Geochemistry and Rb-Sr dating of the Muruvik rhyolite tuff, Trondheimsfjord, Central Norway.

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A geochemical study of a low greenschist facies, felsic lapilli-ash tuff from near the stratigraphic top of the Ordovician Lower Hovin Group at Muruvik, Trondheimsfjord, has shown that the pyroclastite is clearly calc-alkaline and falls in the field of high-K rhyolites in classification schemes for volcanic rocks. The chemical composition of the Muruvik tuff compares well with that of felsic lavas and pyroclastic rocks from the cordilleras of western North and South America. The data lend further support to an earlier paleotectonic model involving generation of these mature-arc, Late Ordovician volcanites along the margin of a continent or microcontinent during the later stages of infilling of a back-arc marginal basin.

An attempt at Rb-Sr dating of the rhyolite tuff produced a 9-point errorchron of 410±27Ma. As the tuff appears to have a depositional age of Late Caradoc (c.445-440Ma), based on faunas in an adjacent pelite along strike from Muruvik, then the Rb-Sr age is interpreted to date the Caledonian (Scandian) greenschist facies metamorphism of this rock.

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Introduction

Over the past fifteen years, investigations of the geochemistry of volcanic rocks in the Caledonian allochthons of Central Norway have led to major reinterpretations of the orogenic evolution of this part of the Caledonian mountain belt. This research, together with detailed mapping, has been concentrated in the thick basaltic greenstone units, as a result of which we can now distinguish fragmented ophiolite assemblages, marginal basin units and both immature and evolved magmatic arc complexes (Gale & Roberts 1974, Prestvik 1974, 1980, Loeschke 1976a, Lutro 1979, Grenne & Roberts 1980, 1981, Grenne et al. 1980, Reinsbakken 1980, Roberts 1980, 1982, Roberts et al. 1984).

By comparison, studies dealing specifically with the geochemistry of felsic volcanic rocks are few. Loeschke's (1976a) comprehensive study of mafic and felsic volcanites from part of the SW Trondheim Region was the first to deal with rhyolitic rocks. Similar, though less detailed investigations are those of Lutro (1979), Reinsbakken (1980) and Roberts et al. (1984), while Oftedahl & Prestvik (1985) have examined felsic pyroclastic rocks from the Hølonda-Horg area southwest of Trondheim.

The present investigation concentrates on the chemistry of a prominent rhyolite tuff from Muruvik (Fig. 1) between Trondheim and Stjørdal, and at the same time reports the results of an attempted isotopic dating of this same rock unit.

Regional setting

The greenschist facies, Ordovician to possibly Early Silurian, volcanosedimentary rocks which occur widely in the western Trondheim Region are divided into three main groups, the Lower Hovin, Upper Hovin and Horg Groups, broadly following the terminology of Vogt (1945). The oldest fossiliferous sediments, in the Lower Hovin, are of mid-Arenig age, and the basal Venna conglomerate lies unconformably upon the eroded surface of the deformed and trondhjemite-intruded Støren ophiolite fragment (Furnes et al. 1980). This Støren unit, as well as the subjacent Gula Complex, was initially deformed and metamorphosed in earliest Ordovician time, an event broadly equivalent in age to the main foliation-producing phase of the Finnmarkian orogeny (Sturt et al. 1978, Dallmeyer 1988) c. 500Ma ago.

In terms of regional tectonostratigraphy, the combined Gula, Støren, Hovin and Horg units

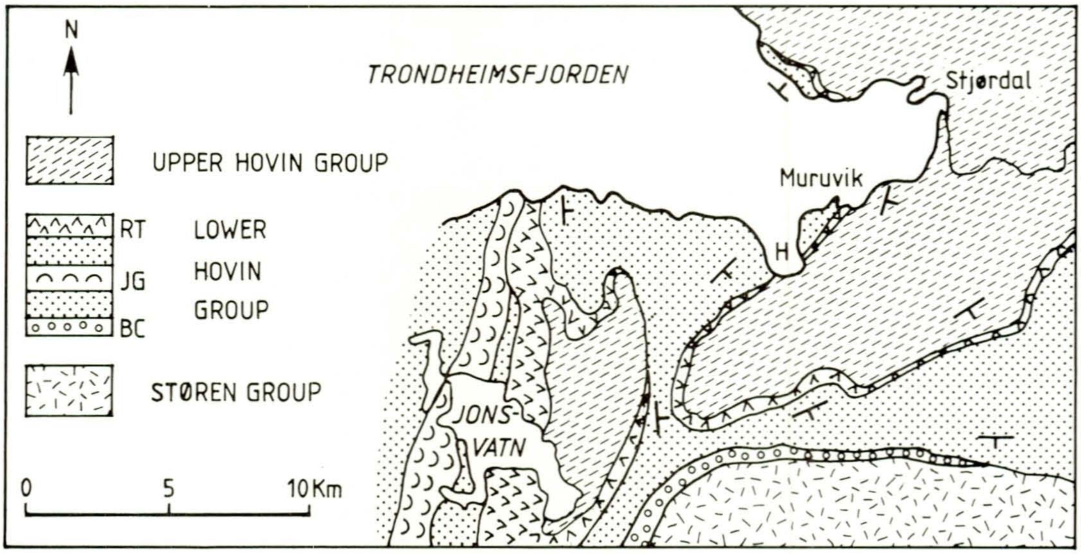

Fig.1. Simplified geological map of the Muruvik district, after Wolff (1976). BC - basal conglomerate: JG - Jonsvatn Greenstone: RT - rhyolite tuff: H - Hommelvik. Dips and strikes of bedding are indicated by the traditional symbol.

are part of the Trondheim Nappe Complex of the Upper Allochthon, which was thrust-emplaced during the Mid to Late Silurian, Scandian orogeny (Gee et al. 1985).

