

# Age Determinations from the Trondheim Region Caledonides, Norway: a Preliminary Report

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Twenty-four potassium-argon age determinations have been made on metamorphic minerals and whole-rocks (phyllites) from the Caledonides of the Trondheim region, Norway. Nineteen of the apparent ages fall between 438 and 402 m.y., while 5 (4 hornblendes and 1 phyllite) range up to 570 m.y. Dates greater than 438 m.y. are provisionally considered anomalous, and  $438 \pm 12$  m.y. is tentatively suggested as a minimum age for the last metamorphic phase in this region.

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## Introduction

The geology of the Trondheim region of the Norwegian Caledonides has been studied in some detail over the past few years by workers from, or associated with, Norges Geologiske Undersøkelse. Investigations have been concentrated in the northern half of the region (e.g. Peacey 1964, Siedlecka 1967, Roberts 1967, 1968, Wolff 1967) and, in connection with the stratigraphic mapping and tectonic studies, an isotope dating project has been initiated of which this is a preliminary report. Unfortunately the region is sparse in material suitable for whole-rock Rb–Sr work, but low-grade phyllites are common and it was hoped that K–Ar determinations on such material might, as in Scotland (Harper 1964, 1967, Dewey & Pankhurst 1970), give dates close to the actual time of orogenesis. Micas and hornblendes from parts of the region of higher metamorphic grade were included in the study for purposes of comparison.

## Geological setting

A résumé of the geological evolution of the Trondheim region has been presented in a recent review article (Roberts et al. 1970). The Cambro–Silurian metasedimentary sequence is believed to be allochthonous, the principal thrusting delimiting the nappe having occurred during the polyphase late-Caledonian major folding. Taken as a whole it is one of the best areas in the Caledonides for fossils, though considerable stratigraphic uncertainties still exist. Sediments range from Cambrian to L.Landoverly with three breaks marked by unconformities and conglomerates. Holtedahl (1920) referred to the tectonic events responsible for these breaks as ‘disturbances’. Special

