Alkaline Rocks and Carbonatites of the World

Part 1: North and South America

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North and South America

Alan R. Woolley
Department of Mineralogy

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Contents

Introduction

Although the great diversity of alkaline rocks, with their relatively exotic mineralogies, has always attracted the interest of petrologists, as have the more recently defined carbonatites, it could be argued that little progress has been made over the past 50 years towards formulating a comprehensive petrogenesis of these rocks. It could also be maintained that as the alkaline varieties have the most extreme compositions of all igneous rocks, so an understanding of their genesis is essential if we are to understand fully the workings of the solid earth, while a knowledge of the most extreme products of differentiation must inevitably cast light on rocks of less extreme compositions. The importance of academic research on these rocks is thus clear. There is, however, also a commercial aspect, in so far as they are an increasingly important source of a wide range of industrial raw materials, which has stimulated not only programmes to discover more occurrences, but also to investigate in greater detail those already known.

In recent years many new occurrences of alkaline rocks and carbonatites have come to light to such an extent, indeed, that they can no longer be considered rare. At the beginning of the century the known and described occurrences of alkaline rocks were probably fewer than 100, while only three carbonatites were known. The geological exploration in particular of Africa, the U.S.S.R., Canada and Brazil, much of it inspired by the search for exploitable mineral deposits, has rather changed the picture from the time when Daly (1933, p. 38) estimated that the alkaline rocks comprised only about 0.1% of all the igneous rocks. Although this percentage has probably only increased a few fold, the number of localities to be described in these volumes is over 2000, including more than 300 carbonatites.

That these very numerous occurrences should be listed and briefly described would seem to be justified for several reasons. Firstly, the alkaline rocks are petrographically, chemically and structurally exceptionally diverse, certainly more so than any other group of igneous rocks, so that it is not easy to compare occurrences meaningfully. Secondly, whereas the study of layered basic and ultrabasic rocks, for instance, has greatly benefitted from detailed investigations of a few key occurrences, the same has not happened in alkaline rock studies, partly because of this diversity. There are, of course, particular occurrences of considerable petrogenetic importance, as for example the Oldoinyo Lengai natrocarbonatite volcano and the Ilimaussaq complex, but comparative studies on alkaline rocks have in general been hampered by the extraordinary variety encountered and the scattered nature of the literature. Only one book in English has been devoted to the alkaline rocks (Sorensen, 1974) and two to carbonatites (Heinrich, 1966; Tuttle and Gittins, 1966); there are rather more books in Russian and there have been several monographs and papers on the occurrences of single countries, but there is no comprehensive, world-wide survey affording rapid and easy access to the field.

Regional studies of the compositions, form, ages and structural setting of occurrences comprising particular provinces have always seemed fruitful, and the association of alkaline rocks and carbonatites with rifting has long been acknowledged. However, many large, diverse and important provinces are not widely known, including the 20 or so major provinces of the U.S.S.R. and some of the major concentrations of South America. Although alkaline rocks are known to be characteristic of stable, intra-plate environments, it is becoming clear that they also play an important role in the igneous activity concentrated at plate margins. In this respect also, therefore, it is concluded that the collation of all the available regional data can make a significant contribution to understanding these rocks.

Sorensen (1974) in the Preface to 'The Alkaline Rocks' noted that owing to the limitations of space 'it was decided not to include a special section on the mineralogy of alkaline rocks and also not to compile a list of all alkaline complexes of the world corresponding to the valuable catalogues of carbonatites compiled by Tuttle and Gittins (1966) and Heinrich (1966).' (*op. cit.*, 1974, p. ix). It is hoped that the present volume will thus complement 'The Alkaline Rocks', while updating the lists of carbonatites described by Gittins and Heinrich.

Considerable thought has been given to the organization of the present publication, and early on it was decided that a mere listing with information in abbreviated form would not be particularly useful. Instead the more discursive style adopted for Currie's 'The Alkaline Rocks of Canada' (1976) and the descriptions of carbonatites compiled by Gittins (Tuttle and Gittins, 1966) were thought more appropriate. What were considered to be the best features of these publications have been adopted, but there are major differences with regard to layout and organization which are aimed at allowing rapid access to descriptions of particular localities, as well as showing, with the aid of numerous maps, the distribution of occurrences. The location of these rocks and their relationship to regional structures, particularly rifts, has always been of interest, and it is thought that this book provides, for the first time for many areas, the data on which meaningful discussion could be undertaken on the relationship between their distribution and temporal, structural and compositional features.

Apart from their scientific interest, the alkaline rocks and carbonatites are of major, and growing, economic importance. They are significant repositories of certain metals and commodities, indeed the only source of some of them, including Nb, the rare earths, Cu, V, phosphate, vermiculite, bauxite, raw materials for the manufacture of ceramics, and potentially for Th, U and diamonds, and many more. The economic potential of these rocks is now widely appreciated, particularly since the commencement of the very lucrative mining of the Palabora carbonatite for copper, and a host of valuable by-products, and it is the exploration efforts of mining companies that have led to the discovery of many important new localities. The present volume is likely to be of considerable interest to mineral exploration companies because there appear to be no published reviews of the economic aspects of the alkaline rocks. The economic importance of carbonatites, however, has been usefully documented by Deans (1966, 1978).

Scope of the Catalogue

The book includes entries for all occurrences of alkaline igneous rocks and carbonatites that could be traced. The definition of alkaline rocks adopted is generally that of Sorensen (1974, p.7): that they 'are characterized by the presence of feldspathoids and/or alkali pyroxenes and amphiboles'. The rocks included are, therefore, the nepheline syenites (phonolites) and ijolites (nephelinites), basanites and feldspathoid-bearing gabbroic rocks; peralkaline (i.e. containing alkali pyroxene and/or amphibole) syenite, quartz syenite and granite, together with peralkaline trachyte, comendite and pantellerite. Fenites are also included because of their intimate association with alkaline rocks and carbonatites, as are certain ultramafic and melilite-bearing rocks, including the alnoites and uncompahgrites. Analcime is treated as a feldspathoid for purposes of the above definition.

The modal rather than normative composition provides the definitive criteria, so that alkali olivine basalts, for instance, containing normative but not modal nepheline, are excluded. However, sometimes these rocks contain such a high proportion of normative nepheline that it must be present as an occult phase in the glass, or has not been recognized, probably because of the fine grain size. A few highly potassic rocks, with 10% or more of K_2O, are included although they would not meet the general criteria.

Carbonatites are taken to be rocks consisting of carbonate minerals that are considered to be igneous or metasomatic in origin. A few occurrences are included because they have been referred to as carbonatites in the literature, although they may be of dubious origin.

Although the great majority of localities included in this publication are igneous, some of the occurrences cited are undoubtedly metamorphic. Their inclusion is justified on the grounds that the origin of many peralkaline schists and gneisses is debatable, some undoubtedly having an igneous origin, while others have a metamorphic or metasomatic petrogenesis. This dilemma is particularly well illustrated by the differences of opinion on the origin of the peralkaline and feldspathoidal rocks of the Haliburton-Bancroft area of Canada.

Kimberlites are not included, partly because they are considered to have been dealt with elsewhere (Dawson, 1980), and partly because kimberlite pipes do not generally lend themselves to the approach adopted here; further, they are neither alkaline rocks, nor carbonatites, although sometimes comprising part of an alkaline rock or carbonatite association.

Organization of the catalogue

The catalogue is to consist of four parts:

1 North and South America (including Greenland)
2 Africa
3 U.S.S.R.
4 Asia and Europe (excluding the U.S.S.R.), Australasia, Antarctica and the oceanic islands.

It is expected that the parts will be approximately equal in size, each containing about 500–600 descriptions. Parts 1, 2 and 4 will be arranged alphabetically by continent and then by country. Because there are so many occurrences, of the order of 500, within the U.S.S.R., Part 3 will be subdivided into some 20 provinces.

