

# THE AGE OF ALKALINE ROCKS FROM WEST FINNMARK, NORTHERN NORWAY, AND THEIR BEARING ON THE DATING OF THE CALEDONIAN OROGENY

By

B. A. STURT, Geology Dept., Bedford College, London N.W.1, England.

J. A. MILLER, Dept. of Geodesy and Geophysics, Madingly Rise, Cambridge, England.

F. J. FITCH, Geology Dept., Birkbeck College, London W.C.1., England.

**Abstract.** The results of 27 new potassium-argon age determinations on alkaline rocks from Söröy, Seiland, and Stjernöy are presented. These fall into two major groups, i.e. 480–491 m.y. and 384–420 m.y., which are thought to correspond with two major phases of the Caledonian orogeny.

## Introduction

In recent years a considerable amount of geological research has been carried out into the problems of the Caledonian orogeny and plutonic activity in West Finnmark (BARTH 1953, KRAUSKOPF 1954, HEIER 1961, BALL *et al.* 1963, RAMSAY & STURT 1963, OOSTERROOM 1963, STURT & RAMSAY 1965, and STUMPFL & STURT 1965). The general pattern that has emerged from this work is of a sequence of complexly folded Eocambrian and Cambro-Silurian metasedimentary rocks intruded by a great variety of igneous rocks, which themselves show varying degrees of metamorphism. The plutonic igneous geology is dominated by large bodies of basic and ultrabasic rocks, which form part of the great Seiland petrographic province (BARTH 1953). Alkaline rocks occur in a number of scattered areas in West Finnmark, and always appear to have been emplaced late in the tectonic-metamorphic sequence (STURT & RAMSAY 1965). The authors contend that these rocks are favourably placed in the time sequence to give infor-

mation regarding the minimum age of the major orogenic episode that has affected the region. The results presented in this paper are mainly potassium-argon age determinations on minerals separated from the alkaline rocks of the island of Söröy, but whole-rock and separated mineral potassium-argon age determinations have also been made on nepheline syenites from the adjacent islands of Seiland and Stjernöy.

### General geological history of Söröy

The island of Söröy is situated off the mainland of West Finnmark near the town of Hammerfest (lat. 70°30'N, longit. 23°43'E), and lies in the main belt of the West Finnmark Eocambrian and Cambro-Silurian successions. The island is composed of a varied series of meta-sedimentary and meta-igneous rocks which have been extensively folded and metamorphosed. The plutonic sequence is complex but is dominated by the emplacement of dioritic, basic, and ultrabasic rocks at a number of intervals during the course of the orogeny.

The meta-sedimentary rocks of the island comprise a sequence of psammites, pelitic and semi-pelitic schists and gneisses, graphite schists, limestones, and calc-silicate rocks. Fossils are absent from the major part of the sequence (see STURT & RAMSAY 1965 p. 8), but limestones containing archaeocyathids have been discovered within the upper part of the Klubben Quartzite Formation. A preliminary study of the archaeocyathids indicates a Lower Cambrian age (C. H. Holland, personal communication). As this formation is the lowest stratigraphical unit yet discovered on Söröy (STURT & RAMSAY 1965, ROBERTS 1965) the bulk of the succession on the island must be of Cambrian or younger age. It would appear that the Klubben Quartzite Formation can be correlated with the Lower Cambrian part of the sequence in the Tana district, i.e. the upper part of the Vestertana group or the lower part of the Digermul group (READING 1965).

The meta-sedimentary rocks have been involved in two major phases of folding and a number of less intense episodes of deformation. During the earliest phase of folding (F1), recumbent folds of considerable amplitude were formed, accompanied by mesoscopic folds varying from overturned asymmetric to isoclinal in style. The F1 folds involve the true stratigraphical succession and the anticlines have an overall easterly vergence. The axes of the early folds are