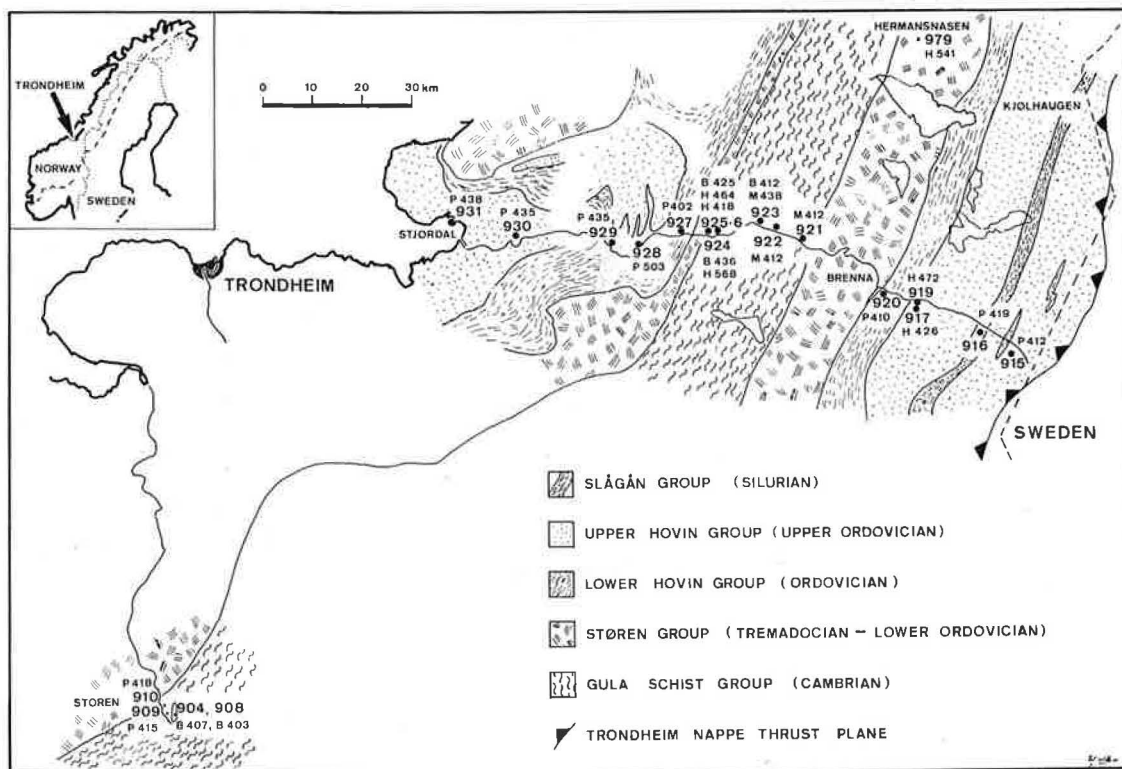


Fig. 1. Sketch map to indicate specimen locations. Geological information taken from plate IV, Wolff (1967). The large figures are the sample numbers and the small figures the apparent ages in millions of years. P: phyllite. B: biotite; M: muscovite; H: hornblende.

interest has been shown in the so-called 'Trondheim disturbance' which is more or less coeval with the main orogenesis of the Scottish and Irish Caledonides (Dewey & Pankhurst 1970, Leggo & Pidgeon 1970), and with metamorphic events in the Bergen and Sørøy areas of Norway (Kvale 1960, Sturt et al. 1967, Pringle & Sturt 1970). The exaggeration of the Trondheim disturbance into a period of major orogenesis (Church 1969, Dewey et al. 1970) has been criticised recently by Roberts (1971). The geochronological results reported here give no encouragement to models involving L. Ordovician orogeny in the Trondheim region.

Orogenesis involved four phases of fold deformation ( $F_1$ – $F_4$ ).  $F_1$  and  $F_2$  were episodes of major folding responsible for the present regional distribution of lithological units, with the main thrusting apparently having taken place towards the end of the second fold phase (Roberts 1967, p. 88). The third phase,  $F_3$ , produced folds of minor dimensions and is widespread throughout the region though variable in intensity. Several of the phyllites dated in this investigation show a good  $F_3$  crenulation cleavage. The last deformation phase,  $F_4$ , was responsible for several sets of kink-bands and associated minor folds of restricted distribution.

Metamorphism, varying from lower greenschist facies to high almandine-amphibolite facies, has affected all stratigraphic units; metamorphic grade, in general, tends to decrease up the stratigraphic column. The pervasive metamorphic fabric was associated with the first folding (Peacey 1963, 1964, Roberts 1967), with crystallisation of biotite and higher grade minerals as porphyroblasts in a static phase between  $F_1$  and  $F_2$ . Metamorphic conditions varied from place to place during  $F_2$ , in parts prograde, in others retrograde. No minerals of  $F_3$  age have been observed.

Finally it must be emphasised that the involvement of L.Landoverly sediments in all identifiable structural and metamorphic events places a maximum age limit on orogeny.

Specimens were collected mainly from the Stjørdal valley, which cuts across the anticlinal structure of the northern Trondheim region, from Stjørdal in the west to Meråker in the east (Fig. 1). Metamorphic grade is highest in the centre (the Gula Schist Group) but the greater part of the profile is through rocks of lower grade, mostly muscovite phyllites. Some of the material comes from the L. Llandoverly Slågån Group, about 12 km south of the graptolite locality discovered by Getz (1890). Phyllites were analysed as whole-rocks. From the central part of the profile lepidoblastic biotite and muscovite, pegmatitic muscovite, and porphyroblastic hornblende were analysed. The pegmatites were emplaced concomitantly with the  $F_1$  folding; lepidoblastic micas derive from the regional schistosity. Porphyroblastic hornblende crystallisation is largely post- $F_1$ , pre- $F_2$  (Roberts 1967). Hornblendes from massive amphibolites of probable pre-tectonic origin were also dated, including one from Hermansnasen, a mountain about 20 km north of the Stjørdal valley. A small trondhjemite intrusion (the Follstad trondhjemite, a few km south of Støren, Fig. 1) was investigated, together with phyllites from the Gula Schist Group in the vicinity.

Specimen descriptions and locations are given in Appendix II.

## Age determinations

Nineteen of the apparent ages are concentrated between 438 and 402 m.y., while 5 (4 hornblendes and 1 phyllite) range up to 570 m.y. (Fig. 2 and Table 1). We believe that the most probable explanation of this pattern is that the range from 438 to 402 m.y. gives a minimum time for the last *metamorphic* phase, while dates greater than 438 m.y. are in some way false.

