Rock

LAMPROPHYRES

BLACKIE

Lamprophyres

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Contents

1 What are Lamprophyres? — History, Definitions, Classification

1.1 A brief history of lamprophyre research

To an uncomfortably large number of geologists, the term 'lamprophyre' conjures up predominantly negative images: of rotten dykes forming miniscule, impersistent outcrops; of legion obscure rock-types named after equally obscure European villages. To many, indeed, the term connotes little more than 'horribly altered', or 'impossible to classify'. This is all a pity, for it has severely delayed the recognition until recently that lamprophyres have an importance out of all proportion to their absolute abundance among igneous rocks: as windows into the deep mantle and mantle processes, as possible indicators for precious mineral deposits (notably diamond and gold), as parental magmas to an extraordinarily wide range of other igneous rock-types, and, in their own right, as sources of innumerable exotic mineral varieties and geochemical compositions. The reasons for this delayed appreciation of lamprophyres are salutory, and deserve a brief historical exposition.

1.1.1 The 19th and early 20th centuries: lamprophyres are characterized

The term 'lamprophyre' was coined by Gümbel (1874), making it one of petrography's oldest; in fact it predates such fashionable *wunderkinden* as komatiite and ophiolite by a full century. The name derives from the Greek *lampros porphyros* (λαμπροσ πορπηψροσ) meaning 'glistening porphyry' (purple rock), and was used because of the large, lustrous biotite phenocrysts which occur in the type-rocks from the Fichtelgebirge (Germany). Today, notwithstanding the blank look it often incites on petrologists' faces, lamprophyre is in fact one of few geological terms (along with *nahcolite* and *bazirite*) which really tells the reader something about what it stands for: 'glistening porphyry' actually describes the field appearance of many lamprophyres rather accurately. In stark contrast, most rock-names merely reflect their type-locality (e.g. *hawaiite, mugearite*), or have origins lost in the mists of antiquity (e.g. *syenite*), and tell the student absolutely nothing about the rock itself. Furthermore, lamprophyre is one of few rock-names ending in *-phyre* which retains its correct connotation of porphyritic character — contrast *granophyre, keratophyre*.

Because lamprophyres are abundant in Germany and Switzerland, where they were first recognized (Chapter 2), they received much attention in these countries during the closing decades of the 19th century, culminating in an influential exposition by Rosenbusch (1897). Parallel, though less numerous, field and petrographical studies were carried out over the same period into the equally abundant lamprophyres of northern Britain (e.g. Bonney & Houghton 1879; Harker 1892). By World War I, most of the macroscopic and microscopic idiosyncracies of lamprophyres described in Chapter 3 had been amply documented. Indeed, descriptive papers by H.G. Smith (1916–1946) and others on the crustal xenoliths in these rocks have scarcely yet been bettered. Over 130 'good quality' chemical analyses of lamprophyres had become available by the time Washington (1917) compiled his celebrated tables. It had also been recognized by then that certain lamprophyres are good indicators for the presence of gold deposits (e.g. McLennan 1915) — although this was soon afterwards forgotten, and neglected for fully 70 years (Section 9.2).

During this early period, when petrographers and petrologists were heavily concerned with classification and nomenclature, it was quickly recognized that lamprophyres show peculiarities which require them to be treated apart from other igneous rocks. For example: (1) conventional classifications based on feldspar compositions and modal ratios are inapplicable, because feldspars may commonly be decomposed and potash carried largely by mica rather than by feldspar; (2) lamprophyres' textures, which came to be described as panidiomorphic (Appendix B) and with a sugary (i.e. aplitic) matrix (Grout 1932) but no feldspar phenocrysts, are unique; (3) the intensity of autometasomatism leads to a superabundance of minerals normally considered secondary (carbonates, chlorite, epidote, zeolites, etc.); (4) lamprophyres' confinement to minor hypabyssal intrusions (dykes, etc.) required separate classification because (at this time), plutonic, hypabyssal and volcanic rocks tended to be treated as three quite distinct groups of igneous rocks. The result was that practically every petrological monograph of the period contained a new, idiosyncratic classification of lamprophyres, often conflicting violently with previous schemes.