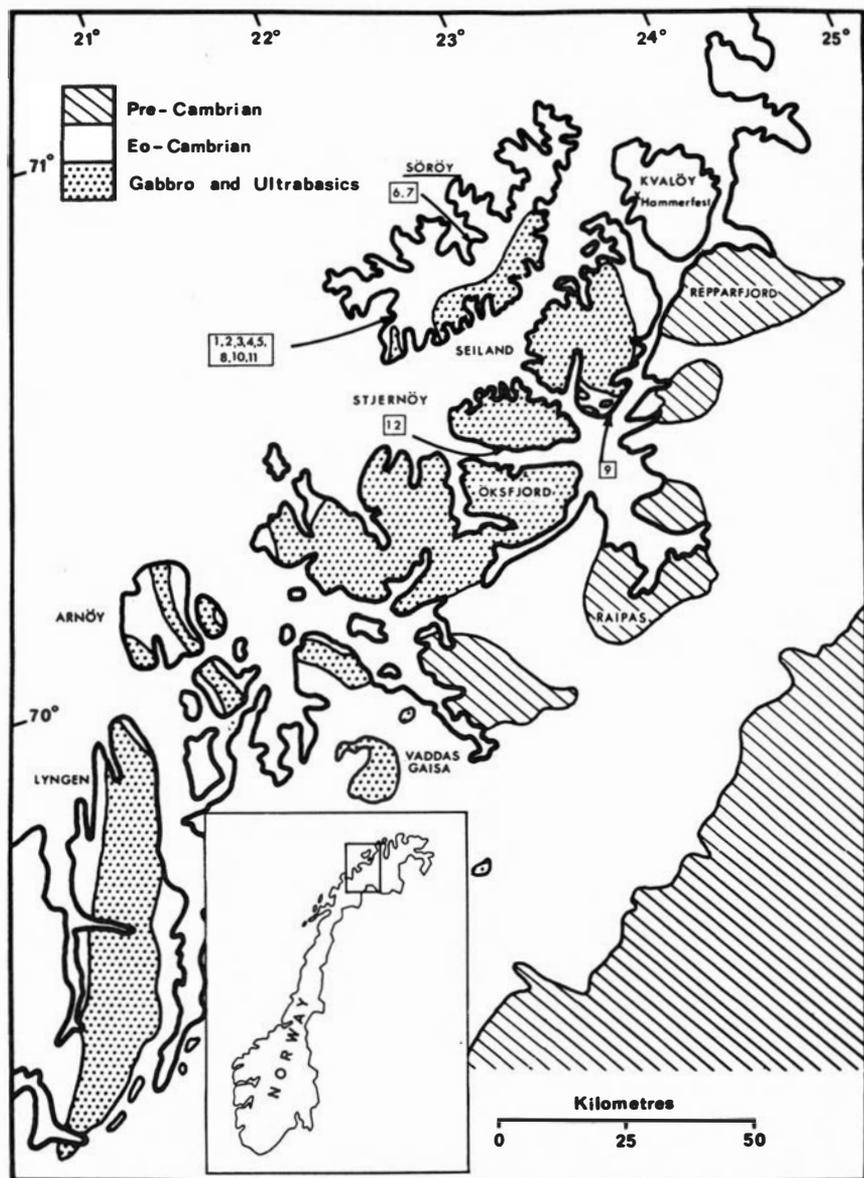


Fig. 1. General distribution of basic rocks in Northern Norway (after N.G.U. 1:1,000,000 Berggrunnskart over Norge 1960). Details of specimen localities given in Table 1.

variable in trend on both the large and small scale, causing major swings in the regional strike pattern. This results in the production of belts with both approximately N-S and E-W trends. On the regional scale, the second phase folds (F2) generally follow the F1 structures in axial trend, though marked changes in structural symmetry occur in the differing trending belts (RAMSAY & STURT 1963, ROBERTS 1965).

The meta-sedimentary rocks are mainly in the almandine amphibolite facies of regional metamorphism, although several phases of metamorphism of differing grade can be distinguished. The highest grade conditions were apparently established during the interval between the two major folding phases, though certain minerals such as garnet continued to crystallize during the second major deformation episode. The main phase of metamorphic recrystallization is characterized by the development of the minerals almandine-rich garnet, staurolite, kyanite, and locally sillimanite in the pelitic and semi-pelitic schists, accompanied by the formation of plagioclase feldspar in the general composition range  $An_{26-35}$ . The minerals diopside and tremolite/actinolite are typical products in the impure calcareous horizons. The main episode of regional metamorphism was also accompanied by widespread though sporadic granitization, which has locally resulted in the development of areas of migmatitic rocks.

The island has had a complicated intrusive history with the emplacement of gabbroic, ultrabasic, dioritic, and granitic masses at a number of stages during its plutonic development (STURT & RAMSAY 1965, STUMPFL & STURT 1965). Major basic intrusions were emplaced in at least three phases:

- (i) Syn-tectonic with the early major deformation (F1).
- (ii) During the interval between the two major deformation phases, and at the peak of the regional metamorphism.
- (iii) During the complicated pattern of movements of the second major deformation phase (F2).