## THE PHYLLITES

The advantage of dating low-grade phyllites is that these rocks usually occur at a high structural position in an orogen and may have cooled more rapidly after metamorphism. Assuming that the rocks were completely recrystallised during the metamorphism, the dates obtained may be quite close to the time of the last significant thermal peak of metamorphism (see Harper 1964, 1967, Dewey & Pankhurst 1970, Dodson & Rex 1971 for examples and discussion).

Table 1. K-Ar analyses of minerals and rocks from the Trondheim region, Norway

Specimen	%K	$^{40}\text{Ar}$ cc(STP)/g $\times 10^{-5}$		% $^{40}\text{Ar}$ radiogenic	$^{40}\text{Ar}/^{40}\text{K}$	age in m.y.
904 biotite	7.00	12.67	A	94	0.0265	407
908 biotite	6.93	12.42	A	95	0.0263	403
909 phyllite	2.01	3.717	A	96	0.0271	415
910 phyllite	1.77	3.296	A	91	0.0273	418
915 phyllite	2.41	4.417	L	92	0.0269	412
916 phyllite	2.60	4.876	L	98	0.0274	419
917 hornblende	0.266	0.5069	A	84	0.0279	426
919 hornblende	0.197	0.4227	A	83	0.0313	472
920 phyllite	3.25	5.956	A	98	0.0269	412
		5.878	L	94	0.0265	407
921 muscovite	8.91	16.154	A	97	0.0266	408
		16.738	A	97	0.0275	421
922 muscovite	8.60	15.785	A	85	0.0269	412
923 muscovite	7.09	13.925	A	93	0.0288	438
923 biotite	6.32	11.619	L	94	0.0269	412
924 biotite	6.85	13.377	L	89	0.0286	436
924 hornblende	0.410	1.065	A	87	0.0381	560
		1.104	A	85	0.0395	576
925 hornblende	0.339	0.6314	A	80	0.0273	418
926 biotite	6.51	12.44	A	91	0.0280	427
		12.31	A	96	0.0277	423
926 hornblende	0.336	0.7027	A	78	0.0308	464
927 phyllite	2.21	3.942	A	97	0.0261	402
928 phyllite	0.955	2.193	A	81	0.0337	503
929 phyllite	2.012	3.921	L	95	0.0286	435
930 phyllite	1.83	3.559	L	90	0.0285	435
931 phyllite	2.19	4.307	L	94	0.0288	438
979 hornblende	0.1134	0.284	L	71	0.0367	541

The analytical precision of these dates is estimated to be  $\pm 3\%$  at the 95% confidence level.

A: Argon measured at Amsterdam

L: Argon measured at Leeds

A very real problem is that with such low-grade material there may not have been complete recrystallisation, and there may be significant quantities of detrital mica present. It has been suggested by Harper, among others, that the low-grade metamorphism and the strain involved in the formation of a slaty cleavage may be sufficient to expel pre-metamorphic argon. A test for the presence of pre-metamorphic argon could be the degree of concordance between slates or phyllites from different lithologies within a small area. Only one of the ten phyllites analysed is markedly discordant, specimen 928 (503 m.y.) and it may be significant that this comes from an outcrop at which sedimentary structures (ripple marks) are preserved. Disregarding specimen 928, the phyllites give dates between 438 and 402 m.y. (Fig. 2.).  $438 \pm 12$  m.y. is taken as the time at which some of the phyllites began retaining argon quantitatively.

#### THE MICAS

Muscovite and biotite dates range between 438 and 403 m.y., a distribution similar to that of the phyllites. The two dates of 436 and 438 m.y. from micas

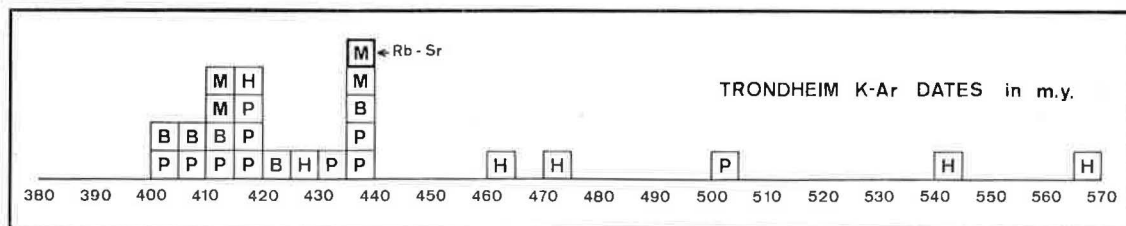


Fig. 2. Histogram of mineral dates from the Trondheim region. The analytical precision of these dates is  $\pm 3\%$ . P: phyllite; B: biotite; M: muscovite; H: hornblende.

of certain metamorphic origin support the suggestion that the low-grade phyllites were completely outgassed during the metamorphism. Specimen 922 has been analysed in duplicate by the Rb-Sr method with the following results, concordant with the K-Ar analyses.