These first 50–60 years of research were in fact marked by four milestone monographs. The first, Rosenbusch's (1897) detailed exposition of the lamprophyre concept, recognized several distinct but broad groups of lamprophyres: he realised that minettes (Appendix B) are typically associated with granites, and spessartites with diorites, but that camptonites and monchiquites usually occur with syenites. In this author's opinion, Rosenbusch's views are far nearer the 'truth' than many subsequent reassessments. One exception is his concept of *diaschistic dykes* — the notion that late-stage differentiates from granitoid bodies split spontaneously into two complementary magmas (lamprophyre and aplite). This idea was meant to explain the paradox that normal igneous differentiation moves from basic to acidic compositions, whereas lamprophyres in granitoid complexes (Section 2.4.1) are often late-stage, representing a return to basic compositions. The diaschistic concept held sway for several decades (e.g. Grout 1932, p.121), and has still not been buried in some countries, although it does contain some elements of truth.

The second monograph, Beger's (1923) monumental work on the lamprophyres of the Lausitz, Schwarzwald and St.Gotthard (Fig.2.5), presented a wealth of analyses, attesting very clearly to the interest lamprophyres had aroused among petrologists by this time. The third, accompanying work by Niggli (1923) marked the introduction of the term *lamproite* for extrusive rocks of lamprophyric aspect ('lamprophyre' itself had hitherto been applied only to minor intrusions). The fourth monograph was Bowen's (1928) classic work, containing a tightly argued chapter on lamprophyres which maintained, among other things, that lamprophyres did not correspond to fully liquid magmas (because of their persistently porphyritic condition), and that resorption of complex phases such as hornblende and biotite into evolved (e.g. granitic) liquids was a plausible model for their origin.

1.1.2 1940–1960: the wilderness period

Bowen's chapter was tantamout at the time to a papal encyclical *ex cathedra*, and comments in a fifth monograph (Tröger 1935), expanding the lamproite concept but adding little else, must have reinforced the impression that there was now little more to be said on the subject.

A further death-knell was dealt immediately afterwards by Knopf's (1936) reassessment of the lamprophyre concept in the Spanish Peaks, USA (Fig.2.10). In the present author's opinion, Knopf in fact managed to obscure totally what lamprophyres are, and what distinguishes them from other igneous rocks; many of his so-called "lamprophyres" are nothing but common andesites, basalts and porphyries. He also derived quite erroneous deductions from a confusion between two quite distinct suites of lamprophyres of different ages, which happen to coexist in this one area (Section 1.7). Unfortunately, Knopf's alternative, "simple descriptive terminology" (a recipe for confusion) was all too often adopted: from Fenner (1938), who described ordinary Antarctic basalts and basanites as "fourchites" (Appendix B), to Currie (1976). It has lurked behind much subsequent literature on the Spanish Peaks itself (e.g. Johnson 1968), to the extent that it is all but impossible to understand second-hand what these rocks are. More insidiously, Knopf's views infected generations of petrologists with the notion that lamprophyres are difficult to define, by not being cleanly separated from common igneous rocks. An unhappy result was that all kinds of other obscure rock-types also became lumped with lamprophyres, merely because they also were difficult to classify: for example, Moorhouse (1959) merged lamprophyres with *beerbachites* (a type of hornfels)! Knopf's influential work has only finally been expiated through reappraisal of the Spanish Peaks by Jahn *et al.*(1979).

When petrology began to recover from World War II, this prior history proved enough to discourage recovery in the study of lamprophyres. These rocks had become a 'problem', and indeed, the very words "lamprophyre problem" appeared in many titles of this period (e.g. H.G.Smith 1946; Bederke 1947; Eskola 1954; Watznauer 1964). Consequently, the number of publications dealing with lamprophyres had barely recovered by 1960 from its immediate pre-War peak (Fig.1.1a). Papers from the late 1940s and 1950s are mostly period pieces, concerned largely with reassessment of earlier work, with local problems, or with obsolete debates such as the granite controversy. They present few new data, and some of the issues so hotly debated in them seem quaint nowadays, even in translation. In textbooks of the period, lamprophyres are treated as little more than obscure petrological curiosities, being relegated to the footnotes or considered unworthy of attention at all.

1.1.3 The late 1960s to the present: lamprophyres come of age

The first serious attempts to resurrect interest were made during the late 1960s and early 1970s by Dr.D.Velde (née Métais) in France, Dr.D.Nemec in Czechoslovakia and Prof.W.

