IGNEOUS ROCKS: A CLASSIFICATION AND GLOSSARY OF TERMS

Decades of field and microscope studies and more recent quantitative geochemical analyses have resulted in a vast, and sometimes overwhelming, array of nomenclature and terminology associated with igneous rocks. Under the auspices of the International Union of Geological Sciences (IUGS), a group of petrologists from around the world has laboured for more than 30 years to collate these terms, gain international agreement on their usage, and reassess the methods by which we categorize and name igneous rocks.

This book presents the results of their work and gives a complete classification of igneous rocks based on all the recommendations of the IUGS Subcommission on the Systematics of Igneous Rocks. Revised from the 1st edition (1989), it shows how igneous rocks can be distinguished in the sequence of pyroclastic rocks, carbonatites, melilite-bearing rocks, kalsilite-bearing rocks, kimberlites, lamproites, leucite-bearing rocks, lamprophyres and charnockites. It also demonstrates how the more common plutonic and volcanic rocks that remain can then be categorized using the familiar and widely accepted modal QAPF and chemical TAS classification systems. The glossary of igneous terms has been fully updated since the 1st edition and now includes 1637 entries, of which 316 are recommended by the Subcommission, 312 are regarded as local terms, and 413 are now considered obsolete.

Incorporating a comprehensive list of source references for all the terms included in the glossary, this book will be an indispensable reference guide for all geologists studying igneous rocks, either in the field or the laboratory. It presents a standardized and widely accepted naming scheme that will allow geologists to interpret terminology found in the primary literature and provide formal names for rock samples based on petrographic analyses.

Work on this book started as long ago as 1958 when Albert Streckeisen was asked to collaborate in revising Paul Niggli's well-known book *Tabellen zur Petrographie und zum Gesteinbestimmen* (*Tables for Petrography and Rock Determination*). It was at this point that Streckeisen noted significant problems with all 12 of the classification systems used to identify and name igneous rocks at that time. Rather than propose a 16th system, he chose instead to write a review article outlining the problems inherent in classifying igneous rocks and invited petrologists from around the world to send their comments. In 1970 this lead to the formation of the Subcommission of the Systematics of Igneous Rocks, under the IUGS Commission on Petrology, who published their conclusions in the 1st edition of this book in 1989. The work of this international body has continued to this day, lead by Bruno Zanettin and later by Mike Le Bas. This fully revised 2nd edition has been compiled and edited by Roger Le Maitre, with significant help from a panel of co-contributors.

IGNEOUS ROCKS

A Classification and Glossary of Terms

Recommendations of the
International Union of Geological Sciences
Subcommission on the Systematics of Igneous Rocks

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Albert Streckeisen

8 November 1901 – 29 September 1998

Albert Streckeisen was born on 8 November 1901 in Basel, Switzerland, into an old Basel family. His father Dr Adolf Streckeisen was a Professor in Medicine. Later he studied geology, mineralogy and petrology in Basel, Zürich and Berne under famous teachers like the Professors Buxdorf, Reinhard and Paul Niggli.

Photographed in Venice 1979

In 1927, under the supervision of Prof. Reinhard, he presented his doctoral thesis dealing with the geology and petrology of the Flüela group in the Grisons of Eastern Switzerland.

In the same year, at the age of 26, he took up the position of ordinary Professor in Mineralogy and Petrology at the Polytechnic of Bucharest in Romania. He also became a member of the Romanian Geological Service and was very active in the mapping programme in the Carpathians. In addition to his interests in alpine petrography and structural analysis he became interested the petrography of the interesting and unique nepheline syenite massif of Ditro in Transylvania, on which he published eight papers. This is almost certainly where his interest in the petrographic classification of igneous rocks started.

In the 1930s Albert Streckeisen returned to Switzerland, as to remain professor in Bucharest he would have been forced to change his nationality. He then decided to become a school teacher and taught Natural Sciences in Swiss high schools until his retirement in Berne in 1939. This also enabled him to become an honorary professorial associate at the University of Berne (1942) and to take part in the scientific and teaching life of the Earth Sciences at Berne, where he was nominated extraordinary professor.