Within the Hovin Groups, mafic to intermediate volcanites are fairly common in the older parts of the lithostratigraphy (Vogt 1945, Carstens 1960), locally with the development of ophiolitic units (Roberts et al. 1984). Higher up, felsic effusive, pyroclastic and mixed pyroclastic-epiclastic rocks become dominant, although they are generally insignificant in terms of volume. In the Hølonda-Horg district, Vogt (1945) mapped out three prominent rhyolite or rhyolite tuff formations, two (Hareklett and Esphaug) within the upper part of the Lower Hovin and the third (Grimsås) in the Upper Hovin. Those in the Lower Hovin occur in close association with a black phyllitic shale containing the Late Caradoc graptolite *Dicranograptus clingani* (Vogt 1945, Bruton & Bockelie 1982); this shale immediately underlies the basal Volla conglomerate of the Upper Hovin Group.

Although there has been disagreement concerning the interpretation of the stratigraphy of the Hølonda-Horg district (Chaloupsky 1970, Oftedahl 1980, Ryan et al. 1980, Oftedahl & Prestvik 1985), the geological map picture (Wolff 1976) shows that the uppermost Lower Hovin felsic volcanites can be traced northeastwards into the Stjørdal district. In this area, and also at Muruvik (Fig.1), the main felsic pyroclastic horizon occurs just below the base of the Upper Hovin Group and again in association with dark phyllitic shales. There is thus good reason for considering these pelites, and the closely related felsic volcanic rocks, to be of Late Caradoc age. In this same Muruvik-Jonsvatn district (Fig. 1) tuffs constitute a significant element on the geological map. Large parts of what is indicated as RT in Fig.1 really straddle the boundary between mixed pyroclastic-epiclastic rocks, or tuffites (Schmid 1981), and pyroclastic deposits.

The Muruvik Rhyolite Tuff

The 80-120m thick rhyolite tuff forms a low NE-SW-trending ridge between Muruvik and Hommelvik (Fig.1). Dipping southeast at 25-30°, the thick-bedded (c. 0.3-1.5 m) tuff is stratigraphically underlain by dark grey to black silty phyllites and phyllitic shales, and overlain by metasediments of the Upper Hovin Group (Carstens 1960, Holtar 1985). In field appearance the tuff is pale grey-white to slightly greenish-grey with a flinty or porcellaneous sheen on some fresh surfaces, weathering an ashy grey-white in colour. It is medium-grained with a moderately developed schistosity and weak particle lineation; pyroclasts of quartz or quartz-feldspar aggregates are up to 6-8mm in length. Some portions of the tuff contain prominent 1-2mm biotite or chloritised biotite metacrysts, giving the rock a speckled appearance.

Thin-sections confirm the schistose fabric, defined by abraded, recrystallised and lenticular clasts of mixed quartz, K-feldspar and less commonly plagioclase in a finer grained matrix of sericite and microcrystalline quartz and feldspars. Biotite metacrysts, up to 2mm across, are only very crudely oriented within the schistosity and show varying stages of alteration to chlorite. The biotites are thought to represent degraded phenocrysts (cf. Loeschke 1976a). Accessory minerals are clinozoisite, zoisite, zircon and opaques with sporadic allanite, limonite, apatite and calcite.

The clasts of quartz and feldspar show variations in grain and subgrain size as well as in texture. Most of the clasts are completely recrystallised, and the new grains highly strained. Some clasts are composed of very fine-grained, almost cryptocrystalline quartz. Feldspar particles are partially or totally recrystallised, and some show cores of the original feldspar surrounded by an aggregate of new small grains. While the bulk of the quartz and feldspar clasts almost certainly represent devitrified volcanic glass fragments, and can thus be designated as pyroclasts (Schmid 1981), it is possible that a very small proportion may be epiclasts of quartzite or chert (cf. Oftedahl & Prestvik 1985). By modern definitions (Le Bas & Sabine 1980, Schmid 1981) the Muruvik rocks can be categorised as lapilli-ash tuffs and prefixed, as will be shown below, as rhyolitic.

Geochemistry

Sampling and analytical procedure

Fifteen of the 18 samples used in this investigation were originally collected for the combined purpose of Rb-Sr isotopic dating and geochemical study. The three additional samples are from a batch of rock samples collected earlier as part of a pilot study and used in obtaining 'average' element values for rhyolites in the Hovin Groups (Roberts et al. 1984). All the samples were obtained from comparatively newly blasted road-cuts or house foundations, and were thus devoid of any weathering material.