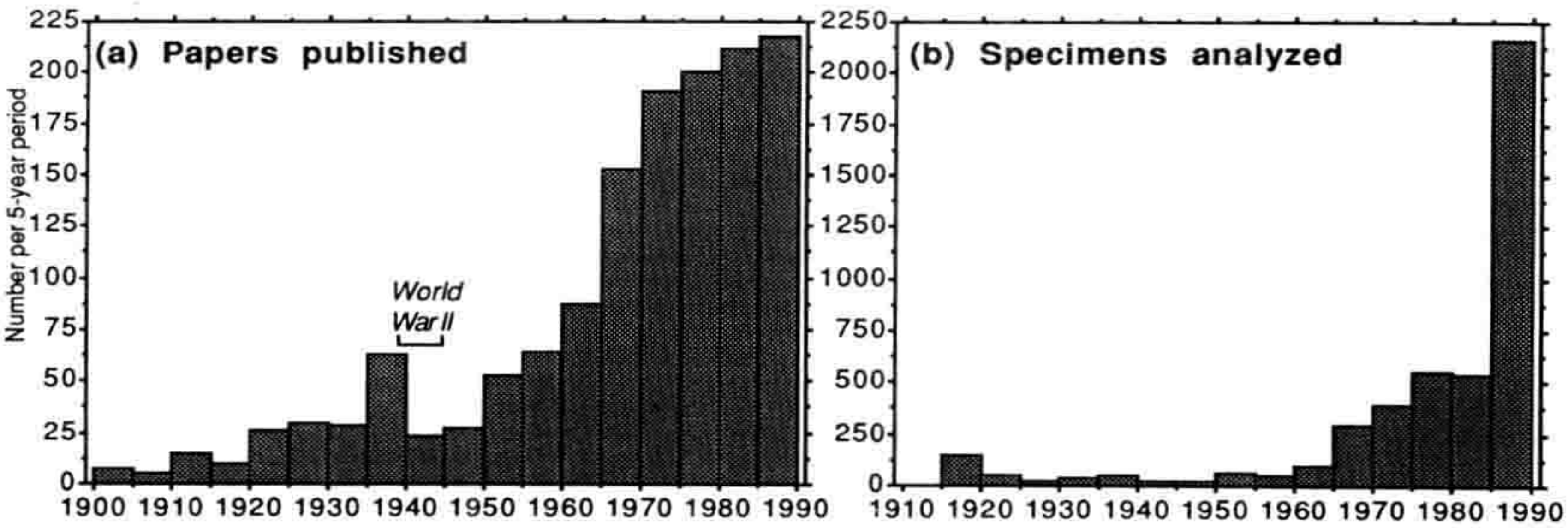

Fig.1.1 *Volume of lamprophyre research during the 20th century.*
(a) Number of publications concerned substantially with lamprophyres over 5-year periods.
(b) Lamprophyre specimens analyzed over the same periods.
Data in (a) derived from non-selective version of the Bibliography in this book, and in (b) from LAMPDA (Appendix D). No distinction is made in (a) between books, papers and abstracts, but papers mentioning lamprophyres only *en passant* are excluded. In (b), total data available for each specimen counted might actually reach several *hundred* individual data-values (e.g. one whole-rock analysis for up to 50 major and trace elements and isotopes, plus dozens of mineral analyses for perhaps 10-15 oxides). The minima in the World War II years are a predictable phenomenon of the literature in general.

Wimmenauer in Germany. Even though lamprophyre specialists were still very few, the prolific output of these workers in particular caused publications to multiply 2½ times over the 10-year period (Fig.1.1a), even though the amount of analytical data did not grow to anything like the same extent for the time being (Fig.1.1b).

The surge of interest had become far more widespread by the late 1970s, and then became firmly established as a long-term phenomenon, after the discovery of the world's richest diamond deposit in the Argyle pipe of NW Australia (Fig.2.8). For a full century, prospectors had relied on the maxim that diamonds only occur in kimberlite (Appendix B), first named after Kimberley (S.Africa) in 1887. Purely for this reason, early descriptions of Argyle referred to it as a "kimberlite" or "kimberlitic rock" (Atkinson *et al.* 1984a). Soon, however, it was realized that Argyle is not a kimberlite but a lamproite (Appendix B), and with that came the implication that diamonds could occur in related rock-types — such as lamprophyres. More or less concurrently, the old prospectors' notion that lamprophyres might be related in some way to gold deposits was briefly resurrected by Boyle (1979, p.250) and reappraised with full force by McNeil & Kerrich (1986).

