SVERIGES GEOLOGISKA UNDERSÖKNING

SERIE C NR 731 AVHANDLINGAR OCH UPPSATSER ÅRSBOK 71 NR 6

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ABSTRACT

Rb-Sr whole rock dating has been carried out on six granite intrusions in the Skellefte District in northern Sweden. The following results were obtained:

Guorbavare granite	1625 ± 35 Ma
Ledfat granite	1680 ± 35 Ma
Adak granite	1770 ± 25 Ma
Arvidsjaur granite	1780 ± 30 Ma

For the remaining two granites only reference lines could be calculated. The age of the Hällnäs granite reference line (which is close to an isochron) is 1735 ± 35 Ma. The reference line for the Duobblon granite represents an age of 1790 Ma.

INTRODUCTION

In the area of the border between the counties of Norrbotten and Västerbotten an important feature of geology is the occurrence of rocks of the Skellefte tectonic-stratigraphic unit. This extensively studied area is composed of folded Svecokarelian metasediments and metavolcanics which have regionally been strongly altered by the intrusion of granitoid rocks in diverse tectonic positions and consequently of different ages. The Skellefte District is situated within the Svecokarelian orogenic belt of the Baltic Shield and constitutes a tectonic unit between the miogeosynclinal supracrustals to the north and the eugeosynclinal sediments to the south. Radiometric datings of rocks from this area have been published by Welin and Blomqvist (1966) and Welin et al. (1971). These results show that the Rb-Sr whole rock age of the late-kinematic Revsund granite is 1785 Ma and that the post-orogenic Sorsele granite has an age of 1625 Ma. The age of the supracrustal rocks penetrated by the Revsund granite in the Skellefte District is unknown but the deposition is probably contemporaneous with the Karelian sedimentation to the north which has been estimated to have occurred 2100–2200 Ma ago (Sakko 1971).

At the Laboratory for Isotope Geology at the Swedish Museum of Natural

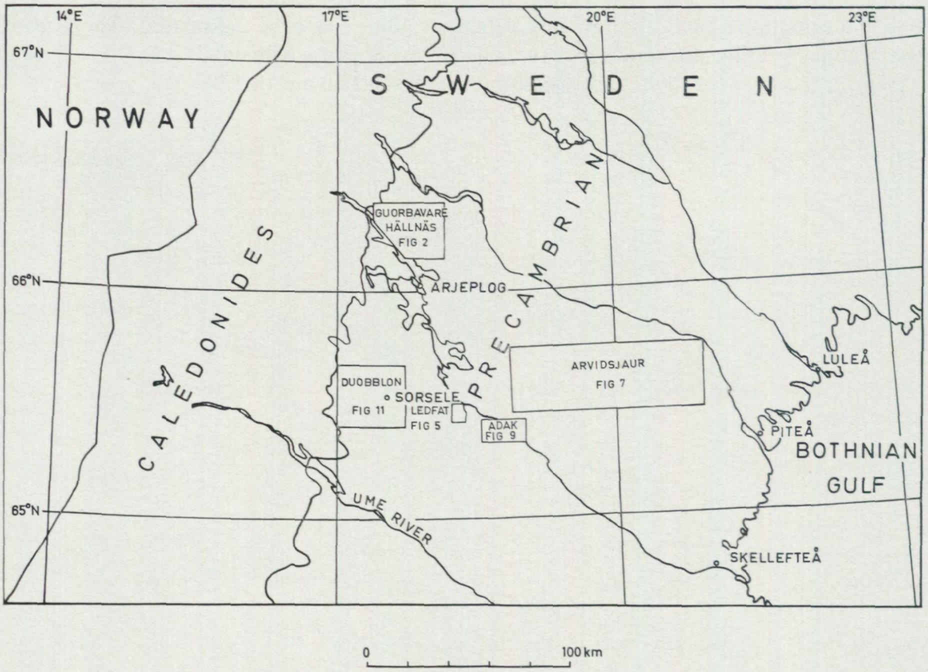

Fig. 1. Location of sampled areas in north Sweden.

History radiometric dating has been carried out during the years 1969 and 1970 on massive granites which intersect the supracrustal rocks on either side of the county border from the central part of the Skellefte District towards the northwest (Fig. 1). The results of these datings and their interpretation are the subject of the present paper.

AGE DETERMINATION PROCEDURES

The samples of the Arvidsjaur granite were analysed for their Rb/Sr ratios and Rb and Sr contents by isotope dilution techniques using spike enriched in ^{87}Rb and ^{84}Sr. The Rb/Sr ratios of all other samples in this investigation have been determined by XRF technique. The standard deviation is one percent for the ID measurements and generally 0.6 percent for the XRF measurement. With high Rb/Sr ratios the standard deviation increases due to the low Sr content and is for example 3.0 % for sample 73258.

The XRF measurements were performed by using a Philips 3 kW 1410 generator, Mo-target 2.7 kW X-ray tube operated at 90 kV and 25 mA, pulse height selection, LiF 220 analysing crystal and scintillation detector. All samples were analysed as pressed-powder pellets as described by Pankhurst and O'Nions (1973).

The isotopic compositions were determined on a 20 cm radius solid source 60° Atlas CH4 mass spectrometer. The measurements were performed by repeated scanning and the signal was amplified by an electron multiplier and a Cary vibrating reed electrometer. The spectra were measured in digital form, data being automatically punched on paper tape and processed in an IBM 360/65 computer. The measurements of the isotopic composition of the Arvidsjaur samples are an exception from this procedure since at the early stage of the laboratory work the results were obtained on a chart recorder. The ^{87}Sr/^{86}Sr ratios were obtained from unspiked strontium and normalized to ^{86}Sr/^{88}Sr = 0.1194. The normalized ^{87}Sr/^{86}Sr ratio for the NBS SRM 987 standard carbonate is 0.7104. The percent standard deviation of a single analysis is 0.20–0.33. The isotopic ratios of two samples of the Duobblon granite (65026 and 65027) and four samples of the Adak granite (72166, 72160, 72157 and 72159) have been measured with an AVCO mass spectrometer. The standard deviation of these analyses is 0.04 %.