Albert Streckeisen – Albert to his many friends in the Commission and the world over – started his work on the classification and systematics of igneous rocks at an age of over 60. This kept him scientifically busy for more than 35 years.

The IUGS asked him to create and lead the then Commission on the Systematics of Magmatic Rocks, that became the IUGS Subcommission on the Systematics of Igneous Rocks when similar groups for Metamorphic and Sedimentary Rocks were formed. This commission, of which Albert Streckeisen was founder and *spiritus rector,* will certainly remain as the "Streckeisen Commission" in the same way and spirit that the QAPF classification will remain the "Streckeisen double triangle".

It is certainly due to his concilient, but determined, firm personality and authority that agreement in his Subcommission on "general recommendations" was achieved. As a

determined petrographic observer Albert Streckeisen's heart was with a quantitative modal approach – what could be observed and quantified under the microscope. However, when the explosive development of geochemical analysis provided large chemical data sets for igneous rocks, Albert directed the work of the Subcommission towards a chemical classification of volcanic rocks as expressed in the now generally accepted and adopted TAS diagram. For his devotion and energy, for his achievements in the systematics of igneous rocks he was honoured by the Deutsche Mineralogische Gesellschaft with the Abraham-Gottlob-Werner medal in 1984.

Albert Streckeisen died in Berne aged 97 in October 1998, during the early stages of the preparation of this second edition, in which he made a considerable contribution.

All members of the Subcommission and igneous petrologists worldwide owe Albert Streckeisen an enormous debt of gratitude for his generosity of spirit, his leadership and inspiration, and for his encyclopaedic knowledge of igneous petrology which enabled so much to be achieved.

Selected Publications

1964. Zur Klassifikation der Eruptivgesteine. *Neues Jahrbuch für Mineralogie. Stuttgart. Monatshefte*. p.195–222.

1965. Die Klassifikation der Eruptivgesteine. *Geologische Rundschau. Internationale Zeitschrift für Geologie*. Vol.55, p.478–491.

1967. Classification and nomenclature of igneous rocks. Final report of an inquiry. *Neues Jahrbuch für Mineralogie. Stuttgart. Abhandlungen*. Vol.107, p.144–240.

1973. Plutonic rocks. Classification and nomenclature recommended by the IUGS Subcommission on the Systematics of Igneous Rocks. *Geotimes*. Vol.18, No.10, p.26–30.

1974. Classification and nomenclature of plutonic Rocks. Recommendations of the IUGS Subcommission on the Systematics of Igneous Rocks. *Geologische Rundschau. Internationale Zeitschrift für Geologie. Stuttgart*. Vol.63, p.773–785.

1976. To each plutonic rock its proper name. *Earth Science Reviews*. Vol.12, p.1–33.

1978. IUGS Subcommission on the Systematics of Igneous Rocks. Classification and nomenclature of volcanic rocks, lamprophyres, carbonatites and melilitic rocks. Recommendations and suggestions. *Neues Jahrbuch für Mineralogie. Stuttgart. Abhandlungen*. Vol.134, p.1–14.

1979. Classification and nomenclature of volcanic rocks, lamprophyres, carbonatites, and melilitic rocks. Recommendations and suggestions of the IUGS Subcommission on the Systematics of Igneous Rocks. *Geology*. Vol.7, p.331–335.

1980. Classification and nomenclature of volcanic rocks, lamprophyres, carbonatites and melilitic rocks. IUGS Subcommission on the Systematics of Igneous Rocks. Recommendations and suggestions. *Geologische Rundschau. Internationale Zeitschrift für Geologie*. Vol.69, p.194–207.

1986. (with Le Bas, Le Maitre & Zanettin) A chemical classification of volcanic rocks based on the total alkali – silica diagram. *Journal of Petrology. Oxford*. Vol. 27, p.745-750.