The result of these developments has been remarkable. The volume of analytical data published on lamprophyres (*excluding* kimberlites) since 1985 has exceeded the total volume accumulated up to that time (Fig.1.1b). The first-ever symposium devoted to lamprophyres was convened in 1985 by the late Prof.Sharon Bachinski at the annual GAC/MAC meeting at Fredericton, New Brunswick, and a special issue of *Canadian Mineralogist* (**26**, no.1, 1988) has since been published to commemorate Sharon's untimely death. Papers dealing exclusively or substantially with lamprophyres (even excluding kimberlites) have proliferated remarkably: whereas the 1st International Kimberlite conference (IKC) in 1973 resulted in only one or two, the 2nd, 3rd and 4th IKCs generated 4, 5 and 26 papers respectively. About 45 are currently published each year (Fig.1.1a), with dozens more mentioning or documenting lamprophyres more superficially. Collectively, these papers now yield new data for some 450 lamprophyre specimens annually (Fig.1.1b), and of the order of 1,000 whole-rock and mineral analyses, which of course means many thousands of new data-values for individual variables, each year.

There is little indication that the present bubble may burst, for interest in lamprophyres now extends along *three* quite different and complementary fronts.

(1) *Diamonds*. The Argyle pipe now alone generates >30% of world diamond production by weight, so there is ample incentive for further exploration. By 1987, this had led to reclassification of several "kimberlites" as lamproites (e.g. Prairie Creek, Arkansas, USA) and to confirmation of the presence of diamond not only in other lamproites (e.g. Luangwa Valley, Zambia), but also in two varieties of lamprophyres (damkjernites and monchiquites) in Western Australia (Section 9.1). The present position is that lamprophyric rocks are the only confirmed *magmatic* sources of diamond, and much research is now being directed towards determining how wide the field of diamondiferous rocks extends, how the extension of the field affects traditional diamond exploration by indicator minerals, and how it can be determined whether a given lamprophyre body is potentially diamondiferous at the earliest stages of its discovery. The diamond exploration industry has had its ups and downs, but seems currently (end-1989) to be in a recovery phase.

(2) *Gold*. The high gold price sustained a 'boom' in research and exploration in the 1980s. The recognition of a recurrent space-time association between mesothermal gold and

lamprophyres has already led to the hypothesis that lamprophyres might transport gold up from the deep mantle in the same way that they bring diamonds. Lamprophyres have consequently made their entry into the biennial Gold conferences (with 5 papers at Gold '88, in Melbourne, Australia), in the same way that they had already entered the Kimberlite Conferences.

(3) *Granitoids*. This most recent front of interest is primarily academic, though it too has economic overtones. The origin of post-orogenic granitoids has of course been debated for decades, but Suzuki & Shiraki (1980) were the first to suggest of late that lamprophyres might be parental to certain granitoids. By 1985, exhaustive isotopic work on British Caledonian granitoids had clearly implicated parent magmas which perfectly fit the compositions of widespread associated lamprophyre dyke-swarms. However, a throwback attitude to the 1960s among some granite specialists, who continued to regard lamprophyres as "grotty mafic dykes" not worth a second look, delayed the forging of the granite–lamprophyre connection itself, and it fell to other groups of workers in 3 countries to do this (Section 8.6). The lamprophyric affinities of widespread mafic enclaves in some granitoids have also recently begun to be realised. Now that lamprophyres have at last begun to be studied in the same petrological and isotopic detail as their associated granitoids, their potentially parental status in some areas is becoming much clearer.

The present author first encountered lamprophyres during his PhD research at Monchique (the *monchiquite* type locality), although his principal study concerned the host nepheline syenite intrusion. In 1977, however, he was given the task of surveying the vast Permo-Carboniferous lamprophyre dyke-swarms in the Scottish Highlands and Islands (Fig.2.7). Although his initial interest was thus imposed rather than chosen, the change in lamprophyres' fortunes had taken place by the time this regional survey was completed, and has now led inexorably to the publication of this book.