Each national section begins with a numbered list of occurrences, which is keyed to an accompanying locality map. The order of the descriptions in each country is geographical with, on the whole, and arbitrarily, the more northerly and westerly occurrences being described first. This simple system is preferred to a genetic one, such as that used by Currie (1976) in his account of Canadian alkaline rocks, because of the difficulty of searching for individual entries in such a system, locating them on the national map when there are a large number, because of the ambiguities in the classification of many occurrences, and because of anticipated changes in classification schemes. In some areas the close proximity of many of the occurrences precludes them from being shown clearly on the national location maps. In these instances a small rectangle and run of numbers is substituted for the usual dot and single number. A larger scale location map will then be found in the text at the beginning of the numbered sequence, for example for the Montreal area of Canada and for central Goais, Brazil.

Number and name
Each occurrence has been assigned a national number, for example Jacupiranga is Brazil 88. This is followed by the preferred name of the occurrence and then, in brackets, by any synonyms, which are in some cases numerous. For a few occurrences it has been necessary to adopt a name, and these are invariably after some local community or geographical feature.

Geographical coordinates
These are quoted to the nearest minute for the approximate centre of the occurrence. For a remarkably large number of occurrences this has proved difficult because the exact location has not been fully described, and in these instances only an approximate coordinate can be given. A range of coordinates is quoted for particularly large occurrences, usually volcanic fields or swarms of dykes or diatremes. Some of these are indicated on the location maps by a numbered rectangle rather than a dot.

State, province etc.
These are quoted for a number of countries to facilitate rapid location.

Principal descriptions
These greatly vary in length and have been tailored as far as possible to reflect the complexity and importance of an occurrence. In some instances, however, very little is known so that the entries contain the only few facts generally available. On the other hand many occurrences are so extensive and complex that the descriptions will only be adequate to give a flavour of the geology. The general aim has been to present a description which is sufficiently full for the overall nature of the occurrence to be grasped. The emphasis in the descriptions has been given to the main rock types represented, and the form of the occurrence, although often in central intrusive complexes in particular little is known of their three dimensional geometry. The petrography has been stressed as being the most fundamental characteristic, with a brief outline of the mineralogy, including noteworthy accessory constituents.

Although it would be ideal for the rock names used throughout the catalogue to be consistent, this would be impossible to accomplish in the absence of thin sections of rocks from all the localities cited. Further, there is not at present an internationally accepted nomenclature for the alkaline rocks, the great diversity of which poses considerable problems for the petrographer. In view of this the rock names used are generally those adopted by the authors whose work has been consulted, although editorial comments have occasionally been added, and general terms such as nepheline syenite have been freely applied. However, the relatively full petrographic descriptions which are often given should allow the reader to decide for himself the nature of the rocks described. It is unfortunate that for some occurrences the presence of 'pyroxene' or 'amphibole' is recorded but not its nature, with the result that it is difficult in these cases to decide whether or not the rock is peralkaline.

For a discussion of the nomenclature of the alkaline rocks the reader should refer to the early chapters in Sorensen (1974) and the very full glossary of rock names (*op. cit.* p. 559). The same subject is discussed by Le Bas (1977, p. 24) who also covers carbonatites (*op. cit.* p.37), as does Heinrich (1966).

More specialized work, such as mineralogical and petrochemical investigations, rare earth, isotope and fluid inclusion studies etc., are cited wherever possible, but it is apparent how such detailed work has been concentrated on a relatively few localities. The exception to this is isotopic age determinations which are available for more than half the localities listed.

Reluctantly, accents have been omitted throughout the text, principally because of the difficulty of handling them with the word processing system adopted.

Economic notes

Notes on economic aspects of occurrences are given, whether to potential deposits or mineral concentrations being worked at present. Production statistics, tenors of ore and determined ore reserves are sometimes quoted when these are readily available, and of some interest.

Ages

Geological ages and methods used in obtaining them are quoted when these are available. If more than one method has been used then this is indicated and the results quoted.

References

The references quoted are generally those used for compiling the entries, and they are often cited in the text to indicate the sources of particular statements. Generally preference has been given to more recent references, and these are usually a source for earlier works, but the best general reference will often also be quoted. The sources of age data and economic information are always given, as are papers on specialized aspects such as isotopic studies, and mineralogical and geochemical work. Occasionally theses have been quoted, but an effort has been made to avoid this on the principle that the authors may be intending to publish their findings in a more widely available form. However, for a surprisingly large number of occurrences theses are the only available sources of information. Published abstracts have also proved to be a considerable source of data, particularly of new occurrences, but are generally unsatisfactory because of their inevitable paucity of detail. A full list of references is given at the end of each national section.

Geological maps

Many small, often simplified, geological maps have been included, mainly on the grounds that a map, however simple, gives a much better idea of the nature of an occurrence than an equivalent amount of text. Unfortunately, maps have been located for less than half the cited occurrences, although a number have also been excluded because they provide very little information. Some attempt has been made to standardize shading throughout, but this has not always proved possible because of the range of rock types involved, and because of the difficulties of showing clearly small areas, for which only a limited range of tints are suitable.

Locality index

This lists all occurrences cited, including synonyms, as well as localities referred to in the text. Entries are cited by country and locality number as well as by page; for example, Qagssiarssuk (Greenland 41).....90. The reader may, however, prefer to turn to the relevant country, which is easily located from the running heads or Contents page, and to scan the full list which is given at the beginning of each national section.

Omissions and errors

Although every effort has been made to include all known occurrences, inevitably there will be omissions. The author would be grateful if such omissions could be drawn to his attention, as the data base is being continually updated. Similarly, he would like to learn of errors of fact and emphasis, as well as omitted important references, for incorporation into planned future editions of the catalogue.

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Canada

Canadian occurrences of alkaline rocks have previously been listed and described in some detail in the monograph by Currie (1976a), although a significant number that have come to light since that publication will be found here. These new localities notably include extensive areas of peralkaline granites in Newfoundland, and of alkaline volcanics and intrusives in British Columbia, and it seems likely that many future discoveries will be concentrated in the latter area.

Many of the more northerly carbonatite occurrences are only poorly known and have not been dated. Although generally badly exposed, many have been drilled but rarely have findings been published. Many Canadian occurrences have been investigated for their economic potential (see, for instance, Ferguson, 1971) and important mining operations for nepheline syenite at Blue Mountain and Nb at St-Honore are taking place, with active exploration and appraisal for phosphate and vermiculite elsewhere. A number of occurrences in Ontario is described by Parsons (1961) and nearly 30 Ontario carbonatites have recently been re-investigated by R.P. Sage, although his internal reports were not available when the present accounts were compiled. K–Ar ages on numerous carbonatites in eastern Canada are given by Gittins *et al.*(1967) and of a broader range of alkaline rocks by Doig and Barton (1968). Rb–Sr ages and Sr isotopic ratios for many Ontario occurrences have been published by Bell *et al.* (1982).