A number of distinct phases of intrusion of granitic, monzonitic, and dioritic rocks occur, and swarms of basic and acidic dikes and sills were emplaced at a number of stages. The various igneous rocks show diverse states of metamorphism as a result of their position in the intrusion-deformation sequence. The latest major phase of plutonic activity on Söröy was the emplacement of a complex of alkaline rocks

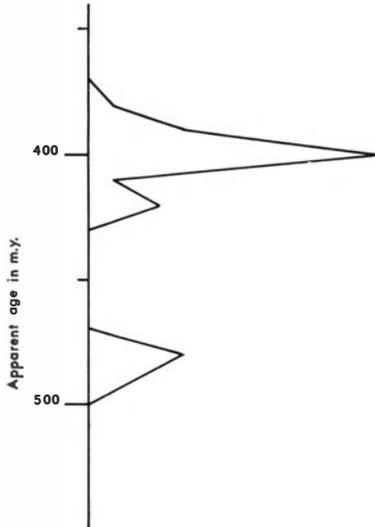


Fig. 2. Histogram of K-Ar age determinations on rocks from Söröy, Seiland, and Stjernöy, West Finnmark.

during the late stages of the second deformation phase (STURT & RAMSAY 1965, APPLEBYARD 1965). All the samples selected for the present study come from this group of rocks. The rock types include nepheline syenite pegmatites and gneisses, carbonatites, and a considerable variety of other syenitic rock-types. The alkaline rocks have been affected by late phases of the F2 deformation and in places are sheared and folded. They are intruded by a set of diabase dikes which themselves are metamorphosed into the epidote-amphibolite facies of regional metamorphism, thus defining the minimum grade of metamorphism of the alkaline host rocks.

Alkaline rocks of similar structural relationship occur in surrounding areas, particularly on the adjacent islands of Seiland (BARTH 1927) and Stjernöy (HEIER 1961, OOSTERROOM 1963).

### New potassium-argon age determinations

The results of twenty-seven new potassium-argon age determinations on rocks and minerals from Söröy, Seiland, and Stjernöy (Fig. 1) are presented in Table 1. One is a whole rock determination on a nepheline syenite and the rest are determinations on mineral concentrates

Table 1.  
*New potassium-argon age determinations by Omegatron*

Sample	Ref.	K <sub>2</sub> O%	At. contam. %	Vol radio- genic 40Ar mm <sub>3</sub> NTP/gm	Age and experi- mental error (mys)
(1) Biotite concentrate from nepheline-syenite-gneiss, Breivikbotn, Söröy. (SB 51)	938	9.32	7.3	0.1315	384 ± 7
		9.32	10.0	0.1321	387 ± 7
(2) Biotite concentrate from deformed nepheline-syenite gneiss, Breivikbotn, Söröy. (SB 117)	939	9.34	5.5	0.1371	399 ± 7
		9.34	6.2	0.1361	397 ± 7
(3) Biotite concentrate from biotite-plagioclase-microcline schist, Breivikbotn, Söröy. (SB 495)	940	8.54	6.2	0.1259	400 ± 8
		8.54	9.5	0.1245	397 ± 7
(4) Biotite concentrate from nepheline-syenite-gneiss, Breivikbotn, Söröy. (SB 528)	941	9.30	5.4	0.1432	416 ± 8
		9.30	6.0	0.1413	411 ± 8
(5) Biotite concentrate from perthite-mica-pegmatite, Breivikbotn, Söröy. (BAS 1)	942	9.59	9.2	0.1428	404 ± 7
		9.59	12.1	0.1419	402 ± 7
(6) Biotite concentrate from nepheline-scapolite-biotite-pegmatite, Dønnesfjord, Söröy. (4047/52-6)	943	8.57	19.4	0.1225	389 ± 8
		8.57	7.1	0.1235	392 ± 8
(7) Biotite concentrate from nepheline-syenite-gneiss, Dønnesfjord, Söröy. (3047/63-16)	944	9.64	14.0	0.1410	398 ± 8
		9.64	10.5	0.1420	400 ± 8