Foreword to 1st edition

In the early summer of 1958 Ernst Niggli asked Theo Hügi and me if we would be willing to collaborate in revising Paul Niggli's well-known book *Tabellen zur Petrographie und zum Gesteinsbestimmen* which had been used as a text for decades at the Federal Polytechnical Institute of Zürich. We agreed and I was placed in charge of the classification and nomenclature of igneous rocks. Quite soon I felt that the scheme used in the Niggli Tables needed careful revision but, as maybe 12 other classification schemes had already been published, Eduard Wenk warned that we should not propose an ominous 13th one; instead he proposed that it would be better to outline the inherent problems of igneous rock classification in an international review article and should present a provisional proposal, asking for comments and replies. This was dangerous advice!

However, the article was written (Streckeisen, 1964), and the consequence was an avalanche of replies, mostly consenting, and many of them with useful suggestions. It thus became clear that the topic was of international interest and that we had to continue. A short report (Streckeisen, 1965) summarized the results of the inquiry. Subsequent discussions with colleagues from various countries led to a detailed proposal (Streckeisen, 1967), which was widely distributed. This was accompanied by a letter from Professor T.F.W. Barth, President of the International Union of Geological Sciences (IUGS), who emphasized the interest in the undertaking, and asked for comments.

The IUGS Commission on Petrology then established a Working Group on Rock Nomenclature, which made arrangements to discuss the nomenclature of magmatic rocks at the International Congress in Prague; the discussion was fixed for 21 August 1968. For this meeting a large amount of documentation was provided; it contained an Account of the previous work, a Report of the Petrographic Committee of the USSR, a Report of the Geological Survey of Canada, and comments from colleagues throughout the world. But political events prevented the intended discussion.

At this stage, Professor T.F.W. Barth, as President of the IUGS, suggested the formation of an International Commission. The Subcommission on the Systematics of Igneous Rocks was formed, under the IUGS Commission on Petrology, to deliberate the various problems of igneous rock nomenclature and to present definite recommendations to the IUGS.

The Subcommission began its work in March 1970. This was done by way of correspondence with subsequent meetings for discussions and to make decisions. Tom Barth suggested beginning with plutonic rocks, as this was easier; his advice was followed.

It was agreed that plutonic rocks should be classified and named according to their modal mineral contents and that the QAPF double triangle should serve for their presentation. A difficulty arose in discussing the nomenclature of granites; the most frequent granites were named quartz-monzonite in America and adamellite in England. With energetic intervention, A.K. and M.K. Wells (Contribution No.12) advocated that a logical classification would demand that quartz-monzonite in relation to monzonite must have the same status as quartz-syenite to syenite and quartz-diorite to diorite. On this critical point, Paul Bateman made an inquiry concerning this topic among leading American geologists (Contribution

No.21) with the result that 75% of the respondents declared themselves willing to accept quartz-monzonite as a term for field 8*, i.e. for a straight relation to monzonite.

In this relatively short period of time, the Subcommission had, therefore, discussed the problems of plutonic rocks, so that in spring 1972 at the Preliminary Meeting in Berne it made recommendations, which were discussed and, with some modifications, accepted by the Ordinary Meeting in Montreal, in August 1972. A special working group had been set up to discuss the charnockitic rocks and presented its recommendations in 1974.

Work then started on the problems of the classification of volcanic and pyroclastic rocks. The latter was dealt with by a special working group set up under the chairmanship of Rolf Schmid. After much discussion and some lengthy questionnaires this group published a descriptive nomenclature and classification of pyroclastic rocks (Schmid, 1981).

The first problem to be addressed for volcanic rocks was whether their classification and nomenclature should be based on mineralogy or chemistry. Strong arguments were put forward for both solutions. However, crucial points were the fine-grained nature and presence of glass that characterize many volcanic rocks, which means that modal contents can be extremely difficult to obtain. Similarly, the calculation of modes from chemical analyses was considered to be too troublesome or not sufficiently reliable. After long debate the Subcommission decided on the following important principles:

(1) if modes are available, volcanic rocks should be classified and named according to their position in the QAPF diagram
(2) if modes are not available, chemical parameters should be used as a basis for a chemical classification which, however, should be made comparable with the mineralogical QAPF classification.