The Rb-Sr whole rock isochron and the errors were computed by means of a least-squares regression analysis as the best-fitted straight line according to the method of Williamson (1968) and the result of the age calculation is given at the 95 % confidence level. A decay constant of $1.39 \cdot 10^{-11}$ yr^{-1} has been used in the calculations. The analytical results are given in Tables 1–6 and the data are also plotted on isochron diagrams in Figs. 3, 4, 6, 8, 10 and 12.

RESULTS OF THE PRESENT STUDY

A. THE GUORBAVARE GRANITE

Geological mapping to the north of Lake Hornavan has recently been carried out by one of the authors (B. Gustafsson), Fig. 2. The oldest rocks in this area consist of tuffites and lavas of intermediate composition, partially in rhythmic bedding with sandstones. The supracrustal complex has been strongly folded along N–S fold axes and been metamorphosed and migmatized contemporaneous with the formation of granites and pegmatites. Later block movements are connected with the intrusion of gabbros. The last rock-forming phase consists of intrusions of potassium-dominant granite diapirs of which the Guorbavare granite is a characteristic example.

Previous investigations in this area has been carried out by Ödman (1957) and in parts by Grip (1946). The latter described a red coarse-grained granite, the Arjeplog granite, which is exposed along the south-eastern part of the Lake Hornavan and along the road to Arvidsjaur. In its essentials the geological features of the Arjeplog granite are similar to the Guorbavare granite. Grip

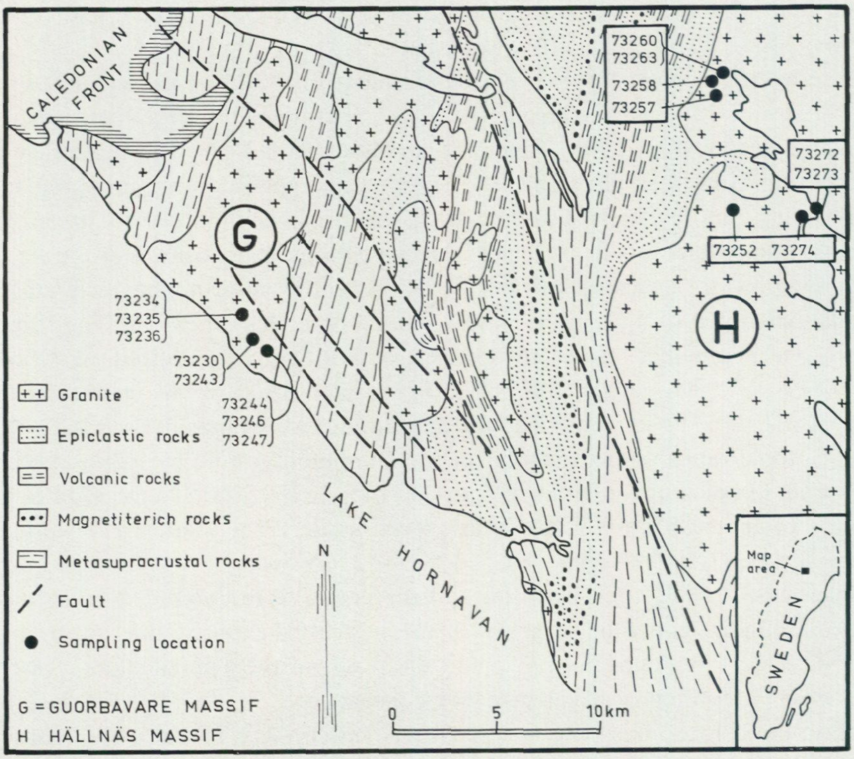

Fig. 2. Location of samples in the Guorbavare and Hällnäs areas in north Sweden.

(ibid.) also noted a recrystallization of the Arvidsjaur granite (section D) and an increased content of the melanocratic minerals in the marginal zones to the Arjeplog granite. The granites to the north of the Lake Hornavan were regarded by Ödman (1957) as Arvidsjaur granites affected by the younger migmatizing granites of the Arjeplog- and Lina-types.

The result of the dating is given in Table 1 and in the isochron diagram Fig. 3.

TABLE 1. Analytical data for the Guorbavare granite.

Sample	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ ($^{86}Sr/^{88}Sr = 0.1194$)
73247	5.19	0.831
73246	5.83	0.846
73243	6.96	0.869
73230	8.39	0.905
73237	9.16	0.915
73234	11.12	0.970
73244	21.13	1.197
73235	27.74	1.342

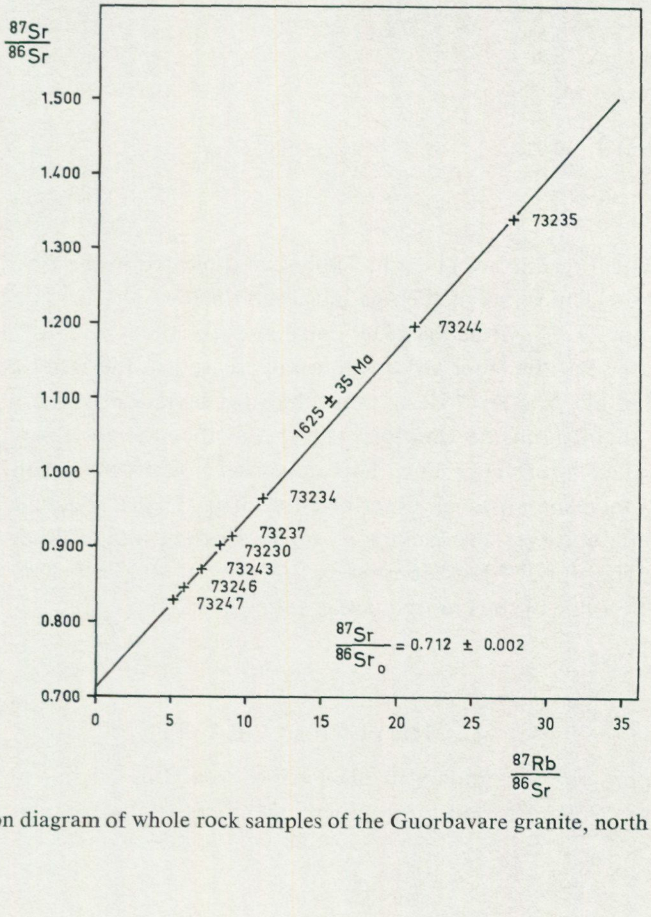

Fig. 3. Isochron diagram of whole rock samples of the Guorbavare granite, north Sweden.

