THE PRECAMBRIAN ROCKS OF THE TELEMARK AREA IN SOUTH CENTRAL NORWAY

IV. Calcite syenite with marginal breccia at Fjone

By

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Abstract: Gas coring and lava flow through a small vent, followed by hydrothermal activity has produced a calcite-baryte-fluorite-anatase-bearing syenite and types of metagabbro which intersect Precambrian gneiss. A pegmatite dike, also of Precambrian age, is cut by diabase dikes. Breccia with xenoliths of diabase and gneiss and a matrix of syenite is locally developed along the rim of the syenite body. Permian or late Precambrian age of the syenite is discussed. The feldspars of the syenite: low temperature albite and highly ordered submicroscopically twinned microcline is assumed to be the result of alteration or original alkali-feldspar mixed crystals by low temperature and high water pressure.

Introduction

Fjone is the name of a group of farms on the west side of lake Nisser in Telemark county, 150 km southwest of Oslo. Dr. S. Foslie († 1951) of the Norwegian Geological Survey nearly completed a geological manuscript map of the quadrangle Nisser, on the scale 1:50,000, during parts of the years 1940–45 and 1947–51. On his map a special colour was used, designated 'syenite' for a small area near Fjone (1 km south of Sundsodd where the ferry crosses the lake). His field notes show that he visited this locality two days in August 1945, and observed 'a lens' containing two rock types, viz., a syenitic rock with red feldspar and black amphibole and another rock which contains aggregates of white quartz.

In 1958 the author travelled in the Nisser area for a period of a fortnight in connection with a general survey of the Telemark area. A series of specimens was collected from Fjone and a preliminary