Various methods of chemical classification were considered and tested by a set of combined modal and chemical analyses. Finally, the Subcommission agreed to use the total alkali – silica (TAS) diagram that Roger Le Maitre had elaborated and correlated with the mineralogical QAPF diagram (Le Maitre, 1984) by using the CLAIR and PETROS databases. After making minor modifications, the TAS diagram was accepted by the Subcommission (Le Bas *et al*., 1986).

Later on, Mike Le Bas started work on distinguishing the various types of volcanic nephelinitic rocks using normative parameters; similar work is also underway to distinguish the various volcanic leucitic rocks. An effort to classify high-Mg volcanic rocks (picrite, meimechite, komatiite) united Russian and western colleagues at the closing meeting in Copenhagen in 1988.

The intention to compile a glossary of igneous rock names, which should contain recommendations for terms to be abandoned, and definitions of terms to be retained, had already been expressed at the beginning of the undertaking (Streckeisen, 1973, p.27). A first approach was made in October 1977 by a questionnaire which contained a large number of igneous rock terms. Colleagues were asked whether, in their opinion, the terms were of common usage, rarely used today, or almost never been used. More than 200 detailed replies were received, and almost all heartily advocated the publication of a glossary, hoping it would be as comprehensive as possible. At the final stage of our undertaking, Roger Le Maitre has taken over the heavy burden of compiling the glossary, for which he will be thanked by the entire community of geologists.

The work of the Subcommission began with the Congress of Prague and will end with that of Washington, a space of 20 years. During this time, 49 circulars, containing 145 contributions and comments amounting to some 2000

pages, were sent to members and interested colleagues — a huge amount of knowledge, stimulation, ideas and suggestions. Unfortunately only part of this mass of knowledge was able to be incorporated in the final documents. However, all the documents will be deposited in the British Museum (Natural History) in London [Ed.: now called the Natural History Museum], so that they will be available for use in the future.

Within this period of time, a large number of geologists have been collaborating as colleagues, whether as members of the Subcommission or of working groups, as contributors of reports and comments, as guests of meetings, and in other ways: in short, a family of colleagues from many different countries and continents, united in a common aim.

On behalf of the Subcommission, I thank all those colleagues who have helped by giving advice, suggestions, criticisms and objections, and I am grateful for the continual collaboration we have enjoyed.

Albert Streckeisen
Berne, Switzerland

November 1988

Chairman's Preface

This 2nd edition contains the same essentials of the QAPF and TAS classification systems as the 1st edition, but with a few corrections and updates. Bigger changes have been made in the area of the alkaline and related rocks. In the ten years between the 1st and 2nd editions, several Working Groups have been working hard on the kimberlitic, lamproitic, leucitic, melilitic, kalsilitic, lamprophyric and picritic rocks with varied success. The Subcommission thanks each member of the Working Groups for their assiduous and constructive contributions to the revised classifications. Being too numerous to identify individually here, they are named in Appendix A.

The lamproites and kimberlites continue to defy precise classification, but we do now have improved characterizations rather than the definitions normally required to give limits between one rock type and the next. The work of the Subcommission continues, not only to resolve these problematic areas but also to tackle new issues as they arise. With the publication of the 2nd edition, I shall retire from the chair and am pleased to pass the reins over to the capable hands of Prof. Bernard Bonin of Université Paris-Sud.

Particular tribute is due to the late Albert Streckeisen who died during the early stages of preparation of this 2nd edition. His long association with igneous rock nomenclature began in earnest in 1964 when he published a review article in which he evaluated the dozen igneous rock classifications current at that time. That stirred much international interest and produced many enquiries, the result of which was that in 1965 he wrote his "Die Klassifikation der Eruptivgesteine". It established the QAPF as the primary means of classification.

Further discussions led to his 1967 paper written in English which he considered would be the "final report of an enquiry". This plenary study aroused the interest of IUGS and was not the final report he had anticipated. Instead, it led to arrangements being made for a discussion meeting at the 1968 International Congress in Prague, but the Russian invasion prevented that taking place. In its place, IUGS created the Commission of Petrology and its Subcommission on the Systematics of Igneous Rocks, with Streckeisen as the Chairman of both.

