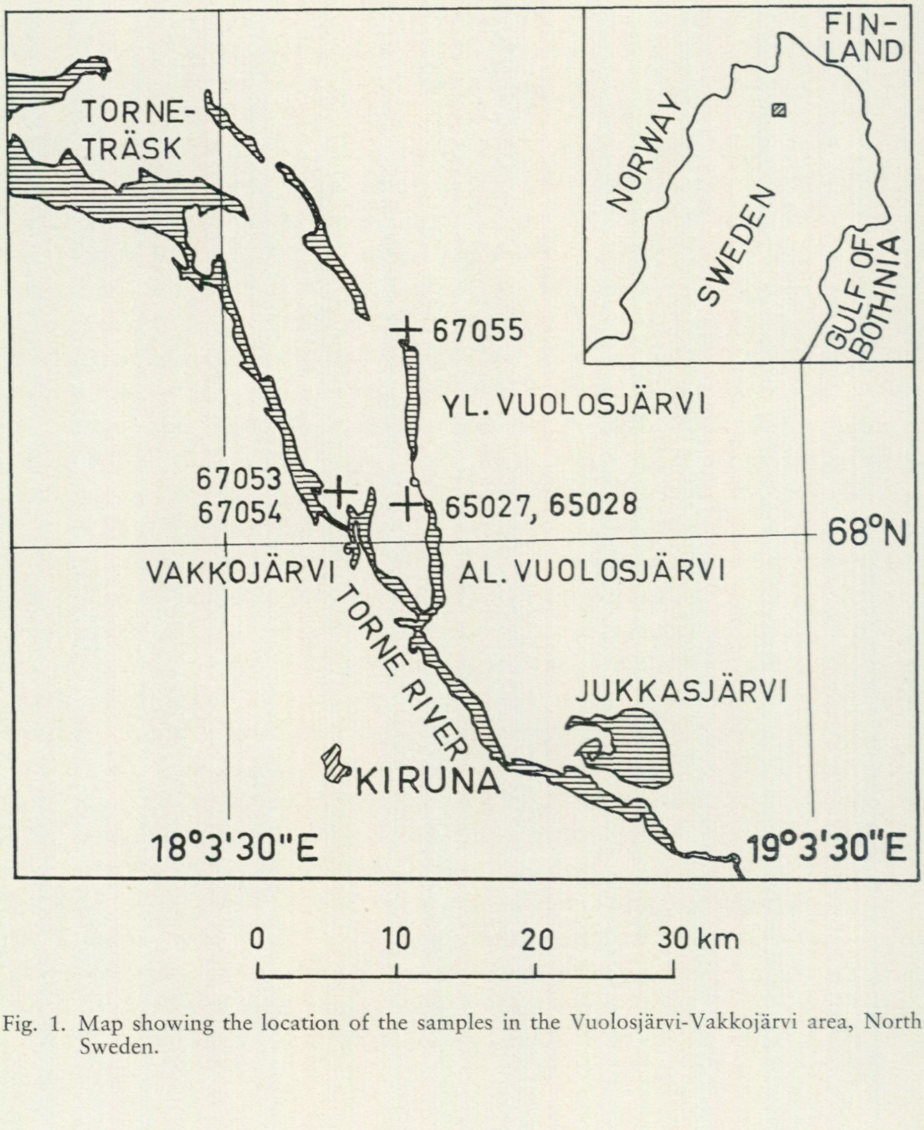

Fig. 1. Map showing the location of the samples in the Vuolosjärvi-Vakkojärvi area, North Sweden.

samples (67053–67055) collected by Dr. G. Kautsky, SGU were included in the investigation. All specimens consist of gneissic granites or quartz-diorite (67055), which often contain large microcline porphyroblasts. According to the geological mapsheets of the Norrbotten county (Ödman 1957) the granites and quartz-diorites form a large massif which extends southwards to the Kiruna-area (Offerberg 1967). Offerberg considers the gneissic granites in the Kiruna-area to be the oldest rocks and separated by a large unconformity from a younger supracrustal formation comprising, for example, greenstones at Kiruna. The sampled area is roadless and mostly covered by moraine and swamps and no detailed geological maps are available. The geological evidence for coevality and cogeneticy of the collected samples is therefore not very firm but have been assumed to be valid for the present investigation and it is possible that the mapping work in progress, (which is based on aero-magnetic data), will modify the picture given above.

The analytical data of table 1 have, with the exception of the biotite samples 65027 Bi and 65028 Bi, been plotted on an isochron diagram (Fig. 2). All samples, except 67054 and 65028 Mi, fit an isochron with an "apparent" calculated age of 1750 m.y. ±105, and an "apparent" initial Sr^{87}/Sr^{86} of 0.716 ±0.002. The biotites also plot on this isochron. If they are included in the regression, the resulting age is 1750 ±40 m.y.. The initial Sr^{87}/Sr^{86} remains unchanged. The MSWD for this regression is 2.94, which is a model 1 fit at the 95 % level.

Table 1. Analytical data for granites from the Vuolosjärvi-Vakkojärvi area

Sample	Rb ppm	Sr ppm	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86} measured (Sr^{86}/Sr^{88} = 0.1194)
65027	111.3	330.5	0.98	0.742
65027 Pl	14.0	124.2	0.33	0.721
65027 Mi	215.5	216.7	2.90	0.788
65027 Bi	718.0	36.8	65.36	2.315
65028	85.4	181.3	1.37	0.750
65028 Pl	16.3	137.6	0.34	0.729
65028 Mi	234.9	149.0	4.60	0.788
65028 Bi	471.0	30.3	50.53	1.967
67053	116.9	100.3	3.41	0.800
67054	162.0	183.3	2.57	0.757
67055	154.5	473.5	0.95	0.736

However, geological evidence implies that the age, 1750 m.y., is too young (Offerberg 1967, Welin 1970, Welin et al 1970). Further an unpublished dating of zircon and sphene from the quartz-diorite 67055, has been made by Dr O. Kouvo, Geological Survey of Finland. Due to the courtesy of Dr G. Kautsky, who supplied Dr Kouvo with this sample, the results of the dating have been

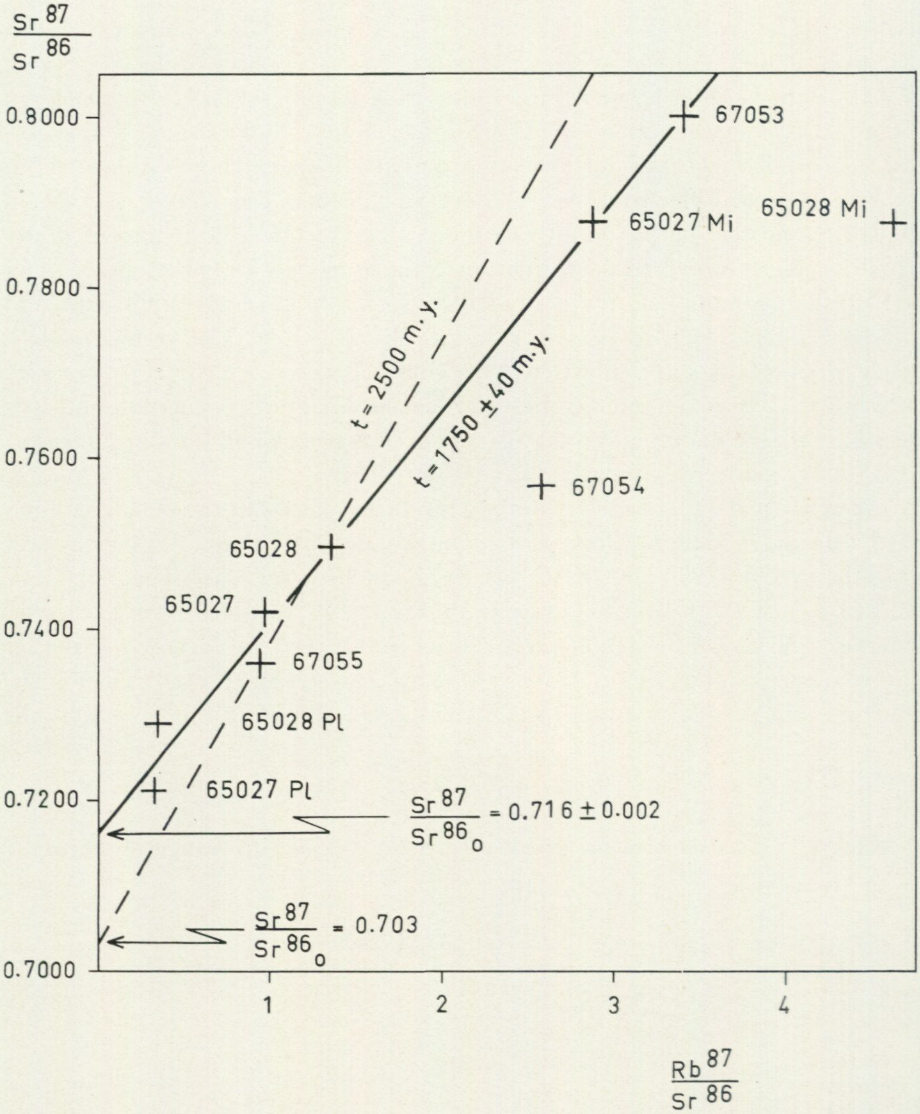

Fig. 2. Isochron diagram of whole rock and mineral samples from the Vuolosjärvi-Vakkojärvi area, North Sweden.

placed at our disposal for the present discussion. The sphene is fairly concordant showing a minimum age of 2750 m.y. whereas the zircon is highly discordant but lies on the diffusion curve of 2800 m.y. (Fig. 3).

The meagre geological evidence and the zircon dating thus imply that the Rb-Sr age 1750 m.y. is apparent. The result of radiometric dating (Heier and Compston 1969, Welin 1970) in northern Sweden and Norway discloses re-

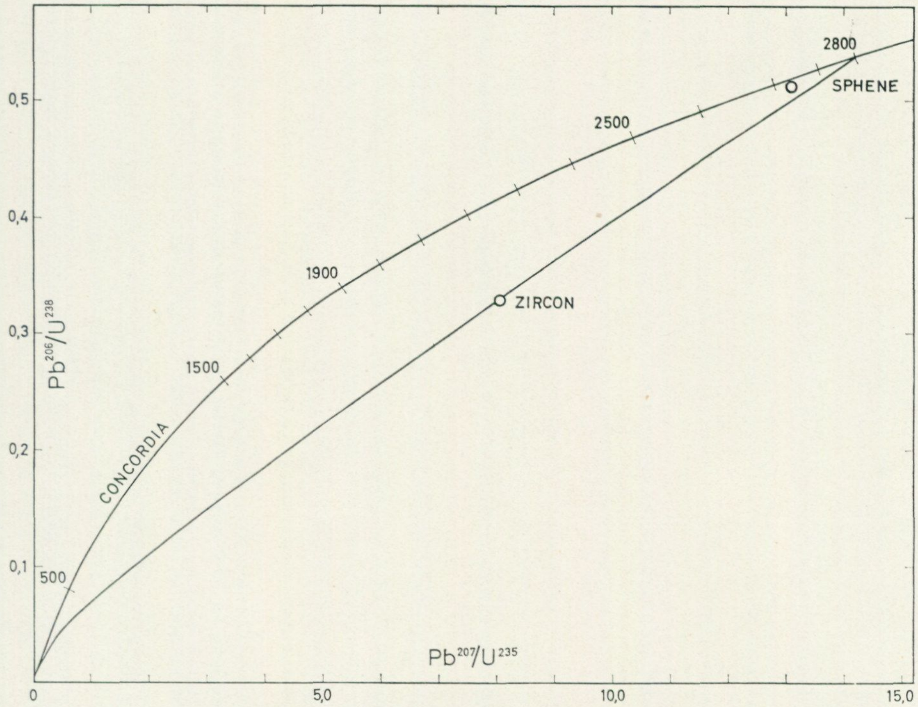

Fig. 3. Concordia-plot of zircon and sphene from sample 67055. Vuolosjärvi-Vakkojärvi area, North Sweden. Analyst: Dr O. Kouvo, Geological Survey of Finland.

peated late-kinematic and post-orogenic igneous activity between approximately 1800 and 1550 m. y. In discussing the present Rb-Sr data it is notable that high initial Sr^{87}/Sr^{86} seems to be found in Northern Sweden mostly in young post-orogenic granites (p. 13 and Gulson 1971) whereas all syn- and late-kinematic granites so far investigated have Sr^{87}/Sr^{86} below 0.710. The high initial ratio of 0.716 of the gneissic granites thus could be a result of an open system behaviour. Considering that the sample 67055 used for zircon and sphene dating is less altered than the other analyzed rock samples (see Appendix) a calculation of the age of this sample can be made. Based on an initial ratio of 0.703, which is a reasonable value for an unaltered, uncontaminated old quartz-diorite, an age of 2500 m. y. is obtained. This is illustrated in Figure 2 by a dashed isochron through 67055 and initial $Sr^{87}/Sr^{86} = 0.703$.