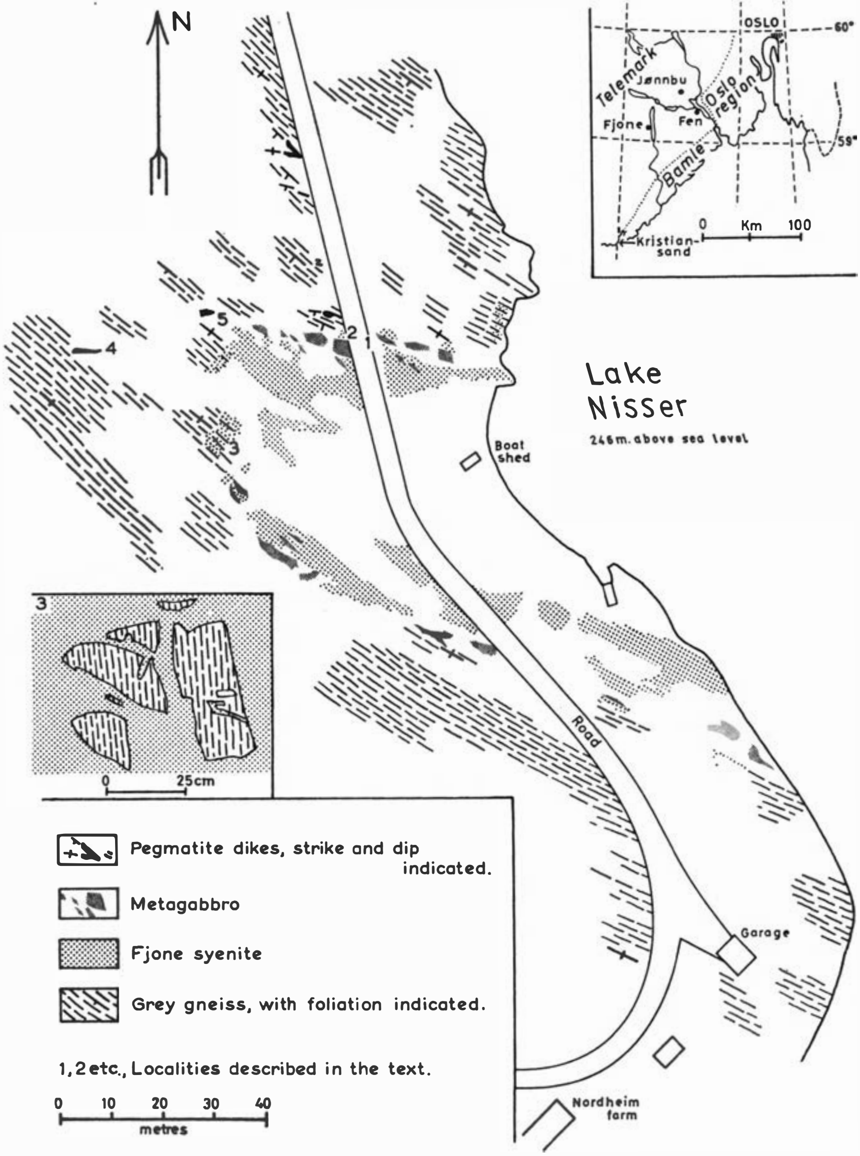

N
8°
10°
11°
60°
59°
OSLO
Telemark
Jønnbu
Oslo region
Fjone
Fen
Bamle
Kristiansand
0 Km 100
1
2
3
4
5
Lake Nisser
246m. above sea level
Boat shed
Road
Garage
Nordheim farm
3
0 25cm
Pegmatite dikes, strike and dip indicated.
Metagabbro
Fjone syenite
Grey gneiss, with foliation indicated.
1,2etc., Localities described in the text.
0 10 20 30 40
metres

Fig. 1

map, supplemented with photographs, was prepared. The breccia structure which was not mentioned by Foslie seemed to be worth a closer investigation. Preliminary results from a study of thin sections and from chemical analysis were compiled by Professor T. F. W. Barth in connection with a description, not yet published, of Norwegian peralkaline rocks.

A detailed field study of the Fjone area was undertaken by the author during two days in August 1963. Part of the mineralogical/petrological study of the collected specimens was made by Professor Barth to whom the author wishes to express his sincere thanks for discussions about the problems involved. The description of the special features of the feldspars is written by T. F. W. Barth.

Geological setting

Fjone is situated in, and very near, the western margin of the easterly plunging Nisserdal syncline which comprises Precambrian supracrustal rocks, now mostly gneisses, as well as Precambrian gabbros, etc. Quartzite has not been observed. A correlation between the supracrustals of this syncline and the supracrustal Telemark-suite (mostly quartz-rich sediments and acid and basic lavas) to the north has not been established. (See map Pl. 7 by J. A. Dons in HOLTEDAHL *et al.* 1960. The same map is also found in DONS 1960.)

The exposed part of the Fjone syenite and associated rocks is shown in Fig. 1 as part of an elongate area, the smaller axis (NNE–SSW) of which is about 50 m in length. The longer axis with a minimum length of 140 m is parallel to the strike (ESE–WNW) of the surrounding gneisses, the eastern continuation of the Fjone syenite disappears under water. The best exposures are along a secondary road. Outcrops of the Fjone syenite rise to an elevation of 30 m above the lake.

The rocks

GNEISS

Migmatitic gneisses surround the Fjone syenite. They are grey in colour and weakly foliated. The same type of rock is found as fragments in the breccia. The gneisses are obviously influenced by the syenite in a zone 20 to 40 metres wide.

Quartz and *feldspar* make up about 75 per cent of the gneisses. Quartz in the form of fragments shows undulose extinction. *Plagio-*

Table 1. *Chemical Analysis of Calcite Syenite from Fjone*

	Weight %	Weight %	Weight %	Cation %	Cation %
	1a	2a	3	1b	2b
SiO_2	52.80	55.54	60.37	50.9	51.5
TiO_2	1.53	1.17	1.09	1.1	0.8
Al_2O_3	15.08	17.32	17.34	17.1	18.9
Fe_2O_3	2.18	1.82	1.92	1.56	1.3
FeO	4.22	3.84	3.07	3.5	2.7
MnO	0.08	0.07	0.19		
MgO	1.90	2.90	1.60	2.7	4.0
BaO	0.31	n.d.	0.31	0.1	—
CaO	6.36	3.55	2.79	6.5	3.5
Na_2O	3.90	4.87	4.88	7.3	8.7
K_2O	4.73	4.36	4.78	5.8	5.2
P_2O_5.......	0.37	0.27	0.47	0.3	0.2
CO_2	2.13	2.47	0.09	2.8	3.1
H_2O+	3.93	1.94	0.62	—	—
H_2O-	0.15	0.14	0.11	—	—
	99.90x	100.26	99.85*		

x Includes: S = 0.13, SO_3 = 0.08, ZrO_2 = 0.02
* Includes: FeS_2 = 0.09, ZrO_2 = 0.13