The Subcommission began with the plutonic rocks and gave a progress report to the 1972 International Congress in Montreal. This resulted in several papers published in 1973–74, all without the author's name. The two most significant ones were a simplified version in *Geotimes* in 1973 and a fuller account in *Geologische Rundschau* for 1974. This was followed by the definitive 1976 paper "To each plutonic rock its proper name". Such was the demand that he rapidly ran out of reprints.

Recommendations on volcanic rocks swiftly followed in 1978, 1979 and 1980, which were longer and shorter versions of the same recommendations, but in journals reaching different readers.

Now the entire geological community was receiving recommendations on how to name igneous rocks. More followed from Streckeisen's tireless efforts with the Subcommission: pyroclastic rocks, charnockitic rocks, alkaline and other rocks, all classified in numerous papers some written by him as sole author, others with co-authors. By means of patient listening, discussing and careful proposals, he was able to produce consensus, and

he was acclaimed "The father of igneous nomenclature and classification". He never owned a computer but produced innumerable spreadsheets of data all laboriously handwritten (and referenced) and then plotted on graph paper, which would be circulated to all members of the Subcommission for discussion. His industry and assiduity were profound. His command of most European languages served him well in finding the best terminology that would stand the test of maintaining meaning during translation. This, he told me, had first been put to the test in 1937 when he was personal assistant to Paul Niggli at Berne University, and under that tutelage had been commissioned to produce a French translation of a lecture that Niggli had given in Paris on petrochemistry. It took, he said, several weeks plus a visit to Paris to attain a satisfactory text.

After 18 years at the helm, he felt in 1980 that he should introduce new leadership to the Subcommission and Bruno Zanettin took over. I followed in 1984. Streckeisen remained a powerful influence on the workings of the Subcommission, offering valuable advice and criticism on the construction of the first edition of this book. He strongly supported the creation of the TAS classification for volcanic rocks (1986). Although no longer Chairman, he continued contributing to the discussions until 1997 when ill-health slowed him down and the stream of authoritative letters ceased. I particularly recall his vigour and valuable advice at an *ad hoc* meeting at EUG95 in Strasbourg, and gladly acknowledge my debt to him for his tutorship since 1972 in the business of naming igneous rocks.

Besides writing up several Swiss geological map sheets for the Survey, he began in the 1980s writing a book *Systematik der Eruptivgesteine* to be published by Springer. He completed some chapters which would "discuss the problem of classification and nomenclature, and present not only the rules but also the reasons by which we were guided in elaborating our proposals." Having been given the opportunity by Streckeisen to see his critique of the CIPW and other normative analyses and of other classification schemes such as the R1–R2 scheme of De La Roche, it is regrettable that this potentially valuable book never reached publication.

Sincere thanks are also owed to Roger Le Maitre for his skilful and painstaking editing of this 2nd edition. Without his commitment to produce on his Mac all the text, figures and tables ready for print by Cambridge University Press, this book would be vastly more expensive. He has served science well, for which we are all most grateful. I am particularly grateful to Alan Woolley for his exemplary secretaryship during my 17 years as Chairman. His unfailing cheerful outlook, good advice, efficiency and all-round helpfulness were his hallmarks. He has also been instrumental in getting all the papers, reports and circulars put into the archives of the Natural History Museum, London where they may be consulted. A full set has also been deposited by Henning Sørensen in Geologisk Central Institut in Copenhagen. The keen co-operation of Wang Bixiang in producing a Chinese translation of the 1st edition, published in Beijing in 1991, and of Slava Efremova for the Russian edition published in 1997 is also gratefully acknowledged.

I would also like to pay tribute to Jean Lameyre who died in 1992 and who contributed so considerably to the 1st edition.

Mike Le Bas
Chairman, IUGS Subcommission on
the Systematics of Igneous Rocks,
School of Ocean and Earth Science,
University of Southampton, UK

August 2001

Editor's Preface

As the member of the Subcommission once again given the responsibility for compiling and producing this publication, my task in editing the 2nd edition, which has taken well over a year, has been somewhat easier than editing the 1st edition.