In conclusion it might be possible that the Rb-Sr age 1750 m. y. is a result of a complete downdating of the older bedrock during metamorphic events between 1800 to 1700 m. y. However, evidently more isotopic work based on a better geological knowledge of the area are needed to elucidate this problem.

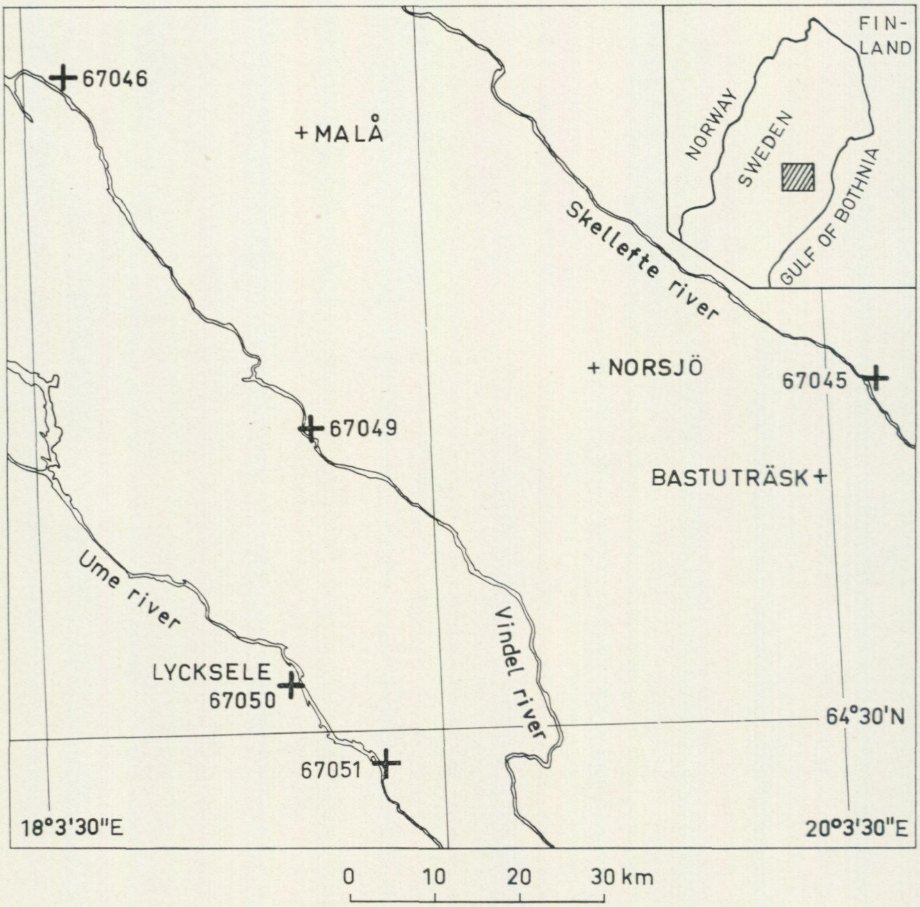

Fig. 4. Map showing the location of the samples in the Lycksele area, North Sweden.

The samples 67054 and 65028 Mi apparently represent an alteration later than the 1750 m.y. event. Possibly the microcline 65028 Mi has suffered a loss of total strontium or Sr^{87} in particular, since the total amount of strontium is low as compared to the microcline 65027 Mi and since a slight sericitization is observable in the 65028 Mi. No explanation can, at the moment, be given for the sample 67054.

B. THE REVSUND GRANITES

The samples of Revsund granite have been taken from a batholith between the Skellefte River and Lycksele (Fig. 4). According to Gavelin (1955) there is a striking conformity between the distribution of Revsund granites on one hand and argillitic metasediments (phyllites and greywackes) on the other. The metasediments are generally developed as schists or veined gneisses. Gavelin interprets this association in the following way: "Either the gneisses are the result of a contact and injection metamorphism on a gigantic scale caused by a Revsund granite magma or are granites and gneisses both products of a regional deep-seated metamorphism initiated by the orogenesis. Many features support the latter. Continuous gradations from gneiss to even-grained granite with relic sedimentary structures are still visible, and analogous gradations from feldspathised gneiss to porphyritic granite evidence the occurrence of metasomatic granitisation in situ at some localities". He states further on: "In most cases, however, the granitised masses must have been mobile enough for behaving intrusive in a certain respect. According to the views of the author the process starts by pregranitic pegmatitisation, proceeds with granitisation, mobilisation and intrusive phenomena, caused by the last orogenic phases, which lead to overthrust and lateral folding in composite volcanite-phyllite regions and ends with post-granitic pegmatites." This view of the granite formation has been given in full as a background for the evaluation of the initial Sr^{87}/Sr^{86} values determined for the rock samples.

The results of the analyses for Rb, Sr and Sr isotopic composition are given in Table 2 and plotted on the isochron diagram, Fig. 5. The biotite 67046 Bi also plots on this isochron but 67050 Bi falls well below the isochron. The calculated ages are given in Table 3. These results show that the regressions (1–3) of the whole rock samples and minerals (the biotite 67050 Bi omitted in all regressions) give nearly the same age and the same initial Sr^{87}/Sr^{86}. However, the MSWD decreases to the minimum value for the third regression where 67050 Mi and 67046 Bi have been omitted. MSWD in this regression is 3.39 which is very near a fit at the 95 % level. The calculated age is 1785 ±40 m.y. and this is considered to be the most appropriate value. The isochron plot shows that the biotite 67050 Bi has suffered a loss of probably Sr^{87}. The microscopic investigation indicates that the biotites have undergone a slight chloritization.

The age 1785 m.y. for the Revsund granites is in good agreement with the Rb-Sr ages 1783 ±60 m.y. and 1769 ±140 m.y. on lepidolites from a pegmatite at Varuträsk located about 30 km. east of sample 67045 (Herzog 1961, recalculated to $\lambda = 1.39 \cdot 10^{-11} yr^{-1}$). This pegmatite is considered to be related to the Revsund granites (Gavelin 1955). The calculated age for the Revsund granites also agrees with previous age determinations on pegmatites associated with the late kinematic Svecofennian granites (Welin and Blomqvist 1964 and 1966).

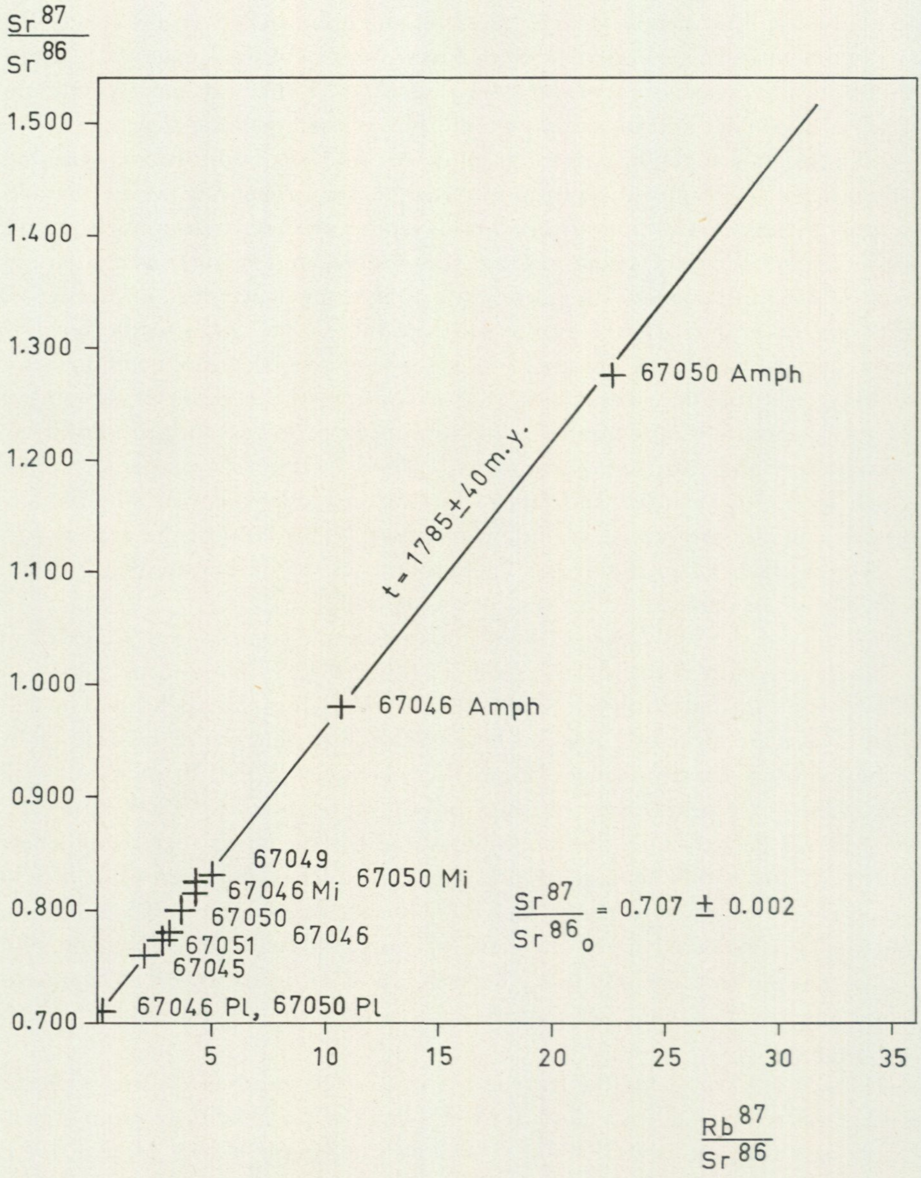

Fig. 5. Isochron diagram of whole rock and mineral samples from the Lycksele area, North Sweden.

Table 2. Analytical data for Revsund granites

Sample	Rb ppm	Sr ppm	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86} measured ($Sr^{86}/Sr^{88} = 0.1194$)
67046	159.1	152.7	3.04	0.780
67046 Pl	3.9	115.8	0.10	0.712
67046 Mi	287.6	198.2	4.22	0.816
67046 Bi	815.0	20.5	162.86	4.951
67046 Amph	121.5	33.4	10.66	0.980
67050	201.2	160.6	3.65	0.799
67050 Pl	3.2	117.9	0.08	0.710
67050 Mi	297.6	202.7	4.30	0.825
67050 Bi	876.6	15.7	250.62	6.339
67050 Amph	310.4	41.0	22.50	1.276
67045	152.9	209.9	2.11	0.759
67049	218.6	129.2	4.96	0.832
67051	185.1	192.2	2.94	0.774

In considering the petrogenetic interpretation of the formation of the Revsund granites (Gavelin 1955), the initial Sr^{87}/Sr^{86} is of particular interest. According to the third regression this ratio is 0.707 ±0.002. A granitization in situ of the metasediments would be reflected in the initial Sr^{87}/Sr^{86} ratio of the granite. However, the Sr^{87}/Sr^{86} of the metasediments is unknown. Published data for metasediments (mainly argillites and greywackes) of similar ages in

Table 3

Regression	Number of specimens	MSWD	Age (m.y.) $\lambda = 1.39 \cdot 10^{-11} yr^{-1}$	Initial Sr^{87}/Sr^{86}
All whole rocks and minerals, less 67050 Bi	12	5.19	1775 ±75	0.7082 ±0.0022
All whole rocks and minerals, less 67046 Bi and 67050 Bi	11	5.45	1805 ±60	0.7069 ±0.0044
All whole rocks and minerals less 67050 Mi, 67046 Bi and 67050 Bi	10	3.39	1785 ±40	0.7067 ±0.0019
All whole rocks	5	3.29	1860 ±215	0.7012 ±0.0098

Canada (Fairbairn, Hurley et al 1967, Fairbairn, Knight et al 1967) show a spread in the initial Sr^{87}/Sr^{86} between 0.706 and 0.719. Even in limited areas, for example the Sudbury region, the initial ratio varies strongly and indicates an origin from different source areas.