1.2 Classification and nomenclature: the Lamprophyre Clan

It is pointless here to recite the endless stream of contradictory classifications of lamprophyres over the past century. Suffice it to say that confusion probably attained its nadir with the Arrow Peak dyke, Montana (USA), variously described as "orthoclase-camptonite" (Rosenbusch 1897), "minette" (Pirsson 1905), "leucite-monchiquite" (Beger 1923), "diopside-lamprophyre" (Knopf 1936) and even "mafic phonolite" (Buie 1941). Mercifully, the IUGS Subcommission on Igneous Rock Systematics has now recognized three groups of lamprophyres (calc-alkaline, alkaline and "melilitic"), each comprising several rock-types (Streckeisen 1979). It has subsequently approved the grouping of lamprophyres, lamproites and kimberlites together as *lamprophyric rocks* (Le Maitre 1989). Overall, this means that we have a *clan* of lamprophyric rocks, to be divided into 5 *branches* (Fig.1.2). IUGS-approved definitions of individual rock-types in Fig.1.2 are outlined in Table 1.1, and amplified in Appendix B.

This book adheres to the latest IUGS recommendations (Le Maitre 1989), which include several minor changes to those in Streckeisen (1979):

(1) Streckeisen's (1979) attempt to fit lamprophyres into the QAPF double-triangle has been abandoned, and Table 1.1 is therefore constructed without reference to QAPF. In truth, QAPF is inapplicable to lamprophyres because: (i) melilite and carbonates can cause