1 Cape Richards
2 Freemans Cove
3 Tombstone Batholith and Spotted Fawn Creek Fawn Creek
4 Ting Creek
5 Bigspruce Lake
6 Easter Island dyke
7 Blachford Lake
8 Thomas Lake
9 Henninga Lake
10 Kaminak Lake
11 Last Lake
12 Atlin
13 Atsutla Range
14 Mount Edziza
15 Galore Creek
16 Lonnie
17 Goosly Lake
Anahim Volcanic Belt
18 Rainbow Range
19 Ilgachuz Range
20 Itcha Mountains
21 Cariboo-Bell
22 Horsefly Creek
23 Takomkane Mountain area
24 Blue River area
25 Verity
26 Rayfield River
27 Semlin
28 Kamloops
29 Perry River
30 Mount Copeland
31 Trident Mountain
32 Kinbasket Lake
33 Mount Laussedat
34 Mount Hunter
35 Ice River
36 Marron Formation and Coryell Intrusions
37 Kruger Mountain
38 Rossland dyke
39 Crowsnest volcanics
40 Sweet Grass Hills
41 Nisikkatch Lake
42 Cinder Lake
43 Carb Lake
44 Lake Harbour
45 Wapikopa Lake
46 Big Beaver House
47 Schryburt Lake
48 Squaw Lake
49 Sturgeon Narrows
50 Bell Lake
51 Poohbah Lake
52 Prairie Lake
53 Coldwell
54 Killala Lake
55 Chipman Lake
56 Nagagami River Belt
57 Martison Lake
58 Paint Hills Islands
59 Argor
60 Hecla-Kilmer
61 Sextant Rapids and Coral Rapids
62 Valentine Township
63 Goldray
64 Lewers Township
65 Clay-Howells
66 Teatzel Township
67 Cargill
68 Shenango
69 Herman Lake
70 Firesand River
71 Nemegosenda Lake
72 Borden
73 Lackner Lake and Portage
74 Seabrook Lake
75 Kirkland Lake
76 Otto stock
77 Venturi Township
78 Kusk Lake
79 Nemag Lake
80 Mckim Township
81 French River
82 Springer Township
83 Iron Island
84 Burritt Island
85 Manitou Islands
86 Callander Bay
87 Powassan
88 Lake Nosbonsing
89 Calvin Township
90 Brent
91 Deux Rivieres
Haliburton-Bancroft area
92 Monmouth and Glamorgan Townships
93 Cardiff and Faraday Townships
94 Dungannon, Monteagle and Carlow Townships
95 York River
96 Brudenell and Raglan areas
97 Wolfe Belt
98 Northeast Haliburton-Bancroft area
99 Blue Mountain
100 Deloro stock
101 Sullivan Island
102 Kipawa complex and Lake Tortue
103 Northwestern Quebec dykes
104 Cabonga Reservoir
105 Baskatong Reservoir
106 Kensington
107 Ste-Veronique
108 Lac Rouge
109 Gracefield
110 Cawood
111 Meach Lake
112 Dam Lake
113 Haycock Property
114 Quinnville and Templeton
115 Francon Quarry – Orleans
116 Chatham-Grenville stock
Montreal area
117 St-Andre
118 St Lin
119 Ste-Monique
120 Brilund
121 Oka
122 Como
123 Ile Cadieux
124 Ste-Anne de Bellvue
125 Ste-Dorothee
126 Francon Quarry – Montreal
127 Mount Royal
128 Brossard
129 Masson Street
130 St-Amable
131 Mount Bruno
132 St Jean
133 Mount St Hilaire
134 Rougemont
135 Iberville
136 Mount Johnson
137 Mount Yamaska
138 Shefford Mountain
139 Brome
140 Mount Megantic
141 Megiscane Lake
142 Obedjiwan
143 Crevier
144 Baie-Comeau
145 Lac Albanel
146 Arvida
147 St-Honore
148 Monts McGerrigle pluton
149 Nachicapau Lake
150 Castignon Lake
151 Goodwood River plutons
152 Strange Lake
153 Flowers Bay and Flowers River
154 Aillik
155 Mann 1
156 Mann 2
157 Red Wine
158 Baie-des-Moutons
159 King's Point
160 La Scie complex
161 Notre Dame Bay area
162 Topsails
163 Hare Hill Terrane
164 St Lawrence granite
165 Mount Champlain pluton

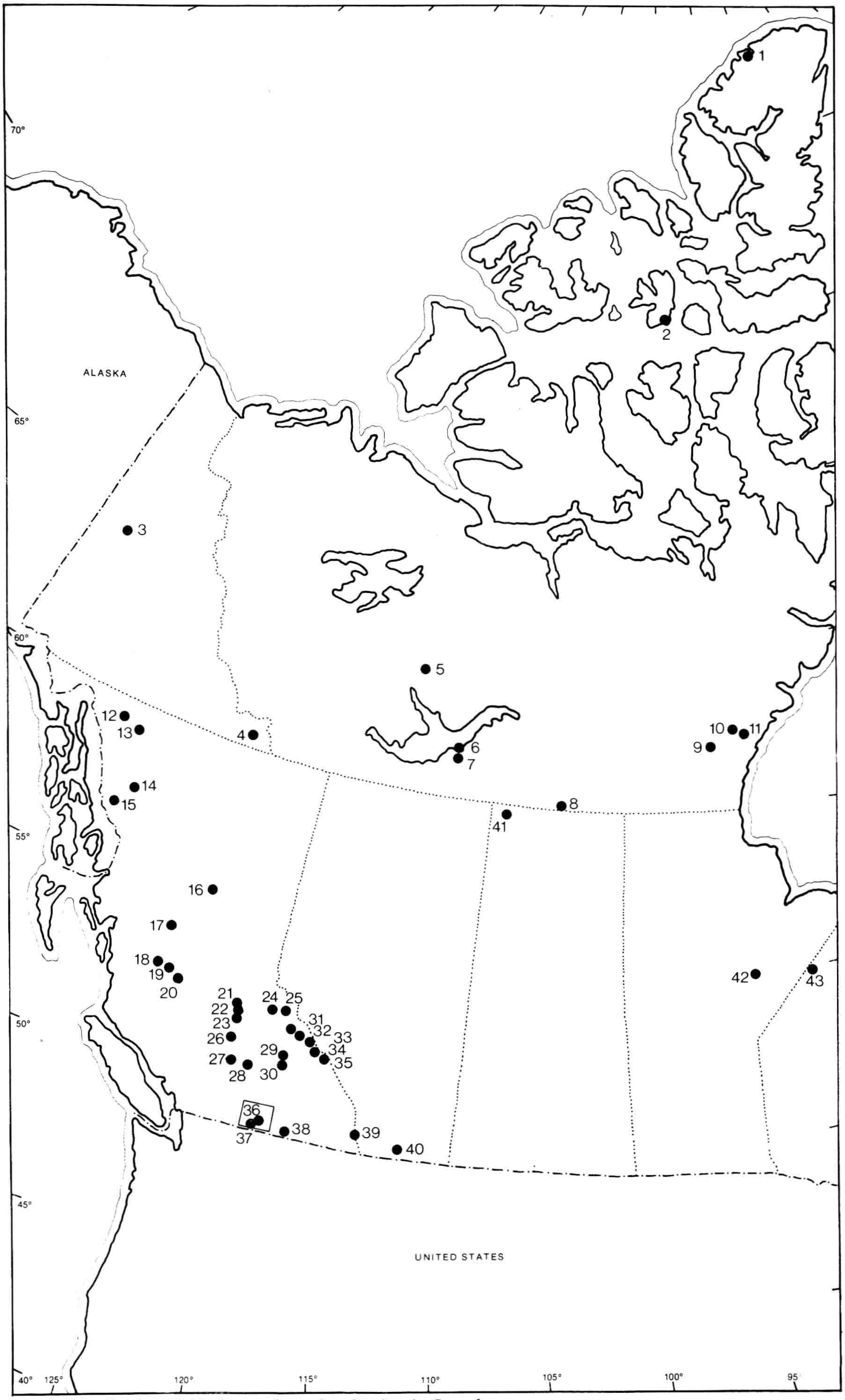
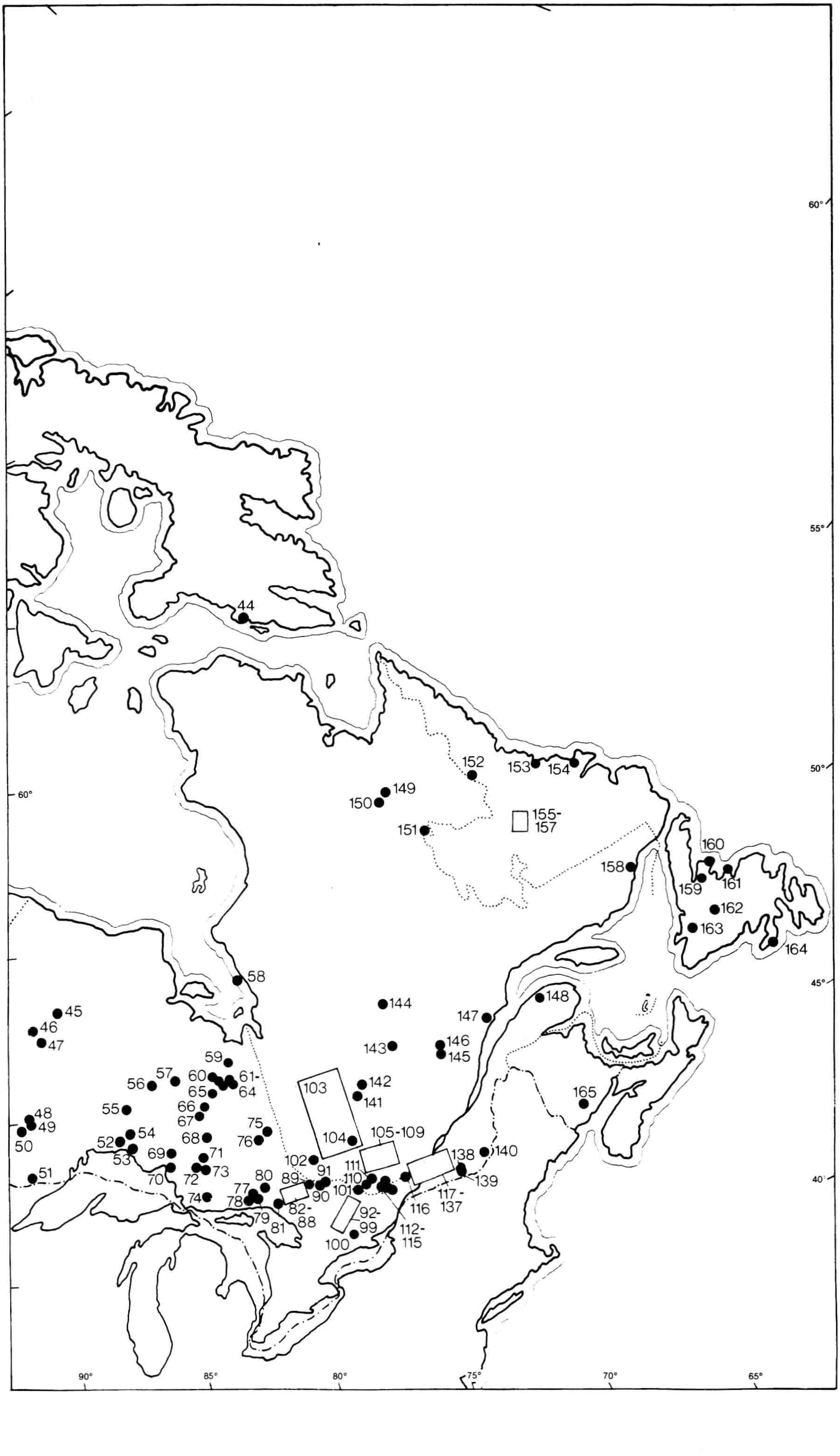