The metasediments of the Skellefte area are dominated by metaphyllites but also sediments of other lithology are present e. g. greywackes, feldspar-rich sandstones and conglomerates. According to Grip (1946) the metaphyllites are of a granitic character. Gavelin (1955) points out that the metasediments generally show a "fairly poorly chemical-sedimentological differentiation. They seem to be a very typical example of the greywacke series . . ., formed under the influence of a starting diastrophism and represent comparatively swiftly accumulated detritus". This description of the metasediments indicates a derivation from different erosional areas which probably consisted of rocks of mainly granitic composition. Therefore it is probable that the initial Sr^{87}/Sr^{86} varies in the different sediments and generally has been rather low. For this reason it is not possible, without a detailed isotopic study of the metasediments, to draw any conclusions about the petrogenetic significance of the initial Sr^{87}/Sr^{86} ratio for the Revsund granite.

C. SORSELE INTRUSIVES

A large igneous complex between Sorsele and Arjeplog has been given the name of the Sorsele granites. All samples have been taken from this area (Fig. 6), two of them (65136 and 65137) in co-operation with Dr H. Sarap and Mr.

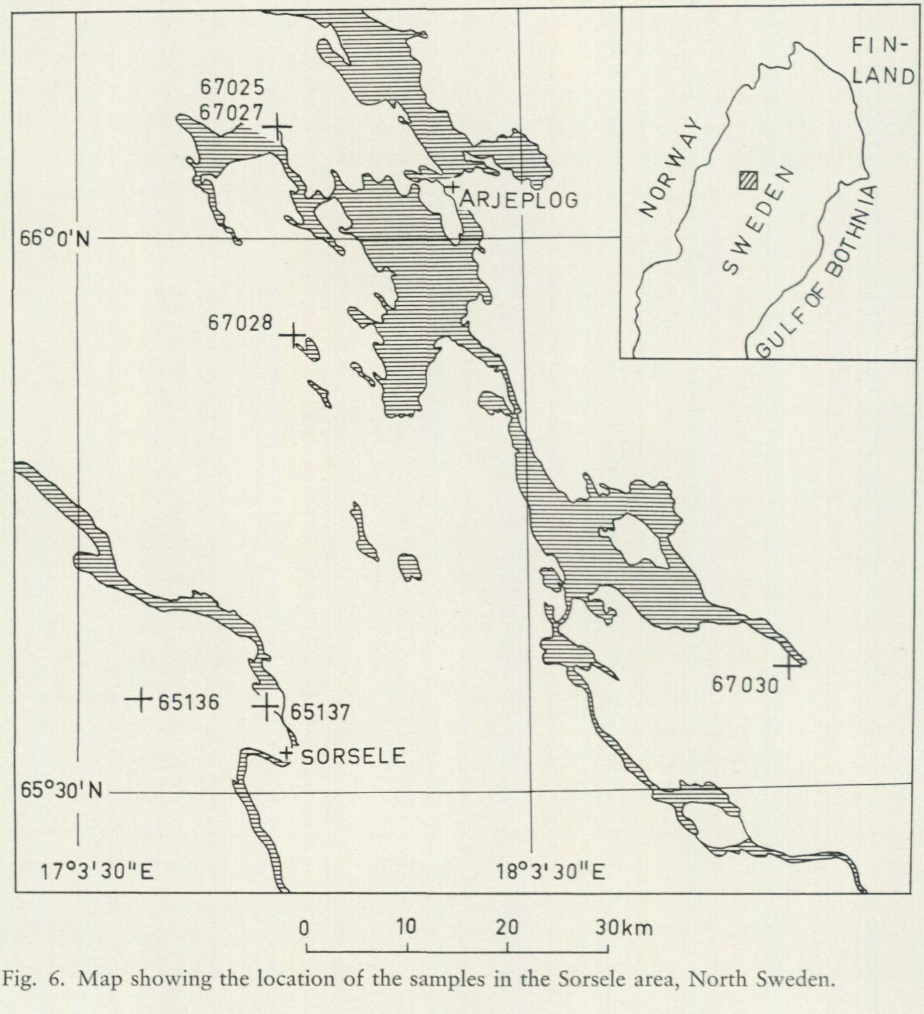

Fig. 6. Map showing the location of the samples in the Sorsele area, North Sweden.

Ö. Einarsson, SGU. Smaller massifs of the Sorsele intrusives occur further to southeast in the direction to the Skellefte area.

The main massif of Sorsele intrusives is fairly heterogeneous and consists of several petrographic modifications (Gavelin 1955). Most widespread are coarse, red to grey-red quartz monzonites (sample 67025, 67027, 67028 and 67030). Other varieties are red granite porphyries (sample 65136) and as a marginal facies, in the southwestern part of the massif, grey hornblende granites or grey quartz monzonites (sample 65137). The latter rocks are only observed in the contact zone towards the Revsund granites and Gavelin (1955) suggests they have been formed by hybridization with the country rock.

The analytical results (Table 4) of the samples, except for 65136 Mi, have been plotted on an isochron diagram (Fig. 7). The results of the regression analyses are given in Table 5. The regression for all whole rock samples (regression 3) gives about the same result as for all whole rocks and the minerals from 65137 (regression 1). The calculations based only on 65137 and the minerals of this rock (regression 4) also agree with the previous regressions although naturally the standard deviation is larger.

Table 4. Analytical data for Sorsele granites

Sample	Rb ppm	Sr ppm	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86} measured (Sr^{86}/Sr^{88} = 0.1194)
65136	244.5	52.1	14.02	1.026
65136 Pl	51.6	54.9	2.75	0.804
65136 Mi	475.2	58.6	24.72	1.248
65137	150.7	234.7	1.87	0.750
65137 Pl	54.3	337.4	0.47	0.719
65137 Amph	94.8	32.7	8.56	0.900
65137 Mi	285.3	280.4	2.97	0.780
67025	93.5	289.7	0.94	0.725
67027	160.1	192.7	2.42	0.766
67028	172.0	132.8	3.78	0.794
67030	84.0	128.3	1.91	0.752

Table 5

Regression	Number of specimens	MSWD	Age (m.y.) $\lambda = 1.39 \cdot 10^{-11} yr^{-1}$	Initial Sr^{87}/Sr^{86}
All whole rocks and all minerals less 65136 Pl and 65136 Mi	9	2.83	1625 ±45	0.7079 ±0.0020
Whole rocks and minerals less 65136, 65136 Pl and 65136 Mi	8	3.22	1635 ±65	0.7076 ±0.0024
All whole rocks	6	2.80	1640 ±71	0.7068 ±0.0030
Whole rock sample 65137 and minerals 65137 Pl, Mi and Amph	4	3.31	1608 ±126	0.7092 ±0.0054
Whole rock sample 65136 and minerals 65136 Pl and Mi	3	1.12	1425 ±235	0.7487 ±0.0254

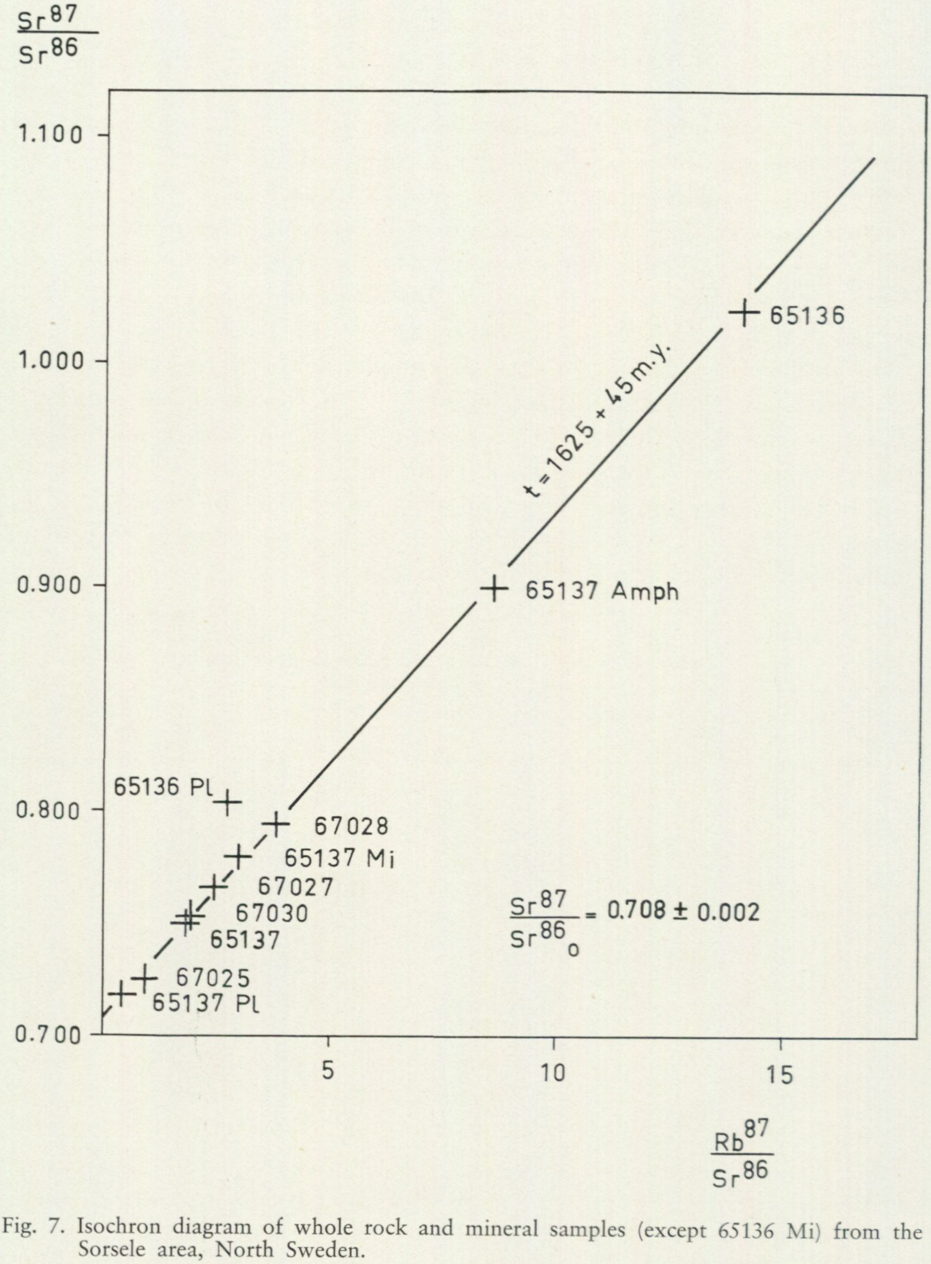

Fig. 7. Isochron diagram of whole rock and mineral samples (except 65136 Mi) from the Sorsele area, North Sweden.