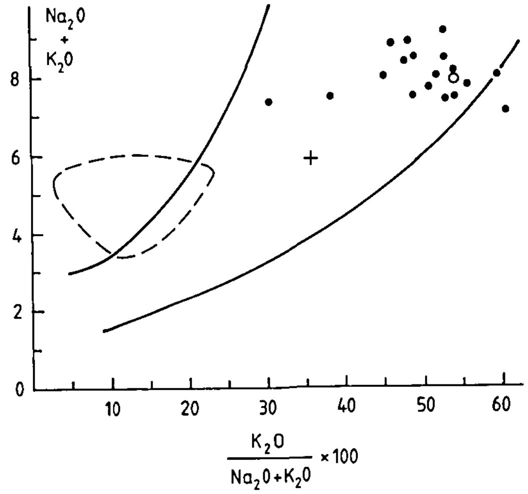

Fig.2. The Muruvik samples on the $Na_2O + K_2O$ vs. $K_2O \times 100/Na_2O + K_2O$ diagram of Hughes (1973). The dashed line encloses the field for spilites. Average values of normal, unaltered igneous rocks fall between the 2 curved lines. Average rhyolite and dacite (Le Maitre 1976) are indicated by an open circle and cross, respectively.

Major and trace elements were analysed on rock powders using an automatic Philips 1450/20 XRF, at the Section for Analytical Chemistry, NGU, Trondheim. Calibration curves were made with international standards. For the determination of major elements the rock samples were melted with lithium tetraborate 1:7. Trace elements were determined on pressed rock powder. Ferrous iron, H_2O+, H_2O- and CO_2 were determined by wet chemical methods.

Major elements

Processes of chemical exchange in volcanic rocks involving post-effusive redistribution of some of the more mobile major elements such as Na, Ca, K and Fe are widely documented (Vallance 1960, 1965, Hart et al. 1974, Loeschke 1976b, Stephens 1980). The degree of element mobility and consequent modification of the original chemistry during, for example, hydrothermal alteration or low-grade metamorphism, thus constitutes a recurring problem in the interpretation of analytical data. In the present case, had such element migration taken place to any appreciable extent then we would be dealing with highly altered felsic rocks, i.e. keratophyres or quartz keratophyres

Sample no.	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8	R-9	R-10	R-11	R-12	R-13	R-14	R-15	32	33	34	Mean	S.D.
SiO_2	68.48	71.27	71.58	74.10	70.73	69.65	71.29	71.27	71.94	71.72	69.14	70.73	68.80	71.00	70.50	74.25	71.94	71.10	71.08	1.53
Al_2O_3	14.89	13.27	13.25	12.91	14.14	14.02	13.66	13.38	14.05	13.76	14.54	14.05	14.01	13.70	13.82	14.29	14.30	13.06	13.84	.52
Fe_2O_3	2.78	2.90	3.08	2.04	2.50	2.58	1.98	2.17	1.83	1.76	3.05	2.37	2.81	2.40	2.63	1.76	2.23	3.40	2.46	.49
TiO_2	.45	.43	.43	.36	.40	.45	.31	.31	.30	.31	.46	.40	.42	.39	.42	.31	.40	.47	0.39	.06
MgO	.68	.72	.69	.37	.55	.51	.51	.46	.46	.46	.78	.57	.77	.67	.58	.46	.49	.83	0.59	.13
CaO	1.05	1.10	.99	.85	1.89	1.03	.63	.81	1.01	.69	1.68	.81	1.35	1.11	1.02	.70	1.08	1.23	1.01	.25
Na_2O	4.60	3.40	3.40	5.10	3.30	3.90	4.30	3.80	4.70	3.20	3.70	3.70	4.40	4.60	3.80	4.20	4.30	2.70	3.95	.62
K_2O	4.23	3.94	3.98	2.23	4.35	4.42	4.10	4.18	4.05	4.78	4.39	3.97	3.55	2.82	3.64	4.82	4.02	4.33	3.99	.63
MnO	.05	.07	.07	.05	.06	.07	.04	.05	.06	.06	.06	.05	.06	.05	.34	.05	.06	.08	0.09	.07
P_2O_5	.04	.05	.05	<.01	.03	.03	.02	<.01	.01	.02	.04	.04	.05	.04	.04	.05	.05	.08	0.04	.02
L.O.I.	.92	.99	1.11	1.12	.88	1.58	1.16	1.36	1.05	1.16	1.85	1.49	1.57	1.63	.75	.93	.71	.86		
Sum	98.17	98.14	98.63	99.13	98.03	98.24	98.00	97.79	99.46	97.92	99.69	98.18	97.79	98.41	97.54	101.82	99.58	98.14		
Nb	19	14	12	18	17	16	19	17	17	17	15	14	14	14	14	17	17	15	16	2
Zr	261	203	189	235	262	294	220	218	222	261	274	218	245	234	220	234	252	241	238	26
Y	38	27	27	33	36	39	35	36	38	39	37	31	33	29	33	37	35	29	34	4
Sr	190	182	152	258	285	277	171	134	285	176	266	159	198	126	210	156	311	211	208	58
Rb	140	137	131	92	142	142	129	134	142	164	144	132	130	106	121	153	127	154	134	17
Zn	50	49	47	42	55	57	37	42	46	56	57	97	47	36	46	56	53	61	52	13
Cu	7	16	6	<5	6	<5	<5	<5	<5	<5	6	<5	<5	<5	<5	<5	6	15	7	3
Ni	8	5	5	<5	5	<5	<5	<5	<5	<5	6	5	<5	5	<5	<5	5	8	5	1
Cr	24	27	27	18	22	25	16	16	10	12	33	22	22	26	20	10	14	26	21	6
V	40	54	56	27	37	38	29	26	22	18	46	44	41	36	37	22	37	66	38	12
Ba	695	637	628	399	762	744	599	528	576	671	770	691	617	502	637	680	723	737	644	98