Fig. 1. Distribution of alkaline rocks and carbonites in Canada.



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1 CAPE RICHARDS 82°53′N; 79°15′W

(Northwest Territories, Ellesmere Island) Fig. 2

Located on the northern tip of Ellesmere Island, the Cape Richards intrusion is about 7×3 km but it is partly covered by ice, snowfields and scree. It is intruded into schists and marbles of Lower Palaeozoic age, or older. The complex consists of an outer zone of quartz monzonite and an inner zone which is essentially syenitic, but in some places dioritic. It is cut by dykes up to 1.5 m thick including peralkaline types. Most of the inner zone rocks are syenites and quartz syenites of perthite (85–95%), clinopyroxene, zoned from pale pink cores to pale green rims and commonly surrounded by hornblende, and a little brown biotite, sphene and opaques. The greater number of dykes are perthite-phyric syenites usually with some quartz, but there are also riebeckite microgranites and quartz syenites with about 10% riebeckite.

Age K–Ar on hornblende from a quartz monzonite gave 390±18 Ma and on co-existing biotite 347 Ma (Frisch, 1974, p. 74).

Reference Frisch, 1974.

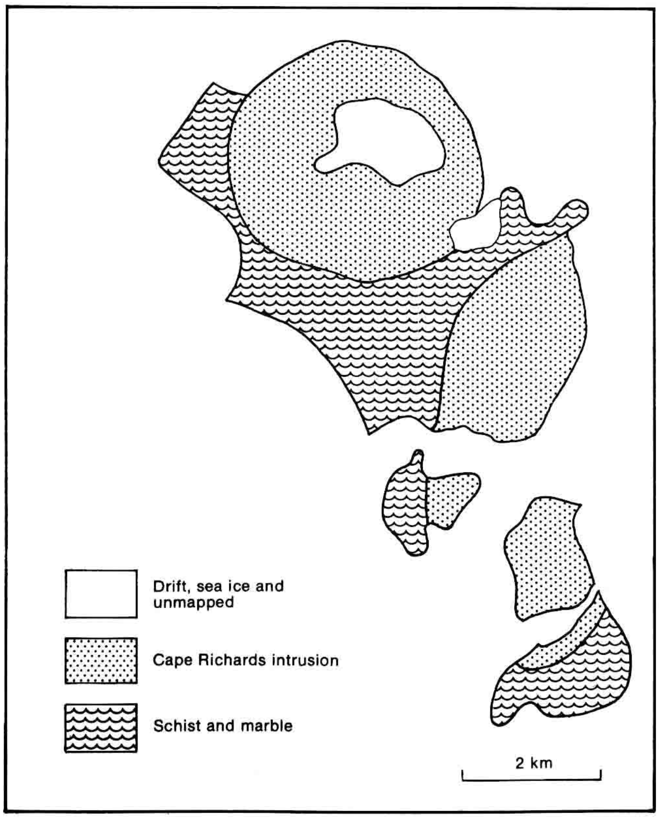

Fig. 2. The Cape Richards intrusion (after Frisch, 1974, Fig. 29D).

2 FREEMANS COVE 75°05′N; 78°10′W

(Northwest Territories, Bathurst Island) Fig. 3

The Freemans Cove suite consists of five agglomerate vents, about 75 dykes and small plugs, as well as several sills, within an area of 40×20 km at the southeast end of Bathurst Island. It is intrusive into Lower and Middle Devonian and Upper Cretaceous sedimentary rocks. Although flows are not now present, lava fragments, bombs and scoria commonly occur as clasts within the agglomerates.. The predominant rock types are nephelinite, basanite, basalt and phonolite. Olivine nephelinites are the most abundant rock type; fresh melilite has been identified from one locality and accessory phlogopite proves to be unusually rich in TiO_2 (10%) and BaO (15%). The nephelinites grade into basanites with increase in modal plagioclase (labradorite–andesine). Basalts are the least abundant mafic rocks and both *ne* and *hy*-normative varieties are found. Phonolites contain nepheline, alkali feldspar, and in mafic phonolites, pyroxene phenocrysts while large, euhedral amphibole crystals are common. Analyses of these rock types are given by Mitchell and Platt (1984) and for REE by Mitchell and Platt (1983).

Age A Rb–Sr isochron on nephelinite–phonolite gave 47.1±4 Ma (Mitchell and Platt, 1983, Fig. 2).

References Mitchell and Platt, 1983 and 1984.