Molecular Norms

	1		2	
Q	2.1	77.6	4.5	74.1
Or	29.0		26.0	
Ab	36.5		43.6	
An	10.0		—	
C	—		5.0	5.0
Wo	2.4	11.0	—	
En	5.4		8.0	10.6
Fs.........	3.2		2.6	
Il	2.2	11.4	1.6	10.4
Mt	2.3		2.0	
Ap	0.8		0.6	
Cc.........	5.6		6.2	

1. Syenite from Fjone; analyst E. Klüver 1945. The sample was collected by Foslie in 1943, and is probably somewhat contaminated by the surrounding dioritic gneiss. It is no longer available for examination.

2. Syenite from Fjone; analyst B. Bruun 1963. The sample is believed to represent the pure, uncontaminated syenite.

3. Nordmarkite porphyry, large dike, Bygdö; (BRÖGGER 1933). For comparison. With addition of 6 % calcite, this analysis would become very similar to No. 2.

clase in its pristine condition is An_{25-30}. But it is frequently changed into a felt of sericite and zoisite (?) with recognizable feldspar remnants which seem to be albitic. Potassium feldspar could not be identified. *Hornblende* is the usual dark mineral constituting about 25 per cent of the rock. It is pleochroic yellow to green to green-blue. There are traces of zoisite-epidote. Accessories are titanite, apatite and ore minerals (oxides and pyrite).

When approaching the syenite from the north, the hornblende of the gneiss is replaced by opaque ore minerals and by chlorite low in iron, almost colourless, birefringence $\simeq 0$. In places much fluorite is concentrated, calcite is also present, and small amounts of quartz and biotite are newly formed as clear, small, idiomorphic crystals. The colour of the feldspar in the gneiss gradually changes towards the contact with the syenite from whitish to pinkish. This change could not be seen in the microscope.

Close to the margin of the syenite, 'hydrothermal' recrystallization of idiomorphic hornblende has taken place. The hornblende shows α = almost colourless, $\beta = \gamma$ reddish brown; (—)2V varies from 80° to 40° with increasing chloritization of the rock.

PEGMATITE

Gneisses north of the Fjone syenite are intersected by dikes of 'pegmatites' containing quartz and albite. In one of the dikes near loc. 2 in Fig. 1, traces of molybdenite have been found. Nowhere are the pegmatites seen to intersect the syenite or the metagabbro. The breccia locally contains fragments of quartz possibly derived from the pegmatite.

FJONE SYENITE

The 'magmatic' rock which covers the greatest area of the complex and also forms the matrix of the breccia is a rather conspicuous red calcite-bearing syenite of coarse texture and massive structure (Fig. 2).

An analysis of this rock was made at Foslie's request in 1945. A new analysis was made for this paper. See Table 1.

The modal minerals are:

Quartz in small amounts interstitially, as myrmekite, and as micrographic intergrowths. *Feldspars* making up 70 to 80 per cent of the