Table 1. (cont.)  
*New potassium-argon age determinations by Omegatron*

Sample	Ref.	K <sub>2</sub> O%	At. contam. %	Vol radio- genic <sup>40</sup> Ar mm <sub>3</sub> NTP/gm	Age and experimen- tal error (mys)
(8) Biotite concentrate from biotite-sövite, Baarvik, Söröy. (BHV 16)	945	9.57	14.0	0.1404	398 ± 8
		9.57	18.4	0.1404	398 ± 8
		9.57	12.8	0.1378	392 ± 7
(9) Nepheline concentrate from nepheline-syenite- pegmatite, Bekkarfjordnes, Seiland. (Se 2)	946	5.39	6.8	0.0987	486 ± 10
		5.39	15.1	0.0975	480 ± 10
		5.39	16.2	0.0978	482 ± 10
(10) Nepheline concentrate from nepheline-syenitepeg- matite, Breivikbotn, Söröy. (BAS 2)	947	5.82	28.6	0.1080	491 ± 11
		5.82	7.7	0.1062	484 ± 10
		5.82	10.0	0.1063	484 ± 10
(11) Muscovite concentrate from nepheline-sodalite- syenite, Breivikbotn, Söröy. (DMR 1)	948	10.64	10.5	0.1661	421 ± 9
		10.64	14.5	0.1660	421 ± 7
(12) Nepheline-syenite, Lillebugt, Stjernöy (Stj 1)	949	9.22	8.2	0.1364	402 ± 8
		9.22	7.9	0.1378	404 ± 9

$\lambda\beta = 4.72 \times 10^{-10} y^{-1}$ .  $\lambda e = 0.584 \times 10^{-10} y^{-1}$ . K<sub>2</sub>O deter. by H. Lloyd.

(nepheline, biotite, or muscovite) separated from nepheline syenite gneisses and pegmatites and from carbonatites. The mineral concentrates were either hand picked from coarse pegmatites or prepared by crushing and electromagnetic separation techniques. Potassium oxide determinations were made by Mr. H. Lloyd at Bedford College, London, using flame photometric methods. Several repeat determinations were made on each sample.

Argon extraction and purification were carried out in the manner described by MILLER & BROWN (1964). Isotopic ratios were measured using the omegatron-type machine described by GRASTY & MILLER (1965). Enriched argon-38 was employed as an internal standard (spike).

Errors in radiogenic argon volume arising from uncertainties in the isotopic ratios of the argon sample and spike volume together with those introduced in the determinations of potassium oxide are combined. The error in millions of years associated with each separate age determination is calculated according to the method set out in MILLER & FITCH (1964).

Petrographic descriptions of the dated rocks from Söröy, Seiland, and Stjernöy can be found in Appendix I.

### Interpretation of the results

The results of the potassium-argon age determinations from the region shown in the map (Fig. 1) are presented in Table 1 and illustrated in the histogram (Fig. 2); they would appear to fit into two general categories:

- (a) 480–491 m.y. apparent ages obtained from nephelines separated from nepheline syenite pegmatites. These must be regarded as minimum ages overprinted by late Caledonian metamorphism. It is thought, however, that they are not severely discrepant, as nepheline is relatively resistant to argon loss (MACINTYRE, YORK & GITTINS 1966).
- (b) 384–420 m.y. 'overprinted' apparent ages obtained from micas separated from nepheline syenite gneisses and pegmatites, from carbonatites and one nepheline syenite whole-rock determination.

In terms of the 1964 Geological Society of London time-scale (*Quart. Jour. geol. Soc. Lond.* 120S, 260–2) it would appear that the first group of ages reflects an event in or before the early part of the Ordovician, and the second group an event or sequence of events close to the end of the Silurian.

#### (a) *The 480–491 m.y. group of apparent ages*

As described in the introduction the plutonic history of Söröy was complex, with several phases of deformation, metamorphism, and emplacement of igneous rocks. The emplacement of the alkaline rocks

was apparently the last major plutonic event to occur on the island (STURT & RAMSAY 1965, APPLEYARD 1965). The apparent ages obtained from the nephelines of the nepheline syenite pegmatites imply that the major plutonic development of Söröy was completed somewhat before 490 m.y. ago, towards the close of a major early phase of the Caledonian orogeny. A considerable part of the stratigraphical succession is younger than strata containing Lower Cambrian fossils, thus giving a maximum age for the phase of orogeny. The conclusion is in keeping with suggestions regarding the major metamorphism of the Eocambrian and Cambrian Dalradian rocks of the British Isles around 500 + m.y. ago (DEWEY 1961, BROWN *et al.* 1965, LEGGO *et al.* 1966). In Norway, however, no clear picture of such a phase of the Caledonian orogeny has emerged from a consideration of published isotopic age determinations (NEUMANN 1960, BROCH 1964). The only isotopic age of this order quoted from the zone of Caledonian deformation in Norway is, interestingly enough, a lead-alpha determination of 520 m.y. on a zircon from Stjernöy. The only comparable group of ages are potassium-argon determinations on certain pegmatites from the Precambrian of southern Norway. BROCH (1964) does, however, mention the possibility of an earlier phase of Caledonian metamorphism around 575 m.y. as suggested by ages obtained from augen-gneisses on the island of Langöy in the Lofoten Islands, and an age of 550 m.y. for a shale in the Bröttum Sparagmite. This general contention is supported by HERNES (1963), who alludes to a possible early Caledonian event around 570–600 m.y. ago, partly on the basis of ages from pegmatites in the Precambrian.