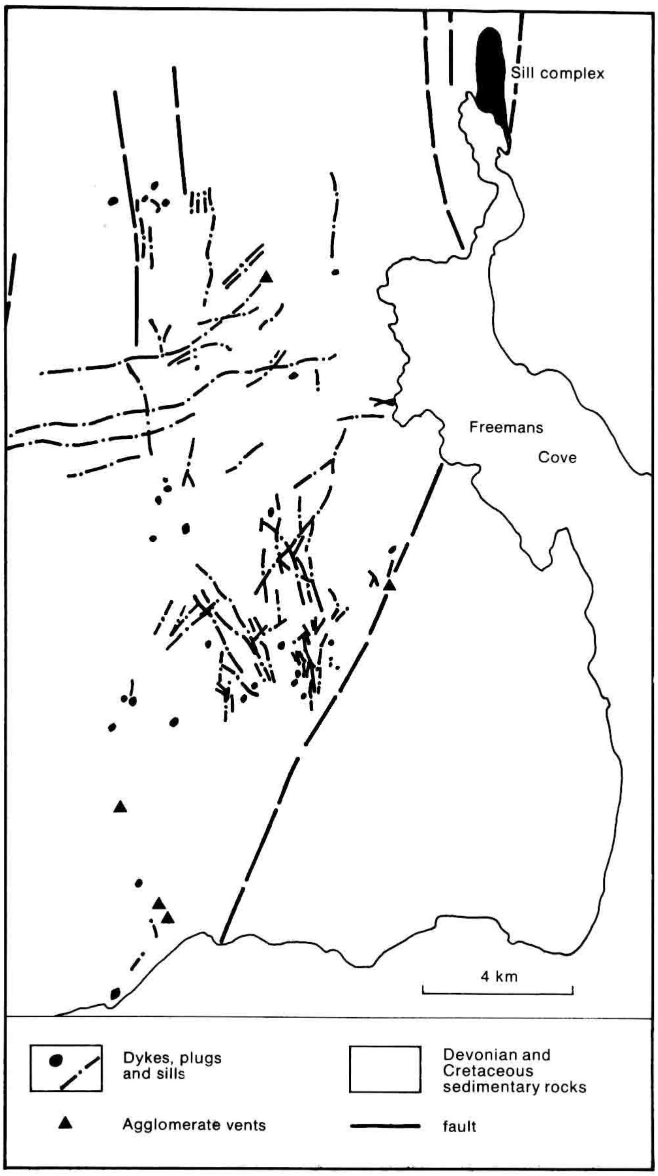

Fig. 3. Distribution of Freemans Cove suite (after Mitchell and Platt, 1984, Fig. 1).

3 TOMBSTONE BATHOLITH AND SPOTTED FAWN CREEK 64°25′N; 138°41′W

(Northwest Territories, Yukon) Fig. 4

The Tombstone Batholith comprises two approximately circular intrusions, the larger of which is about 11 km in diameter. It intrudes early Cretaceous orthoquartzites, and grades from alkali syenite at its centre through monzonite and quartz monzonite to quartz diorite near the margins. The syenite, which makes up about three-quarters of the intrusion, comprises phenocrysts of orthoclase in a groundmass of microperthitic orthoclase, lesser andesine, aegirine–augite, arfvedsonitic amphibole, biotite and minor quartz; melanite occurs locally, and sphene, zircon, apatite and opaques are accessory. An intrusion of pseudoleucite tinguaite has been emplaced along the southern margin of the batholith at Spotted Fawn Creek, where it forms a dyke-like mass up to 1 km across with sharp contacts. A second occurrence with the same field relationships is found further west, but a third locality, covering about 1600 m^2, lies wholly within the syenites into which it grades. The rock of the first locality contains euhedral pseudoleucites (30%) up to 4 cm in diameter and orthoclase phenocrysts (10%) up to 1 cm, in a groundmass of aligned K-feldspar prisms, nepheline, dark green to yellow biotite and a little melanite, carbonate, sphene, fluorite and cancrinite. The pseudoleucites consist of K-feldspar (60%),nepheline (20%), cancrinite (10%), calcite (5%), plagioclase (3%), biotite (1%) and melanite (1%). The pseudoleucite rock at the locality within the batholith is somewhat coarser, pseudoleucite forming about one third of the rock, and the biotite is pleochroic in shades of brown. Chemical analyses of whole rocks and pseudoleucites are available (Templeman-Kluit, 1969, Tables 1 and 2).

Age K–Ar on co-existing amphibole and biotite from the Tombstone Batholith gave 80±13 and 91±5 Ma (Templeman-Kluit, 1969, p. 55).

Reference Templeman-Kluit, 1969.

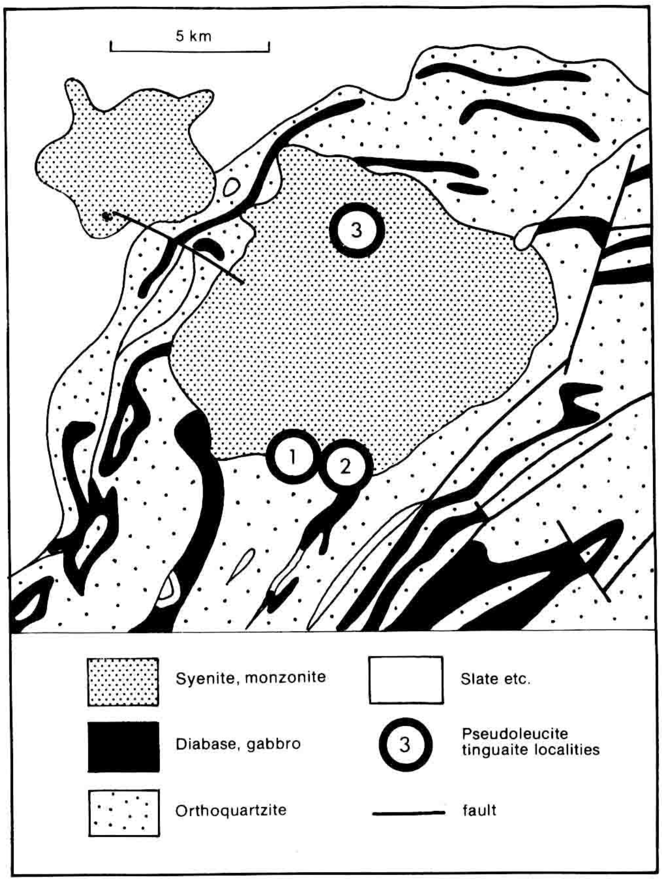

Fig. 4. Tombstone Batholith and pseudoleucite tinguaite localities (after Templeman-Kluit, 1969, Fig. 1). 1. Spotted Fawn Creek; 2. & 3. Other pseudoleucite localities referred to in text.

4 TING CREEK approx. 60°25′N; 126°W
(Northwest Territories, Yukon)

Situated in the Beaver River area of the southeast Yukon, Ting Creek covers about 4 km^2 and is the only known 'Laramide' intrusion in the northern Rocky Mountain Fold and Thrust Belt. The order of emplacement of the multiphase ring complex was phonolite and igneous breccia, quartz syenite, sphene–nepheline syenite, leucocratic nepheline syenite and tinguaite, foyaite and tinguaite, segregation veins and tuff breccia. Five magmatic suites have been identified on the basis of their chemistry by Harrison (1981) who has mapped the complex in detail (*op.cit.* Map 3).

Age 53.1 Ma by K–Ar.

Reference Harrison, 1981.