Rb ppm	Sr ppm	$^{87}\text{Rb}/^{86}\text{Sr}$	$^{87}\text{Sr}/^{86}\text{Sr}$	age
540	9.22	188.6	1.858	$437 \pm 12$ m.y.
544	9.22	190.0	1.860	$434 \pm 12$ m.y.

An initial ratio of  $^{87}\text{Sr}/^{86}\text{Sr} = 0.710$  was assumed.

#### THE HORNBLENDES

Two of the six hornblende dates fall between 438 and 400 m.y., but the rest are in excess of 460 m.y. If these dates are genuine then some or possibly all the hornblendes are Ordovician or older and therefore pre-date the main metamorphism in the Trondheim region. The observed spread could result from partial outgassing during the Silurian orogeny. Such an interpretation would imply that some of the hornblendes grew before  $568 \pm 17$  m.y., the oldest date, and this event would pre-date the lower Ordovician orogenic event in Scotland and in Sørøy (Stuart et al. 1967, Dewey & Pankhurst 1970, Pringle & Sturt 1970). Three of the hornblendes, two of which give dates of 472 and 541 m.y., come from massive coarse-grained amphibolites, which are probably of pre-tectonic origin. Conceivably these bodies could have been converted to amphibolite during some pre-Silurian orogenic event. The other hornblendes are porphyroblasts from the schists of the Cambrian Gula Schist Group. The hornblende of specimen 925 gives a date of 418 m.y. and its textural relationship to the schistosity indicates that it grew during or after F<sub>1</sub>. Specimen 926 from the same locality has hornblende with a date of 464 m.y., yet the relationship of porphyroblast and foliation is virtually identical. It would be difficult to accept that these hornblendes were of different generations. The hornblende in specimen 924 (560 and 576 m.y.) is different in appearance, though a detrital origin would still be difficult to accept.

An alternative explanation, and one which we currently favour, is that for some reason these hornblendes are giving dates in excess of their crystallisation age. Possibly they contain excess radiogenic argon, as has been demonstrated in metamorphic hornblendes from the Sulitjelma region in the Norwegian Cale-

donides (Wilson 1972). Hornblendes from eight more rocks are currently being investigated and it is hoped that the results of these further analyses may shed some light on this problem.

#### SIGNIFICANCE OF THESE DATES

The fact that the phyllites and micas give apparent ages as high as  $438 \pm 12$  m.y. suggests that this figure could be a minimum age for the last metamorphic phase of the orogeny in the Stjørdal valley area. We cannot be sure whether this gives a minimum age for  $F_2$  or for  $F_3$ .  $F_4$  is so uncommon that we consider that it did not have a significant effect on the dated rocks.  $F_2$  was the last phase clearly accompanied by metamorphism.  $F_3$  involved intense crenulation of the existing mica fabric in the noses and short limbs of folds, and this deformation may well have been enough to remove argon from the deformed micas. But no sign of mineral growth during  $F_3$  has been observed, except for quartz and calcite veining, and the effect of this phase on the K-Ar ratios of rocks without the  $F_3$  crenulation cleavage may be slight. Specimen 931 gives a date of 438 m.y. despite showing an  $F_3$  crenulation of the weakly developed cleavage and might indicate that  $438 \pm 12$  m.y. is indeed a minimum for  $F_3$ . It is hoped that a proposed comparison of dates from rocks with and without  $F_3$  crenulation cleavage may resolve this problem.

#### Comparisons with published dates from other parts of the Scandinavian Caledonides

Rb-Sr dates quoted below are calculated using  $\lambda(^{87}\text{Rb}) = 1.39 \times 10^{-11} \text{yr}^{-1}$ . The absolute value of this constant is at present unknown and some workers prefer  $1.47 \times 10^{-11} \text{yr}^{-1}$ , giving Rb-Sr dates 6% lower. Use of an intermediate value has been discussed (e.g. Lambert 1971).