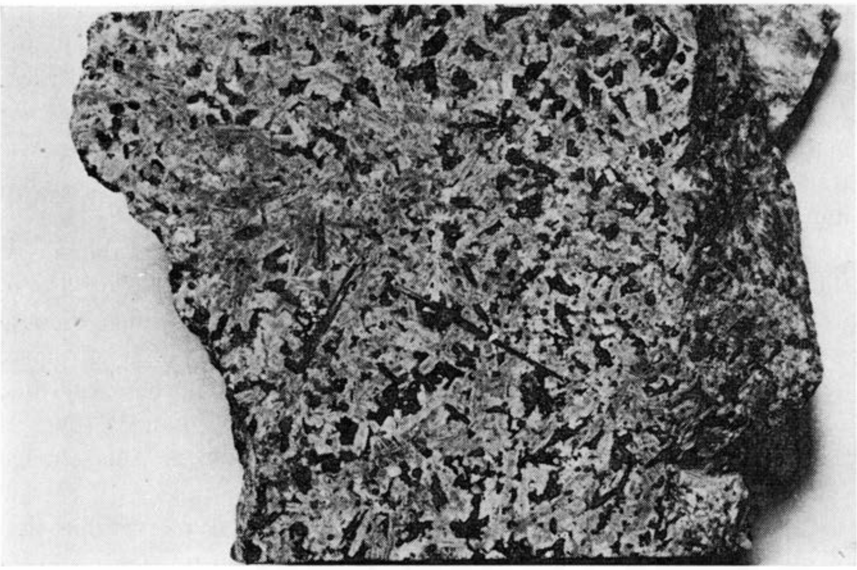


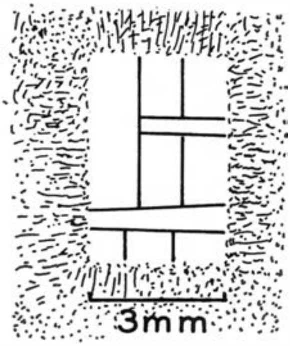
Fig. 2. The red Fjone syenite. Greatest dimension of the figured polished specimen is 8 cm.

rock are of two kinds, microcline and albite. They will be described below. *Chlorite* in large, idiomorphic platy or needle-like crystals (greatest dimension 3.5 cm), makes up 10 to 20 per cent of the rock, and is the chief dark mineral. This was the hornblende of Foslie. *Hornblende* is present as small corroded remnants. *Calcite* makes up 5 to 8 per cent. *Accessories* are pyrite in large cubes (pseudomorphs ?), magnetite, titanite, apatite. *Anatase* can be seen in most thin sections. *Baryte* has been identified.

The *feldspars* warrant special mention. In the typical syenite there are idiomorphic tabular crystals of microcline and of pure albite without any other plagioclase. The albite is usually clear, but often framed by similarly orientated, strongly clouded microcline, exhibiting extremely fine M-twinning which can hardly be seen with the microscope. X-ray powder diagrams show, however, that the microcline is highly ordered with $\Delta \simeq 0.9$. Albite is the ordered, low-temperature modification with maximum 5 An. The optical axial angle of the albite is $(+)2V = 81°$; maximum extinction in the zone [010] is 16°.

The K feldspars are apparently non-perthitic. But with the highest

Fig. 3.



Idiomorphic crystal of albite enclosed in clouded microcline. The albite is supposed to represent recrystallized perthite material. Fjone syenite.

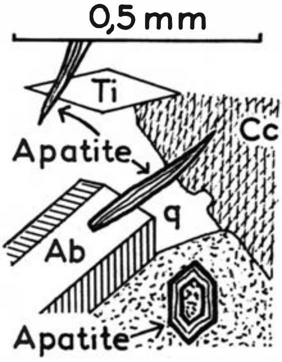


Fig. 4.

Acicular apatite is younger than albite (Ab), calcite (Cc) and titanite (Ti). It is hollow as shown by cross-section (lower right corner, where the scale is exaggerated). Metagabbro.

possible magnification certain details in the cloudy microcline are revealed. The clouding is due to the presence of numerous minute, dark brown particles distributed throughout the crystal. The nature of the particles is obscure. It has been suggested (POLDERVAART and GILKEY 1954) that in clouded minerals there are minute surfaces of physical discontinuity that provide passages for diffusion of material. Such surfaces can be seen to exist in the present microclines. There is a pattern of almost submicroscopically fine streaks (revealed by small differences in the refractive index) streaming through the clouded microcline, and converging at the contiguous albite (see Fig. 3). It gives the impression that the alkali feldspar during unmixing was drained of albitic material concentrating in large albite tablets leaving behind microclinic material together with all other exsolution products (iron compounds and others originally present in the lattice). New materials of various kinds may have been subsequently introduced into the residual microcline following the same passages as did the rejected albite.

'METAGABBRO'

Irregular streaks and patches of basic rocks are frequent along the borders of the syenite. They show all stages of hydrothermal alteration, recrystallization, and of having been digested by the syenite.

Fig. 5. Irregular patches of quartzite (white) surrounded by metagabbro (black) and syenite (dotted black and white). Direct contact is never found between quartzite and syenite. Loc. 1. Greatest dimension of the figured hand specimen is 16 cm.

They are studded with the feldspars of the syenite — idiomorphic crystals, attaining several millimetres diameter of clouded microcline and clear albite with interstitial quartz and calcite. There are also large idiomorphic crystals, up to 1 cm across, of diopsidic pyroxene exhibiting (100), (010) and (110) surfaces, large plates of brown hornblende, relatively large cubes of pyrite, and large crystals of titanite. Acicular apatite crystals, which are hollow, are younger than titanite, and also younger than the recrystallized calcite and quartz (see Fig. 4).