Records of orogenic activity in the Tremadocian or Arenig can be found in several parts of the Norwegian Caledonides. In the Trondheim region, evidence of orogenic movements is given by a major unconformity between the Lower Hovin Series and underlying rocks (STRAND, *in* HOLTEDAHL 1960). Overlying the Sparagmite Series is the Rörös Group, near the top of which occurs the Nordaunevoll mica-schist. This mica-schist contains a *Dictyonema flabelliforme* fauna indicating an early Tremadocian age. The Stören Group overlies the Rörös Group without any marked break, and comprises a series of spilitic greenstones, green schists, jaspers, etc., which have not yielded any zone determinative fauna. The succeeding Lower Hovin Series are unconformable upon the lower horizons and generally have conglom-

erates at their base, known locally as the Venna Conglomerate (Hölonde-Horg area, VOGT 1945), the Fjeldheim Conglomerate (Fjeldheim-Gåsbakken area), the Stokkvola Conglomerate (Gauldal area), etc. The conglomerates contain fragments of the rocks beneath the unconformity and also of igneous rocks intrusive into the Stören Group. The exact age of the Lower Hovin transgression cannot normally be defined; however, in the Fjeldheim-Gåsbakken area the fossiliferous Bogo shale occurs fairly closely above the conglomerate (CHADWICK *et al.* 1963). SKEVINGTON (1963) has demonstrated that the graptolite fauna of the Bogo shale places it within the zone of *Didymograptus hirundo*. The earth movements responsible for the break between the Lower Hovin and Stören groups are referred to as the Trondheim Orogeny or disturbance (HOLTEDAHL *et al.* 1960), and can thus be defined as having occurred between the Lower Tremadoc and beneath or within the *Didymograptus hirundo* zone of the Arenig. Important evidence confirming an early Ordovician phase of metamorphism in the Trondheim area has recently been obtained by Spjeldnæs (personal communication). In separations of the Caradocian (4b) Kalstad Limestone, Spjeldnæs has found abundant detrital grains of hornblende, the hornblende appearing to be identical with that of the Stören Greenstones. This indicates that a major phase of metamorphism affected the Stören Group earlier than the deposition of the Kalstad Limestone. As the Kalstad Limestone is part of a continuous sequence of the Lower Hovin Series, the phase of metamorphism must be considered as having occurred during the Trondheim Orogeny.

Further indications of orogenic movements at about this time are given by SKJESETH (1962) in his description of the Trysil disturbance in the Lake Femund area of Österdalen. Here Arenig (3b) rocks rest with profound unconformity upon various zones of the Cambrian, the Tremadocian apparently not being represented. BJÖRLYKKE'S (1965) description of the geochemistry of Ordovician shales from the Oslo area provides indirect evidence of orogenic movements and possibly metamorphism in the same general period. A progressive change in composition has apparently taken place from dominantly illite-bearing shales in the Cambrian and Lower Ordovician (3b) to increasingly chloritic shales in 4aa<sub>1-2</sub> and the *Trinucleus bronni* zone (4aa<sub>4</sub>), allied to a marked increase in the magnesium content. Björ-

lykke concludes that these changes result from the erosion of material uplifted and exposed during an early phase of nappe emplacement.