In the latter the samples are distributed on an isochron representing an age of 1625 ± 35 Ma. The initial $^{87}Sr/^{86}Sr$ composition 0.712 ± 0.002 implies a substantial component of crustal material in the granite.

B. THE HÄLLNÄS GRANITE

The Hällnäs granite is also localized in the area north of Lake Hornavan (Fig. 2) and the general geological description in the preceding section is thus applicable. In contrast to the Guorbavare granite the Hällnäs granite contains some biotite and hornblende. These two minerals have a parallel orientation giving the Hällnäs granite a foliated structure. The properties of the Hällnäs granite correspond to the description by Grip (1946) of the recrystallized and metasomatically altered Arvidsjaur granite.

TABLE 2. Analytical data for the Hällnäs granite.

Sample	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ ($^{86}Sr/^{88}Sr$ = 0.1194)
73274	3.65	0.799
73252	6.86	0.877
73272	9.32	0.927
73273	13.76	1.038
73263	23.75	1.311
73257	30.31	1.465
73260	33.07	1.495
73258	111.77	3.40

The analytical results are given in Table 2 and plotted in the isochron diagram (Fig. 4). Two calculations of the age have been made. The first one includes all samples except 73258, while the other calculation includes 73258. The calculated age is the same but the standard deviation decreased in the latter case giving an age of 1735 ± 25 Ma. An F-test shows that the deviation of the plots from the isochron is slightly outside the 95 % level and that the isochron 1735 merely should be called a reference line. This deviation might be a result of recrystallization and metasomatism as described by Grip (1946). Chemical and petrographical data, however, are lacking to such an extent that a closer discussion is impossible. The initial $^{87}Sr/^{86}Sr$ ratio is 0.708 ± 0.002, which is considerably lower than the value of the Guorbavare granite.

C. THE LEDFAT GRANITE

A folded supracrustal complex in the Ledfat area (Fig. 5) has been described by Offerberg 1959. The most prominent members of the sequence are clastic

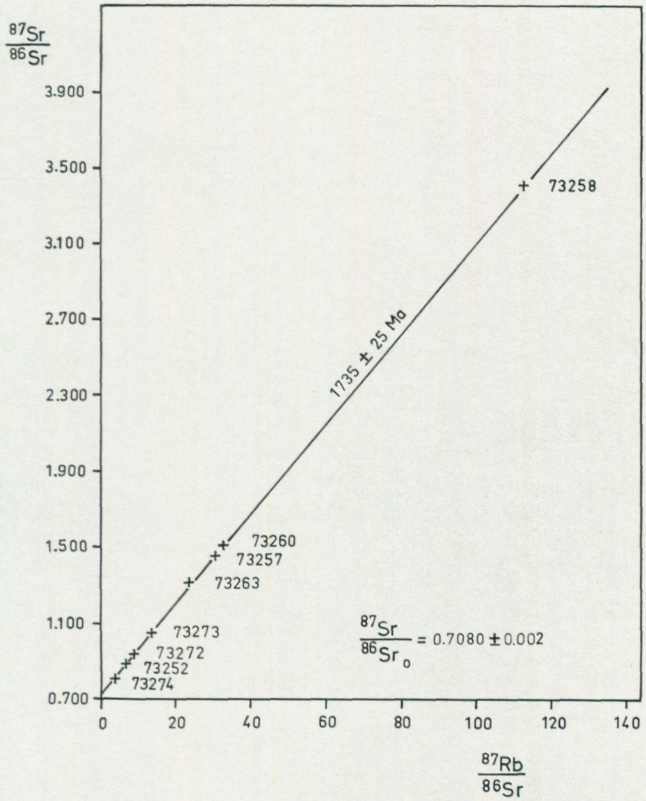

Fig. 4. Isochron diagram of whole rock samples of the Hällnäs granite, north Sweden.

sedimentary rocks among which a conglomerate horizon has an estimated thickness of approximately 100 m.

The total thickness of the sequence is approximately 2000 m. Offerberg refers the conglomerates in the upper part of the sequence to the Vargfors formation as defined by Gavelin (1955). The stratigraphical position of the Vargfors formation is, however, disputed (Kautsky 1957) and the discussion has been previously summarized (Welin et al. 1971). In the Ledfat area the supracrustal complex rests unconformably on older Svecokarelian metavolcanics, and has been deformed into a basin shaped structure. In the latter the strata have variable dips and have occasionally even been overturned.

The sedimentary rocks are cut by granites, granite porphyry and porphyry dikes. The granite, of red or grey colour, has developed a porphyritic texture towards the intrusive contact to the supracrustals. The porphyry dikes are concentrated into those parts of the sediment area where the granite is abundant. The dikes are of variable width. The wider dikes have a granite core.