5 BIGSPRUCE LAKE (Big Spruce Lake, Snare River Complex) 63°33′; 115°55′W
(Northwest Territories, Mackenzie) Fig. 5

An oval body of about 8×4 km, Bigspruce Lake is emplaced in Precambrian equigranular and porphyritic biotite granites. Almost all of the complex is now covered by the waters of Bigspruce Lake because of a power dam built on the Snare River. The internal structure of the complex is unknown but it includes ijolite, ultramafic rocks, syenite and carbonatite. The ultramafics are essentially amphibolite with up to 50% magnetite, other opaque minerals, and a little apatite, carbonate and possible altered feldspar. Nepheline syenite contains perthite, nepheline, aegirine/aegirine–augite, bluish amphibole, biotite, sodalite, which forms conspicuous bright blue veins on some outcrops, zeolite, carbonate, sphene, apatite and opaques. A syenite with sodic amphibole and pyroxene, biotite and a little quartz is described as nordmarkite by Lord (1942, p. 35), but may be fenite. Leech *et al.* (1963, p. 60) describe a gradation from nepheline syenite, through syenite and quartz syenite to granite. Ijolites comprise approximately equal proportions of nepheline and aegirine with a little

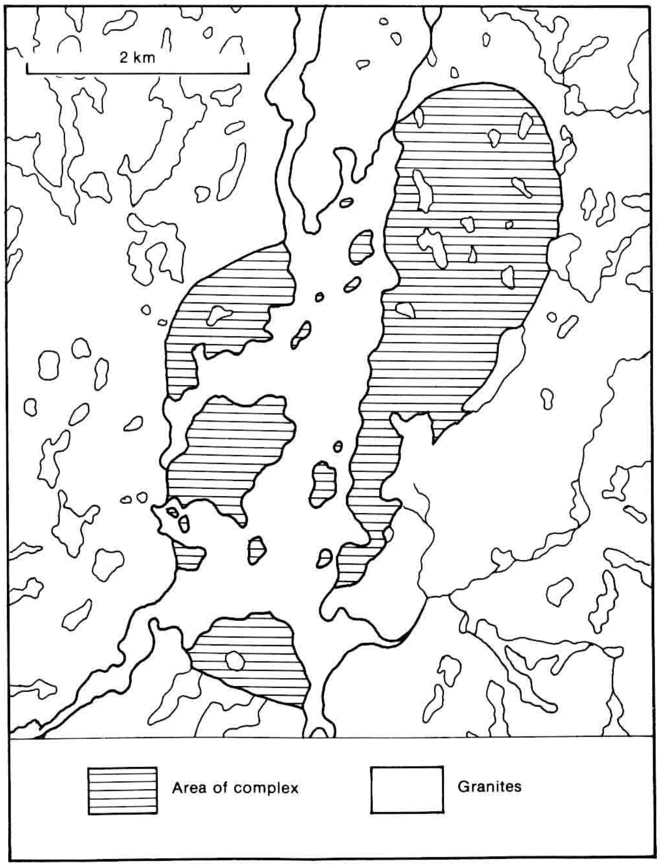

Fig. 5. Bigspruce Lake intrusion (after Lord, 1942, Map 690A, Snare River).

biotite, sodalite and carbonate. A body of white, banded limestone, undoubtedly carbonatite, occurred on the original northwest shore of the Lake with purple fluorite concentrated at its margin.

Economic Currie (1976a, p. 103) reports drilling of the carbonatite by COMINCO to test the radioacative and rare earth contents, but apparently with discouraging results.

Age 1785 Ma by K–Ar on biotite from nepheline syenite (Leech *et al.*, 1963, p. 6).

References Currie, 1976a, p. 103; Leech *et al.*, 1963; Lord, 1942.

6 EASTER ISLAND DYKE 61°30′N; 112°40′W

(Northwest Territories, Mackenzie) Fig. 6

This dyke, orientated approximately east–west, extends over a distance of 29 km but there are discontinuities due to shearing and displacement. Deeper levels of the dyke are exposed to the west, and a higher heterogeneous roof zone to the east. In the west the dyke is some 80 m thick and ultramafic, the rock consisting of 40% olivine, 25% Ti–augite, together with very minor antiperthite, interstitial Ti-alkali amphibole, biotite and 10% opaques including ilmenite, magnetite and Fe–Ni–Cu sulphides. Further east such olivine-bearing rocks occur along the margins of the dyke, the central zone consisting of about 35% antiperthite, 25–30% Ti-augite rimmed by green sodic pyroxene and blue sodic amphibole, and about 12% Ti-alkali amphibole with blue rims, biotite and ilmenite. There is a thin central pegmatitic zone of alkali feldspar, blue amphibole and abundant apatite. Further eastwards the dyke becomes more feldspathic still, the mafic border zone disappears, and the pyroxene decreases but becomes more sodic. The most easterly parts of the dyke are essentially albitites and bostonites with chloritized mafic minerals and abundant hematite throughout the rock. There are three lines of diatreme pipes running parallel to the dyke, some of the pipes of the middle line being in contact with the Easter Island dyke. They contain various angular or rounded blocks of country rock in a matrix of comminuted rock fragments or red bostonite. Major and trace element analyses for 20 Easter Island dyke rocks are available (Badham, 1979).

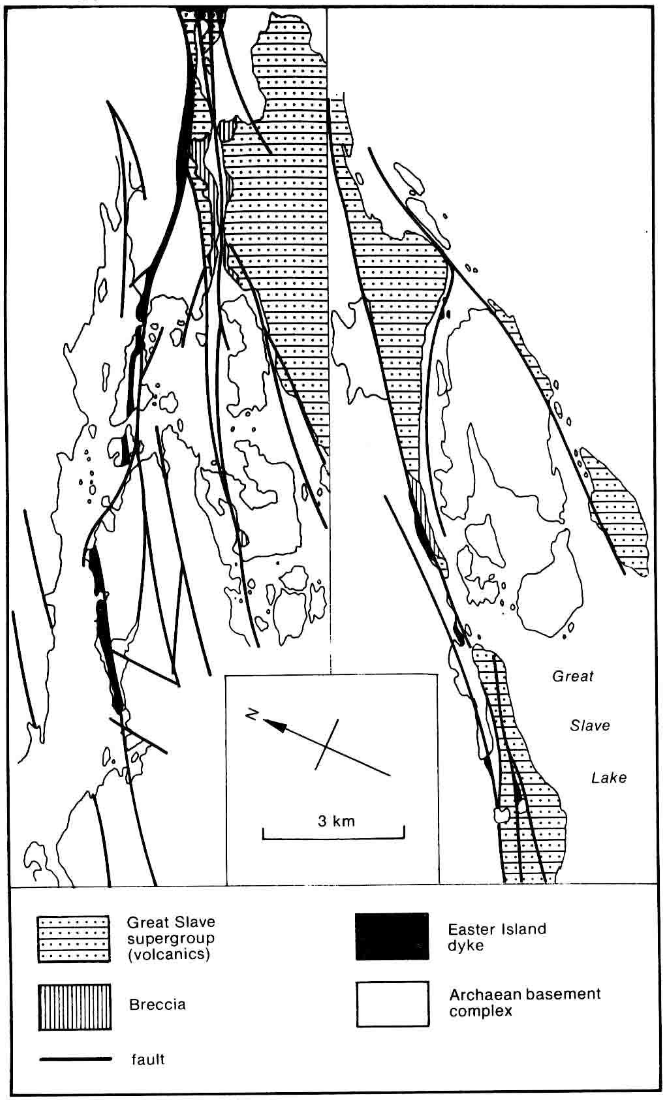

Fig. 6. Easter Island dyke (after Badham, 1979, Fig.2.)

Economic Sulphide mineralization is described by Badham (1978).

Age K–Ar on biotite gave 2170 Ma (Leech *et al.*, 1963, p. 61) and in a separate study K–Ar on biotite gave 2200 Ma (Burwash and Baadsgaard, 1962, p. 28).

References Badham, 1978, 1979; Burwash and Baadsgaard, 1962; Leech *et al.*, 1963.

