Age and tectonic setting of the uraniferous Precambrian basement rocks at Orrefjell, Salangen, Troms

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Precambrian basement gneisses at Orrefjell occur in a north-south trending mountain north of the Precambrian Salangsdalen tectonic window in Troms. The Orrefjell alaskite pegmatite and the Precambrian gneiss, which it intrudes, are overlain by a series of relatively thin flat-lying Caledonian nappes. The uranium mineralization, hosted by the alaskite pegmatite, is interpreted to represent late stage differentiates and late magmatic fluids of the alaskite pegmatite, enriched in uranium together with trace elements like Nb, Y, Ce and the REE. A Rb-Sr whole-rock isotope study of the pegmatite failed to define an isochron, but the errorchron points towards a Middle Proterozoic magmatic event. The high $^{87}Sr/^{86}Sr$ initial ratio (0.735) suggests that the pegmatite was derived by anatexis from continental crustal material. U-Pb isotope studies of uraninite from the mineralized zone yielded an age of 1745 Ma, suggesting a Svecofennian age of the mineralization as well as the alaskite pegmatite. The obtained ages and the general geology of the area indicate that the Precambrian rocks at Orrefjell constitute a separate Precambrian basement window, although it cannot be excluded that it represents a detached slice, separated from the rocks of the Salangsdalen window by a subhorizontal thrust.

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Orrefjell is situated in Salangen kommune, Troms (Fig. 1). The geology of the region is dominated by allochthonous Caledonian rocks. The Caledonian nappe sequence is characterized by thin and relatively flat-lying, partly discontinuous units. Precambrian basement rocks occur as windows on the valley floors of Salangsdalen and Østerdalen 20–30 kilometres south-southeast of the area (Gustavson 1974). The uranium mineralization at Orrefjell occurs in a coarse-grained to pegmatitic alaskite, which intrudes the dominantly granitic Precambrian gneisses. The igneous rocks at Orrefjell were by Gustavson (1974) considered to be Caledonian intrusives, surrounded by Caledonian schists and gneisses.

Except for a brief description of the occurrence in a review paper on uranium mineralization in Norway (Lindahl 1983), little has been published so far about the Orrefjell Precambrian rocks and the associated uranium mineralization. This paper gives a brief presentation of field, chemical and age data from the Orrefjell alaskite pegmatite and its uranium mineralization. The tectonic setting of the assumed Precambrian basement rocks at Orrefjell is discussed in relation to the Precambrian rocks in the Salangsdalen window and the Steinelv window, the latter an area of basement rocks recognized during the prospecting work in the Orrefjell area (Rundberg 1981).

The uranium mineralization hosted by the Orrefjell alaskite pegmatite was discovered by a private prospector in 1960, and was later examined by the Geological Survey of Norway (NGU) (Sverdrup et al. 1967, Øvereng 1969). A reexamination of the Orrefjell mineralization was undertaken from 1977 to 1982 as part of a project for Investigation of State-owned Claims (USB). Several unpublished reports are available from this investigation: Håbrekke (1980), Lundmark & Ulvebäck (1980), Rindstad (1980, 1982, 1983), Rundberg (1981), Furuhaug (1982a, b) and Zwaan & Mathiesen (1984).

Geological setting

Gustavson (1974) subdivided the rocks in the Orrefjell-Salangsdalen region into three main units: (1) an autochthonous Precambrian base-