In places the metagabbro merges into ultrabasic concentrations of serpentine-chlorite and garnet in dense aggregates. In other places there is a gradual transition to red syenite. At loc. 1 (Fig. 1) the metagabbro contains some of the syenitic material as well as irregular pieces of quartzite with granoblastic mosaic structure. The metagabbro is always found to separate the quartzite from the syenite (see Fig. 5). It is believed that the metagabbro is a basic derivative of the same magma which later formed the syenite.

THE BRECCIA

The breccia is exposed only along the north and west borders of the syenite, at the contact with the gneisses (Fig. 6 and inset in Fig. 1). All kinds of transitions exist between gneiss intersected by veins of syenite (usually poor in chlorite needles) and syenite containing fragments of gneiss. In the fragments, as well as in the gneisses adjacent to the breccia, the feldspar has a reddish tint which sometimes makes it difficult to say, even in thin section, if the feldspar belongs to the gneiss or to the syenite. A study of the direction of foliation in the gneiss-fragments reveals that some of the fragments have been rotated.

At loc. 2 (see Fig. 1) the breccia also contains, in addition to randomly arranged gneiss fragments with pronounced foliation, fragments of a dark fine-grained rock composed of hornblende, chlorite and feldspar, now mostly albite. One of the fragments contains the sharp boundary between this melanocratic rock and gneiss (Fig. 6).

At loc. 5 (Fig. 1) the syenite contains angular fragments 1 to 3 cm across of pegmatitic quartz.

DIABASE

Two diabase dikes 3 to 20 cm thick are found at loc. 4 (Fig. 1), where they partly intersect and partly follow the border of a pegmatite dike. They cannot be followed to the margin of the syenite, or into it, due to lack of outcrop. Ophitic texture is evident; the pyroxene has a small positive axial angle. It is assumed that the dark fragments of the breccia come from such a diabase dike and that the mineral composition of the fragments was altered by later igneous activity.

Mode of formation

The mineral associations of the syenite, metagabbro, and of the altered zone of the gneiss surrounding the syenite, viz., chlorite, calcite, albite, pyrite, etc., suggest at first sight low-temperature hydrothermal conditions. The brecciation must have been accompanied by vapour and aqueous solutions penetrating into the wallrocks, resulting in low-temperature recrystallization. Furthermore, one may presume that late hydrothermal activity of long duration and high hydrostatic

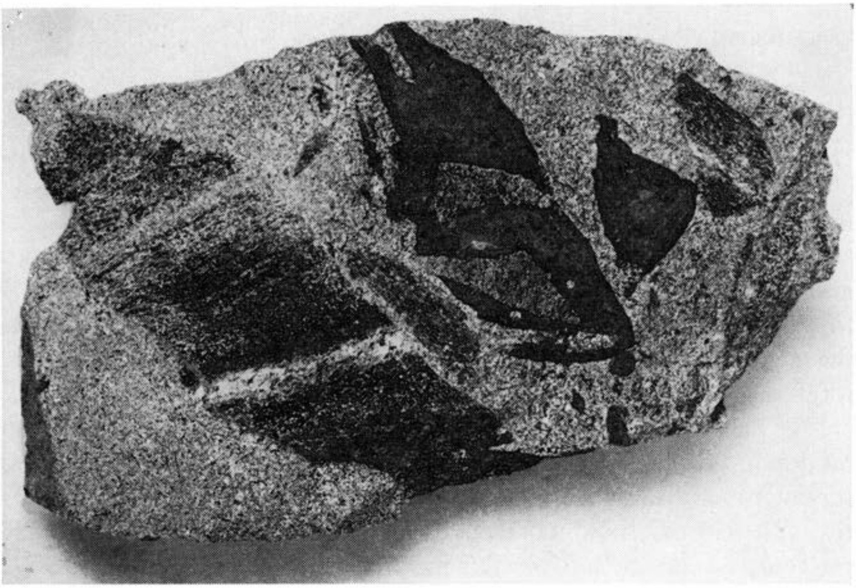


Fig. 6. Breccia containing randomly orientated fragments of foliated gneiss and of diabase. Loc. 2. Greatest dimension of figured hand specimen is 21 cm.

vapour pressure could effect complete recrystallization, obliterating almost all primary features. However, remnants of pyroxene testify to a former higher temperature, so does the M-twinning of the microcline of the syenite. The brecciation phenomena, the intrusion relations of the syenite, the presence of fluorite, baryte and anatase indicate real volcanic conditions with gas coring and lava flowing through the vent at high temperatures.