7 BLACHFORD LAKE 62°06′N; 112°40′W

(Northwest Territories, Mackenzie) Fig. 7

The Blachford Lake complex intrudes Archaean granites and granodiorites and metasedimentary schists of the Yellowknife Supergroup, and is cut by diabase dykes and small plutons of diorite and granodiorite. The complex outcrops over some 235 km^2, but another 140 km^2 may be hidden beneath the Hearne Channel of the Great Slave Lake to the south. The successive phases of the complex changed with time from mildly alkaline gabbros, through increasingly alkaline diorite, syenite and granite, to peralkaline granite and syenite. The early olivine gabbro has a little hornblende and biotite. A later quartz syenite/granite contains pale green pyroxene and fayalite. The Grace Lake granite is by far the largest unit of the complex covering 155 km^2, and it grades into the central Thor Lake syenite. The granite consists of perthite, an average of 25% quartz, and about 7% riebeckite, which increases slightly inwards. Fluorite is

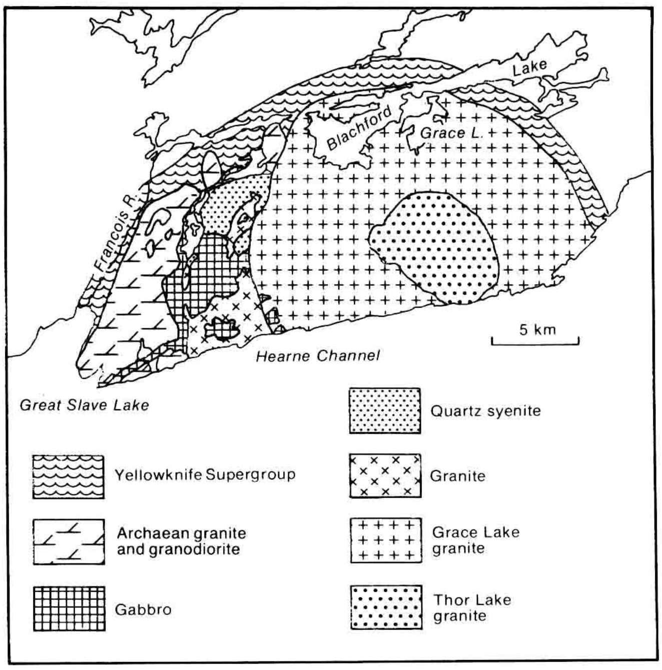

Fig. 7. Blachford Lake complex (after Davidson, 1978, Fig. 26.1).

invariably present together with zircon, monazite and occasional green pyroxene with riebeckitic rims. Aegirine is sometimes found as overgrowths on riebeckite and is locally associated with astrophyllite. The contact with the Thor Lake syenite is gradational over a few metres. Five varieties of syenite can be distinguished, the outer one of which is a fayalite-pyroxene syenite. Both the syenite and granite are traversed by aegirine aplites and pegmatites in the north of the Thor syenite. An extensive area of aegirine aplite, rich in fluorite, is associated with U and Th mineralization. Pegmatites with aegirine, fluorite, astrophyllite, zircon and bastnaesite also occur in the Grace granite. The geochemistry of the complex including REE and a microprobe study of some of the rock-forming minerals has been investigated by Davidson (1982). Initial $^{87}Sr/^{86}Sr$ ratios are 0.700–0.703 for the earlier units, but the later peralkaline rocks give 0.711–0.714 (Wanless *et al.* 1979; Davidson, 1982, p. 77).

Economic U, Th, Nb, Y and rare earth mineralization has been investigated; ixiolite, uranothorite, xenotime and phenakite have been identified (Davidson, 1978, p. 125; Badham, 1978, p. 1480).

Age A K–Ar age of 2057±56 Ma was obtained on riebeckite from granite. K–Ar ages determined on biotite, muscovite, hornblende and riebeckite range from 2057 to 2166 Ma (Wanless *et al*, 1979, pp. 34–8) with the peralkaline rocks significantly younger (Davidson, 1982, p. 77). These ages are indistinguishable from the overall ages defined by a Rb–Sr isochron.

References Badham, 1978; Davidson, 1978 and 1982; Wanless *et al.*, 1979.

8 **THOMAS LAKE** **60°09′N; 105°13′W**
(Northwest Territories, Mackenzie)

A strong nearly circular aeromagnetic anomaly 3–4 km in diameter occurs some 3 km north of Thomas Lake. Exposure is poor, only three outcrops having been sampled. Two proved to be a moderately foliated nepheline syenite of orthoclase, nepheline, cancrinite and a little albite, green biotite, sphene, apatite and rare arfvedsonite, aegirine–augite and magnetite. The rock of the third outcrop comprises andesine with abundant inclusions, particularly of epidote, rimmed by clear oligoclase, oligoclase anhedra and porphyroblastic perthite, with lesser amounts of biotite, blue–green amphibole, apatite, epidote, magnetite and carbonate. This is possibly a fenite.

Reference Taylor *et al.*, 1970.

9 **HENNINGA LAKE** **62°00′N; 96°24′W**
(Northwest Territories, Keewatin)

This approximately circular stock some 3 km in diameter, is emplaced in Archaean volcanics, which are fenitized near the contact, and unconformably overlain by Aphebian sediments of the Montgomery Lake and Hurwitz Groups. Rock types in the stock are trachytic porphyritic syenites, melanocratic aegirine-rich syenites and a carbonate-rich mafic syenite cut by veins of pink syenite.

Reference Ridler, 1972.

10 **KAMINAK LAKE** **62°35′N; 94°40′E**
(Northwest Territories, Keewatin) Fig. 8

This is an ellipsoidal body of 7×2 km lying along the north shore of an arm of Kaminak Lake beneath which 35% of the complex lies. It is intruded between Archaean greenstones and tonalite, both of which are fenitized for up to 300 m from the contact. The southern part of the complex is occupied by pyroxenite and melteigite which grade northwards into ijolites and leucocratic rocks composed essentially of nepheline and nepheline–orthoclase intergrowths. The northern and northeastern parts of the intrusion consist of syenite and nepheline syenite which also form dykes cutting the ijolites and pyroxenites. Carbonatite is present as lenses and dykes in all the other rock types, including the fenites. The ijolites and pyroxenites contain varying proportions of nepheline and aegirine–augite, melanite, magnetite, biotite, cancrinite and apatite, and they display a vague, steeply dipping layering sub-parallel to the margins. The rocks containing vermiform nepheline–orthoclase intergrowths may be solely composed of this, or it may form only a small proportion of the rock Descriptions, illustrations and analyses of nepheline and feldspar are given by Davidson (1970b). The syenites are principally coarse-grained K-feldspar leucosyenites with less common varieties containing nepheline, melanite, biotite, cancrinite, vishnevite, calcite and sphene, with accessory apatite, magnetite and pyrite. The carbonatites consist of calcite and varying proportions of apatite, biotite, magnetite, pyrite, a blue amphibole and pyroxene. The fenites are syenitic rocks with aegirine and a blue amphibole.

Age Biotite from an alkali syenite gave 1820±60 Ma. (Davidson, 1970c, Table 4) but a Rb–Sr isochron gave an age of 2686 Ma. (Wanless, pers.comm., 1973, in Currie, 1976a, p.103).

References Currie, 1976a; Davidson, 1970a, 1970b, 1970c.

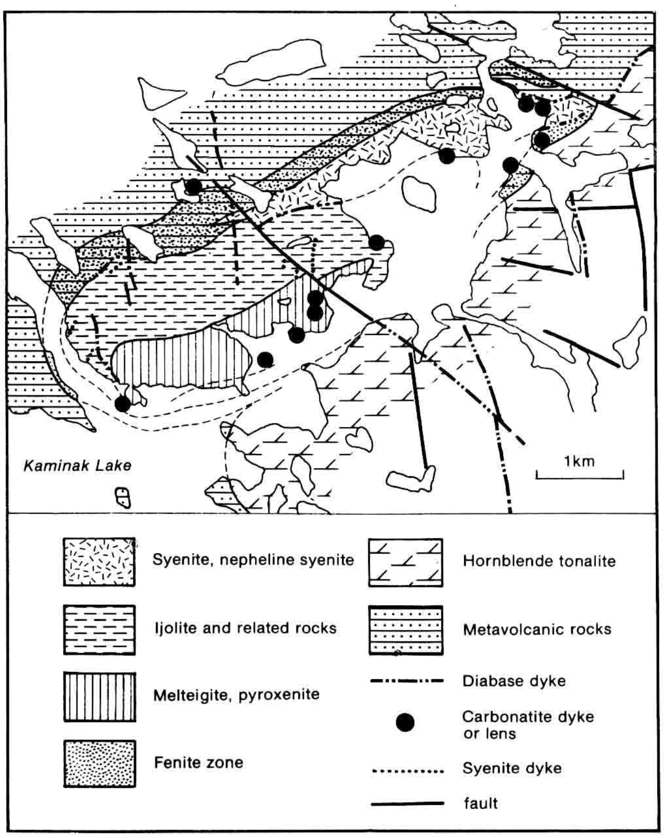

Fig. 8. Kaminak Lake (after Davidson, 1970a, Fig. 1.).