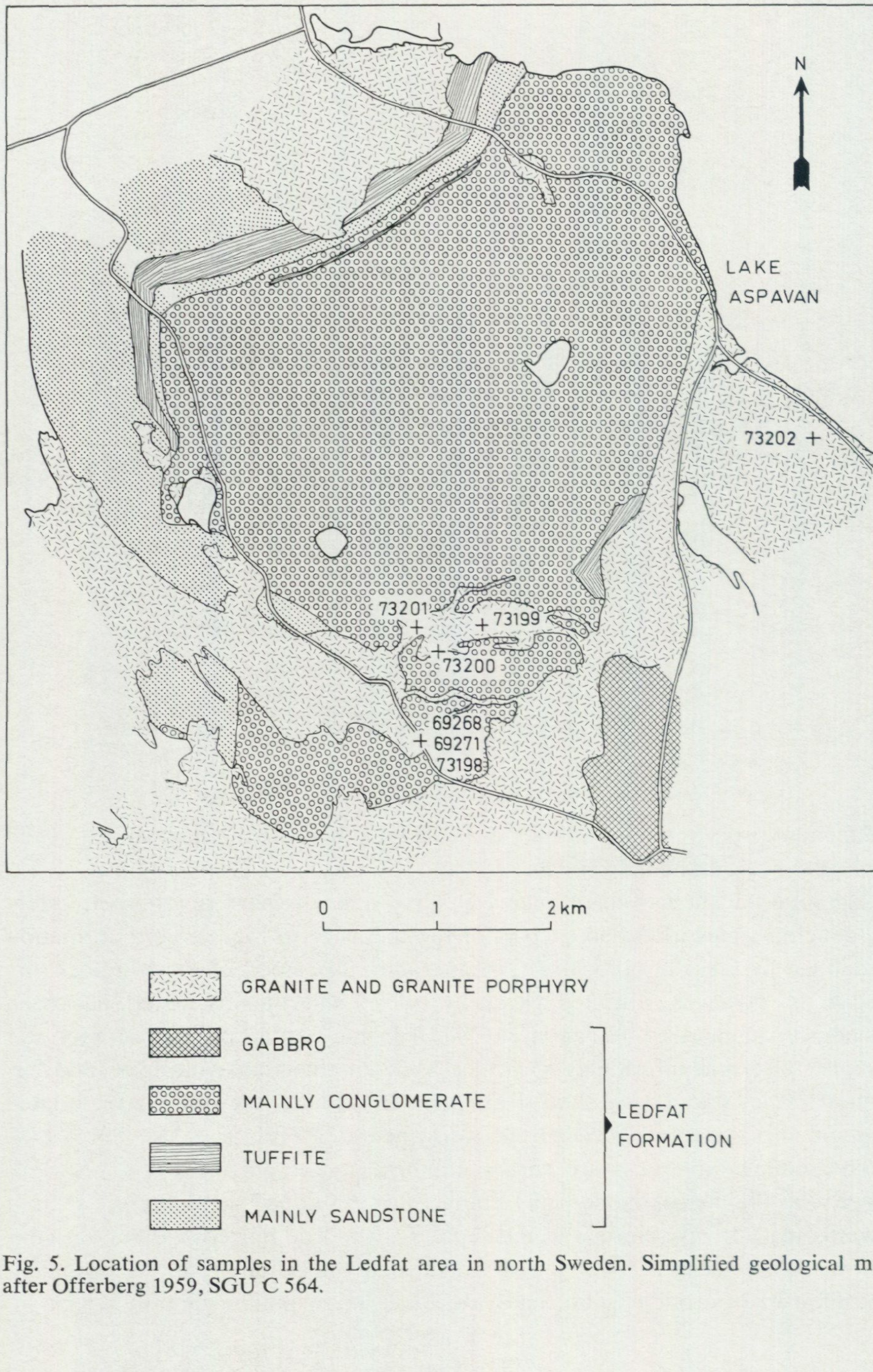

Fig. 5. Location of samples in the Ledfat area in north Sweden. Simplified geological map after Offerberg 1959, SGU C 564.

TABLE 3. Analytical data for the intrusive rocks at Ledfat.

Sample	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ ($^{86}Sr/^{88}Sr = 0.1194$)
73201	3.92	0.796
73199	4.15	0.801
73198	7.78	0.894
69271	8.57	0.915
73202	11.95	0.995
73200	20.34	1.182
69268	53.87	1.968

According to Gavelin (1955) the Ledfat granite passes towards the north to coarse microcline granites which enclose remnants of the Vargfors sedimentary sequence. Similar coarse-grained massive granites also extend towards the south-east to Adak and Malå. All these granites have been distinguished petrographically from the Revsund granites and referred to a common set of intrusions including also the Ledfat granite (Gavelin ibid.).

The analytical results are given in Table 3 and Fig. 6. The calculated age is

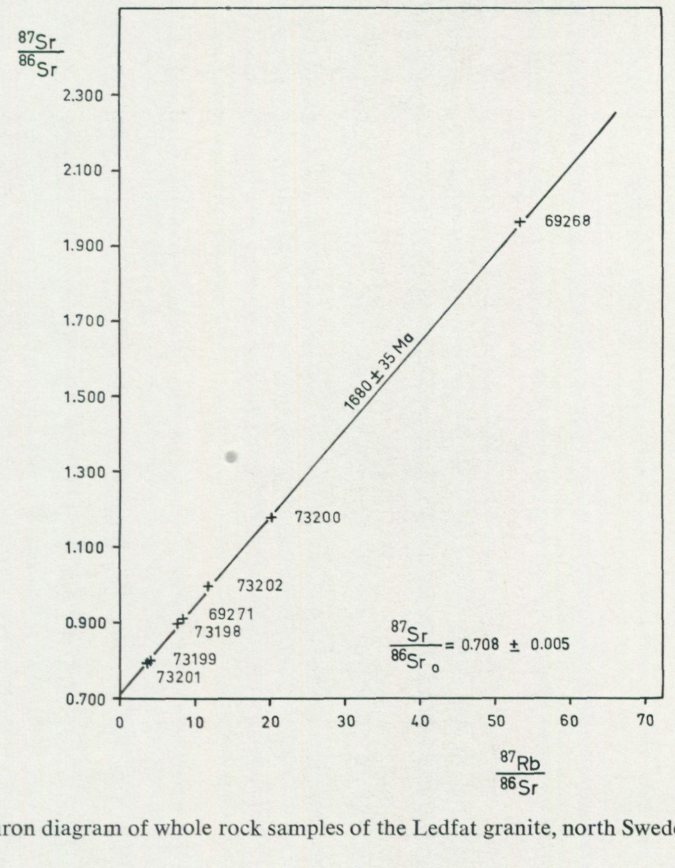

Fig. 6. Isochron diagram of whole rock samples of the Ledfat granite, north Sweden.