#### EARLY SYNTECTONIC GRANITES, RB-SR WHOLE-ROCK ISOCHRONS

The minimum age for the Trondheim region metamorphism can be usefully compared with Rb-Sr whole-rock isochrons on syntectonic granites in Sulitjelma and N. Västerbotten. These granites were intruded between the local  $F_1$  and  $F_2$  phases. Significant differences might result from diachronism, or might give information on the duration of orogenic phases. In Sulitjelma granitic dykes give  $433 \pm 11$  m.y. and the Furulund granite a less precise  $443 \pm 16$  m.y. (Wilson, unpublished results). The Vilasund granite from Koli Group rocks of N. Västerbotten, Sweden, gives  $447 \pm 6$  m.y. (Gee & Wilson, in preparation). These isochron dates are statistically indistinguishable from the minimum date of  $438 \pm 12$  m.y. suggested in this account.

#### MINERAL DATES

A number of publications give determinations on micas from other parts of the belt (e.g. Broch 1964, Priem et al. 1967, Sturt et al. 1967, Bryhni et al. 1971, Brueckner 1972, Wilson 1972). Excluding those which appear to be affected

by excess radiogenic argon they range from about 440 to 350 m.y., with the majority between 420 and 380 m.y. The Trondheim dates thus have a higher than average range. We interpret this as a real difference in the time of cooling caused by variations in structural level. An alternative explanation of the difference could be that the Trondheim region, or rather, that part of it so far investigated, missed some thermal/orogenic event which was responsible for overprinting elsewhere. Bryhni et al. (1971), on the basis of a  $^{40}\text{Ar}/^{39}\text{Ar}$  study of a mica concentrate, believe that such overprinting occurred in the basal gneiss region southwest of Trondheim at around 400 m.y. We are not convinced, however, that their results do not merely indicate that the more westerly parts of the belt were at a deeper level and remained hot for a much longer time after the last deformation phase than did the Trondheim region. The sequence of orogenic phases appears to be just as complex and complete in the Stjørdal area as in the regions giving the younger dates. Nevertheless, the existence of dates as low as 350 m.y. (Broch 1964, Wilson, unpublished results), dates around the Carboniferous/Devonian boundary, raises the possibility that in some parts of the orogen complete closure of Sr and Ar isotopic systems was not reached until so late because of recurrent localised thermal phases. This suggestion could be supported by the limited evidence of localised Devonian folding, thrusting and igneous activity (Holtedahl 1960). Unpublished work (D. R.) has also confirmed weak post-Lr. Devonian metamorphism in the Røragen area.

### Concluding discussion

Perhaps the most important assumption we have adopted in our discussion of these new dates is that the minerals and rocks giving dates between 438 and 402 m.y. do not contain significant amounts of extraneous radiogenic argon (either excess argon or argon derived from detrital minerals). We believe that the close grouping within this range, and the concordance between dates from whole-rocks and separated biotites and muscovites, are in support of this assumption. Eighteen more phyllites from a wide area north and south of the Stjørdal valley are currently being analysed and the distribution of these dates should give an indication of the validity of the assumption.

If the dates are reliable then the most reasonable interpretation is that the last metamorphic phase of the orogeny occurred before  $438 \pm 12$  m.y. In comparison with other parts of the orogen this is an age much closer to the time of emplacement of the early syntectonic granites than to the post-metamorphic cooling.

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## Appendix I

### ANALYTICAL METHODS

The analyses reported in this paper were conducted in the Z.W.O. Laboratorium voor Isotopen-Geologie, Amsterdam, and in the Department of Earth Sciences, University of Leeds. Argon was extracted in bakable glass vacuum apparatus and determined by isotope dilution using  $^{38}\text{Ar}$  as a tracer. Analyses at Leeds were measured on an A.E.I. MS10 gas source mass spectrometer and in Amsterdam using a Reynolds type glass mass spectrometer. All measurements were made by the static method. The potassium analyses were performed in Amsterdam by standard flame-photometric methods using Li as internal standard. The Rb-Sr determination of muscovite 922 was conducted at Amsterdam using stable isotope dilution with spikes enriched in  $^{87}\text{Rb}$  and  $^{84}\text{Sr}$ . Isotope measurements were made on a 20 cm,  $60^\circ$  mass spectrometer with digital output, utilising multiplier detection. Correction for the effects of isotope fractionation and mass discrimination was made by normalising to  $^{86}\text{Sr}/^{88}\text{Sr} = 0.1194$ .