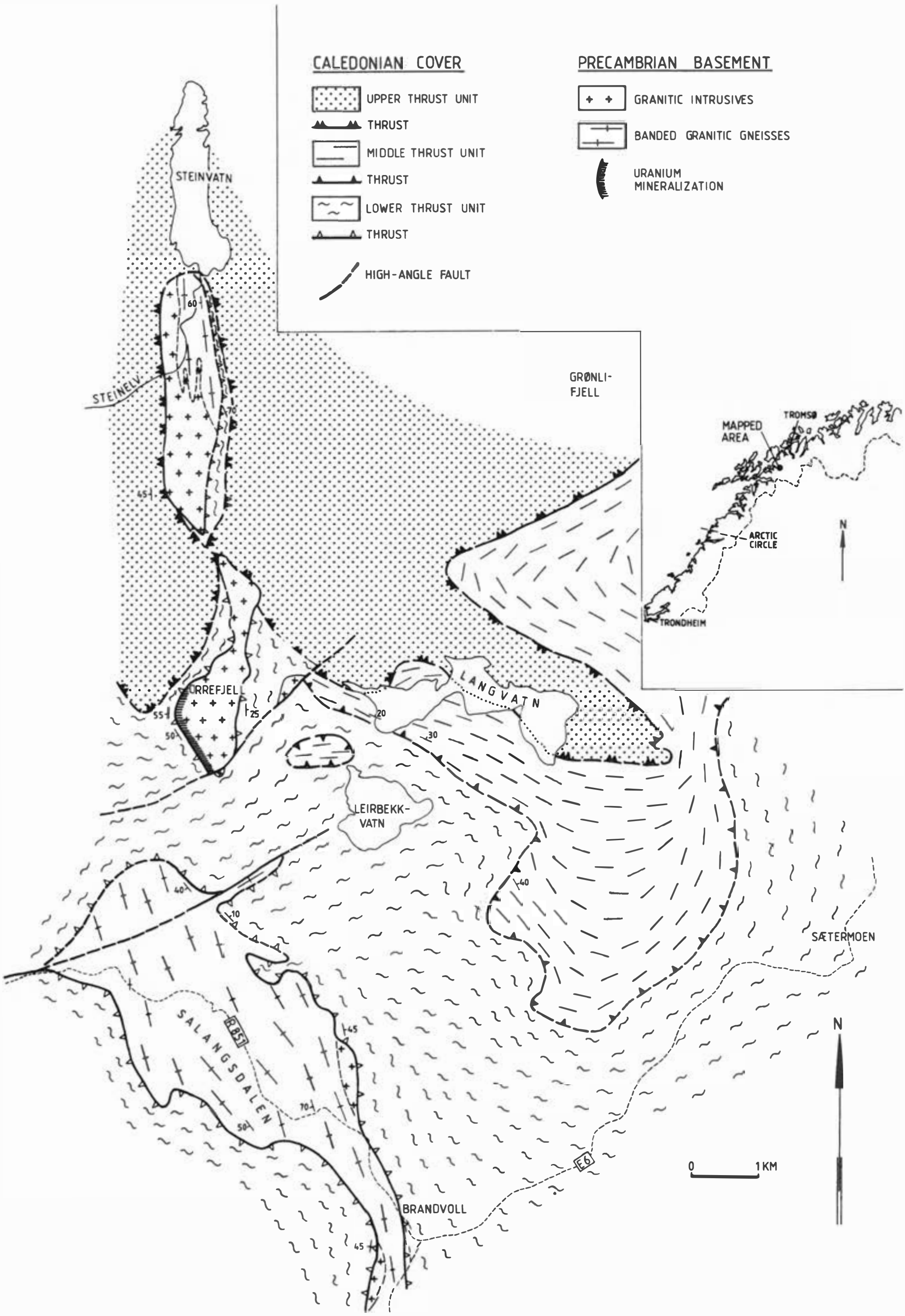

Fig. 1. Simplified map of the Orrefjell area, Salangen.

ment in Salangsdalen, tectonically overlain by (2) a lower allochthonous unit of generally low-grade schists and marbles succeeded by (3) a thrust sheet of quartzites, amphibolites, marbles, mica-schists and minor granitic intrusives. According to Gustavson (1974) the granitic rocks at Orrefjell are one of these intrusives.

Our field investigations have confirmed the subdivision of the Caledonian allochthons into a lower thrust unit of generally low-grade metamorphic rocks overlain by a sequence of high-grade metamorphic gneisses for the southeast part of the area (Fig. 1). This subdivision is less obvious for the northwestern part of the area because of structural complications. The high-grade gneisses appear to be overlain by a new sequence of garnet-mica schists, marbles and quartzites of generally lower grade which we interpret as a separate tectonic unit. This situation is similar to the one encountered between Balsfjord and Malangen, where the high-grade Dyrøy Nappe is sandwiched between the Senja and the Lyngen Nappes (Andresen et al. 1985).

Autochthonous Precambrian rocks are found in a 12 km^2 large window in Salangsdalen (Fig. 1). The dominant rock type is grey granitic gneiss. Darker biotite-rich gneisses and amphibolites occur locally. The amphibolites are generally concordant with the gneiss foliation which is dipping steeply towards the west, and distinctly different from the foliation in the overlying Caledonian rocks. Two small bodies of the Orrefjell-type alaskite pegmatite are apparently intruded in the gneisses close to Brandvoll (Fig. 1).

The mapping has led to the discovery of a new Precambrian window (Rundberg 1981) south of Steinvatn (Fig. 1), described by Zwaan & Mathiesen (1984) as the Steinelv Massif and in the following text referred to as the Steinelv window. The overlying Caledonian rocks are dipping gently outwards from the window, steepest on the eastern and western sides. The basement gneisses are similar to those in the Salangsdalen window and have the same steep westerly dip, but are extensively intruded by alaskite pegmatitic rocks similar to the type at Orrefjell. More than half the window is made up of this intrusive rock, and the gneisses are often transected by quartz-feldspar veins related to this intrusive (Fig. 2).

The area marked as granitic intrusives on Fig. 1 is dominated by alaskite pegmatite, but contains xenoliths and partly assimilated remnants of granitic gneisses and amphibole gneisses. The latter are lithologically similar to the basement gneisses found in the Salangsdalen and Steinelv windows. The alaskite pegmatite is relatively homogeneous along the southwestern margins of the Orrefjell massif where the uranium mineralization occurs (Lindahl 1983). From Fig. 1 it appears as if the alaskite pegmatite of the Orrefjell type occurs along a north-south trending line from the Steinelv window, through Orrefjell and to the Salangsdalen window.

Fig. 2. Pegmatite veins intruding basement gneiss in the Steinelv window, looking towards north (Photo: Y. Rundberg).