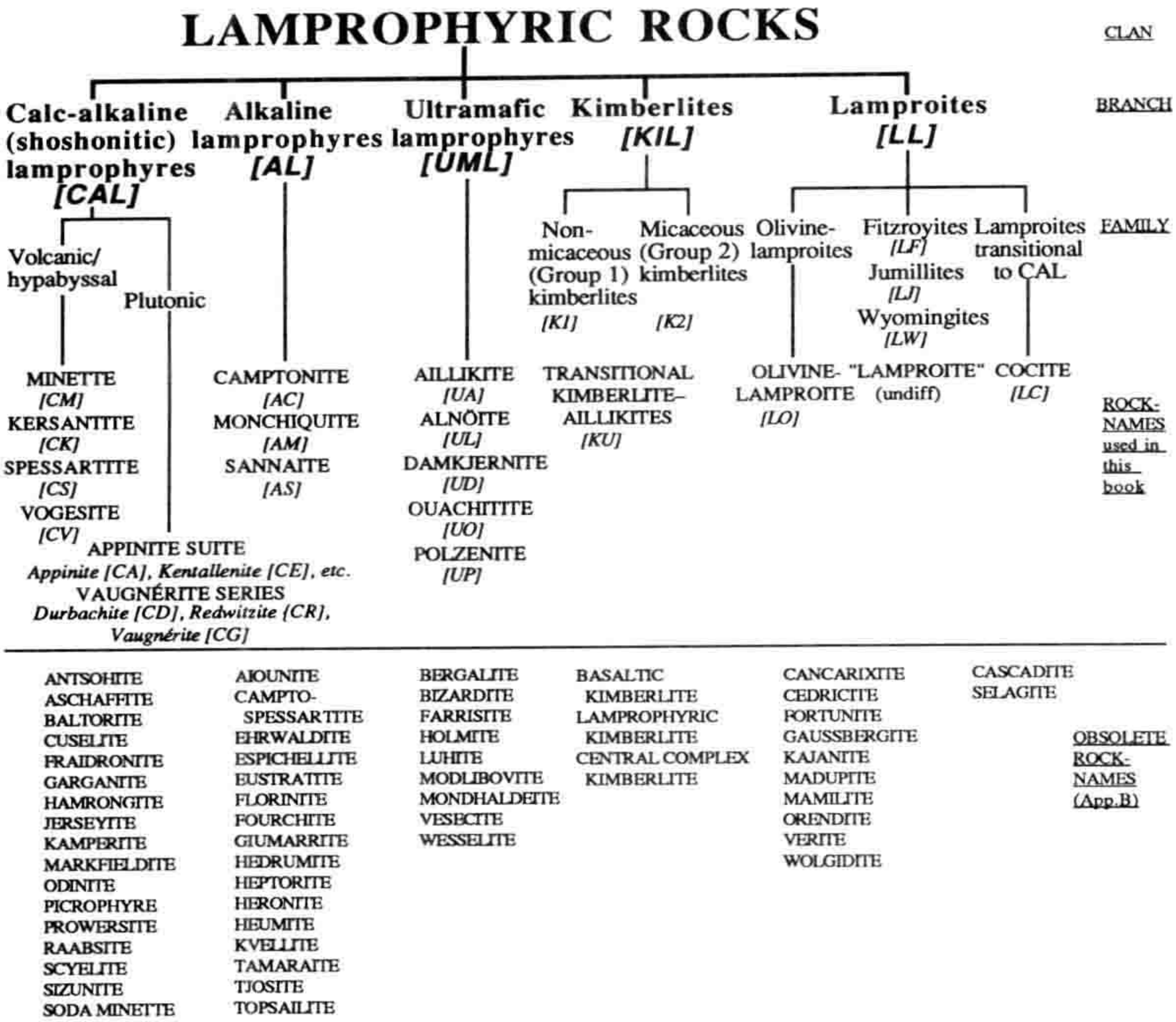

Fig.1.2 *Hierarchical classification of lamprophyric rocks adopted in this work.* After Streckeisen (1979), Le Maitre (1989). Hierarchical levels *clan, branch, family* defined by Rock (1981). Individual rock-names explained in Appendix B. Codes *[in square brackets]* as used throughout this book.

confusion, being light-coloured yet 'mafic'; (ii) melilite has often also been considered as a feldspathoid (Streckeisen 1976, p. 6); (iii) as the colour index of UML is around the critical value of 90%, small modal variations change their QAPF field in an exaggerated fashion, or cause the rock to enter fields which the scheme does not cover; (iv) monchiquites and many lamproites carry essential glass; (v) the feldspar ratio in lamprophyres is commonly indeterminate.

(2) Streckeisen's *melilitic lamprophyres* have been redefined as *ultramafic lamprophyres,* because melilite-rich and melilite-free lamprophyres commonly coexist (Rock 1986).

(3) *Ouachite* has been redefined as an ultramafic, not alkaline, lamprophyre.

(4) *Fourchite* is no longer approved, presumably because 21% of "monchiquites" (including the type-rocks) are olivine-free, and because there is no corresponding term for the 43% of described "camptonites" lacking olivine (Gallagher 1963; Rock 1977).

Three incidental adjustments are also made to Le Maitre's (1989) recommendations:

(a) Merely for brevity's sake, *lamprophyric rocks* is generally shortened to *lamprophyres.*

(b) Following Dawson (1987, 1989) and Skinner (1989), kimberlites are considered to represent a branch (i.e. several rock-types), and *not* a single rock-type (Section 1.3.2).

(c) Three rock-names (*aillikite, damkjernite, ouachitite*), not apparently approved by the

IUGS, are retained here. (In fact, there is doubt as to which names *are* IUGS-approved: for example Le Maitre's glossary (p.41) states that aillikite is among the approved names in his table B.3, but it is in fact missing).

Careful use of this IUGS terminology should overcome much of the lamprophyre mystique, provided that: (i) similarities and differences between the 5 branches (Chapters 4–5) are properly balanced; (ii) the term *lamprophyre* itself is reserved primarily for field use, and the more precise rock names in Fig.1.2 employed in more detailed descriptions. Both changes are necessary because *lamprophyre* alone covers an inordinate range of compositions from ultramafic to mesotype, ultrabasic to intermediate, Na- to K-rich, melilite- to quartz-bearing, and peraluminous to perpotassic. Among rocks requiring wholesale renaming are "central complex kimberlites", which become *aillikites* (Rock 1986), together with "peralkaline minettes" (Velde 1967; Hall 1982), "leucite-lamprophyres" and "mica-peridotites" (e.g. Sarkar *et al.* 1980), which become *lamproites.*

1.3 In defence of the Lamprophyre Clan

Although the clan concept has effectively been sanctioned by the IUGS, and Chapters 2–9 will hopefully illustrate to the reader the hard factual basis behind it, the following general arguments are nevertheless proferred in its favour at this stage, for the benefit of sceptics:

(1) Fig.1.2 allows similarities and differences to be balanced. 'Splitters' and 'lumpers' can be accommodated. The hierarchical structure allows rocks to be classified accurately, at every stage of their description, *according to how much information is available.* Thus

Table 1.1 Classification of lamprophyric rocks by light-coloured minerals present in the mode[1]
(expanded from Streckeisen 1979, Le Maitre 1989)