Table 1. Chemical analyses of the Muruvik rhyolite tuffs, with mean values and standard deviations. Major elements in wt %, trace elements in ppm. Total iron is here given as Fe_2O_3. In Table 2, mean values of FeO and Fe_2O_3 are presented separately.

(Schermerhorn 1973), involving enrichment in Na_2O and depletion in K_2O and CaO contents. From the chemical data (Table 1), and comparison with mean values for quartz keratophyres from the Støren Group (Loeschke 1976a) and from the Skorovatn and Stekenjokk volcanites of Norway (Reinsbakken 1980) and Sweden (Stephens 1980), respectively (Table 2), there is however little reason for considering the Muruvik felsic rocks to be significantly altered. This is also confirmed by a Hughes (1973) alkali variation plot (Fig. 2) where the samples fall well away from the spilite field but largely within the boundaries of the igneous spectrum.

Following the work and recommendations of the IUGS Subcommission on the Systematics of Igneous Rocks (Le Bas et al.1986), a non-genetic classification of fine-grained volcanic rocks into their root names may now be based on chemical parameters and in particular on the 'Total Alkali Silica' (TAS) diagram (Fig. 3). Although the TAS classification was designed for fresh, unaltered volcanic rocks, it has been shown by Sabine et al. (1985) that many low-grade metavolcanites can be satisfactorily classified by TAS, the felsic rocks in particular showing the least spread. In this figure (Fig. 3) the Muruvik felsic pyroclastic rocks cluster in the 'rhyolite' field. Adopting the peralkaline index (P.I.), mol (Na_2O + K_2O)/Al_2O_3, for distinguishing between rhyolite and alkali rhyolite (Le Maitre 1984), the P.I. for the Muruvik rocks averages c.0.76, placing them unambiguously in the field for rhyolites. Traditional classification on SiO_2 content alone, averaging 72.35% calculated anhydrous, also designates the rocks as rhyolites (e.g. Ewart 1979).

The Na_2O: K_2O ratio for the Muruvik tuff of slightly less than 1 differs appreciably from that of 4 for Støren, 22 for Skorovatn and 13 for the Stekenjokk quartz keratophyres, a disparity already noted by Carstens (1960) for felsic volcanites from the Trondheim Region. Carstens observed that the younger rhyolitic rocks were noticeably richer in K_2O than the older spilitised volcanites, a feature also pointed out by Loeschke (1976a). It would thus seem that the high K_2O contents constitute a primary chemical signature. Adopting the simple but effective plot of SiO_2 v.K_2O (Peccerillo & Taylor 1976, Ewart 1979), the Muruvik rhyolite tuffs fall mostly in the field for high-K rhyolites (Fig.4).

That the rocks in question are subalkaline

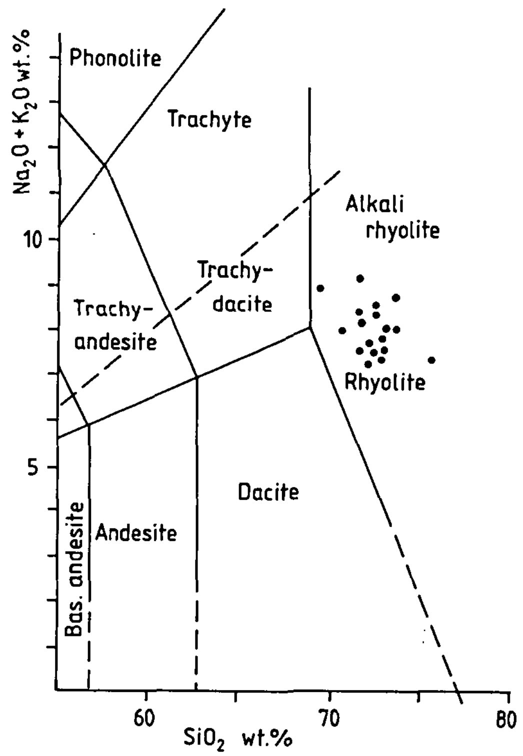

Fig.3. The Muruvik rhyolite tuff samples plotted on part of the TAS diagram of Le Bas et al. (1986), showing the fields of the various volcanic rock-types. The dashed line through the trachyandesite/trachydacite fields separates alkaline (above) and subalkaline rocks (Irvine & Baragar 1971). The analyses are recalculated to 100 % on an H_2O- and CO_2-free basis.