In only one locality along the basement-cover contact of the Salangsdalen window has autochthonous Vendian or Cambro-Silurian sediments (Dividal Group) with depositional contact against the Precambrian basement been recognized. A few metre thick weakly metamorphic quartzite, interpreted as Vendian, is found with a depositional contact against pagmatite of the Orrefjell type close to Brandvoll (Zwaan & Mathiesen 1984), which proves the pegmatites to be of Precambrian age. The contact between the basement and its Caledonian cover rocks appears elsewhere to be of tectonic character.

The reconnaissance mapping (Fig. 1) of the Caledonian allochthons indicates that several of the lithologic boundaries in the area are tectonic. The evidence for this includes: (1) sudden change in metamorphic grade, (2) occurrence of mylonitic gneisses and tectonic breccias, (3) the discontinuity of lithologies, (4) abrupt change in orientation of the dominant foliation, and (5) occurrence of ultramafic rocks along lithologic boundaries. Except for the thrust contact between basement and Caledonian cover, none of the thrusts are easily traced across the entire map area. The occurrence of both brittle and ductile thrust zones indicates that they were probably

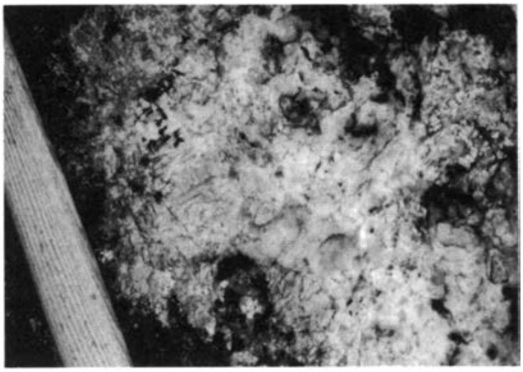

Fig. 3. Typical alaskite pegmatite from Orrefjell. Feldspar light grey, quartz darker grey (Photo: I. Lindahl).

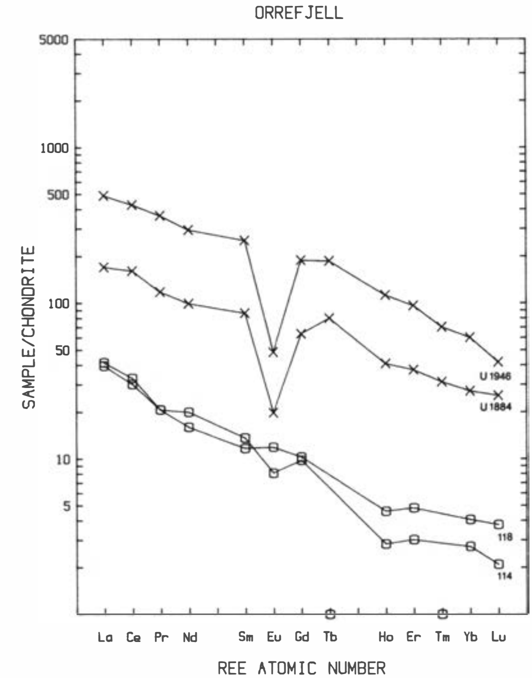

Fig. 4. Chondrite-normalized rare-earth pattern of four samples of alaskite pegmatite from Orrefjell. Samples 114 and 118 are from unmineralized rock (10–20 ppm U). Sample U1884 and U1946 contain respectively 0.15 and 0.28% U. The samples were analyzed at the U. S. Geological Survey by inductively coupled argon plasma/atomic emission spectrometry (Crock & Lichte 1982). Chondrite values from Evensen et al. (1978) are used.

formed at different stages in the assembly of the nappe pile.

Despite the difficulties in tracing tectonic and lithologic units across the map area, the sequence above the Precambrian gneisses with intrusives can be subdivided roughly into four litho-tectonic units (Fig. 1):

1) Autochthonous Vendian sediments (not on the map).
2) Low-grade metamorphic nappe with schists and marbles (lower thrust unit).
3) High-grade metamorphic unit with gneisses, augen-gneisses and biotite-hornblende schists (middle thrust unit).
4) Marbles, mica (± garnet)-schist, and quartzites (upper thrust unit).

Besides the low-angle thrusts separating the various litho-tectonic units, several high-angle brittle faults running NE-SW to ENE-WSW cut through the whole nappe sequence as well as the basement (Fig. 1). One of these high-angle faults can be traced across the Salangsdalen window. A parallel fault represents the southeastern boundary of the Orrefjell massif. This late brittle faulting may be of Mesozoic age (Bartley 1981b).

Precambrian granite rocks at Orrefjell

Field relations

The Orrefjell Precambrian granitic rocks occur as a north-south trending elongated body covering about 2 km^2. This is surrounded by lowgrade metamorphic rocks belonging to the lowest allochthonous unit. The contact between the massif and the Caledonian allochthon is well exposed along the western slope of the Orrefjell mountain and is clearly tectonic in origin. The contact, as well as the foliation in the allochthon, are here dipping 40–60° towards the west. On the eastern side the dip is 20–30° towards east. A major highangle fault (Fig. 1) marks the southeastern boundary of the Orrefjell massif. The same faults are the reason that a small isolated body of the Orrefjell alaskite pegmatite is found to the east of Orrefjell. North-south striking high-angle faults are also found on Orrefjell in the schists along the eastern and western side of the mountain.