Light-coloured minerals	Plagioclase > Af	Af > plagioclase	No feldspars	+Melilite,no Fp
No Na-foids[3] or leucite;	{KERSANTITE	MINETTE		
↓ *minor quartz may occur*	{SPESSARTITE*	VOGESITE*	VERITES[4,8]	—
↓ *Leucite occurs, no Na-foids[3]*	—	JUMILLITES[4,6]	ORENDITES[4,7]	—
↓ *Na-foids occur[3], no leucite*	CAMPTONITE*	SANNAITE*	MONCHIQUITE*[4]	POLZENITE
↓ *Carbonate[5], Na-foids[3] occur*	—	DAMKJERNITE[10]	OUACHITITE	ALNÖITE
↓ *Carbonate[5] essential, no foids*	—	—	{AILLIKITE,	
			{KIMBERLITE[9]	—
	→→→→→→→→→→	→→→→→→→→→→	→→→→→→→→→→	→→→→→→→→[2]

[1] As dark-coloured minerals, *all* lamprophyres carry essential phlogopite-biotite, amphibole (calcic, sodic-calcic or alkali, e.g. kaersutite, richterite, arfvedsonite), or both, together commonly with olivine and clinopyroxene. Phlogopite-biotite normally dominates amphibole except in rocks marked *, where the reverse holds true.

[2] → arrows indicate direction of increasing undersaturation with SiO_2

[3] Na-foids = analcime, cancrinite, haüyne, nepheline, nosean and/or sodalite.

[4] Rocks commonly containing glass, which may occlude foids/feldspars, but is not considered in classification.

[5] Primary magmatic carbonate (calcite, dolomite or other Ca-Mg-Fe-Ba carbonates), where distinguishable.

[6] Includes cancarixite, cocite, jumillite.

[7] Includes cedricite, fitzroyite, kajanite, mamilite, orendite, wolgidite, wyomingite.

[8] Includes fortunite, madupite, verite.

[9] These two rock-types carry the same olivine-phlogopite-calcite-ilmenite±diopside mineral assemblage; they can only be distinguished on textural features (kimberlites have more rounded olivine macrocrysts, higher Si/Al and Mg/Ca whole-rock ratios, generaly more Mg-rich ilmenites, lack amphibole, etc.; see Chapters 4-5).

[10] Accessory alkali feldspar only, no plagioclase.

lamprophyre is a broad field term implying knowledge only of mode of occurrence and macroscopic petrology, whereas *kimberlite* is a precise petrological term implying detailed knowledge of both rock and mineral chemistry (R.H.Mitchell 1986, 1989). At present, geologists involved in diamond exploration are obliged to call a rock "kimberlite" before they have enough information to do so confidently; this has led to incessant arguments as to what is and what is not kimberlite, to endless reclassification of many diamond pipes, and to considerable resulting confusion in the literature.

(2) Lamprophyres are currently unified as the only confirmed magmatic source of diamond (Section 9.1), and hence have the deepest origins of igneous rocks. This unity can only be embodied in the present type of clan concept.

(3) As detailed in Chapters 4–5, the petrology of lamprophyres is a consistent picture of unity in diversity: of small (though important) differences between the branches, within a continuous overall gradation between one lamprophyre and another. Differences between the 5 branches are in every significant respect far less than those between the lamprophyre clan as a whole and common igneous rocks. Boundaries between the branches themselves are not sharp but gradational (Fig.1.4a), and populated by numerous transitional occurrences (Fig.1.4b). Two groups in particular are sufficiently common to warrant special symbols on Fig.1.2: namely, 'LC' and 'KU'. Again, this picture can only be accurately represented within a hierarchical clan concept.

(4) If kimberlites/lamproites were separated from lamprophyres, rare alkaline rocks would receive 5 classification schemes (+ those for carbonatites, melilitic rocks), as against only two (plutonic and volcanic) for 99% of igneous rocks: a *reductio ad absurdum*!

1.3.1 Further arguments for including lamproites within the lamprophyre clan

Comment is necessary because Bergman (1987) — alone among recent published commentaries, and contrary to the IUGS recommendations — considers lamproites *not* to be lamprophyres. However, Niggli (1923) used the prefix *lampro-* in his original definition, precisely to embody lamproite/lamprophyre affinities, and most lamproite definitions have retained the word *lamprophyric*, for example (author's italics):

Tröger (1935): "group name for K- and Mg-rich extrusive rocks = syn. *lamprophyric* extrusive rock"
Wade & Prider (1940): "ultrapotassic leucite-bearing rocks, commonly of *lamprophyric* aspect"
Sørensen (1974): "A group name for K- and Mg-rich extrusive rocks = *lamprophyric* extrusives..."
R.S.Mitchell (1985): "...a *lamprophyric* extrusive rock..."
Jaques *et al.*(1984a,1986): "...a potash and magnesia-rich *lamprophyric* rock..."
MacKenzie *et al.*(1982, p.133): "...extrusive equivalent of potassic *lamprophyre*..."
Hughes (1982, p.322): "...volcanic *lamprophyre* with mica phenocrysts..."
Middlemost (1987): "....*lamprophyre-like* rocks..."