This is due to several facts. Firstly, I was not directly involved in any of the working groups; secondly, only minor editing had to be done to the Glossary; and thirdly, improvements in computer technology – in particular e-mail which, with over 450 transmissions, enabled me to obtain quick responses to my editorial queries with colleagues around the world. However, the occasional phone call to speak to another human being also made life more bearable and speeded things up.

This edition has been much easier to produce than the 1st edition, which was produced from photo-ready copy. That involved printing the entire book on a Laserwriter and sending large parcels of paper to the publishers. To produce this edition all I have had to do is to generate PDF (Portable Document Format) files which I have then sent to the publishers by e-mail. The book was then printed directly from the PDF files by the printer – a much simpler task!

The software used to do this included Adobe PageMaker®, for editing the entire text and producing the PDF files; Adobe Illustrator® for producing all the figures and tables; and FileMaker Pro® for maintaining the relational databases of rock descriptions, references, journal names and contributors.

In addition, FileMaker Pro® was scripted to export the information in rich text format (RTF) so that when imported into Adobe PageMaker® the text was italicized, bolded, capitalized etc. in all the right places. The glossary, bibliography and appendices were all produced in this manner. This, of course, saved an enormous amount of editing time and minimized the possibility of errors.

However, since the 1st edition the amount of information has increased considerably, with the main changes, additions and deletions being outlined in the Introduction (see p.1–2). As a result the number of pages has increased from 193 to 236.

In the Glossary an extra 51 rock terms have been added to bring the total number to 1637, of which 316 are recommended by the Subcommission, 413 are regarded as obsolete and 312 are regarded as local terms.

Of the 316 recommended rock names and terms 179 are strictly speaking IUGS root names; 103 are subdivisons of these root names, including 33 specific names for the various "foid" root names, e.g. nepheline syenite; and 34 are rock terms.

The Bibliography has 18 new references bringing the total number of references to 809, and an extra 37 people have contributed to the classification in various ways, bringing the total number of contributors to 456 – from 52 different countries.

To take account of the extra data in the Glossary and the list of references, the statistics given in Chapters 3 and 4 have been completely recalculated. Unfortunately, during this process I discovered that, in some cases, the number of references used in the 1st edition had included some that should not have been present. I apologise for these errors and, after much checking, am now sure that the present numbers are correct.

Without the help of my colleagues this task would not have been possible. My thanks to all

those who have helped in the preparation and proof reading of this edition, in particular: Mike Le Bas and Alan Woolley for much guidance, helpful comments and suggestions; Giuliano Bellieni, Bernard Bonin, Arnost Dudek, Jörg Keller, Peter Sabine, Henning Sørensen and Bruno Zanettin for meticulous proofreading, many helpful suggestions and locality checking; in addition Jörg Keller for checking some of the older German references and helping to update the pyroclastic classification; George J. Willauer of Connecticut College for checking on an early American reference; Louise Simpson of the Earth Sciences Information Centre (located via the internet), Natural Resources Canada, for help with an early Annual Report; and Mrs Z.J.X. Frenkiel of the Natural History Museum, London, for help with the Russian references.

I have also been able to include a new Appendix C, with the approval of the Subcommission, giving details of a C++ package called IUGSTAS for determining the TAS name of an analysis. Although this is code has been used for a considerable time by myself and many of my colleagues it has never been generally available until now. As IUGSTAS was developed on a Power Macintosh, I would like to thank John Semmens for making sure that the code also ran on a PC under Windows and for writing the small amount of machine specific code required to allow the user to abort execution at any time – a feature not available with standard C++.

I would also like to thank Susan Francis (my CUP editor) for being extremely helpful in promptly dealing with my many queries with what is not a normal run-of-the-mill book; and Anna Hodson (my copy editor) for patiently explaining the idiosyncrasies of the CUP style (most of which were adopted) and for meticulously correcting my punctuation and grammar.

Finally, I would like to sincerely thank my wife, Vee, for once more putting up with me in editorial mode.

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August 2001