Microscopic examination discloses that the minerals in sample 65136 are altered; the plagioclase is fairly sericitized and the biotite marginally chloritized. Consequently on the isochron diagram the plagioclase 65136 Pl plots above and microcline 65136 Mi plots below, the line. A regression of 65136 whole rock and its plagioclase and microcline gives an age considerably lower than a similar regression for 65137 (regression 5). The plagioclase 65137 Pl is slightly sericitized but less than 65136 Pl. Evidently a slight degree of sericitization has not significantly changed the position of the plagioclase on the isochron diagram in this particular case. The degree of sericitization is, however, excessive in 65136 Pl. In the second regression, the 65136 whole rock plus minerals have been omitted. The calculated age is 1635 ± 65 and initial Sr^{87}/Sr^{86} 0.708 ± 0.002. If the whole rock 65136 is included in the regression nearly the same result (1625 ± 45 m. y.) is obtained.

D. THE LINA GRANITES

The Lina granite in northernmost Sweden an northern Finland is named by the type locality near the Lina älv railway station. It has been characterized by Geijer (1966) in the following way. The granite "shows a characteristic development over an extensive region. The writer maintains that this granite, which is migmatitizing, cannot derive from remelting of the older geological units known in these parts, and that all its various batholiths must stem from a common deep-seated magma chamber. The phenomena observed to be associated with it are not palingenic, but illustrate the effects of a serorogenic, presumably palingenic granite on the formations into which it is intruded". Ödman (1957) on the contrary arrived to the conclusion that "the migmatitic granites are the result of palingenic processes in the older rocks. The source material was mainly pelitic sediments of Karelian age, but other rocks were also involved in these processes. In many cases the granites are believed to have passed through a magmatic stage and are unquestionably intrusive in their wall rocks, but on the other hand, there often occur gradual transitions from sediments to granites, containing ghost-like remnants of the former". Ödman further states that several different types of granites are recognized within the migmatite granite series. "The most common type is the Lina granite which is fairly uniformly developed throughout the whole Norrbotten". Other types show only slight differences from the Lina granite and may be local varieties of the latter.

Two of the problems mentioned above may be partly elucidated by radiometric dating. The first regards the possibly contemporaneous intrusion of all the "Lina" granite batholiths. The second problem concerns the genetic implication of the initial Sr^{87}/Sr^{86} of the different petrographic varieties. The

Table 6. Analytical data for Lina granites

Sample	Rb ppm	Sr ppm	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86} measured (Sr^{86}/Sr^{88} = 0.1194)
67001	185.1	71.6	7.73	0.916
67003	206.2	170.4	3.58	0.797
67005	424.8	44.1	30.30	1.480
67006	184.6	43.6	12.78	1.029
67009	161.1*	32.5*	14.77*	1.023
67010	205.3*	58.5*	10.40*	
67010	207.1	60.4	10.29	0.946
67011	66.8	9.5	21.31	1.179
67012	109.7	46.9	6.88	0.862
67013	62.7*	4.9*	40.08*	
67013	62.2**	5.4**	37.13**	1.538**
67014	122.5	228.6	1.56	0.746
67015	148.0	109.4	4.00	0.805
67015 Mi	378.8	105.4	10.65	0.943
67015 Pl	30.0	181.5	0.48	0.728
67015 Bi	746.8	24.8	105.70	2.877
67016	198.6	40.6	14.68	1.073
67017	196.8	72.6	8.01	0.913
67018	130.2*	131.6*	2.88*	0.777
67023	208.8*	120.9*	5.06*	0.829
67024	120.8*	72.5*	4.88*	0.832

* XRF-values
** mean of two set of values

Table 7

Regression	Number of specimens	MSWD	Age (m.y.) $\lambda = 1.39 \cdot 10^{-11} yr^{-1}$	Initial Sr^{87}/Sr^{86}
Samples 67009–67013	5	5.51	1565 ±65	0.7115 ±0.0107
Samples 67009–67013, 67014	6	4.14	1565 ±35	0.7117 ±0.0027
Samples 67015, 67015 Mi, 67015 Pl	3	2.01	1520 ±250	0.7180 ±0.0100
Samples 67001, 67005, 67006, 67016, 67017, 67024	6	4.59	1790 ±60	0.7112 ±0.0075
Samples 67001, 67005, 67006, 67016, 67017, 67024 and 67003	7	4.45	1820 ±50	0.7071 ±0.0047

results given in this paper are only an introduction to the solution of the problems.

In the present investigation one sample (67015) has been selected from the type locality near the Lina älv railway station (Fig. 8). To the southeast of this locality, in the neighbourhood of the Malmberget community (Fig. 9) petrographic varieties of this granite have been collected at Parvavaara (67011, 67012 and 67013), Kungsryggen (67009) and from a waste dump between the ore bodies Baron and Hermelin (67010, 67014). These latter samples originate from some of the granite dikes in this area as indicated on the map of Geijer

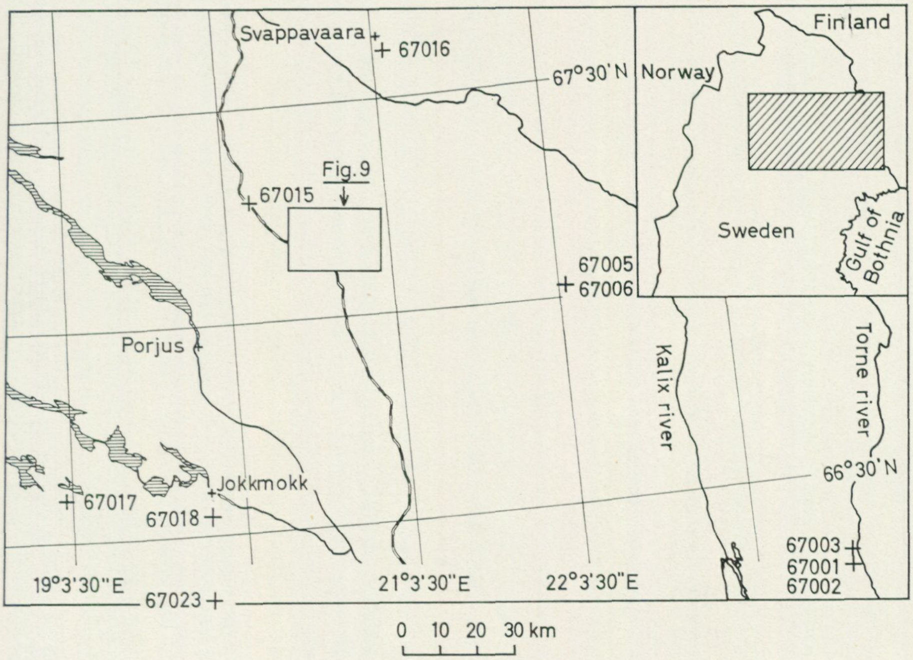

Fig. 8. Map showing the location of the Lina granite samples, North Sweden.

(1930). Nine more samples (67001, 67003, 67005, 67006, 67016, 67017, 67018, 67023 and 67024) were selected from various batholiths of the Lina granite type distributed within the Norrbotten county.

The analytical results are given in Table 6 and have been plotted on an isochron diagram in Fig. 10. The whole rock samples 67011, 67012 and 67013 from Parvavaara, 67009 from Kungsryggen, 67010 from the neighbourhood of the Baron and Hermelin ore bodies and the microcline 67015 Mi clearly fit one isochron and the samples 67001, 67017, 67006, 67016 and 67005 fit another isochron. The samples with low Sr^{87}/Sr^{86} i.e. 67015 Pl, 67014, 67018, 67003, 67015, 67023 and possibly also 67024 could fit either of these two isochrons.

Excluding 67015 Mi the whole rock samples of the first group are the basis for the first regression (Table 7). Since the sample 67014 obviously originate from the same granite dike as 67010 another age calculation has been made by adding 67014 to the previous group of samples. The calculated age is 1565 ± 35 m.y. and the initial ratio is 0.712 ± 0.003.

According to the geological maps by Geijer (1930) and Ödman (1957) the sample 67015 from the type locality may represent a batholith extending south-

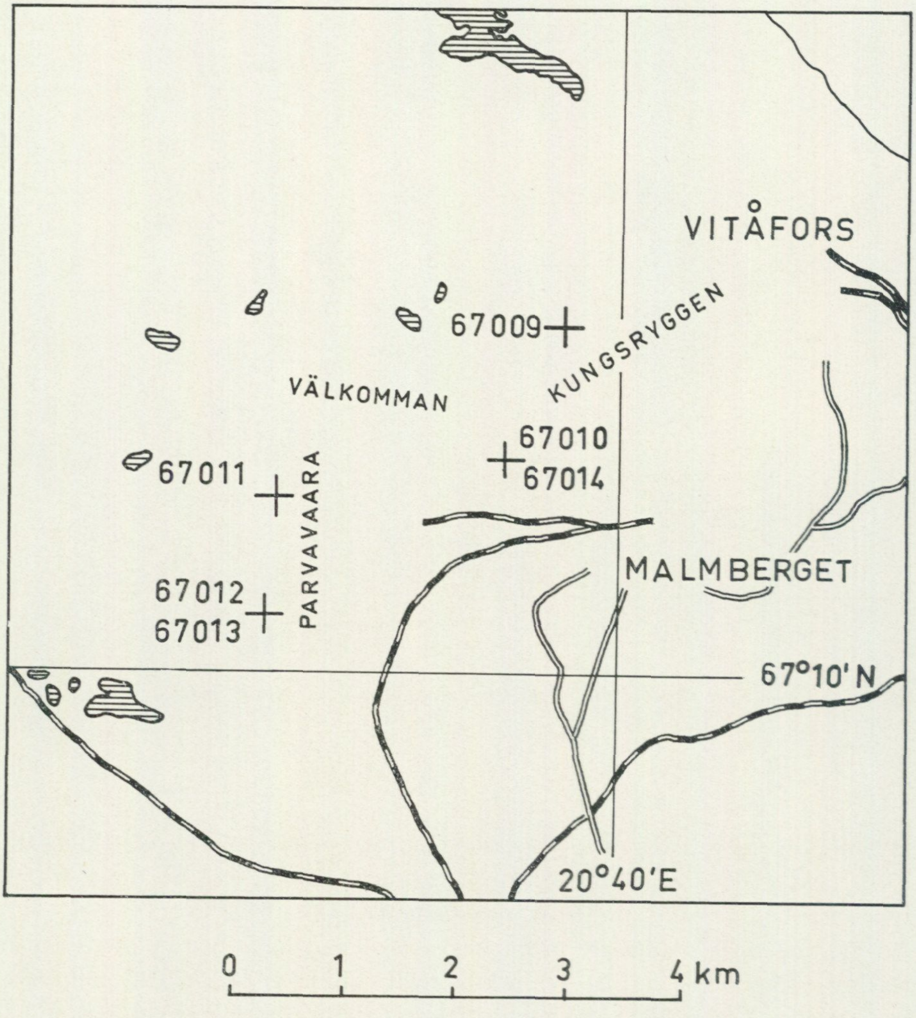

Fig. 9. Detailed map showing the location of the samples in the Malmberget area, North Sweden.

eastwards to Gällivare and Malmberget. In this area the sample 67009 should, according to the above mentioned maps, represent the same batholith. The petrographic characteristics of these two samples are, however, not the same (see Appendix). The sample 67009 clearly belongs to the younger isochron as does 67015 Mi. However, the Rb^{87}/Sr^{86} ratios of the whole rock 67015 and the plagioclase 67015 Pl are low and the samples may belong to either of the two isochrons. Furthermore 67015 is petrographically very similar to 67024 from Varjisträsk; the latter may (Fig. 10) belong to the older group of "Lina"