The analytical precision of the dates is estimated at  $\pm 3\%$  at the 95% confidence level. The following constants were employed:

$$\begin{aligned}\lambda(^{87}\text{Rb}) &= 1.39 \times 10^{-11} \text{yr}^{-1} \\ ^{40}\text{K} \lambda_e &= 0.584 \times 10^{-10} \text{yr}^{-1} \\ \lambda_\beta &= 4.72 \times 10^{-10} \text{yr}^{-1} \\ ^{40}\text{K}/\text{K} &= 0.0119 \text{ at. \%}\end{aligned}$$

## Appendix II

### SPECIMEN LOCATIONS AND DESCRIPTIONS

Specimens from south of Støren

#### 904 *biotite* 407 *m.y.*

From a small body of trondhjemite (the Follstad trondhjemite) intruded into the Gula Schist Group. Small quarry owned by A/S Norsk Labrador, 2–3 km south of Støren. A medium-grained quartz-plagioclase-biotite rock without any deformation fabric visible to the naked eye. The plagioclases are zoned with centres partly altered to muscovite and epidote. Muscovite and hornblende are also present in the rock. The quartz is mainly strained but with straight uncomplicated boundaries. The biotites are often bent or broken. Biotite concentrate 99% pure.

#### 908 *biotite* 403 *m.y.*

From Follstad trondhjemite (see 904). Biotite concentrate 99% pure, but muscovite and quartz observed.

#### 909 *phyllite* 415 *m.y.*

From the Gula Schist Group, about 1 km north of the Follstad trondhjemite quarry and about 2 km south of Støren. A fine-grained muscovite phyllite. The schistosity has been strongly folded into an  $F_3$  crenulation cleavage.

#### 910 *phyllite* 418 *m.y.*

From Gula Schist Group about 1 km south of Støren. A fine-grained muscovite phyllite with  $F_3$  crenulation cleavage.

Specimens taken along the E75 highway in the Stjørdal valley between the Swedish frontier and the coast.

*915 phyllite 412 m.y.*

Phyllite from Kjølhøgen Group (Upper Hovin). Location about 3 km west of the Swedish frontier on E75. A very fine-grained muscovite phyllite with random biotite porphyroblasts. The biotite post-dates the  $F_1$  cleavage but pre-dates the  $F_3$  crenulation cleavage. Quartz, muscovite, calcite, biotite, and minor amounts of chlorite and opaques.

*916 phyllite 419 m.y.*

Phyllite from the Silurian (L. Llandovery) Slågån Group. Location about 3 km west of specimen 915. A black fine-grained muscovite phyllite with excellent  $F_3$  crenulation cleavage. Random biotite porphyroblasts pre-date  $F_3$ . Quartz, muscovite, biotite, and opaques.

*917 hornblende 426 m.y.*

Coarse-grained amphibolite ('hornblende gabbro'). At Turifoss Bridge, about 1 km east of Turifoss. This amphibolite body may represent a pre-tectonic intrusion. Consists of large hornblendes broken up and altered. There has been new growth of small clean hornblende crystals. Opaque minerals have altered rims. Plagioclase feldspar, calcite and epidote also abundant. Concentrate is only 90% hornblende, the impurity being mainly epidote.

*919 hornblende 472 m.y.*

From the same outcrop as specimen 917. A coarse-grained amphibolite with hornblende, plagioclase ( $An^{10}$ ), epidote, pyroxene partly replaced by hornblende, altered opaque minerals. Cut by veins of calcite. As in 917 two generations of hornblende are present; large altered grains and small fresh grains. The rock appears more altered than 917. Concentrate 99% hornblende, 1% epidote.

*920 phyllite 410 m.y.*

Phyllite from Sulåmo Group (Lower Hovin). Location - Brenna. A muscovite phyllite with a good  $F_3$  crenulation cleavage. Small biotite porphyroblasts also present, some aligned parallel to muscovite schistosity, and all clearly pre-dating the crenulation cleavage. Muscovite, quartz, biotite, and opaques.