	Muruvik rhyolite tuff	Støren Qtz-kerato-phyres	Skorovatn metarhyo-dacites	Stekenjokk felsic rocks
n	18	15	11	20
SiO_2	71.08	72.23	70.21	75.20
TiO_2	0.39	0.20	0.55	0.34
Al_2O_3	13.84	14.31	12.07	11.80
Fe_2O_3	0.74	1.04	2.42	1.60
FeO	1.47	0.80	2.16	2.10
MgO	0.59	0.57	0.80	1.30
CaO	1.01	2.24	1.16	1.70
Na_2O	3.95	5.16	6.84	5.20
K_2O	3.99	1.29	0.31	0.40
MnO	0.07	0.05	0.09	0.07
P_2O_5	0.04	0.07	0.11	0.06
L.O.I.	1.75	2.25	1.42	–

Table 2. Comparison of mean major element compositions of the Muruvik rhyolite tuffs, Støren quartz keratophyres (Loeschke 1976a), Skorovatn metarhyodacites (Reinsbakken 1980), and Stekenjokk felsic volcanites and high-level intrusive rocks (Stephens 1980).

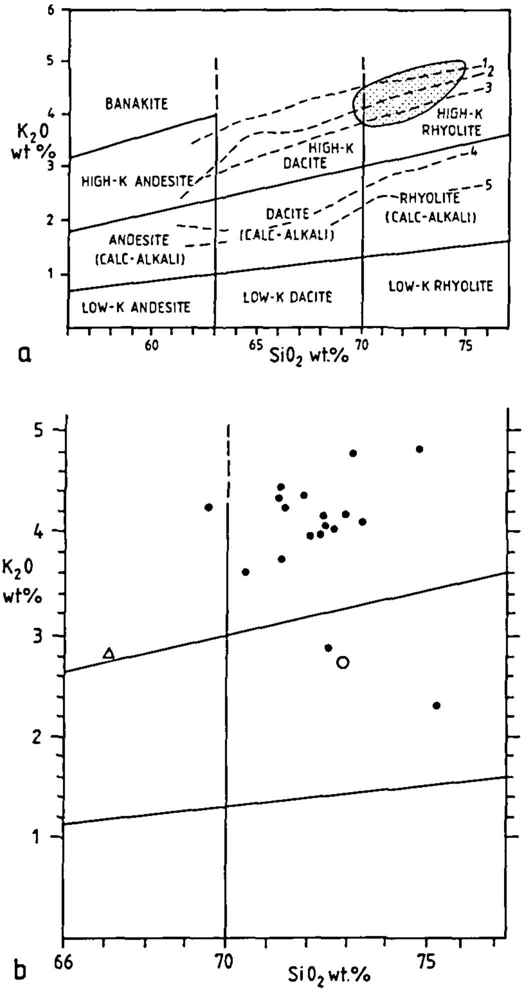

Fig.4(a)The K_2O vs.SiO_2 diagram of Peccerillo & Taylor (1976) and Ewart (1979) for classification of intermediate and felsic volcanic rocks. The shaded area shows the approximate field for the analysed samples of Muruvik high-K rhyolite tuffs (see Fig. 4b). The dashed lines are trend lines for volcanic rock products from the following regions (Ewart 1979): 1. Western USA, eastern zone: 2. Western USA, western zone: 3. Western (Andean) South America: 4. SW Pacific region: 5. Japan-Taiwan-Kamchatka region. (b) Enlargement of part of Fig.4a showing the plots for the Muruvik tuffs. The open circle and open triangle represent the average rhyolite and average dacite, respectively, of Loeschke (1976a).

is denoted both by the total alkalis/silica diagram (Fig. 3) and also by a TiO_2/silica plot, not shown here. In an AFM diagram, although it is difficult to distinguish between tholeiitic and calc-alkaline trends near the alkalis corner, the Muruvik data closely follow a trend which is taken (Ewart 1976) to be representative of active continental margin, calc-alkaline effusives.

Trace elements

The clear high-K character of the Muruvik tuff is also reflected in the trace element abundances, and in particular in the comparatively high values for Ba, Rb and Sr (Table). Although Sr and Ba may be mobile under certain conditions, evidence has been presented above suggesting that element redistribution has been minimal in these rocks and consequently the element ratios should provide a fair assessment of overall chemical character. This is, in fact, indicated by Rb-Sr and Rb-K/Rb plots (Figs. 5 & 6); the Muruvik analyses show a reasonably good clustering, and plot close to the ratios and abundances determined for high-K rhyolitic rocks from the western Americas continental margin and particularly with those from western South America.

As compared with low-K volcanites the higher Rb contents and lower K/Rb ratios for the Muruvik rocks correlate well with averaged data (Ewart 1979) for the high-K rhyolite series (Fig. 6, Table 3). Of the other elements, the small high-valency cations Zr and Nb, which