In the nappe area of western Norway KVALE (1960 p. 15) refers to an 'important phase of folding and metamorphism' occurring in either the Lower or Middle Ordovician. The exact age of this event is not certain, but the Moberg conglomerate of presumed Middle or Upper Ordovician age contains well-rounded pebbles of 'various types of gabbroic rocks, trondhemite, green schists, and, locally, quartzites and white limestone'. The rocks beneath the conglomerate, according to Kvale, are of higher metamorphic grade than those above, and are intruded by a varied group of plutonic rocks, blocks of which are contained in the conglomerate (see also STRAND, *in* HOLTEDAHL 1960 p. 228). STRAND (1959, 1961, 1962), in his discussions of the stratigraphical position of the Valdres Sparagmite, suggests a Taconic age of emplacement of the Lower Jotun Nappe. The Valdres Sparagmite, however, has recently been shown to consist of a group of allochthonous rocks mainly of Eocambrian and latest Precambrian age, in an inverted position in the Mellene type area (LOESCHKE 1967, NICKELSEN 1967). The conclusions of Strand on a possible Middle or Upper Ordovician event can still be upheld, though on different premises, as the youngest sediments in the Valdres Nappe are early Middle Ordovician and material most probably derived from the Valdres Nappe is found in early Silurian sandstones of the northern part of the Oslo Region (STRAND 1959). In the autochthonous Cambro-Ordovician succession of Sweden, evidence of considerable tectonic instability during the upper part of the Tremadocian and throughout the Arenig is provided by a number of important disconformities and non-sequences (TJERNVIK 1956).

Thus it can be seen that considerable tectonic activity and possibly metamorphism took place in many parts of the Scandinavian Caledonides during early Ordovician times. The stratigraphic dating of the movements, however, is not entirely clear in some of the areas. The authors tentatively correlate the 490+ m.y. early Caledonian orogenic phase of West Finnmark with the Trondheim Orogeny. If this is correct, the orogenic folding and metamorphism of Söröy and parts of the surrounding areas probably took place during the interval between the Lower Tremadocian and the *Didymograptus hirundo* zone of the Arenig. It is of interest in this context that the Digermul penin-

sula in eastern Finnmark has a continuous stratigraphical succession from Eocambrian rocks including tillites through the Cambrian into the lower part of the Tremadocian. This implies that no strong tectonical disturbance occurred before the Lower Tremadocian in the Digermul area. The rocks of the Digermul peninsula have been strongly folded by Caledonian earth-movements. The folds were then truncated by a thrust group of metamorphic rocks of mainly Precambrian age — the Laksefjord Group (FÖYN 1937, HOLTEDAHL *et al.* 1960, READING 1965). The age of the 'mise en place' of the Laksefjord Group of allochthonous rocks is not known, but the youngest rocks beneath the thrust are Lower Tremadocian, indicating that the maximum age of the emplacement of the Laksefjord Group is post-basal Tremadocian. Geochronological studies in this area might well produce results comparable with those reported in this paper.

In the British Isles the general consensus of opinion is that the main deformation and metamorphism of the Dalradian Series was probably a late Cambrian to early Ordovician event, based on evidence both of isotopic age determinations and the probable overstep of Arenig strata onto metamorphosed Dalradian rocks in Connemara, Ireland (DEWEY 1961, BROWN *et al.* 1965, LEGGO *et al.* 1966). The possibility of even earlier events in the Dalradian have been indicated by FITCH *et al.* (1964) and LEGGO *et al.* (1966). Recent geochronological work in Connemara (LEGGO *et al.* 1966) indicates that the maximum age of the late post-tectonic Oughterard granite, intruded into the Lower Dalradian Connemara Schists, is  $510 \pm 35$  m.y. The base of the Arenig rocks in Connemara must, by implication, be younger than this. There would thus appear to be a fairly strong case for equating the  $490 \pm$  m.y. orogenic phase, identified in West Finnmark, with the  $500 \pm$  m.y. phase of Caledonian orogeny of the Dalradian Series.

SIMPSON (1967) has recently described an inter-Lower Ordovician deformation of the Skiddaw Slates, in the Lake District of England, followed by uplift and deep erosion before the accumulation of the Borrowdale Volcanic Series. The deformation is concluded to be a late-Llanvirn event.

Evidence of a phase of the Caledonian orogeny in late Cambrian to early Ordovician times is also found in other parts of Europe. SAMSONOWICZ (1960) describes folded and metamorphosed Cambrian rocks (including Upper Cambrian), unconformably overlain by Middle

Tremadocian sediments from the Klimontow anticlinorium in Poland. The period of deformation, responsible for the folding of the Cambrian strata, is known as the Sandomirian orogeny. In Vestspitzbergen, BIRKENMAJER (1960) also draws attention to possible orogenic movements between the deposition of Upper Cambrian and Ordovician strata. Although no general pattern of such an early phase of Caledonian orogeny has yet been established in eastern Greenland, HALLER & KULP (1962 p. 24) discuss the significance of a polymetamorphic migmatite from Grandjeansfjord which gives a K-Ar age of 490 m.y. This particular rock was originally metamorphosed as part of the Precambrian basement, but is now in an area that has been involved in Caledonian regeneration. Haller and Kulp make the suggestion that 'the first phase of the Caledonian orogeny in this area actually occurred about 490 m.y. ago, which completely restarted the K-Ar clock in these biotites and then the late Caledonian event did not significantly affect them'. This suggestion accords well with the postulated age of the early Caledonian orogenic phase in West Finnmark.