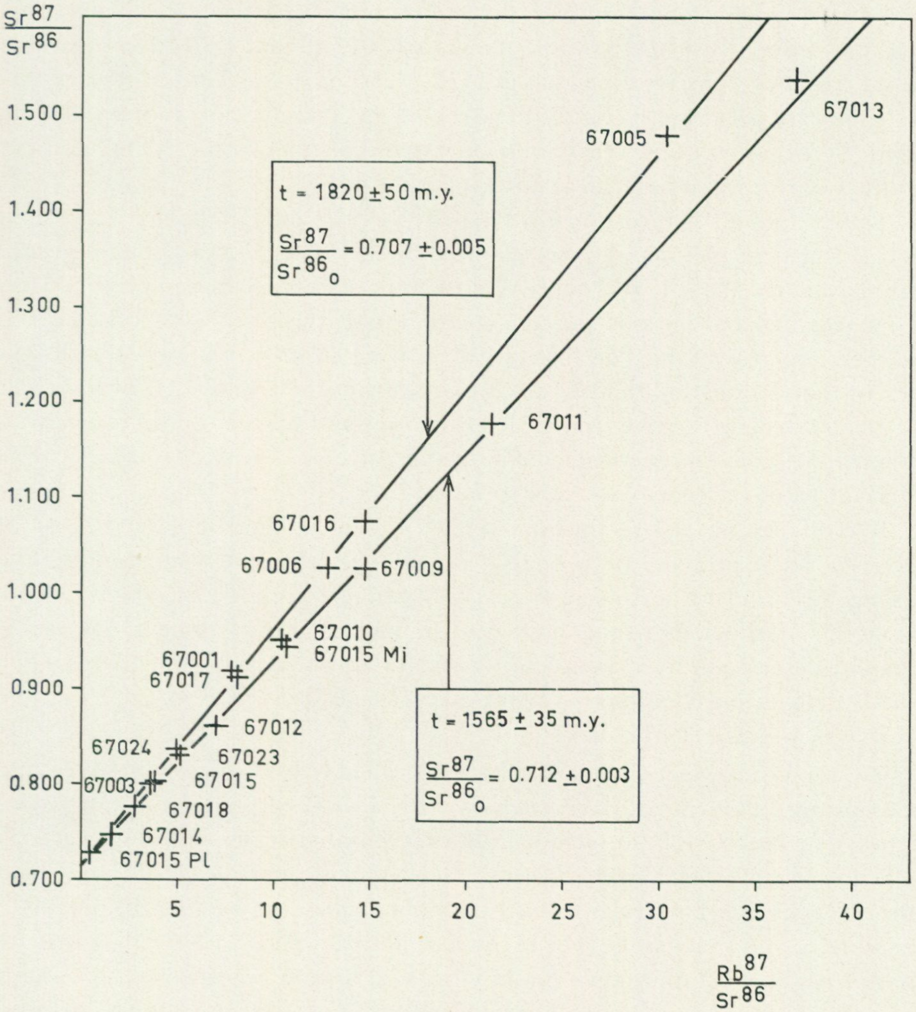

Fig. 10. Isochron diagram of whole rock and mineral samples (except 67015 Bi) of Lina granites, North Sweden.

granites. According to the petrographic description given in the Appendix the sample 67015 is altered, the plagioclase is extensively sericitized and the biotites are marginally chloritized. These alterations may indicate a loss and/or a redistribution of Sr^{87}. If 67015 in fact represents the older group of "Lina" granites this supposed loss of Sr^{87} may have occurred in connection with the formation of the younger, 1565 m.y. event. For these reasons, 67015 and separated minerals have not been included in the regressions of the younger group of "Lina" granite samples. A third regression has been calculated only on the whole rock 67015 and the minerals 67015 Pl and 67015 Mi separated from this rock. The resulting age is 1520 ±250 m.y. Evidently further investigations are necessary to clarify the detailed age relationships in the Gällivare area. At the present time it may only be stated that some of the "Lina" granites in the Gällivare area have an age of 1565 ±35 m.y.

The samples 67024, 67017, 67001, 67006, 67016 and 67005 have been used in the fourth regression as representatives of the older "Lina" granite group. The calculated age is 1790 ± 60 m.y. In the fifth regression the sample 67003 has been included since it is of the same petrographic type as 67001 and collected in the same area of the Torne river valley. With all probability they both represent the same batholith. The other two samples (67018, 67023) of low Sr^{87}/Sr^{86} could belong to either of the two isochrons and have not been considered. The fifth regression is considered to represent the most probable age, 1820 ±50 m.y., of the older Lina type granites.

Recently Heier and Compston (1969) presented data of granites east of Narvik. These granites are probably a continuation of the Vassijaure granite on the Swedish side of Riksgränsen. The Vassijaure granite is regarded by Ödman (1957) to belong to the migmatite granite series. According to the petrographic description by Ödman the Vassijaure granite is very similar to sample 67017. Heier and Compston (1969) give an age of 1715 ±90 m.y. for the Narvik-Riksgränsen granite.

To the southwest of Narvik (Hinnöy, Tjeldöy and Tysfjord) Heier and Compston (1969) have dated gneisses with an overall granitic composition. These gneisses have been included with the basal gneisses which are variably affected by the Caledonian orogeny. Heier and Compston (1969) state that these "rocks may have been formed throughout the time interval from 1500 to 1800 m.y. and thus not belong to any single event. Alternatively they may all have been formed approximately 1550 m.y. ago from a heterogeneous source material giving rise to variable initial Sr^{87}/Sr^{86} ratios". Heier and Compston (1969) do not give the calculated initial ratios.

Welin and Blomqvist (1964 and 1966) have published U-Pb ages of minerals collected from pegmatites in Northern Sweden. These ages were all approximately 1800 m.y. and the pegmatites have been considered to be associated with the "Lina" type granites. Another recent result has been published by Gulson (1971). He found the age of a perthite granite in Masugnsbyn and syenites in Sjaunja, both localities in Northern Sweden, to be 1535 ±30 and 1565 ±25 m.y. respectively. The initial ratios are 0.713 ±0.004 for the perthite granite and 0.710 ±0.002 for the syenites.

The result of the above investigations thus supports the present preliminary investigation which indicates that the rocks classified as Lina granites or migmatite granites in Northern Sweden may have been formed by intrusions at approximately 1800 and 1550 m. y. and thus separated in time by approximately 250 million years. The "apparent" initial Sr^{87}/Sr^{86} of the younger "Lina" granites is 0.712 ±0.003 and of the older intrusives 0.707 ±0.005. No definite conclusions can be drawn from these initial ratios due to large errors. However, the result implies that a difference in initial Sr^{87}/Sr^{86} between the two groups of granites may exist and does not contradict the geological interpretation about these rocks (p. 17) as being of palingenic origin.

E. ACID VOLCANICS AT DUOBBLON

The acid volcanics at Duobblon have been referred to the oldest volcanic suite, the Skellefte-Arvidsjaur-volcanics (Gavelin 1955). In the Duobblon area the volcanics overlie a conglomerate which in turn overlies a coarse-grained, phenocryst-rich granite. This granite has been compared to both the Revsund granite (Gavelin 1955), and the Jörn granite (Kautsky 1959). The age of the Duobblon granite is not known. According to the present work (p. 11) the age of the Revsund granite is 1785 m. y. and it is estimated that the age of the Jörn granite lies between 1785 and 1900 m. y. (Welin 1970). Both the Revsund and Jörn granites from the Skellefte area are intrusive into the Skellefte-Arvidsjaur volcanics; these volcanics are thus separated from the Duobblon volcanics by a marked unconformity. The volcanics in Duobblon are intersected by the Sorsele intrusives, which have an age of 1625 ±45 m. y. (p. 17).

Table 8. Analytical data for Duobblon volcanics

Sample	Rb ppm	Sr ppm	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86} measured (Sr^{86}/Sr^{88} = 0.1194)
65128	250.1	68.5	10.84	0.975
65129	209.1	182.7	3.34	0.786
65130	163.1	55.8	8.09	0.898
65131	211.5	56.7	11.08	0.972
65132	138.0	408.1	0.98	0.726
65134	115.7	74.7	4.53	0.813
65135	141.8	84.7	4.89	0.814

Table 9

Regression	Number of specimens	MSWD	Age (m.y.) $\lambda = 1.39 \cdot 10^{-11} yr^{-1}$	Initial Sr^{87}/Sr^{86}
All samples	7	3.60	1745 ±50	0.7013 ±0.0037
All samples except 65135 and 65128	5	0.53	1725 ±75	0.7030 ±0.0048

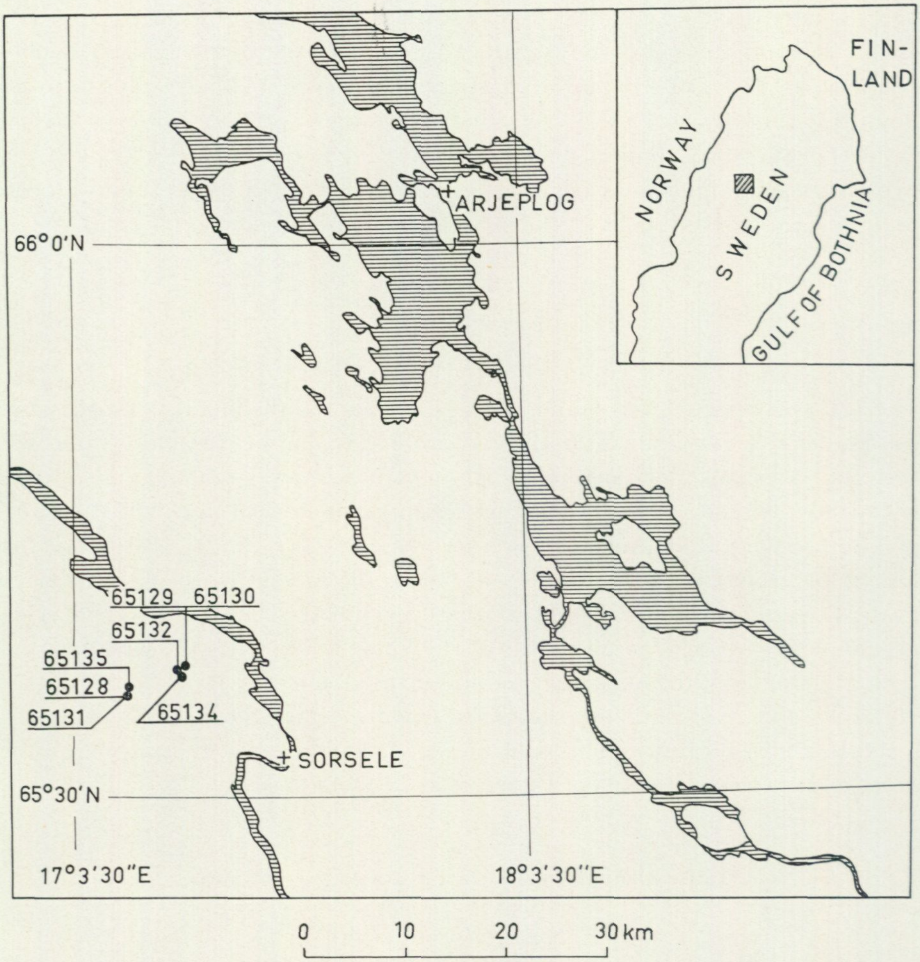

Fig. 11. Map showing the location of the samples in the Duobblon area, North Sweden.

The samples from Duobblon (Table 8 and Fig. 11 have been collected in co-operation with Dr H. Sarap and Mr. Ö. Einarsson, SGU. The volcanic rocks, rhyolitic in composition (Ö. Einarsson personal communication), have been called quartz-porphyries and feldspar-porphyries. Two regression analyses have been made (Table 9). The first regression is based on all samples, in the second regression the samples 65135 and 65128 are omitted. Both regressions give nearly the same result. However, the MSWD is lower on the second regression and this age, 1725 ±75 m.y., has been given on the isochron diagrams (Fig. 12). The volcanics are thus older than the Sorsele granites (1625 ±45 m. y., p. 17) but younger than the Revsund granites (1785 ±40 m. y.,

p. 11). This is in accordance with the geological observations although the age difference does not exceed the limits of the estimated analytical error. The initial Sr^{87}/Sr^{86} is 0.703 $\pm$0.005.