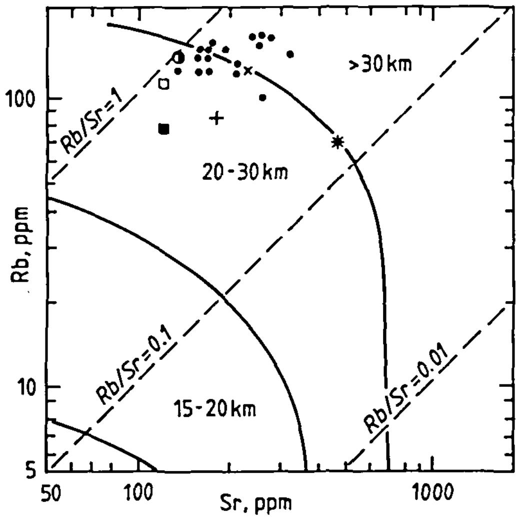

Fig.5. Log Rb/Sr distribution of the Muruvik tuff samples. Other symbols (for average values) are as follows: x - Western USA (eastern zone) high-K rhyolites: + - Western USA (western zone) high-K rhyolites: half-filled circle - Western South America, all rhyolites: open square - SW Pacific rhyolites: filled square - Japan-Taiwan-Kamchatka rhyolites: asterisk-Tonga-Kermadec rhyolites. The curved lines separate ranges of inferred crustal thickness, after Condie (1973).

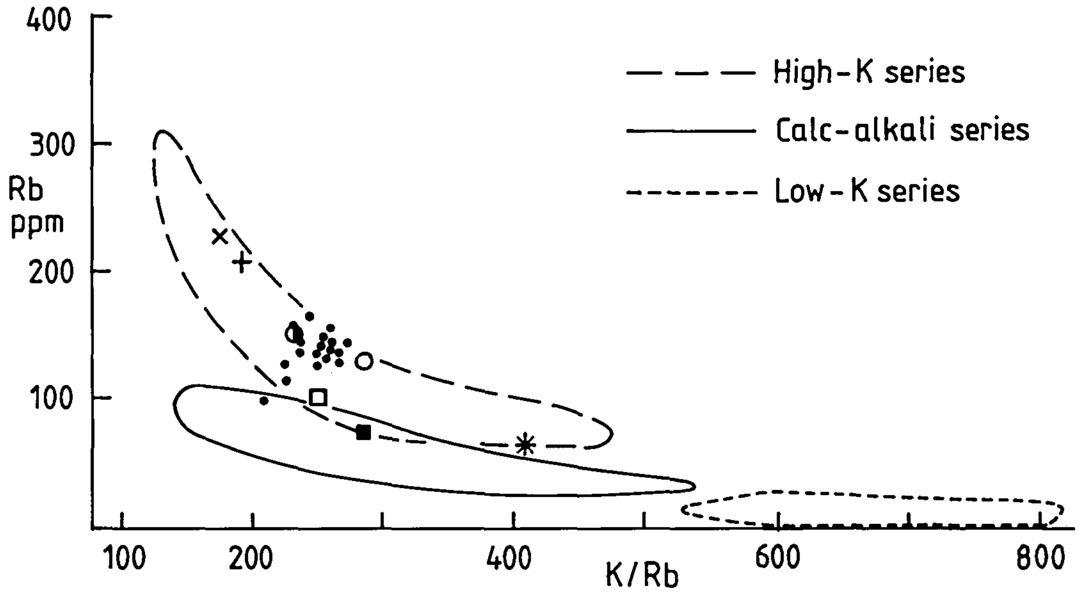

Fig.6. Rb vs.K/Rb variation for the Muruvik rhyolite tuffs, showing the fields for the low-K, calc-alkali and high-K volcanic rock series; after Ewart (1979). Other symbols are for ratios of averaged values and are the same as in Fig. 5, with one addition — the open circle is for the high-K rhyolitic rocks of western South America.

	Muruvik rhyolite tuff	Western S. America	Western U.S.A. (W.belt)	SW Pacific calc-alkali	SW Pacific low-K	Iceland high-K	S. Queensland Australia
n	18	27	58	142	100	16	18
SiO_2	72.35	75.41	75.94	75.15	72.31	74.81	76.02
TiO_2	0.40	0.21	0.14	0.25	0.46	0.24	0.17
Al_2O_3	14.09	13.25	13.14	13.28	13.70	12.85	12.30
Fe_2O_3	1.01	1.08	0.75	0.88	1.42	1.20	0.72
FeO	1.49	0.20	0.50	1.01	2.40	1.14	1.16
MgO	0.60	0.36	0.21	0.31	0.86	0.12	0.15
CaO	1.03	1.18	0.82	1.52	3.65	0.92	0.68
Na_2O	4.01	3.66	3.58	4.23	3.93	4.77	3.42
K_2O	4.06	4.53	4.82	3.27	1.06	3.81	5.32
MnO	0.07	0.06	0.05	0.06	0.09	0.07	0.03
P_2O_5	0.04	0.05	0.04	0.05	0.11	0.06	0.02
Zr	238	307	129	176	88	388	387
Y	34	—	33	25	33	50	74
Sr	208	126	79	103	173	98	11
Rb	134	132	192	108	12	119	165
Zn	52	56	36	32	63	116	145
Cu	7	15	6	7	26	9	8
Ni	5	4	2	3	2	1	6
Cr	20	—	2	4	2	3	1
Ba	644	649	363	782	283	1000	96
Nb	16	—	19	17	—	30	35
V	38	32	5	10	36	14	3

Table 3. Mean major and trace element compositions of the Muruvik rhyolite tuff compared with mean values for high-K and other rhyolitic rocks from western North and South America, the SW Pacific region, Iceland and Queensland, Australia. Major elements are recalculated to 100%, anhydrous. Data from the Americas, SW Pacific, Iceland and Australia from Ewart (1979).

follow K during magmatic crystallisation, are accordingly enriched relative to their low-K counterparts (Table 3). Compared with anorogenic within-plate rhyolites (Table 3), contents of Zr and Nb, and also Y, are noticeably lower in the Muruvik rhyolites, a feature which helps to underline the calc-alkaline, magmatic arc character of the Muruvik rocks.