Fig. 5. Radiometric map from ground measurements (Furuhaug 1982a), showing the uranium mineralization in the basement close to the cover contact. The foliation in the basement is indicated.

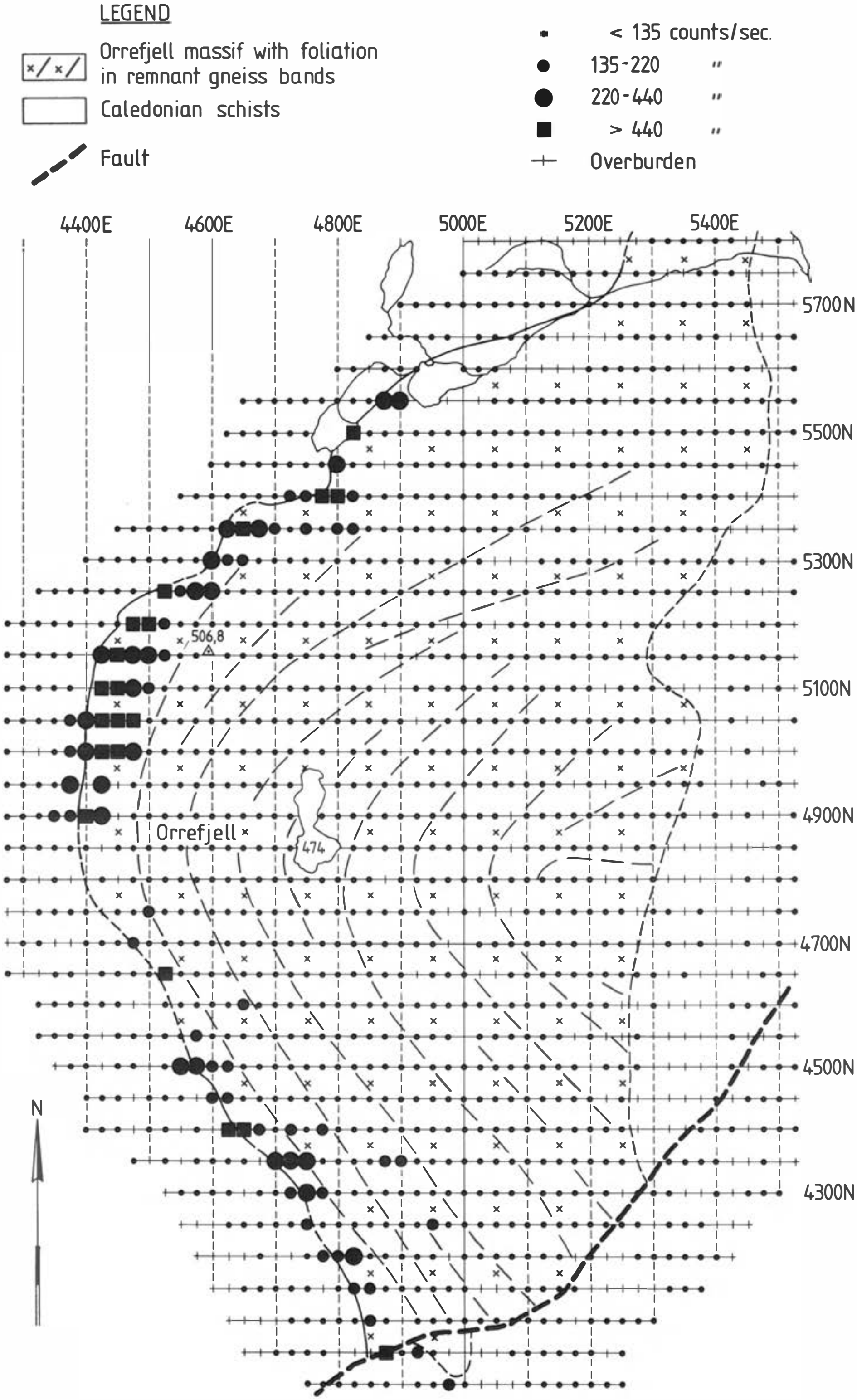
LEGEND
Orrefjell massif with foliation in remnant gneiss bands
Caledonian schists
Fault
< 135 counts/sec.
135-220 "
220-440 "
> 440 "
Overburden
4400E
4600E
4800E
5000E
5200E
5400E
5700N
5500N
5300N
5100N
4900N
4700N
4500N
4300N
506,8
Orrefjell
474
N

Table 1. Trace elements in the Orrefjell alaskite pegmatite. The samples were analyzed at NGU with XRF except for U and Th which were analyzed by gamma spectrometry. When calculating the x̄ and s values on analytical results below detection limit, 3/4 of this value is used (Miesch 1976).
n – number of samples below detection limit.
x̄ – arithmetic mean
s – standard deviation
Average values are taken from Tischendorf (1977) and Vinogradov (1961).