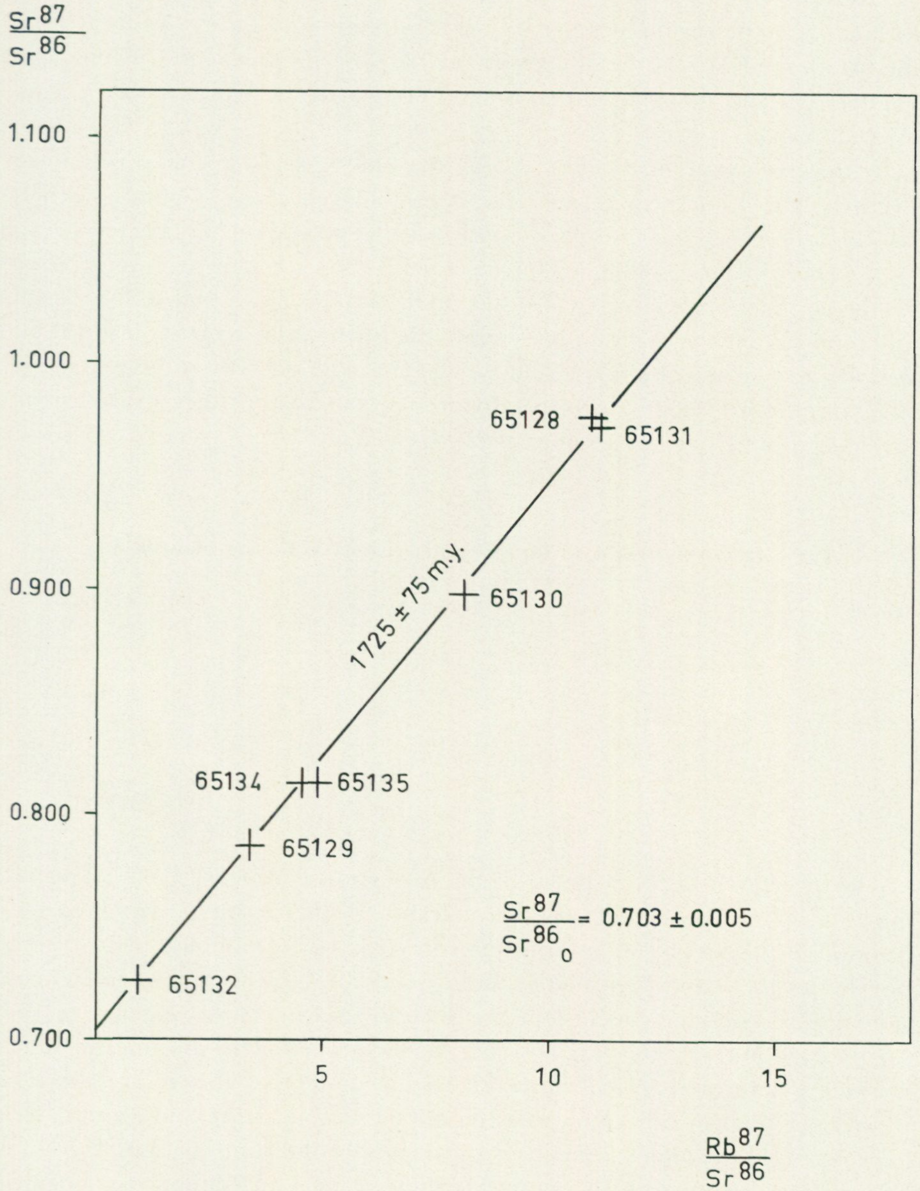

Fig. 12. Isochron diagram of whole rock samples from the Duobblon area, North Sweden.

F. ACID VOLCANICS AT KASKA TJÅUREK

To the south of the small lake Stuor-Ratek, 50 km. west of Kiruna, the bedrock consists of acid volcanics with minor intercalations of clastic sediments. The volcanic formation is gently folded to form an open anticline with a fold axis dipping to the southwest. On the basis of field relationships both Geijer (1931) and Offerberg (1967) refer the volcanics at Kaska Tjåurek to the same formation as the Kiruna porphyries, which occupy a large area eastwards. To the north and south the extension of the volcanic formation is limited by younger perthite or migmatite granites. Westwards the volcanics are covered by Caledonian rocks.

At the flat mountain Kaska Tjåurek the oldest layers in the anticlinal are exposed (Fig. 13). The samples have been collected in co-operation with Dr G. Nilsson, SGU, and consist of dark syenite porphyry (65010, 65011 and 65012) and rhyolite (65008, 65009 and 65013). Five samples have been plotted on the isochron diagram (Fig. 14), the sixth (65013) has a high Sr^{87}/Sr^{86} ratio and plots far off the diagram and below the isochron. A regression of the five samples give an age of 1635 $\pm$90 m.y. which is a model 1 fit at the 95 % level. The sample 65013 does not fit this isochron and indicates either a substantially lower age, which is not geologically possible, or "open" system behaviour. Possibly a loss of Sr^{87} has occurred.

Table 10. Analytical data for volcanics from the Kaska Tjåurek area

Sample	Rb ppm	Sr ppm	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86} measured (Sr^{86}/Sr^{88} = 0.1194)
65009	110.4	46.9	6.92	0.871
65010	71.9	76.7	2.73	0.783
65011	81.0	238.6	0.98	0.733
65012	99.4	52.4	5.56	0.841
65013	183.7	17.8	31.74	1.374
65008	114.4	60.2	5.57	0.839

The initial Sr^{87}/Sr^{86} calculated in the regression is 0.714 $\pm$0.005. This is a higher ratio than measured for other volcanics of the same type and geological position in the Svecofennian orogenic zone (compare Duobblon p. 24, Kiruna porphyries p. 30 and Welin and Lundqvist 1970). However, the error is considerable and definite conclusions are difficult to draw. Some possible reasons for the high initial ratio may, however, be mentioned. The volcanics at Kaska Tjåurek exhibit a recrystallization of the groundmass. This recrystallization is stronger than in other volcanics described in this paper and would likely have occurred in connection with the intrusion of the younger "Lina" granites and perthite granites approximately 1550 m.y. ago. An isotopic homogenization at this time could at most have lowered the calculated age of the volcanics

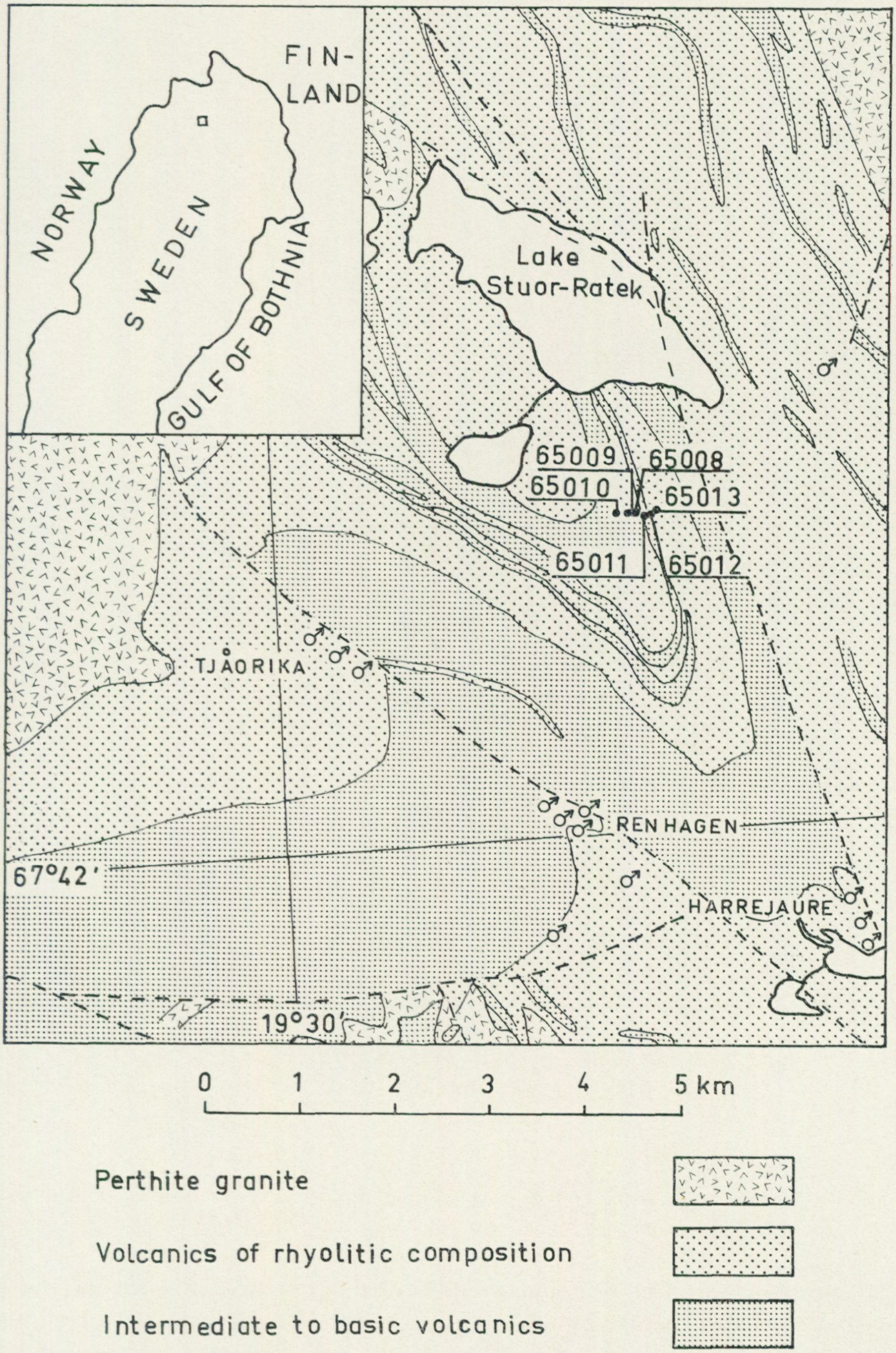

Fig. 13. Schematic geological map of the Kaska Tjåurek area, North Sweden, compiled from Offerberg (1967). Numbers refer to specimen localities.