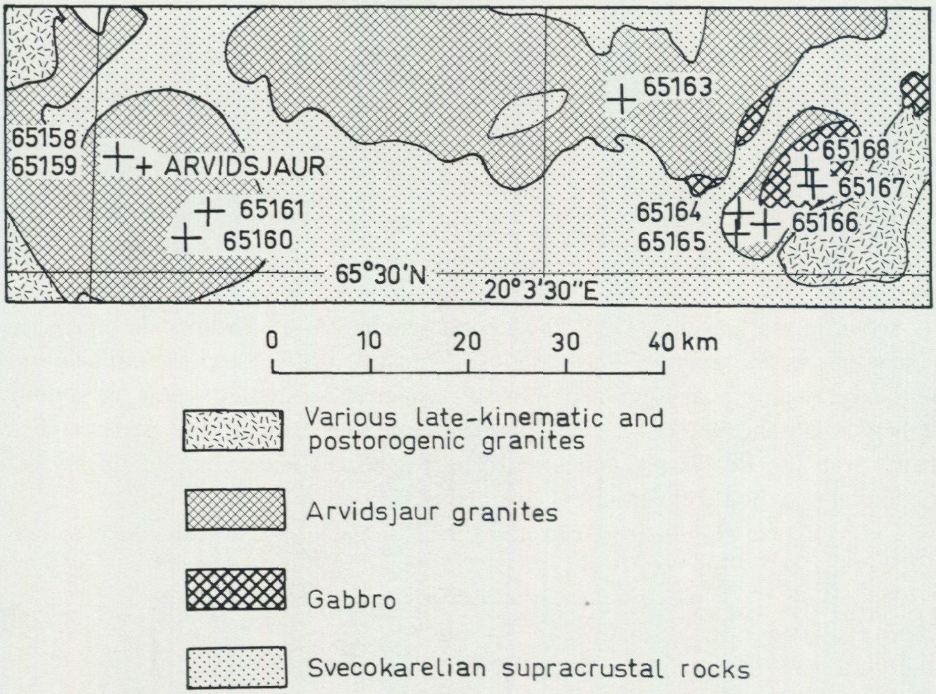

Fig. 7. Location of samples in the Arvidsjaur area, north Sweden. Simplified geological map after Gavelin 1955, SGU Ca 37.

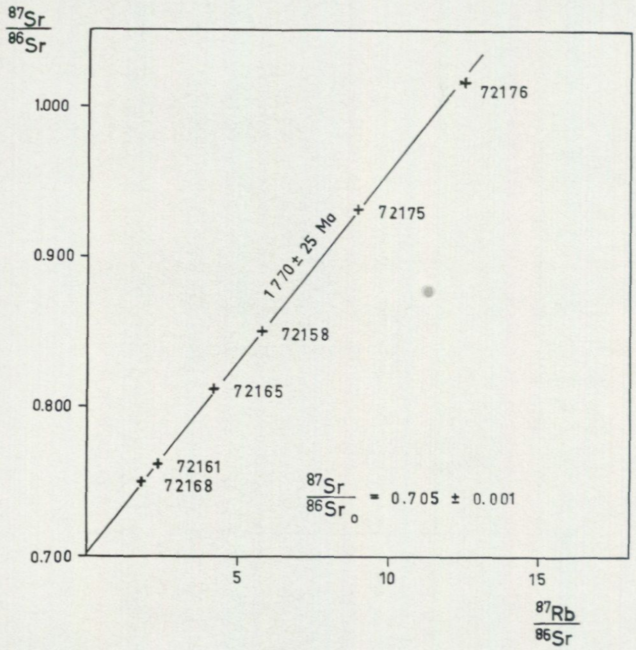

Fig. 8. Isochron diagram of whole rock samples of the Adak granite, north Sweden.

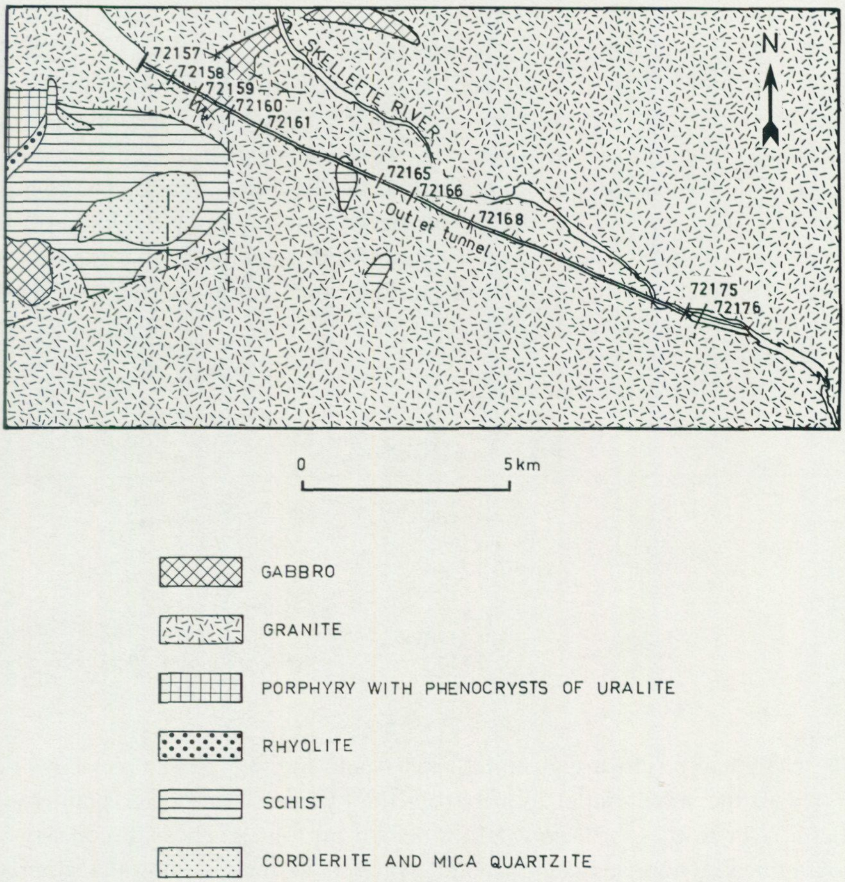

Fig. 9. Sketch map of the Adak area, north Sweden, showing the position of the water outlet tunnel from a hydro-electric plant site. The samples have been collected along the tunnel.

1680 ± 35 Ma. Sample 69268 is an aplite dike intersecting the granite porphyry. Sample 73201 represents a porphyric contact facies rock type. The calculation of the isochron is thus based on the different petrographic varieties, granite, porphyries and aplites, occurring in the Ledfat area.

D. THE ADAK GRANITE

In the Adak area (Fig. 9) volcanics of the Svecokarelian Skellefte sequence are intersected by two granites. The older one, which is not the subject of this investigation, intruded the volcanic sequence during an early stage of the folding, causing a dome-shaped structure to develop. The lowest members of the volcanic sequence have been altered to a cordierite-cummingtonite-quartzite (Lindberg

1970). This oldest granite is not exposed but has been struck at a depth of 700 m in a drill hole in the central part of the cupola.