It is too early a stage in our present knowledge of geochronology to say whether the main orogenic movements and metamorphism in these widely separated areas were strictly coeval. Indeed there does appear to be a limited amount of evidence that, within the restricted time span under consideration, the maximum expressions of orogenic deformation and metamorphism might have occurred at slightly different times in some of these areas. One feature, however, is clear: a major early phase of the Caledonian orogeny took place in late Cambrian to early Ordovician times over wide areas of the European Caledonides.

The alkaline rocks of West Finnmark occur in an unusual geological situation, having been emplaced in an orogenic environment. Forming an arc to the east of the zone of Caledonian deformation, in Scandinavia, are a number of well-documented examples of alkaline intrusive complexes of the central type (ECKERMANN 1948, SÆTHER 1957, MAGNUSON *et al.* 1960, RAMBERG & BARTH 1966) emplaced into the Precambrian crystalline basement. Evidence of isotopic age determinations from these complexes is rather scanty, though several dates are available from the Fen Complex, S. Norway (BROCH 1964, RAMBERG & BARTH 1966). These give a range of 565–603 m.y. in K-Ar age determinations. VON ECKERMANN & WICKMAN (1956) present one U-Th

age, from a pyrochlore in a sövite from Alnö, at 562 million years. These dates indicate emplacement in early Cambrian or late Precambrian times, and suggest that these 'non-orogenic' alkaline complexes are older than the West Finnmark alkaline rocks. However, it would appear that both types are probably 'Caledonian' in the widest sense of the term.

(b) *The 384–420 m.y. group of apparent ages*

The second major group of K-Ar ages obtained from the alkaline rocks of West Finnmark falls within the range 384–420 million years. The implication is of a late or end-Silurian event, or a succession of events near the end of the Silurian. This group of dates conforms well with the major peak of K-Ar and Rb-Sr ages from rocks affected by the Caledonian orogeny in Norway (BROCH 1964, Fig. 3).

Taking into account the experimental errors, the scatter of apparent ages between 420 m.y. and 384 m.y. could be interpreted in a number of ways:

- (i) That the scatter results from the partial to complete 'overprinting' of older ages by a single low-grade end-Silurian metamorphism.
- or (ii) It could be suggested that there were a number of related events that occurred during the Silurian and Devonian, the combined effect of which produced the scatter of the results.

Evidence of late or end-Silurian orogenic movements and metamorphism is indeed to be found in the nearby Honningsvåg area, on the island of Magerøy. Here rocks containing Silurian fossils (HOLTEDAHL *et al.* 1960, HENNINGSMOEN 1961) have been strongly folded and metamorphosed to low-grade assemblages. The relationships of these fossiliferous rocks to the strata of higher metamorphic grade in western and northern Magerøy, however, is by no means clear. The folded Ordo-Silurian strata of the Honningsvåg area are intruded by a large gabbro complex, indicating that basic igneous activity was also important during this later phase of the Caledonian orogeny in West Finnmark. The late Silurian deformation and metamorphism are well documented throughout the Scandinavian Caledonides (HOLTEDAHL 1960, MAGNUSSON *et al.* 1960, STRAND 1961). Indeed the 'mise en place' of many of the major nappe units can be demonstrated to have taken

place during this orogenic phase. The results also accord well with the postulated age of the late Silurian orogenic movements in the British Isles (FITCH *et al.* 1964).

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## PETROLOGICAL APPENDIX

Brief petrological descriptions of the dated rocks. Serial numbers refer to the rock collection in the Geology Dept., Bedford College, London.