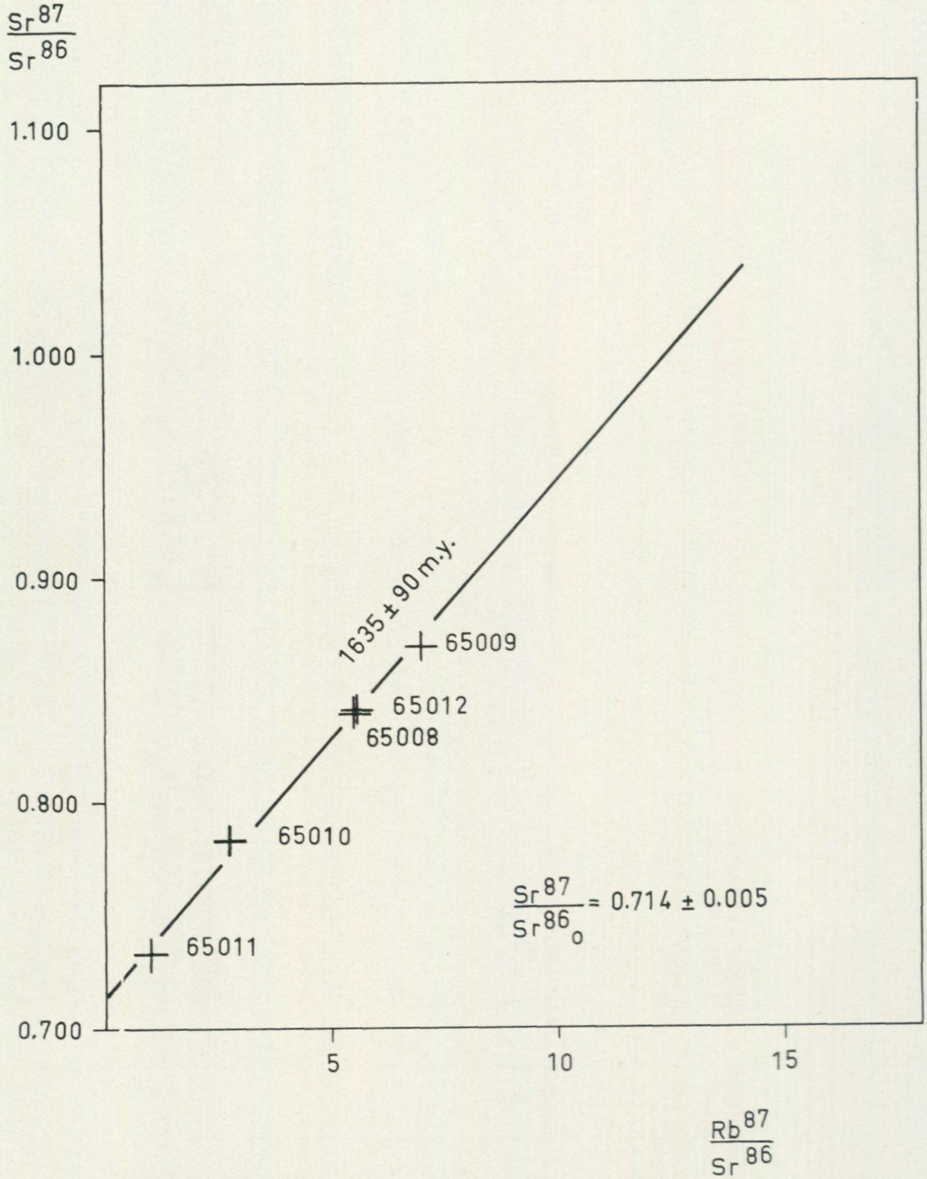

Fig. 14. Isochron diagram of whole rock samples from the Kaska Tjåurek area, North Sweden.

by approximately 100 m.y. and would probably not have affected the initial Sr^{87}/Sr^{86}. Another explanation is the commonly accepted view that a high initial ratio is an indication of assimilation of crustal material by the magma. This is not an unlikely explanation for the Kaska Tjåurek volcanics. This period of the geological evolution of the Svecofennian orogenic zone is characterized by the intrusion of palingenic magmas which might be genetically related to the volcanics (Lundqvist 1968, Ödman 1957). However, as already pointed out, other acid volcanics of the same geological position have initial ratios in the order of 0.703–0.707.

G. ACID VOLCANICS AT KIRUNA

The acid volcanics in the Kiruna area, generally called Kiruna porphyries, are geologically well known as country rock to the large iron ore in Kirunavaara. The volcanic formation has a steep dip towards the east. Between syenite porphyry as foot wall in the west and quartz porphyry as hanging wall in the east the intrusion of the magnetite ore has taken place. The volcanics in Kaska Tjåurek and in Kiruna belong, as mentioned in the previous chapter, to the same formation of acid volcanics. The eruption of these lavas has probably occurred during a time span which is short compared to the error in the age determination. It is therefore possible to regard the Kaska Tjåurek and Kiruna volcanics as contemporaneous eruptions. The volcanics are separated by an unconformity from underlying greenstones (Offerberg 1967, Welin 1970).

Table 11. Analytical data for porphyries from the Kiruna area

Sample	Rb ppm	Sr ppm	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86} measured ($Sr^{86}/Sr^{88} = 0.1194$)
65042	35.5	36.0	2.872	0.770
65043	41.9	61.0	1.997	0.748
65046	32.1	53.7	1.736	0.740
65047	67.4	55.7	3.548	0.793
65048	74.9	25.5	8.664	0.902
68073	57.3	26.5	6.343	0.845
68077	15.6	25.1	1.808	0.752
68078	27.9	27.4	2.966	0.773
68080	64.2	36.7	5.117	0.816
68082	36.9	100.0	1.071	0.732

The samples have been collected in co-operation with Dr J. v. Feilitzen, Luossavaara-Kiirunavaara AB. The syenite porphyry is represented by the samples 65047 and 65048 from Luossavaara and by 65043 from the Kiruna mine where the amygdaloidal variety (65042) and a porphyry vein (65046) were also collected. Other samples from the Kiruna mine have been taken from the drill core Bh 143, which cuts the quartz porphyry (68073, 68077, 68078), and the drill core Bh 631 which at the 507 m. level cuts through the syenite porphyry (68080, 68082). The drill core 143 is drilled from the surface and strikes the ore at 700 m. The samples have been collected approximately

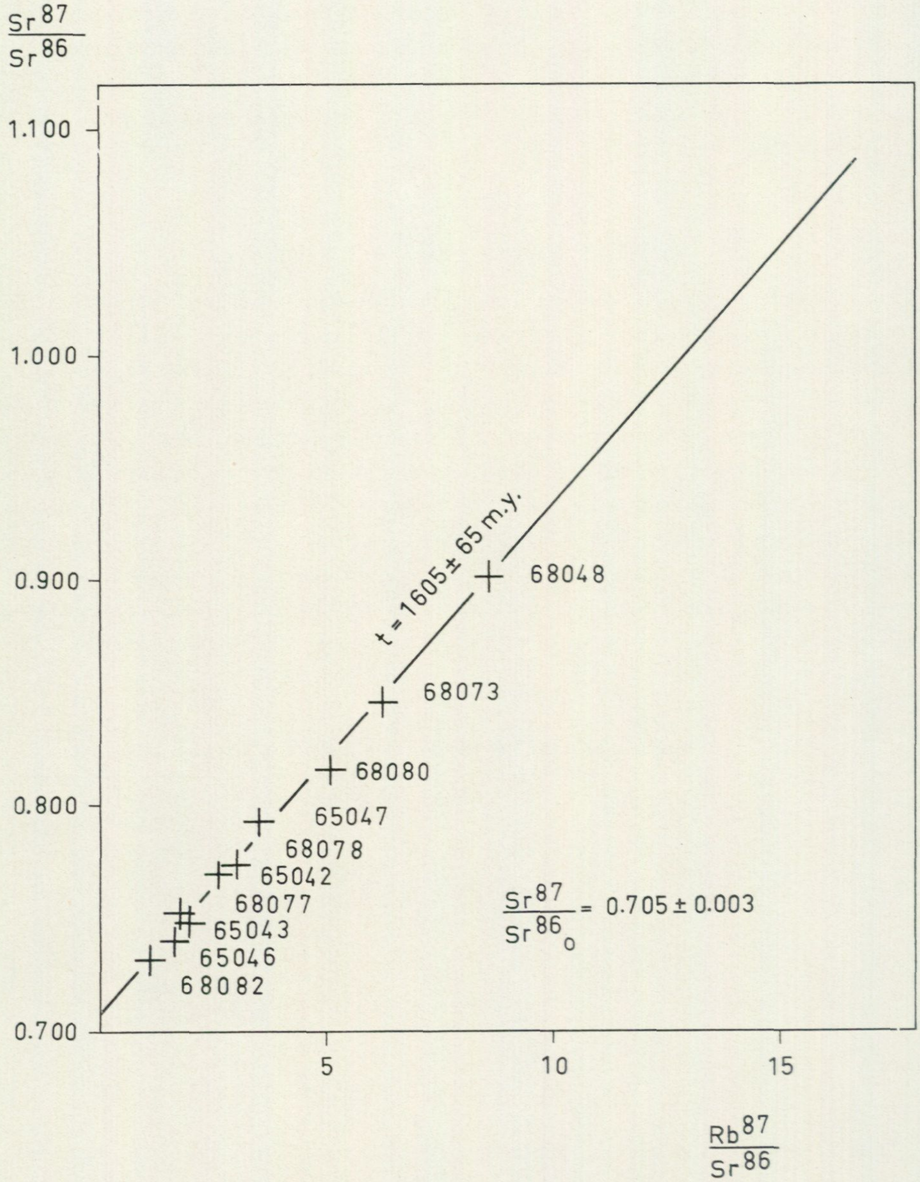

Fig. 15. Isochron diagram of whole rock samples from the Kiruna area, North Sweden.

285 and 34 m. apart. This corresponds to a vertical distance of approximately 160 and 18 m. in the original bedding of the lava flows.

A regression of all samples (Table 11, Fig. 15) gives an age of 1605 $\pm$65 m. y. The MSWD is 3.50 which is a model 1 fit at the 95 % level. This age is in good agreement with the age of the Kaska Tjåurek volcanics. The volcanics are according to Ödman (1958) cut by the Lina granite. The age of the youngest Lina granites is 1565 ±35 m. y. (p. 22). Since, however, fine-grained rocks more easily may suffer isotopic homogenisation further geochronological investigations in the Kiruna area are desirable for a confirmation of the age of the porphyries.

Concluding remarks

The results presented in the preceeding chapters as well as the result of Gulson (1971) imply a general pattern for the development of the Svecofennian orogenic zone. A preliminary discussion of this development has been the subject of another paper (Welin 1970). Since that discussion is partly based on the present results, a short abstract, with reference to the data presented above, will be given here.

The Svecofennian supracrustals were deposited on an approximately 2700 m.y. old basement which is represented in the present investigation by the gneissic granite samples from Vuolosjärvi-Vakkojärvi. The deposition of the geosynclinal rocks probably occurred between approximately 2100 to 1900 m.y. During this period of deposition supracrustal rocks of eastern, Karelian facies were formed in the northeastern part and of western, Svionian facies in the southwestern part of the orogenic zone. These geosynclinal rocks then became the subject of orogenic movements and during a period of intrusion and deformation between approximately 1900 and 1775 m.y. the main tectonic development occurred and most granites were formed (e.g. Revsund granites and parts of the Lina granites). During the subsequent generally post-deformative period a widespred volcanic activity, when e.g. the Duobblon and possibly the Kaska-Tjåurek and Kiruna volcanics were extruded, occurred in the western and southwestern part of the orogenic zone combined with the intrusion of intermediate and acid rocks (e. g. the Sorsele granites and parts of the Lina granites). In some areas the supracrustal rocks have been intensively folded during the emplacement of the intrusive rocks of this period. The youngest intrusives have been dated at around 1565 m.y. (parts of the Lina granites) and this may mark the end of the Svecofennian orogenic cycle.

Appendix

Petrographic data of analyzed samples. Longitude is referred to the Greenwich meridian.

A. GNEISSIC GRANITES FROM THE VUOLOSJÄRVI-VAKKOJÄRVI AREA

Sample 65027, 68°01′N, 20°22′E.
Coarse grained, grey gneissic granite with large microcline megacrysts. The rock consists of plagioclase (An 30, approx. 35 %) wich is partly altered to sericite and calcite, perthitic microcline as 15 mm phenocrysts (approx. 35 %), quartz exhibiting undulose extinction (approx. 20 %), biotite and xenoblastic green chlorite (together approx. 10 %). The chlorite is associated with magnetite and calcite. The accessories magnetite and apatite comprise some few percent of the rock.

Sample 65028, 68°01′N, 20°22′E.
Coarse grained, grey gneissic granite with microcline megacrysts. Very similar to sample 65027 but a slight sericitization of the microcline megacrysts is visible.

Sample 67053, 68°02′N, 20°15′E.
No thin section available.
Sample 67054, 68°02′N, 20°15′E.
No thin section available.
Sample 67055, 68°09′N, 20°22′E.

Coarse grained, slightly gneissic quartz diorite. The rock consists mainly of hypidiomorphic granular plagioclase (approx. 65 %), sericitized and intersected by small grains of secondary quartz and epidote. Flakes of green colored biotite associated with chlorite, sphene, apatite and epidote are frequently observed. Quartz showing undulose extinction (approx. 25 %), a few grains of microcline and calcite make up the rest of the rock.