11 **LAST LAKE** **62°29′N; 93°45′W**
(Northwest Territories, Keewatin)

This circular magnetic anomaly is considered to be the signature of an alkaline complex. Hand specimens which unfortunately have not been described, are anomalously radioactive.

Reference Ridler, 1972.

12 ATLIN 59°30′N; 132°45′W
(British Columbia)

Approximately 50 km east of Atlin and 2 km north of the Mount Llangorse quartz diorite intrusion five small intrusions of nephelinite cut thermally altered Permian–Pennsylvanian cherts. Three of the intrusions are carbonate-rich nephelinites (Higgins and Allen, 1982), but two are fresh olivine nephelinites with olivine and clinopyroxene phenocrysts, some of the latter altered to amphibole, in a groundmass of clinopyroxene (40%), nepheline (40%), a little (?)analcime and zeolite. One of the olivine nephelinite intrusions contains locally abundant xenoliths which are principally spinel lherzolites and harzburgites with a few of websterite, spinel peridotite and orthopyroxenite; megacrysts include kaersutite and biotite. Chemical data for xenolith-free rock are available (Higgins and Allen, 1985, Table 1).

Age Late Pleistocene.

References Higgins and Allen, 1982 and 1985.

13 ATSUTLA RANGE 59°15′N; 131°35′W
(British Columbia)

Several peralkaline dykes up to a metre thick have been described from the central part of the Atsutla Range. The dykes are banded and contain abundant, zoned spherulites up to 6 mm in diameter of alkali feldspar, albite, quartz, riebeckite and aegirine. Rock analyses are available.

Reference Mathews and Watson, 1953.

14 MOUNT EDZIZA 57°40′N; 130°37′W
(British Columbia) Fig. 9

This is the largest (65×24 km) and most complex of a group of late Tertiary and Quaternary volcanoes that lie along a north–south zone of normal faults on the eastern side of the coast geanticline in northwest British Columbia. It is a composite shield volcano of gently dipping basaltic and peralkaline trachytic and rhyolitic lavas and pyroclastic deposits above tilted early Tertiary lavas and clastic sediments. Superimposed on the predominantly basaltic shield is the composite dome of Mount Edziza which rises to a circular summit crater nearly 3 km in diameter. The more acid magmas piled up near the central vent as thick, short flows, or lava domes, or erupted explosively to form ash flows and widespread ash falls. Tills, glacial-fluvial and glacial lacustrine deposits are interspersed with the volcanics and subglacial eruptions gave rise to hyaloclastites and pillow lavas. Four magmatic stages are recognized from field evidence, each beginning with large volumes of basalt and closing with relatively small volumes of more acid lava (Souther and Symons, 1974). However, more recent chronological work (Souther *et al.*, 1984) indicates five magmatic cycles. There is a spectrum of rock types from picritic alkali olivine basalts through trachybasalts and peralkaline trachytes to comendites. All the basalts contain olivine but two types can be distinguished depending on whether the pyroxene is ophitic purple titanaugite or intergranular pale green sodic augite. Olivine does not occur in the trachybasalts which comprise zoned plagioclase (An_{50-30}), augite phenocrysts, usually with aegirine–augite rims, and with alkali feldspar in the matrix. The trachytes consist of phenocrysts of sanidine and/or sodic plagioclase in a very fine grained groundmass of feldspar microlites, magnetite granules and glass. Phenocrysts or groundmass aegirine and aegirine–augite occur in some samples and may contain clusters of arfvedsonite and aenigmatite crystals, the last forming 15% of some rocks. The comendites which form ash falls and flows and lava domes, all contain abundant phenocrysts of quartz, sanidine and anorthoclase, and sparse phenocrysts of aegirine, aegirine–augite and aenigmatite, and these phases, together with arfvedsonite, are found in the groundmass. Rock analyses are available in Souther and Symons (1974) and a detailed study of aenigmatite was made by Yagi and Souther (1974). Rb–Sr and Sr isotope analyses are given by Souther *et al.* (1984).

There are numerous other volcanoes in this area which are known to be composed principally of alkaline olivine basalts, and it is very probable that alkaline and peralkaline products will be found when they are investigated in detail.

Age A detailed chronology based on 45 K–Ar and fission

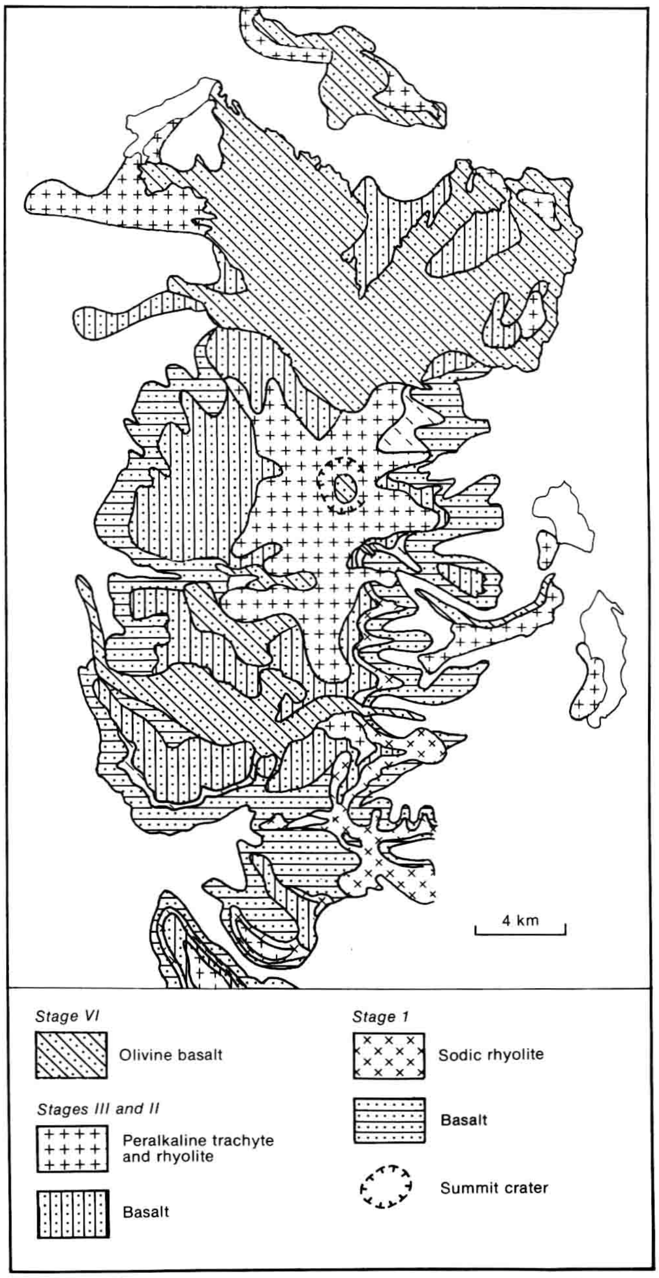

Fig. 9. Mount Edziza volcanic complex (after Souther and Symons, 1974, fig. 2).