Idiomorphic non-perthitic crystals of pure potassium feldspar and of pure sodium feldspar with a highly ordered Al/Si-distribution are believed to have developed during the hydrothermal stage from an ordinary alkali feldspar mixed crystal typical of an igneous syenite (e.g. a nordmarkite). The bulk composition of the feldspars is similar to that of the typical nordmarkite feldspar (around $Or_{40}Ab_{60}$ with small amounts of An). It is now known that the pressure of H_2O dramatically catalyses the migration of the ions of the feldspar lattice. In many papers WYART *et al.* (1956, 1961) have analyzed the mechanism of the movements and have shown by experiments that at temperatures of 500° both Si^{4+} and Al^{3+} diffuse with a measurable speed. K^{1+} and Na^{1+} move at still lower temperatures (300° to 400°) under high water vapour pressure. Thus, original alkali feldspar mixed crystals are considered to have exsolved into two phases, microcline and low albite that recrystallized into idiomorphic individuals of the respective feldspars as now seen in the red Fjone calcite syenite.

Age relationship

The Fjone syenite with its associated metagabbro and breccias is cross-cutting the surrounding gneisses. No pegmatite is found to transect the syenite, etc., and the syenite, as well as the metagabbro, contains fragments of quartz which may be derived from the pegmatite. The altered diabase in the composite fragments of the breccia may have the same origin and age as the diabase dikes found at loc. 4 (Fig. 1). Diabase dikes are found in an increasing number east and northeast of Fjone where they are connected with the Permian igneous activity of the Oslo Region. Within the Oslo Region itself, injections of diabase dikes are known from various phases of the igneous period.

The chemical and mineralogical composition of the syenite is comparable to that of certain igneous rocks of the Oslo Region, viz., some types of nordmarkite (see Table 1).

The nearest known explosion vents are: 1) The Fen area at Norsjö, and 2) Jönnbu at Lifjell (see inset map of Fig. 1).

The Fen area is an explosion centre of carbonatite and peralkaline rocks; the age is 560 million years.

The Jönnbu explosion breccia is a diatreme 50 to 150 m in diameter of Permian (?) age (SIGGERUD in DONS 1960). Fragments of quartzite and amphibolite may represent shattered country rock, but several xenoclasts of red as well as of black schists are foreign to the environment. Radiating joints are filled with rock dust and fragments of rock. No igneous matrix is found.

On the basis of present knowledge it can not be decided whether the Fjone syenite is of the Fen area-age (Late Precambrian) or Permian age. Further investigations will show if the Fen explosion centre represents an early expression of an igneous activity which reached its maximum in Permian time. If that is the case, the question of the age may not be 'either/or'; it may be any time in between.

REFERENCES

BRÖGGER, W. C. 1933. Die Eruptivgesteine des Oslogebietes, VII. Norske Vid.-Akad. Skrifter, Mat. Nat. v. klasse 1933, No. 1, p. 85.

DONS, J. A. *et al.* 1960. The stratigraphy of supracrustal rocks, granitization and tectonics in the Precambrian Telemark area, Southern Norway: Guide to excursion No. A 10 of XXI International Geological Congress in Norden 1960. (Also published Norges geol. Undersök. No. 212 h, Oslo 1960) 30 pp.

HOLTEDAHL, O. (editor) 1960. Geology of Norway. Norges geol. Undersök. No. 208, 510 pp.

POLDERVAART, A. and GILKEY, K. 1954. On clouded plagioclase. Am. Mineralogist v. 39, pp. 75–91.

WYART, J. and SABATIER, G. 1956. Mobilité des ions alcalins et alcalino-terreaux dans les feldspaths. Soc. franç. minéralogie Bull. 79, p. 444, *Idem* 79, p. 574.

— — 1961. Echange des atomes dans les feltspaths, Action de l'eau. Inst. 'Lucas Mallada' Cursillos y Conferancias, Fasc VIII p. 23. Madrid 1961.

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