B. REVSUND GRANITES

Sample 67045, 64°53′N, 20°09′E.
Sample 67046, 65°15′N, 18°08′E.
Sample 67049, 64°52′N, 18°43′E.
Sample 67050, 64°35′N, 18°41′E.
Sample 67051, 64°30′N, 18°54′E.

All the samples are very similar, and consist of a grey, coarse-grained massive rock with abundant large, (20 to 30 mm.) grey to white phenocrysts of microcline or perthitic microcline. The texture of the rock is hypidiomorphic-granular. The groundmass consists of quartz, microcline, plagioclase, biotite and hornblende. Quartz, occasionally undulose, is developed as hypidiomorphic grains. Large flakes of biotite (approx. 10 %) often show a slight chloritization. Minor amounts of slightly sericitized plagioclase (An 20) and green hornblende make up the rest of the rock-forming minerals of the groundmass. As accessories, abundant idiomorphic zircon and apatite, as well as some euhedral sphene have been observed. The plagioclase is sometimes zoned and occassionally the mineral is developed as a rim around the microcline phenocrysts. The separated amphibole fractions from 67046 and 67050 contain a few percent biotite.

C. SORSELE GRANITES

Sample 65136, 65°35′N, 17°11′E.
Medium-grained, red, massive granite with 6–7 mm. phenocrysts of microcline perthite (approx. 50 %). Quartz showing undulose extinction (approx. 30 %) occasionally exhibits a myrmekitic intergrowth towards the microcline. A partly altered plagioclase An 20 (approx. 10 %), and small amounts (less than 5 %) of chloritized biotite make up the rest of the rock.

Sample 65137, 65°35′N, 17°28′E.
Grey, coarse to medium-grained, quartz monzonite of massive structure. Phenocrysts of microcline perthite and plagioclase (An 25) and anhedral quartz make up approx. 80 % of the rock. The plagioclase is slightly sericitized. Unaltered biotite, green hornblende and accessories (apatite and opaque minerals) constitute the rest of the rock. The amphibole fraction may contain a few percent biotite.

Sample 67025, 66°06′N, 17°21′E.
Sample 67027, 66°06′N, 17°21′E.
Sample 67028, 65°55′N, 17°33′E.
Sample 67030, 65°36′N, 18°37′E.

All these samples are very similar. They consist of a red to grey-red, coarse grained quartz monzonite, which in sample 67028 is slightly schistose. All other samples are massive and exhibit a granitoid texture with 8–10 mm. phenocrysts of plagioclase, An 30. The plagioclase phenocrysts are partly or only slightly altered and occasionally contains poikilitic inclusions of microcline and quartz. Perthitic microcline may, however, also occur as phenocrysts. The groundmass consists of plagioclase, microcline and quartz encloses large flakes of biotite and green hornblende. The latter minerals often occur as clusters with inclusions of magnetite and sphene which give some of the samples a characteristic red and black, spotty appearance. The biotite is often marginally chloritized. The hornblende-biotite clusters make up approx. 20 %, microcline 40 %, plagioclase 30 % and quartz 10 % of the rock.

D. LINA GRANITES

Sample 67001, 66°17′N, 23°37′E.
Medium-grained, grey massive rock. Microcline perthite occurs as slightly hypidiomorphic grains and constitutes approx. 65 % of the rock. Undulose quartz (approx. 20 %), a partly sericitized oligoclase and biotite (approx. 5 %) make up the rest of the rock. The biotite grains are occasionally marginally chloritized. The texture is hypidiomorphic-granular.

Sample 67003, 66°19′N, 23°37′E.
Very similar to 67001 although less sericitized and no alteration of the biotite is visible.

Sample 67005, 67°00′N, 22°03′E.
Medium-grained, pale red rock with graphic texture. Fine grained microcline and a slightly sericitized oligoclase occur between graphically intergrown microcline and undulose quartz. Some flakes of muscovite are visible.

Sample 67006, 67°00′N, 22°03′E.
Coarse grained pegmatite segregation in rock 67005. Reddish microcline occur in clusters up to 5 cm. in diameter in a groundmass of oligoclase-albite, undulose quartz and biotite. No alteration of the minerals is visible.

Sample 67009, 67°12′N, 20°39′E.
Very similar to 67011. Microcline is more abundant and the plagioclase is slightly sericitized.

Sample 67010, 67°11′N, 20°39′E.
Very similar to 67014.

Sample 67011, 67°11′N, 20°36′E.
Medium-grained, pale red, slightly gneissose rock. Quartz (approx 40 %) occurs both as large allotriomorphic, slightly corroded 2–3 mm. grains and in the groundmass, which also contains microcline (approx. 40 %) and plagioclase (An 10). Some pale green amphibole and accessories (sphene, apatite and opaque) are also observed. The texture is granitoid. No alteration of the minerals is visible.

Sample 67012, 67°10′N, 20°36′E.
Very similar to 67011. The rock is, however, massive and biotite and hornblende are more abundant.

Sample 67013, 67°10′N, 20°36′E.
Very similar to 67011.

Sample 67014, 67°11′N, 20°39′E.
Medium-grained massive rock of red colour. The texture is hypidiomorphic-granular. Quartz and microcline make up approx. 90 % of the rock. Plagioclase (oligoclase), some pale biotite and pale green hornblende occur sparsely.

Sample 67015, 67°17′N, 20°12′E.
Coarse-grained, red rock with massive structure. The texture is hypidiomorphic-granular with large allotriomorphic phenocrysts of microcline (approx. 50 ‰) and plagioclase (An 10) (approx. 15 ‰). The plagioclase is extensively sericitized and the biotite (approx. 5 ‰) is marginally chloritized. The quartz grains show undulose extinction. As accessories sphene, apatite and zircon have been observed.

Sample 67016, 67°37′N, 21°06′E.
Pale red, medium to coarse-grained massive rock. Phenocrysts of microcline, slightly sericitized plagioclase (An 20) and weakly undulose quartz make up 95 ‰ of the rock. Small amounts of biotite and muscovite have been observed. Micrographic texture is observed in some microcline-quartz grains. The texture of the rock is hypidiomorphic-granular.

Sample 67017, 66°36′N, 19°00′E.
Coarse-grained, massive rock of hypidiomorphic and partly allotriomorphic texture with large phenocrysts of perthitic microcline (approx. 40 ‰). Undulose quartz (40 ‰), and large flakes of biotite (15 ‰) which is partly decomposed to an isotropic mineral enclosing opaque grains. Plagioclase (An 15) which occurs in small amounts is often sericitized and intersected by small quartz and microcline grains.

Sample 67018, 66°33′N, 19°51′E.
Coarse grained pegmatitic rock consisting of microcline and quartz. Some opaque grains are visible.

Sample 67023, 66°25′N, 19°41′E.
Medium grained, massive rock of brown-red colour. The texture is allotriomorphic. The rock consists of microcline(approx. 35 ‰), sericitized plagioclase (approx. 30 ‰), quartz showing undulose extinction (approx. 30 ‰) and small amounts of a slightly chloritized biotite.

Sample 67024, 66°02′N, 19°31′E.
Very similar to 67015.

E. VOLCANIC ROCKS AT DUOBBLON

Sample 65128,
Sample 65131, } 65°36′N, 17°10′E.

Grey porphyry with phenocrysts of idiomorphic to hypidiomorphic quartz (size 1–2 mm.) and lesser amounts of hypidiomorphic chessboard albite (size 0.5–2 mm.). The albite phenocrysts are occasionally slightly sericitized. The groundmass is an aphanitic (20–30 μ) mixture of albite and quartz with specks of sericite. An increased grain size around the phenocryst indicates an increasing recrystallization.

Sample 65129,
Sample 65130,
Sample 65132,
Sample 65134, } 65°36′N, 17°15′E.

Sample 65135, 65°36′N, 17°10′E.

Red brown to grey brown porphyries with 1–3 mm. idiomorphic to hypidiomorphic phenocrysts of feldspar and occasionally some phenocrysts of quartz. The feldspar phenocrysts usually consist of plagioclase (albite to oligoclase) with chessboard texture. These phenocrysts are often altered to sericite and intersected by small grains of quartz, calcite and epidote. A few phenocrysts of K-feldspar with perthite exsolutions of albite have also been observed. The indistinct phaneritic or aphanitic groundmass consists of quartz, sodic plagioclase, and subordinate magnetite, epidote and apatite. Spherulitic quartz is observed in the groundmass which also often exhibits a micropoikilitic texture. With increasing grain size the groundmass becomes granophyric.

F. VOLCANIC ROCKS AT KASKA TJÅUREK

Sample 65008,
Sample 65009,
Sample 65013, } 67°44′N, 19°33′E.

Red brown porphyry with grey to red, generally 2–4 mm. phenocrysts of hypidiomorphic plagioclase and microcline. The plagioclase is a rather pure albite which contains antiperthite exsolutions of K-feldspar. Sericitization is often discernible. The microcline phenocrysts are often perthitic. Generally albite is the dominating feldspar. The groundmass is partly aphanitic with sporadic micropoikilitic texture or a pseudofluidal texture. Partly the groundmass shows micro-granitic texture as a sign of a higher degree of recrystallization. The groundmass consists of quartz, feldspar, sericite and minor amounts of biotite and chlorite. Magnetite and apatite are acessories.

Sample 65010,
Sample 65011,
Sample 65012, } 67°44′N, 19°33′E.

Grey to dark grey syenite porphyry with 2–3 mm. hypidiomorphic phenocrysts of a sodium-rich plagioclase. The phenocrysts are often altered and intersected by sericite, biotite and calcite. This alteration is especially pronounced in sample 65012. The groundmass consists of plagioclase, biotite, chlorite and some quartz. Magnetite, apatite and sphene are accessories. The groundmass is usually phaneritic, rarely aphanitic. A parallel texture may also be observed. This texture is a result of a high recrystallization causing patches of more coarse-grained quartz and feldspar in the groundmass.

G. VOLCANIC ROCKS AT KIRUNA

Sample 68073. Drill core 143, depth from surface 150.5 m., Kiruna mine.
Sample 68077. Drill core 143, depth from surface 435.0 m., Kiruna mine.
Sample 68078. Drill core 143, depth from surface 469.1 m., Kiruna mine.

Pale red porphyries (quartz porphyries) with 1–3 mm. hypidiomorphic phenocrysts of alkali feldspar (<10 % An). The plagioclase phenocrysts often contains antiperthitic patches of K-feldspar and in most samples the phenocrysts are abundantly intersected by small grains of sericite, chlorite, quartz, magnetite and calcite. The usually aphanitic groundmass consists mainly of alkali-feldspar and quartz. As accessories are sphene, magnetite and chlorite needles. The texture varies; in the aphanitic types micropoikilitic and fluidal textures are observed, whilst in other samples recrystallized areas of coarser-grained feldspar and quartz are common.

Sample 65042, 370 m. level, Kiruna mine
Sample 65043, 370 m. level, Kiruna mine
Sample 65047 Luossavaara
Sample 65048 Luossavaara
Sample 68080. Drill core 631, 507 m. level, 36.7 m., Kiruna mine.
Sample 68082. Drill core 631, 507 m., level, 44.1 m., Kiruna mine.

Grey to grey brown syenite-porphyries with 2–3 mm. phenocrysts of akali-feldspar (generally <10 % An) containing patches of antiperthitic K-feldspar. The phenocrysts are often intersected by minute grains of quartz, chlorite, sericite, calcite and magnetite. The aphanitic to phaneritic groundmass consist of feldspar, pale green hornblende, some quartz, sphene, apatite, zircon, calcite and magnetite. The groundmass of the sample 65048 is recrystallized and schistose with fairly abundant biotite and hornblende in parallel bands. Sample 65042 contains amygdules filled with pale green hornblende, sphene, magnetite and apatite.

Sample 65046, 250 m. level, Kiruna mine.
Collected from a vein of syenite porphyry. Very similar in petrographic character to the syenite porphyries. The alkali plagioclase phenocrysts of this particular sample are frequently somewhat altered to sericite, calcite and epidote.

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