Quite apart from this historical consensus, arguing that lamproites are not lamprophyres is like arguing that granites are not granitoids — an etymological as well as petrological cul-de-sac. In all major bibliographical databases (e.g. *Bibliography and Index of Geology*), lamproites are classified under lamprophyres for this very good etymological reason. Furthermore, there is complete mineralogical and geochemical gradation between lamproites and other lamprophyres, particularly minettes (Fig.1.4; Chapters 4–5). For this reason, many recent papers (e.g. Middlemost *et al.* 1988) have indepdendently affirmed the IUGS view that lamproites must logically be grouped with lamprophyres (Le Maitre 1989, p.11).

1.3.2 A brief note on lamproite nomenclature

Lamproite nomenclature is burdened with a plethora of locality-based names (see Appendix

B), most of which fail to recognize similarities between varieties (e.g. *jumillite* and *wyomingite*). Unfortunately, neither the IUGS (by its own admission) nor recent lamproite reviews have arrived at a more satisfactory alternative. R.H.Mitchell (1985) recommends distinguishing *phlogopite-lamproites,* with resorbed phenocrystic phlogopite (cedricites, orendites, etc.) from *madupitic lamproites,* with poikilitic groundmass phlogopite (madupites, jumillites, etc.), whereas Bergman (1987, p.108) states that this tends to "over-simplify the mineralogy of a given rock". Meanwhile, the IUGS considers *madupite* to be obsolete. Furthermore, by no means all lamproite descriptions specify whether the phlogopite is phenocrystic or groundmass. Bergman (1987) suggests following Scott Smith & Skinner (1984b), in using the modal abundance of principal primary minerals, so as to yield phlogopite–sanidine-lamproites, olivine–leucite-lamproites, etc., but this suffers from the same drawback of inadequate modal data in most lamproite descriptions.

Since the fine details of lamproite classification are largely immaterial in this book, Fig.1.2 divides lamproites for convenience into three families based on locality, and a fourth (olivine-lamproites) based on a natural bimodal distribution of MgO content (Fig.8.2); the latter division is analogous to the distinction between basalts and komatiites.

1.3.3 Further arguments for including kimberlites within the lamprophyre clan

Although the IUGS view, grouping kimberlites with lamprophyres, is more novel than grouping them with lamproites, it does also have a strong historical precedent. This case has been argued at length by Rock (1989a), and will only therefore be summarised here.

(1) Wagner (1914) divided kimberlites into *basaltic* and *lamprophyric* types. Many subsequent texts describe them as lamprophyric. Hughes (1982) — and presumably also the IUGS — took this as one reason for grouping kimberlites and lamprophyres.
(2) Kimberlites and aillikites (Appendix B) are very similar in thin section, and have long been confused (i.e. true kimberlites versus "central complex kimberlites"). They can only be distinguished on fine mineralogical details such as *trend* of spinel or mica compositions. Classifying them into totally separate rock clans is thus taking 'splitting' to absurd extremes, and making classification impossible for the non-specialist.
(3) Kimberlites share all the characteristics of lamprophyres defined in Section 1.4, and their mineralogy and geochemistry overlap substantially with other lamprophyres (Chapters 4–5). Even rare mica-free (Group I) kimberlites are sufficiently rich in volatile components to be retained within the clan.
(4) R.H.Mitchell (1979,1986,1989) has argued that true kimberlites are nowhere associated with contemporaneous lamprophyres. This is now known to be false, as there are in fact several well-documented examples (Fig.1.4c; Table C6).
(5) R.H.Mitchell (op.cit.) has also argued that kimberlite–lamprophyre transitions do not occur. This too is untrue (Fig.1.4b,c), and leads to self-contradiction: R.H.Mitchell & Meyer (1989) called one group of rocks "micaceous kimberlites" and yet stated (p.96): "it would seem unreasonable to continue referring to them as kimberlites".

1.4 Summary of criteria for identifying lamprophyres as a clan

A hierarchy of criteria, in roughly decreasing importance, is outlined below and detailed in Chapters 2–5; criteria for each branch are summarised in (Rock 1977,1984,1986,1987a).