The main part of the mapped area is occupied by a red microcline granite which intersects the volcanic rocks and all the observable tectonic features. This younger granite, the Adak granite, was referred to the Ledfat group by Gavelin 1955 and regarded as younger than the Revsund granite. The mapping in the Adak area, carried out by one of the present authors (R. Lindberg) has, however, shown that the Adak granite cannot be distinguished from the Revsund granites. The investigations by Lindberg have not concerned the relationship between the Adak and Ledfat granites.

TABLE 4. Analytical data for the Adak granite.

Sample	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ ($^{86}Sr/^{88}Sr = 0.1194$)
72166	1.59	0.7444
72168	1.83	0.750
72161	2.36	0.761
72160	2.84	0.7744
72165	4.25	0.812
72157	4.97	0.8277
72159	5.10	0.8310
72158	5.82	0.851
72175	9.09	0.931
72176	12.49	1.012

The analytical results are given in Table 4 and Fig. 8. The samples have been collected in the water outlet tunnel from the hydroelectric power plant by the Skellefte river to the north of Adak as shown on Fig. 9. They all consists of a petrographically homogeneous granite which nevertheless shows a comparatively large spread in the $^{87}Rb/^{86}Sr$ ratio. The calculated age is 1770 ± 25 Ma which is, within the limits of error, similar to the age of the Revsund granite of 1785 ± 40 Ma (Welin et al. 1971). The initial $^{87}Sr/^{86}Sr$ ratio is 0.705 ± 0.001.

E. THE ARVIDSJAUR GRANITE

The Arvidsjaur intrusives in the southern part of the Norrbotten county are a differentiated igneous suite which intersects both the northernmost outliers of the schists of the Svecokarelian Skellefte complex and the possibly time-equivalent Arvidsjaur porphyries (Grip 1946), Fig. 7. The Arvidsjaur granite is normally a massive medium-grained granite which, however, often passes into more fine-grained or porphyric varieties. In the border areas it possesses a gneissic structure. The subsilicic members of the suite are quartz-diorite, diorite and gabbro. Grip (ibid.) has pointed out that the area occupied by the granites coincides with the porphyries and observed a chemical-petrographical similarity between these rock types. He considers this to be an indication of a comagmatic relationship despite the fact that the granites in all observed contacts always intersect the porphyries. The Arvidsjaur granite is considered to have been intruded during the early orogenic stage, contemporaneous with the Jörn granite which is regarded as the oldest synkinematic intrusion in the Skellefte District (Grip 1946, Gavelin 1955 and Ödman 1957).

TABLE 5. Analytical data for the Arvidsjaur granite.

Sample	Rb ppm	Sr ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ ($^{86}Sr/^{88}Sr = 0.1194$)
65168	11.3	445.4	0.072	0.708
65166	56.4	296.2	0.55	0.718
65167	66.0	349.7	0.55	0.718
65165	153.7	132.5	3.39	0.791
65164	165.7	126.5	3.83	0.803
65164 Bi	999.4	18.7	224.7	5.349
65158	115.7	69.0	4.91	0.831
65159	105.1	48.5	6.37	0.862
65161	111.7	45.5	7.23	0.886
65160	133.5	8.9	48.61	1.929

In the present investigation samples have been collected from the granite in the neighbourhood of Arvidsjaur and from the area around Storsund which includes gabbro, diorite and granite. Furthermore one sample of medium grained granite has been collected between Lauker and Vitträsk. The results are given in Table 5 and Fig. 10. Obviously the large spread in the $^{87}Rb/^{86}Sr$ ratios is due to the petrographically very different samples. All the samples, however, fall within the analytical errors on an isochron representing an age of 1780 ± 30 Ma. The age is also calculated by omitting the sample 65160, which because of its high Rb/Sr ratio has a strong control on the slope of the isochron, but the result remains unchanged. Similarly an age calculation without the subsilicic samples Nos. 65166, 65167 and 65168 yields the same result, although the standard deviation is higher. These results seem to support a comagmatic origin for all the samples.

F. THE DUOBBLON GRANITE

The bedrock in the Duobblon area (Fig. 11) is of great stratigraphic significance (Högbom 1937, Gavelin 1958, Kautsky 1957, 1959 A and B). During 1970 one of the present authors (Einarsson 1970) undertook detailed mapping. According to Einarsson the oldest rock unit consists of metagreywackes folded along N–S axes and subsequently intruded by the Duobblon granite. These metagreywackes were referred to the same supracrustal complex as the Skellefte sequence. A younger supracrustal complex was deposited discordantly upon these rocks.

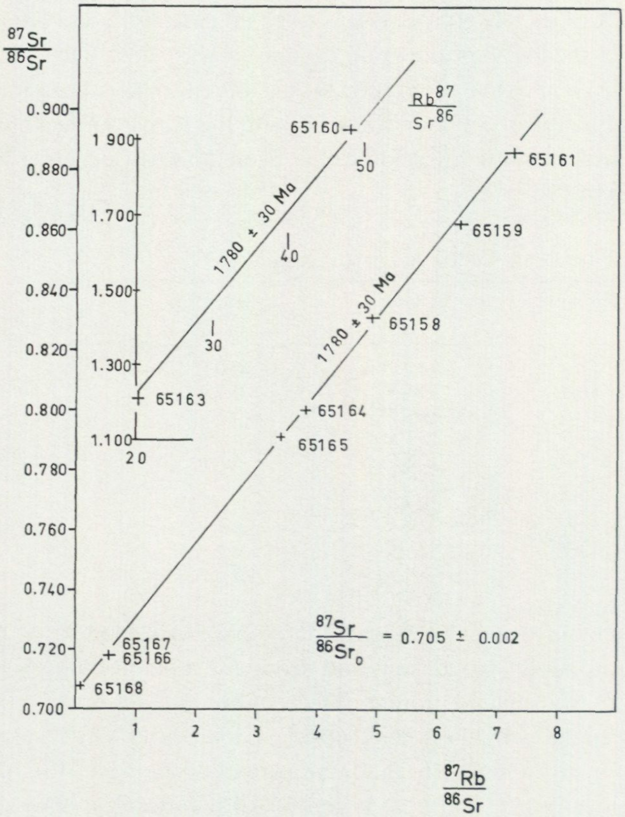

Fig. 10. Isochron diagram of whole rock samples of the Arvidsjaur granite, north Sweden.