Element	Detection limit	Pegmatite with U < 100 ppm (102 samples)			Pegmatite with U > 100 ppm (42 samples)			Mica schist and gneiss lenses (34 samples)			Average values
		n	x̄	s	n	x̄	s	n	x̄	s	
Nb	5	25	8.6	5.0	5	24.1	25.9	1	13.8	5.3	21
Zr	-	-	89.7	72.9	-	148.6	149.2	-	151.1	69.6	175
Y	5	4	14.4	8.4	-	40.8	42.8	-	37.0	20.0	34
Sr	-	-	96.5	48.2	-	126.9	79.2	-	130.6	75.3	100
Rb	-	-	113.7	46.0	-	132.3	46.9	-	126.2	64.4	170
Zn	5	21	20.4	24.5	-	53.9	59.2	-	105.4	42.3	60
Cu	5	80	10.5	19.3	17	45.8	75.3	2	118.1	101.2	20
V	5	48	37.5	70.5	3	83.6	74.5	-	355.5	132.8	40
Ba	-	-	285.9	282.1	-	353.9	201.3	-	329.8	174.5	840
Mo	5	83	7.0	14.4	5	93.7	133.3	11	19.2	18.3	3.5
U	5	18	20.3	21.9	1	632.7	864.8	9	45.9	77.5	3.5
Th	5	19	17.6	18.7	2	75.5	99.4	11	11.1	8.1	18
Pb	10	21	18.0	9.3	-	109.8	148.0	17	15.4	11.3	20
Co	5	87	5.7	6.7	29	6.7	6.1	3	23.6	13.0	5
Ce	10	26	32.2	25.4	6	96.5	180.6	10	22.2	14.8	100
La	10	12	23.5	12.8	2	56.6	90.0	1	23.0	7.6	60
U/Th			1.2			8.4			4.1		

The Precambrian rocks at Orrefjell consist mainly of granitic gneisses intruded by the Orrefjell alaskite pegmatite. The pegmatite is the dominant rock type in the western part of the massif, whereas coarse-grained gneisses dominate in the eastern and northern areas. These are in part amphibole and biotite gneisses. The foliation in the southern and western part of the massif is curved, in general following the form of the western contact (Fig. 5). The foliation is found in partly assimilated remnants, while the alaskite pegmatite itself shows no foliation.

Petrography

The petrographic study of the Precambrian rocks at Orrefjell focused on the intrusive pegmatitic rock, using samples systematically collected in profiles across the body, as well as samples taken from the drill cores. The pegmatite shows large textural and mineralogical variations. White to light grey, feldspar crystals of size 5–10 cm are often found (Fig. 3). K-feldspar, albite and quartz are the dominant minerals and generally make up more than 90 percent of the rock. Other minerals are biotite and muscovite. 'Pockets' or small lenses of biotite occur locally.

The proportions of K-feldspar, albite and quartz vary considerably, but in most thin sections K-feldspar appears to dominate over albite. Quartz seldom makes up more than 30 percent of the modal composition. The amount of dark minerals as assessed from thin-section studies and field observations is normally only a few percent. This, together with the rock chemistry (Lindahl 1983), classifies it as an alkali granite (Streckeisen 1973). The average low content of iron and manganese, resulting in a minor content of dark minerals, qualifies it to be termed *alaskite pegmatite* (Spurr 1900) or *leuco-granitic pegmatite*.

An extensive alteration is observed in almost all thin sections investigated. The albite grains are all strongly sericitized, and in some sections a weak saussuritization is seen. The K-feldspar shows signs of sericitization. In about half of the investigated thin sections, both K-feldspar and albite show evidence of bending and brittle fracturing. In some of the annealed fractures large euhedral crystals of muscovite have grown. Most of the quartz grains show undulating extinction, which also indicates the influence of stress.

Muscovite occurs as sericite in albite and in some cases as larger crystals. The biotite is brown, sometimes with a greenish tint, and is often strongly chloritized. Primary muscovite and biotite are present in minor amounts. Chlorite may occur in radiating aggregates between larger feldspar crystals. Accessory minerals are zircon, epidote, zoisite and apatite. Identified opaques are the sulphides: pyrite, pyrrhotite and molybdenite, and the oxides: magnetite, ilmenite and uraninite. Alterations of ilmenite to leucoxene, forming broad coronas (Fig. 6), and epidote/zoisite along cracks and grain boundaries are also observed.

Fig. 6. Weathered idiomorphic uraninite in the photo centre. Uraninite is in central part of the crystal and secondary uranium minerals form the rim (black). Small crystal of molybdenite (light) and altered ilmenite with a broad rim of leucoxene (reflected light, oil).

Chemistry

The geochemical investigations of the Orrefjell alaskite pegmatite were done in connection with the drilling of the uranium mineralization. Samples for analyses of major elements were picked from non-mineralized drill cores of lengths 1–2 m of typical pegmatite rock. The results were presented by Lindahl (1983). In spite of the coarse-grained nature of the rock, the analyses show little variation. Both the chemistry and mineralogy of the pegmatite correspond to the definition of alaskite (Spurr 1900). The chemical data correspond well to those of the alaskites in the Rössing uranium deposit in South West Africa (Berning et al. 1976, M. Cuney, personal comm.).