Discussion

The very nature of these pyroclastic volcanic products, with the possibility that some epiclastic material may have been present prior to metamorphic reconstitution, indicates that the chemical signatures of such rock-types cannot strictly be directly equated with original magma composition. In the present case, however, in view of the general lack of features of spilitisation and the fact that the samples show very little chemical variation, it is fair to assume that the analytical data constitute a reasonably close approximation to the composition of the acidic source magma.

Large-ion lithophile elements, such as K, Rb, Ba and Sr, are particularly sensitive elements with regard to detecting even minor changes in magma chemistry. These very same elements, however, are those most prone to mobility during various sea-floor weathering, hydrothermal and regional metamorphic processes (Hart et al. 1974, Humphris & Thomson 1978). For the Muruvik rhyolite tuffs, it seems clear that the high K_2O contents reflect the original source chemistry; they show little variation from sample to sample, a homogeneity which is also reflected in the abundances of Rb, Sr and Ba. Taking the immobile elements Nb and Zr, they show values closely comparable to those in subduction-related calc-alkaline rhyolites and plot firmly within the field of high-K rocks (Fig. 7) (Leat et al. 1986).

Given the calc-alkaline and high-K character of the described samples, as well as the nature of the associated Hovin Group sediments, there is every reason for considering the Muruvik pyroclastites as products of magmatic arc activity in a continental margin setting (Roberts et al. 1974). Oftedahl & Prestvik (1985) reached a similar conclusion for dacitic to rhyolitic tuffs occurring in the SW Trondheim region. Earlier, Loeschke (1976a) had proposed a comparable paleotectonic model for these SW Trondheim region felsic volcanites, and regarded them as arc effusives of transitional character, i.e. they were believed to have developed at an intermediate stage of arc construction, part-way between the immature oceanic and advanced stages during a period of gradual thickening of the crust. The chemical data presented here favour the existence of an even more mature arc development than that envisaged by Loeschke, involving subduction in a continental margin milieu. Accepting that Rb and Sr contents are fairly representative of primary values, then the local crustal thickness at the time of accumulation of these Upper Ordovician rocks may have been in excess of 30 km (Fig. 5) (Condie 1973). In a regional context the Lower and Upper Hovin Groups are considered to have accumulated in a back-arc marginal basin to the east of a gradually maturing magmatic arc positioned above eastward-subducting oceanic lithosphere (Roberts et al. 1984). In this model the basin developed upon intermediate-type crust along the margin of a continent or microcontinent.

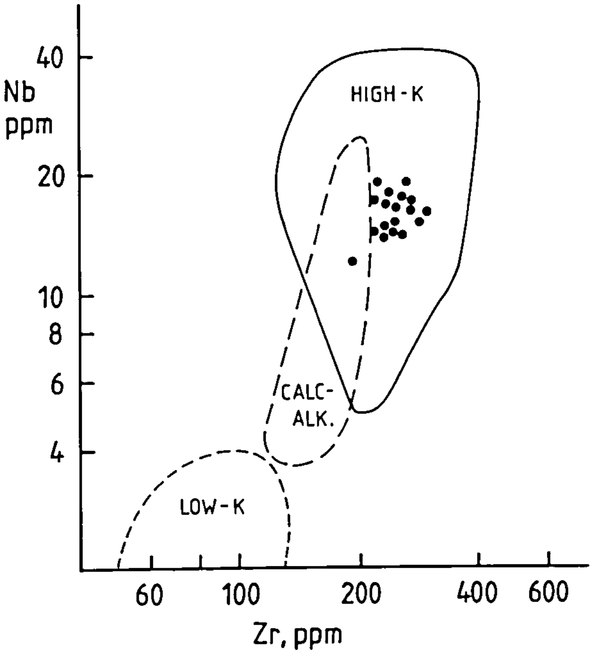

Fig.7. Nb-Zr variation for the samples of Muruvik rhyolite tuff, after Leat et al. (1986).

Geochronology

The fifteen samples taken for potential Rb-Sr whole-rock dating were crushed and analysed for concentrations of Rb and Sr at NGU. From the ratios of Rb:Sr thus determined, nine samples were chosen for isotopic analysis; these samples were spaced fairly evenly over the spread of Rb:Sr ratios, from minimum to maximum values.

Rb and Sr concentrations were determined on a Philips X-ray fluorescence spectrometer at the Mineralogisk-Geologisk Museum, Oslo, adopting the procedures of Pankhurst & O'Nions (1973). Variable mass discrimination in ^{87}Sr/^{86}Sr was corrected by normalising ^{88}Sr/^{86}Sr to 8.3752. The ^{87}Rb decay constant used is 1.42 x 10^{-11}y^{-1}. Age and intercept errors are noted at the 2σ level.