The lowest members consist of a conglomerate with rounded fragments of the Duobblon granite. On the conglomerate beds of tuffites, rhyolitic lavas and a polymict conglomerate have been deposited. This complex has been folded along E–W axes and intersected by the Sorsele granite. The lowest conglomerate has been compared to the Ledfat conglomerate (section C). Rb-Sr age data are available for the rhyolites (1725 ± 75 Ma) and the Sorsele granite (1625 ± 45 Ma) (Welin et al. 1971). As the standard deviations of these ages are large, it is impossible to draw any firm conclusions about the position of the rhyolite in the stratigraphy of the Skellefte area. The discussion concerning the stratigraphical position of members of the Skellefte supracrustal complex (Gavelin ibid., Kautsky ibid.) has also been concerned with the Duobblon granite. Kautsky (ibid.) has regarded this granite to be contemporaneous with the synkinematic Jörn granite, while others have compared the Duobblon granite to the late-kinematic Revsund granite. Einarsson (1970) has made chemical and petrographic investigations and shown that these clearly point to the latter alternative.

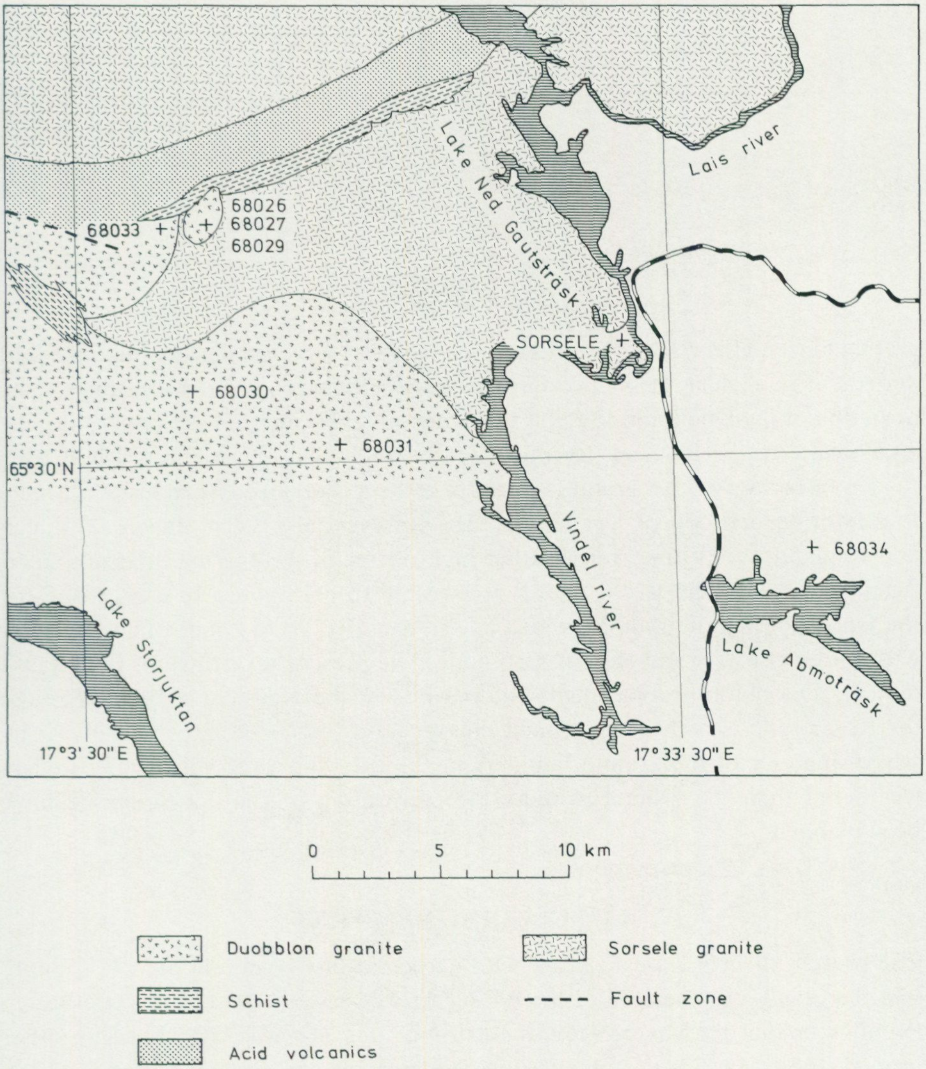

Fig. 11. Location of samples in the Duobblon area, north Sweden.

The analytical results are given in Table 6 which also includes the data of a sample of Revsund granite (68034) collected from an outcrop close to the Duobblon area (Fig. 11). In the isochron diagram Fig. 12 the data of the Duobblon granite are marked by crosses. Previous analyses of the Revsund granite (Welin et al. 1971) and the sample 68034 have also been plotted (circles). The isochron diagram clearly demonstrates that sample 68034 coincides with the general position of the other Revsund granite samples. The previously calculated age for this granite 1785 ± 40 Ma (Welin ibid.). The samples of the Duobblon

TABLE 6. Analytical data for samples from the Duobblon area.

Sample	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ ($^{86}Sr/^{88}Sr = 0.1194$)
68034	2.99	0.781
68029	8.68	0.927
68027	9.80	0.941
68031	9.37	0.947
68026	11.24	1.005
68030	13.34	1.034
68033	22.15	1.238

granite have higher $^{87}Rb/^{86}Sr$ ratios than all the Revsund granite samples analysed and there is a clear distinction in this respect between the two granites. The deviation of the Duobblon samples from any possible isochron are larger than the analytical errors. The cause for this spread is unknown but may possibly be due to a weathering of the granite which is more pronounced than usual for the Precambrian bedrock of Sweden. It has, however, also been shown (Fullagan and Ragland 1975) that even a rather high degree of weathering does not significantly influence the Rb-Sr age. It is possible to calculate a reference line for the Duobblon granite samples which has an age of 1790 Ma and which coincides with the isochron of the Revsund granites. The present investigation thus shows that the Duobblon granite might be coeval with the Revsund granite although the Rb/Sr ratio is higher. Continued investigations either by zircon dating or by Rb-Sr analyses of the granite boulders in the conglomerate, which may be less weathered than the granite forming the substratum of the conglomerate have been planned.