A number of drill-core samples (178) of pegmatite, most commonly 1–2 m in length, have been analyzed for uranium and trace elements. The samples were grouped in: (1) non-mineralized alaskite pegmatite, (2) mineralized alaskite pegmatite, and (3) alaskite pegmatite containing mica schist and gneiss lenses. A summary of the results is given in Table 1. The trace-element chemistry of the three different sample groups shows a significant increase in content for all the trace elements from unmineralized to mineralized pegmatite. Comparing unmineralized pegmatite and pegmatite with mica schist and gneiss, the trace-element concentrations are higher in the latter, except for Th, Pb, and Ce. La shows more or less the same value in both groups.

The fact that all the incompatible elements analyzed are enriched in the uranium mineralized zone indicates a magmatic enrichment. The difference in chemical character of the elements in respect to transportation by hydrothermal solutions would have given a different enrichment pattern. The enrichment factors from unmineralized to mineralized pegmatite, however, are different for each element. Uranium and molybdenum show the strongest enrichment. This indicates that uranium partly has been concentrated by late magmatic fluids. Also, the U/Th ratios given in Table 1 could indicate that.

When the trace element content of unmineralized alaskite pegmatite is compared with average values for granites (Table 1, Tischendorf 1977, Vinogradov 1961), it appears that all element concentrations, except uranium, are signifi-

Table 2. Rb-Sr analytical data from the Orrefjell alaskite pegmatite.

Sample no.	Rock type	Rb(ppm)	Sr(ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ (SE=1)
Or 1	Granite pegm. with enrichment of chlorite	59.29	81.82	2.1095	0.75424 ± 0.00163
Or 2	Coarse-grained granite with accessory biotite and chlorite	81.86	78.17	3.0596	0.81124 ± 0.00008
Or 4	Medium-grained alkali-granite with some biotite and chlorite	102.74	69.07	4.3622	0.83020 ± 0.00009
Or 5	Fine- to coarse-grained granite with accessory amounts of biotite	123.45	120.62	2.9776	0.80050 ± 0.00008
Or 6	Coarse-grained granite with some chlorite	137.72	101.80	3.96603	0.79005 ± 0.00003
Or 9	Coarse-grained pegm. with lenses of biotite	52.43	90.74	1.6837	0.78387 ± 0.00086
Or 10	Fine- to medium-grained granite with minor biotite	78.07	21.48	10.7791	0.97794 ± 0.00003
Or 11	Coarse-grained granite with biotite and chlorite	24.85	39.67	1.8259	0.77543 ± 0.00008

cantly lower than the average. Considering the pegmatitic nature of the rock an opposite trend could be expected. The degree of differentiation of the pegmatite seems to be low, from the actual content of Rb, Sr, and Ba. The pegmatite could be diluted in trace elements and REE because of its high quartz and feldspar content (Henderson 1984), which, however, is not supported by the Rb, Sr and Ba ratios.

Four representative samples from the drill cores were chosen for analyses of all the REE. These represent two non-mineralized samples, and two alaskite pegmatite samples with uranium mineralization. The non-mineralized samples have 10–20 ppm U while the mineralized samples contain respectively 0.15 and 0.28 % U. The results are presented in the chondrite normalized REE-diagram in Figure 4. The pattern shows a similar fractionation ratio for the light REE and the heavy REE, and the negative Eu-anomaly is moderate ($Eu/Eu^* = 4$) (Henderson 1984) in the mineralized samples. The non-mineralized alaskite pegmatite shows no significant Eu-anomaly.

Uranium mineralization

The uranium mineralization occurs along the western margin of the Orrefjell alaskite pegmatite. It can be followed in length for approximately 2 km. The exposed mineralization is easily recognized from helicopter-borne radiometric surveys (Håbrekke 1980). The mineralization is mapped in detail by radiometric ground measurements (Furuhaug 1982a) as shown in Fig. 5.

The mineralization is erratic and varies in thickness from almost nothing up to 20 m, a feature partly seen in Fig. 5. The contact with the Caledonian schists and, as far as we know, also the mineralization, have a westerly dip of 40–60°. To study the mineralization, 31 holes were drilled from 1979–1981, mostly by penetrating the Caledonian schists and intersecting the mineralized zone. The dominating host rock is the alaskite pegmatite. Uranium enrichment may, however, also occur in coarse-grained granitic gneiss. The mineralized pegmatite may locally contain lenses of amphibolite, biotite-schist and gneiss which are normally not mineralized. The amphibolites and pegmatite have minor amount of sulphides, mainly pyrrhotite and pyrite.

Uraninite is the main uranium mineral occurring as up to 2–3 mm large idiomorphic to hypidiomorphic crystals, which can be observed macroscopically. Zircons show a high content of radioactive elements, giving extensive halos in biotite and chlorite, and partly show a metamict texture. The 'pockets' or small lenses of large biotite crystals often show uranium and molybdenum enrichment.

Molybdenite can be seen macroscopically in the pegmatite throughout the uranium mineralization, with the highest concentration in the biotite 'pockets' and lenses. The molybdenite shows folded and curved crystals. Ilmenite shows thick rims with fine-grained leucoxene as an alteration product (Fig. 6), and some magnetite occurs as idiomorphic crystals.