- (1) S.B.51. Nepheline-Syenite-Gneiss.  
1 km south of Haraldseng, Söröy.  
Minerals: Nepheline, Plagioclase ( $An_{10}$ ), Microcline, Muscovite, Biotite, ilmenite, cancrinite, pyrite, pyrochlore.  
Schistosity delineated by mica 001. Nepheline as porphyroblasts in feldspathic areas, or in fine-grained bands rich in nepheline. (Modal analysis in Table 1 STURT & RAMSAY 1965.)
- (2) S.B.117. Deformed Nepheline-Syenite-Gneiss.  
0,5 km south of Haraldseng, Söröy.  
Minerals: Nepheline, Plagioclase ( $An_{12}$ ), Microcline, Biotite, cancrinite, muscovite.  
Nepheline mainly in lenses strongly rodded parallel to the axes of F2 minor folds (STURT 1961). Mica occurs as small flakes delineating schistosity — up to 0.3 mm long.
- (3) S.B.495. Hornblende-Biotite-Nepheline Schist.  
Ovreflågvann, Breivikbotn, Söröy.  
Minerals: Hornblende, Biotite, Plagioclase ( $An_{10}$ ), Plagioclase ( $An_{28}$ ), Nepheline, apatite, sphene, calcite, epidote, zeolite.  
Partly fenitized shear-zone in Breivikbotn gabbro. Schistosity delineated by hornblende and biotite in grains up to 0.2 mm long. (Modal analysis in Table 1 STURT & RAMSAY 1965.)
- (4) S.B.528. Nepheline-Syenite-Gneiss.  
1 km west of Breivikbotn, Söröy.  
Minerals: Nepheline, Plagioclase ( $An_8$ ), Microcline, Biotite, Muscovite, zircon, pyrochlore, magnetite, sodalite, zeolite.  
Schistosity delineated by biotite 001, flakes up to 0.2 mm long, and as occasional porphyroblasts up to 1.5 mm across. Nepheline occurs as porphyroblasts and as glomeroporphyroblastic aggregates showing slight alteration into muscovite, sodalite, and zeolite. (Modal analysis in Table 1 STURT & RAMSAY 1965.)
- (5) B.A.S.1. Alkali Feldspar-Biotite-Pegmatite.  
Hvitness, 4 km south of Breivikbotn, Söröy.  
Minerals: Perthite, Biotite, zircon, magnetite.  
Biotite occurs as large plates up to 15 cm across, often showing strong deformation features such as kink-bands. Feldspars show poor crystallographic shapes and are up to 30 cm in length.

- (6) 4047/52–6. Nepheline-Scapolite-Biotite-Pegmatite  
Dönnesfjord Öen, Söröy.  
Minerals: Nepheline, Scapolite, Biotite, Plagioclase ( $An_8$ ), zircon, zeolite.  
Biotite occurs in large plates up to 12 cm across, which are often kinked.  
The scapolite occurs as a replacement of plagioclase and nepheline.
- (7) 3047/63–16. Nepheline-Syenite-Gneiss  
Dönnesfjord Öen, Söröy.  
Petrographic details not available.
- (8) B.H.V.16. Biotite-Sövite.  
Baarvik, Söröy.  
Minerals: Calcite, Biotite, apatite, sphene, magnetite, allanite.  
Biotite books up to 10 cm across set in matrix of calcite with euhedral apatite and sphene crystals.
- (9) Se.2. Nepheline-Syenite-Pegmatite.  
Bekkarfjordnes, Seiland.  
Minerals: Nepheline, Perthite, Antiperthite, Microcline, biotite, magnetite, zircon, calcite.  
Irregularly textured pegmatite, nepheline grains show poor crystal form and are up to 25 cm across.
- (10) B.A.S.2. Nepheline-Syenite-Pegmatite.  
Hasfjordvann, Söröy.  
Minerals: Nepheline, Antiperthite, Microcline, biotite, magnetite, zircon, sphene, sodalite, muscovite.  
Coarse irregularly textured pegmatite with poorly shaped nepheline crystals up to 70 cm across. Nepheline slightly altered to sodalite.
- (11) DMR.2. Nepheline-Sodalite-Syenite.  
Roadside exposure 3 km northeast of Breivikbotn.  
Minerals: Nepheline, Plagioclase ( $An_{11}$ ), Microcline, Muscovite, Sodalite, cancrinite, biotite, apatite, zircon, pyrochlore, sphene, calcite, magnetite, pyrite.  
Slightly foliated rock with fine-grained micas 001 delineating foliation. Conspicuous large subhedral books of muscovite up to 3 cm across, one of which was dated sample. Nepheline much altered to sodalite. (Modal analysis in Table 1 STURT & RAMSAY 1965.)
- (12) Stj.1. Nepheline-Syenite  
Lillebugt Mine, Stjernöy.  
Minerals: Nepheline, Perthite, Albite ( $An_4$ ), pyroxene, biotite, magnetite, zircon.  
Irregular granular mosaic of hair-perthite and nepheline, with narrow rims of albite around the perthite grains. Medium-grained: average grain size of feldspathic components around 0.6 mm though nepheline grains up to 2 mm across do occur.