CONCLUDING REMARKS

The present investigation together with earlier results (Welin et al. 1971) imply that the granites in the area of the border between Norrbotten and Västerbotten counties belong to two periods of intrusion, one around 1780 Ma, the other around 1650 Ma. To the older group are referred the Revsund granite (1785 ± 40 Ma, Welin et al. 1971), the Arvidsjaur granite and associated subsilicic rocks (1780 ± 30 Ma) and the Adak granite(1770 ± 25 Ma), and to the younger the Ledfat granite (1680 ± 35 Ma), the Guorbavare granite (1625 ± 35 Ma) and the Sorsele granite (1625 ± 45 Ma, Welin et al. 1971). The geological observations in this area indicate, however, that there are also older, synkinematic granites (e. g. the Jörn granite), which have not yet been dated. It was not possible to draw an isochron for the Hällnäs granite data and the precise age and mode of formation of this granite is still uncertain.

The older group of intrusives can be referred to the late-kinematic stage of the Svecokarelian orogeny and may be analogous to similar and contemporaneous

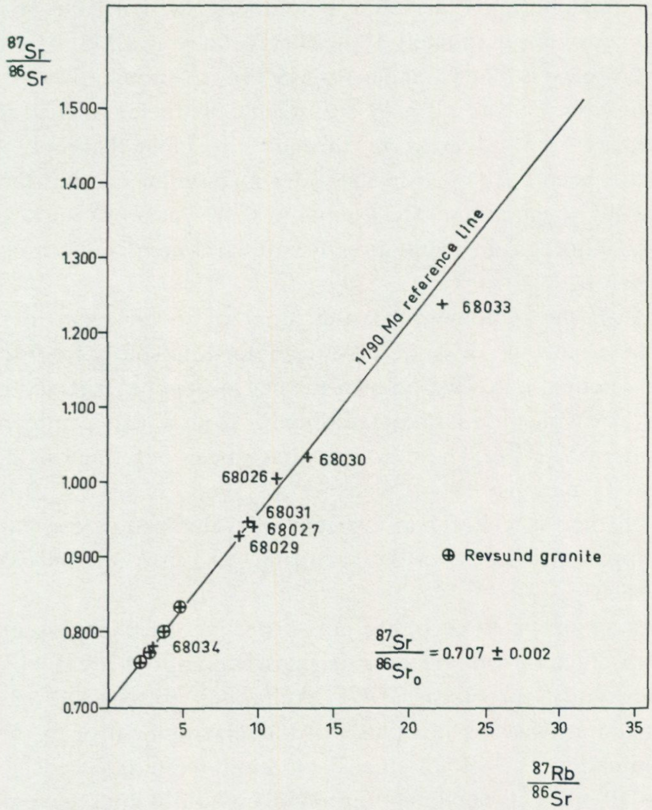

Fig. 12. Diagram showing the position of whole rock samples of the Revsund granite (Welin et al. 1971, SGU C 666) and from the Duobblon area. A reference line for 1790 Ma has been drawn in the diagram.

rocks both in the north (older "Lina granites", Welin et al. 1971) and to the south (Welin and Blomqvist 1964, 1966).

The nearest equivalent to the granites of the younger group may be the intrusive rocks, situated in the miogeosynclinal belt close to the old basement, which have been dated by Gulson (1972). The "perthite" granite in Masugnsbyn has an age of 1545 ± 30 Ma and the syenite from Sjaunjatuottar 1565 ± 25 Ma. Furthermore it is evident that a part of the granites referred to the Lina group have an age of approximately 1565 Ma (Welin et al. 1971). South of the large area of geosynclinal metasediments granites have been dated in the Los area in the Gävleborg county. The Dala granite of Garberg type (Welin and Lundqvist, unpublished manuscript) has an age of approx. 1670 Ma, similar to the age of the cogenetic Dala porphyries (Welin and Lundqvist 1970) and the age of the Rätan granite is 1685 ± 25 Ma (Welin and Lundqvist 1977). The large composite batholiths in Småland and Värmland in southern Sweden have, at least for the most part, an age of approximately 1700 Ma (Welin et al. 1966; Åberg in preparation; Welin, Gorbatschev and Lundegårdh 1978).

These intrusive rocks are all of post-orogenic character relative to the Svecokarelian orogeny; they clearly cut through the older bedrock, occasionally hornfelses have been developed in the older metasediments and they are rarely accompanied by pegmatites. Occasionally there occur associated subsilicic igneous rocks. Through differentiation syenitic and monzonitic rocks have been formed.

The results of the radiometric dating program so far seem to indicate that the ages of these igneous rocks increase from north to south, from the Svecokarelian miogeosynclinal belt, passing over the eugeosynclinal metasediments, to the sequences of acid volcanics and metasediments from a near continental environment in southern Sweden. These granites have been described as post-orogenic Svecokarelian (Lundqvist 1968, Welin et al. 1966, Welin 1970). The present knowledge of the Svecokarelian orogenic development does not, however, explain the apparent increase of the age of the post-orogenic intrusions towards southern Sweden.

Rb-Sr ages, similar to those of the post-orogenic Svecokarelian granites, have recently been obtained from the suite of gneissic granitoid rocks which penetrate the Åmål Megaunit (Gorbatschev 1975, Welin and Gorbatschev 1976) and also from rocks from at least the last phase of the development of the veined orthogneisses dominating the ”Pregothian” of south-western Sweden (Welin and Gorbatschev 1976). The Småland-Värmland batholiths thus have a connection both in time and space with the distribution of the south-west Swedish ”Pregothian” gneisses. However, so little is known about the fundamentals of the geological development of this part of the Baltic shield that it would be premature to speculate as to whether the Småland-Värmland granites are genetically related to deep tectono-magmatic processes in south-west Sweden or to the post-orogenic Svecokarelian development of the type described by Lundqvist (1968).

With regard to the Skellefte District the results of the present dating do not solve the problem of the stratigraphic position of the Vargfors conglomerates. If these conglomerates are synchronous, their minimum age, 1680 ± 35 Ma, is given by the age of the intersecting Ledfat granite. The maximum age, as represented by the basement of Duobblon granite, is less well known but all the present evidence points to the Duobblon and Revsund granites being contemporaneous.

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