Uranium-mineralized outcrops are locally coloured by iron oxides and hydroxides caused by weathering of iron sulphides. Secondary uranium minerals with yellow to orange colours are also present. Sverdrup et al. (1967) identified the secondary uranium mineral uranotil. Polished sections from the outcrops show extensive weathering of the iron sulphides. The pyrrhotite is altered to pyrite and marcasite and shows birdseye textures (Ramdohr 1980). The uraninite crystals may be totally altered to secondary uranium minerals, but in some samples the unaltered core of the crystal can be observed, as shown in Fig. 6.

The uranium content in samples from outcrops of the mineralized zone varies from a few ppm to up to one percent metal. Analyses of drill cores may vary from a few hundred ppm up to 4000 ppm U over a few metres. It is difficult to give an estimate of tonnages and grades based on the work so far, but Rindstad (1982) gave an estimate for a part of the mineralized zone. The tonnage was calculated to 50 m depth, giving 150,000 tons with 615 ppm U as an average grade. This would give approximately 100 tons uranium metal. However, the uranium content as a function of depth is not established. The grade could increase, be constant or decrease. The future potential of Orrefjell is that of a low-grade resource with large tonnages, with coarse-grained uraninite indicating easy dressing and good recovery. With today's prices it is not economic.

Geochronology

A geochronological study of the host rock, as well as of the uranium minerals, was undertaken, in order to make comparisons with other uranium occurrences in Norway, and in similar environments in Sweden (Lindahl 1983, Stuckless et al. 1982). The age of the Orrefjell alaskite pegmatite was investigated by the Rb-Sr whole-rock method, whereas lead isotopes were used for age calculations regarding the uranium minerals.

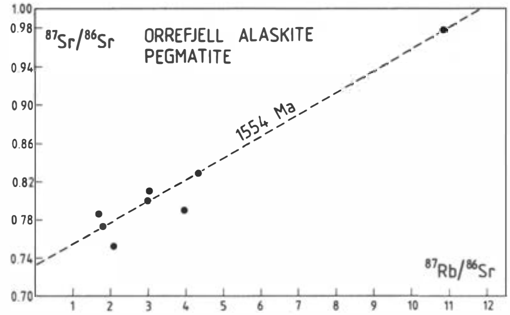

Fig. 7. Isochron diagram of whole-rock samples from the Orrefjell alaskite pegmatite. The dashed line is the best-fit isochron.

Sampling and analytical techniques

The whole-rock samples for Rb-Sr isotope investigations were all collected in the area around the uranium mineralization. Sampling was not without problems as the alaskite pegmatite is strongly fractured with frequent alteration of biotite to chlorite. To reduce the effect of alteration associated with the fractures, most samples collected were relatively small (2–4 kg). The samples were crushed in a steel jaw crusher and finely ground in a tungsten carbide sieve mill. Rb and Sr were determined by X-ray fluorescence spectrography on duplicates of all samples following the method described by Norrish & Chappel (1977). Unspiked measurements of $^{87}Sr/^{86}Sr$ were made for all samples, and variable mass-discrimination in $^{87}Sr/^{86}Sr$ was corrected by normalizing $^{88}Sr^{86}Sr$ to 8.3752.

Mass spectrometry was performed on an MS 30 (Micromass) mass spectrometer using procedures similar to those described by Pankhurst & O'Nions (1973). The ^{87}Rb decay constant used in calculations was $1.42 \times 10^{-11} a^{-1}$. The regression technique of York (1969) was used. In assigning errors to the regression points, the coefficient of variance for $^{87}Rb/^{86}Sr$ is taken as 1 percent. The standard error of $^{87}Sr/^{86}Sr$ for each sample is listed in Table 2.

The three samples used for uranium-lead investigations were all collected at localities with high gamma radiation, as determined by gamma scintillometer. Uraninite was separated by the

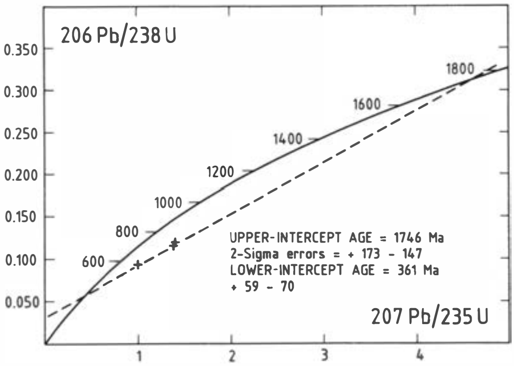

Fig. 8. Concordia diagram for three fractions of uraninite from the mineralization in alaskite pegmatite.

help of heavy liquids. The lead-isotope determinations were carried out commercially by IGS (Institute of Geological Sciences) in London by I. G. Swainbank. Sample 6400 was run on a Thomson THN 206 mass spectrometer, whereas the other two samples were run on the Micromass M 30. Isotopic and decay constants used are those recommended by the IUGS Subcommission on Geochronology (Steiger & Jäger 1977, $(^{238}U) = 0.155125 \times 10^{-9}a^{-1}$; $(^{235}U) = 0.98485 \times 10^{-9}a^{-1}$; $^{238}U/^{235}U = 138.88$).