*921 muscovite 412 m.y.*

Muscovite from  $F_1$  pegmatite in Gula Schist Group at grid reference 288 390, 2 km west of Gudå. Pegmatite consists of large augen of oligoclase in a matrix of quartz and muscovite. The muscovite grains are bent and broken. Muscovite concentrate contains no visible impurities.

*922 muscovite 412 m.y.*

Muscovite from  $F_1$  trondhjemitic pegmatite. Grid reference 267 398, about 4 km west of Gudå. Large books of muscovite. The muscovite concentrate contains no visible impurities.

*923 muscovite 438 m.y., biotite 412 m.y.*

Gula Schist Group at Maadalen (245 402). A medium-grained two-mica schist with quartz and minor amounts of opaques, epidote and tourmaline. Muscovite concentrate 98%, the flakes containing minute spots of opaque mineral and brown stains. The biotite concentrate 95% pure with chlorite and muscovite as impurities.

*924 hornblende 568 m.y., biotite 436 m.y.*

Gula Schist Group at Florholmen (204 391). A medium-grained calcareous hornblende-biotite schist. Hornblende is present as rather spongy crystals (symplectitic) and forms clusters together with quartz inclusions around which the schistosity is bowed. Quartz, biotite, hornblende, calcite (10%), and opaques. The hornblende concentrate is 95% pure, the impurity being mainly quartz attached to some of the grains. The biotite concentrate is 99% pure with quartz and hornblende observed as impurities.

*925 hornblende 418 m.y.*

Gula Schist Group at a location just east of Storfloren, an outcrop on a track off the main road (195 396). A fine-grained muscovite phyllite with large biotite grains and large porphyroblasts of hornblende and garnet. The hornblendes are well-shaped and contain vague trails of inclusions, often slightly sigmoidal, indicating syn-tectonic growth. The hornblendes are slightly altered. The garnets contain no inclusions but have chloritised margins. The hornblende concentrate is 95% pure with quartz and biotite present.

*926 hornblende 464 m.y., biotite 435 m.y.*

Gula Schist Group, same locality as specimen 925. The rock is similar to specimen 925 with large hornblendes in a fine-grained muscovite-phyllite matrix. Biotites are larger than the average muscovites. The hornblendes are slightly altered with fractures filled by calcite or chlorite. No inclusions can be seen but the hornblendes are otherwise identical to those of 925. The hornblende concentrate is 98% pure with quartz as contaminant, the biotite concentrate is 98% pure with quartz and chlorite as contaminants.

*927 phyllite 402 m.y.*

Phyllite of Lower Hovin Group, at Flornes Bridge (174 395). A fine-grained muscovite-phyllite with folds and crenulation cleavage of  $F_3$  age. No new mineral growth along  $F_3$  axial planes. Muscovite, quartz, and opaques.

*928 phyllite 503 m.y.*

Phyllite from Lower Hovin Group, northwest of Brataas (132 380). There are ripple marks at this outcrop.

*929 phyllite 435 m.y.*

Phyllite of Upper Hovin Group at grid reference 098 384. A fine-grained muscovite-phyllite with high calcite content. Deformation not as extreme as in 927. Both  $F_1$  and  $F_3$  structures can be seen in the outcrop, although no  $F_3$  structures are present in the specimen taken. Muscovite, calcite, quartz and opaques.

*930 phyllite 435 m.y.*

Greywacke-phyllite of the Upper Hovin Group, south-west of Berg (006 388). A fine-grained quartz-muscovite rock. The quartz grains are rounded and give impression of original sedimentary shape. The muscovite is deformed around the quartz grains and has only a poor preferred orientation.

*931 greywacke-phyllite 438 m.y.*

Greywacke-phyllite from Upper Hovin Group on Sutterøy peninsula. Sedimentation structures are present at locality along with  $F_1$  and  $F_3$  structures. A fine-grained rock with quartz, muscovite and calcite. The  $F_1$  schistosity is crumpled. Despite these structures the rock appears to be less thoroughly deformed and recrystallised than the phyllites from further west.

## Material from north of the Stjørdal valley

*979 hornblende 541 m.y.*

Hornblende from coarse-grained amphibolite, Hermansnasen mountain (1035 m) about 25 km north of the Stjørdal valley. This specimen kindly supplied by Dr. Ferry Fediuk, Prague. Concentrate prepared from coarse crystals, no visible impurities.