Results

Regression analysis of all 9 of the chosen samples yields an errorchron date of 410±27Ma (Fig. 8, Table 4). The initial Sr ratio is 0.7069 ± .0003 and the MSWD = 10.7. A 5-point best-fit line, arrived at by omitting the most discrepant samples from the 9-point calculation, showed a 'selectochron' date of 413 ± 11 Ma with an MSWD of 1.59. It must be stressed, however, that this number is without statistical significance in view of the selection and bias involved.

Sample no.	Rb ppm	Sr ppm	^{87}Rb/^{86}Sr	^{87}Sr/^{86}Sr	SEx10^5
2	129.6	176.8	2.1227	.71884	1
3	127.7	151.1	2.4477	.72062	1
4	84.4	243.4	1.0031	.71292	1
5	136.2	281.9	1.3989	.71512	1
8	123.7	130.6	2.7447	.72381	1
10	152.6	167.3	2.6427	.72253	1
12	129.3	166.2	2.2534	.72038	1
13	123.6	194.1	1.8440	.71751	1
15	110.2	198.7	1.6063	.71629	1

Table 4. Rb-Sr analytical data from the samples of rhyolite tuff from Muruvik.

Discussion

Taking the faunal evidence into account (p. 44), a depositional age for the Muruvik rhyolite tuff would fall in the time range c.446-442 Ma based on the latest time-scale adopted by Caledonian-Appalachian IGCP projects (McKerrow et al. 1985). The 410 ± 27 Ma errorchron date presented here thus does not show any correspondence with the assumed age of accumulation of the pyroclastic deposit.

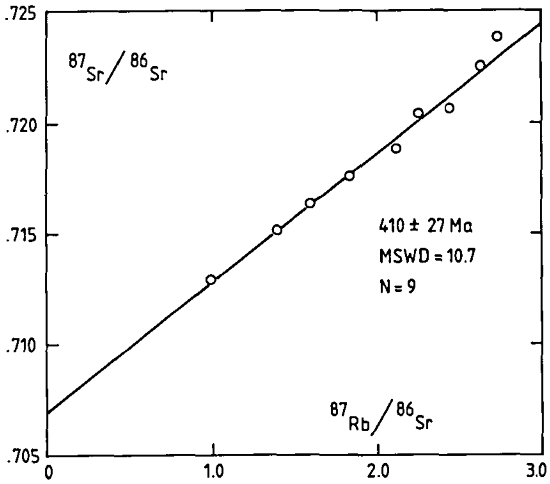

Fig.8. Rb-Sr isochron diagram for whole-rock samples of the Muruvik rhyolite tuff. Data are presented in Table 4.

A more reasonable interpretation would be to regard the isotopic data as reflecting the Late Silurian deformational and low-grade metamorphic event which has affected these rocks, and the volcanosedimentary rock assemblage of the western Trondheim Region as a whole (Strand 1961), prior to deposition of ORS molasse sediments. Roberts (1967) narrowed down the polyphase deformation to the period Late Llandovery to Early Ludlow (c.430-418Ma ago), but because of the complex nature and diachroneity of the Scandian orogeny it is conceivable that deformation and metamorphism extended up into the Late Silurian (Pridoli) in some of the rock units in the Trondheim Region (Roberts & Gee 1985). On the basis of the data presented here the Scandian metamorphism of the Muruvik rocks can be put at around 410Ma. This compares well with conclusions reached from a U-Pb study on zircons and sphenes from an area just southwest of Trondheimsfjord (Tucker et al. 1986a) where Scandian orogenesis is placed in the time range 423 to 396Ma, with the oldest ages appearing in the very highest nappes (Tucker et al. 1986b).

The intermediate value of the initial ^{87}Sr/^{86}Sr ratio of 0.7069 is not without interest. Similar ratios are known from the subduction-related, continental margin volcanites of western South America, from Ecuador down to Argentina (Francis et al. 1977, Hawkesworth 1982), where processes such as selective and complex crustal Sr contamination and variable degrees of partial melting and fractional crystallisation have been invoked to explain the isotopic compositions. In western Norway, Middle Ordovician continental margin rhyolites and andesites from Bømlo have comparable initial $^{87}Sr/^{86}Sr$ ratios of around 0.707 (Furnes et al. 1983).

Conclusions

Investigation of the geochemistry of a felsic lapilli-ash tuff from Muruvik, in the uppermost part of the Lower Hovin Group, has shown that this pyroclastic deposit is of clear calc-alkali character and can be classified along with the high-K rhyolites of destructive plate margins. The chemistry compares well with that of felsic lavas and pyroclastic rocks from the cordilleras of western North and South America. The data reported from the Muruvik occurrence support earlier models for the origin of Ordovician, mature-arc, intermediate to felsic volcanites in this region, along the margin of a continent or microcontinent.

An attempt at isotopic dating of the rhyolite tuff by the Rb/Sr method produced an errorchron of 410±27Ma with a MSWD of 10.7 and i.r. of 0.7069. As the tuff is believed to be of approximately Late Caradoc age, i.e. around 446-442 Ma B.P., then the Rb/Sr isotopic age of c.410Ma is interpreted to date the Scandian greenschist facies regional metamorphism in this part of the Caledonian nappe pile.

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