Results

The Rb, Sr, $^{87}Sr/^{86}Sr$ and $^{87}Rb/^{86}Sr$ data for the Orrefjell alaskite pegmatite are given in Table 2. Fig. 7 is a graphic presentation of the isotope data. As seen from the isochron diagram it is not possible to join all 8 data points along one isochron indicating that the analysed samples are not in isotopic equilibrium. This was not unexpected because of the common occurrence of chloritized fractures and frequent alteration of biotite to chlorite in many of the samples. Despite the scatter of data points, a Svecofennian age for the Orrefjell alaskite pegmatite is indicated. A regression analysis using all eight data points gives an errorchron age of 1602 ± 550 Ma (MSWD = 317). If samples Or-6 and Or-11, which fall considerably below the best fit line, are excluded in the regression analyses, an errorchron age of 1567 ± 232 Ma (MSWD = 60) is the result. The four data points Or-1, Or-5, Or-4 and Or-10 define an age of 1554 ± 32 Ma (MSWD = 2.4). The 8, 6, and 4 points regression analyses give high initial ratios, 0.731 ± 0.022, 0.736 ± 0.009 and 0.734 ± 0.001 respectively, indicating that the parent material had a relatively long crustal history.

The U, Pb and Pb isotope data from the uraninite concentrates are given in Table 3. A concordia plot for the three samples shows that all three analyses are strongly discordant (Fig. 8). The three analyses define a straight line with a lower-intercept age of 360 + 58/− 69 Ma and an upper-intercept age of 1746 + 172/− 147 Ma. Both the upper and lower intercept ages represent known geologic events, Svencofennian and Late Caledonian, respectively. Our interpretation of the U-Pb isotope data is that the uraninite crystallized during the Svecofennian orogenic event and underwent lead-loss or gained uranium during the Caledonian orogeny. The relatively low lower-intercept age is compatible with cooling ages from the Ofoten area (Bartley 1981a, Dallmeyer & Andresen 1984, Andresen & Tull in prep.). The interpreted crystallization age of the uraninite supports the interpretation of the Orrefjell alaskite pegmatite as a Svecofennian intrusion into older gneisses.

Table 3. Analytical data for uraninite concentrates from the uranium mineralization.

Sample no	U	Pb	^{204}Pb*	^{206}Pb	^{207}Pb	^{208}Pb	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$
6425	49.80	4.50	0.0376	88.57	7.46	3.929	0.0925	0.9987
6432	53.70	6.13	0.0177	89.07	7.91	2.995	0.1179	1.4001
6400	45.30	4.98	0.0099	89.80	7.97	2.219	0.1147	1.3795

* Pb isotopes given as atomic per cent

Discussion and conclusions

The Salangsdalen window is considered to be autochthonous (Gustavson 1974). The detailed mapping in the region has led to the discovery of an additional Precambrian window, the Steinelv window. Even though the basement-cover contact for this window is 250 m above the similar contact around the Salangsdalen window, it is supposed to be autochthonous or parautochthonous. The basement rocks in the Steinelv window have the same orientation of foliation as the Salangsdalen window. NE-SW trending late high-angle block-faults, which have uplifted the northern area including the Steinelv window, may account for this (Fig. 1).

The late high-angle block-faulting is the latest major tectonic event cutting through the nappe thrusts and extending into the basement. One distinct fault cuts through the northern end of the Salangsdalen window (Fig. 1) and another one constitutes the southern limitation of the Orrefjell basement rocks. The block between these two faults is down-faulted with the largest displacement along the southern end of Orrefjell, which is correspondingly uplifted. In addition north-south trending faults occur on both sides of Orrefjell, as shown on the geological map (Fig. 5). Intrusive alaskite pegmatites of the Orrefjell type occur along a north-south trending line through all three areas of Precambrian rocks. The tectonic and intrusive pattern thus suggests that the Precambrian rocks at Orrefjell most likely constitute a window, and that its high elevation, 400 m above the Salangsdalen window and 150 m above the Steinelv window is due to late faulting. The other possibility is that the Orrefjell massif represents a slice of Precambrian rock included in the nappe complex. Before a final conclusion can be drawn, more detailed field work of the entire region is needed.

The Orrefjell alaskite pegmatite shows a significant lower concentration of trace elements than an average granite (Tischendorf 1977, Vinogradov 1961), suggesting an initial low degree of differentiation. The uranium mineralizations show enhanced values for all the trace and REE elements analyzed. The U/Th ratio in the pegmatite is close to 1 and in the mineralized zone averages 8 (Table 2). This indicates an influence of late magmatic fluids in addition to the magmatic enrichment. A minor content of iron sulphides in the mineralized zone may have extracted the uranium from such fluids.

The Rb-Sr whole rock dating of the Orrefjell alaskite pegmatite did not define an isochron. The most likely reason for this is the relatively extensive post-magmatic brittle fracturing and the alteration of biotite to chlorite which is seen in most thin sections. Despite this, an errorchron indicates an age of 1554 ± 32 Ma or older. This Middle Proterozoic age for the host rock is supported by the U-Pb data on uraninite. A concordia plot based on three samples gives an upper-intercept of $1746 + 172/-147$ Ma and a lower-intercept of $360 + 50/-69$ Ma. We interpret the Svecofennian upper-intercept age to represent the magmatic emplacement of the Orrefjell alaskite pegmatite and its mineralization. The lower-intercept age most likely represents the timing of the last pulse of the Caledonian orogenesis in the region.

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