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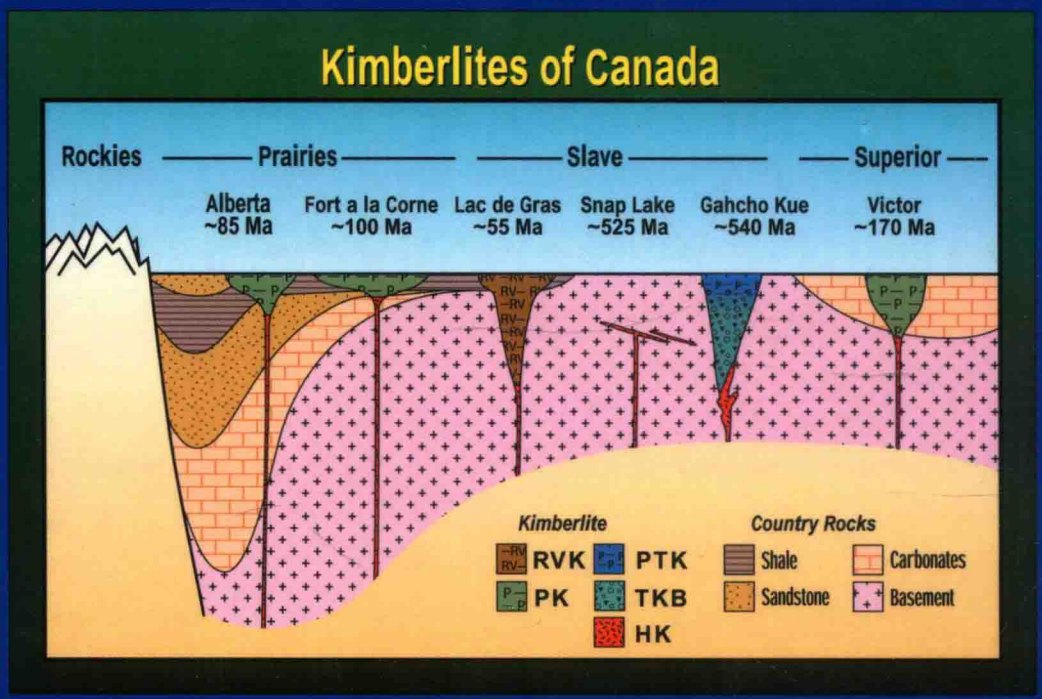

Edited by

R.H. MITCHELL | H.S. GRÜTTER | L.M. HEAMAN
B.H. SCOTT SMITH | T. STACHEL

8TH INTERNATIONAL KIMBERLITE CONFERENCE

Selected Papers

VOLUME 1

The C. Roger Clement Volume

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B.H. SCOTT SMITH
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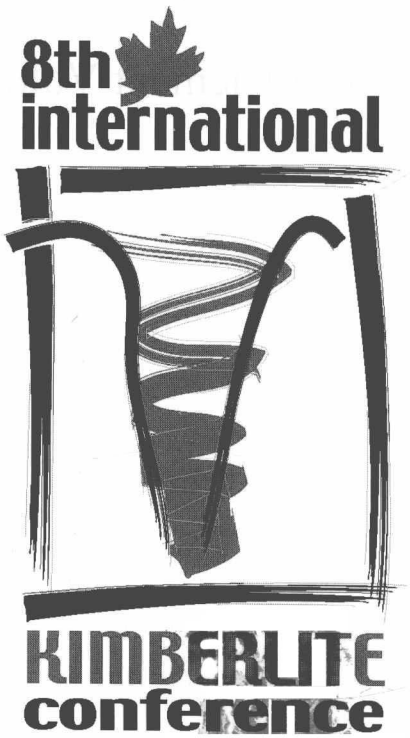

This volume, and its companion, contain selected papers from the 8th International Kimberlite Conference (in the same format as they appeared in Lithos volumes 76 and 77). The Conference was held in Victoria, BC, Canada, 22-27 June 2003.

Special Issue

Selected Papers from the 8th International Kimberlite Conference, Victoria, BC, Canada, 22–27 June 2003
Volume 1: The C. Roger Clement Volume

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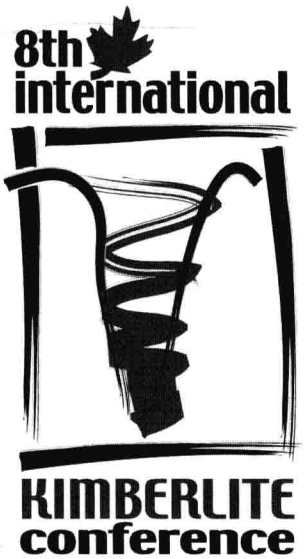

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Foreword

The Eighth International Kimberlite Conference was held in Victoria, British Columbia, Canada from June 22nd to 27th, 2003. These two volumes record some of the presentations made at the conference and are dedicated to Roger Clement (Volume 1) and Barry Hawthorne (Volume 2), in recognition of their contributions to, influence on, and encouragement of, kimberlite and upper mantle studies over the past 35 years.

The conference was attended by 585 full delegates who listened to 86 oral presentations and perused 185 posters. Many of these presentations gave for the first time detailed information on the geology and petrology of the kimberlites discovered in Canada during the past decade, the mantle-derived xenoliths and xenocrysts they contain, together with data on the diamonds from the recently opened Ekati and Diavik mines. An especially innovative feature of the conference was the opportunity for delegates to examine some of these newly discovered kimberlites at the "Large Core Exhibit" where approximately 2 km of drillcore was on display. The conference was preceded and followed by field excursions to the Ekati and Diavik diamond mines in northern Canada. Other field excursions visited areas in which kimberlites, lamproites and alkaline rocks occur in Colorado, Wyoming, Montana, British Columbia and Ontario.

Kimberlite conferences, which typically are held every 4 years, are unusual in that they bring industrial and academic geoscientists together in a symbiotic forum. This is a direct consequence of both groups realizing that this mutual cooperation is a catalyst leading to improved exploration techniques for kimberlites and better evaluation methods of diamond deposits, coupled with an increased understanding of kimberlite geology, diamond genesis and upper mantle petrology. Each conference culminates with the publication of a proceedings volume. Papers presented in these volumes usually record important steps in our understanding of a particular topic. Commonly, these build upon the results of the preceding conference. This incremental approach results in the proceedings volumes having lasting scientific value. Thus, geoscientists today still quote the seminal papers published in the proceedings of the first conference held in 1973.

These two volumes present 86 papers drawn from the oral and poster presentations. The volumes are organized according to themes reflecting the character of the conference. Volume 1—the Clement Volume—details advances in kimberlite geology, mineralogy and petrogenesis. Volume 2—the Hawthorne Volume—describes studies of diamonds, eclogites, the upper mantle and cratons together with exploration methods for diamond-bearing rocks.

The editors of these proceedings consider the papers included in these volumes to be novel and substantive, and that they will stand the test of time and be widely quoted in future studies of kimberlites, diamonds and the upper mantle.

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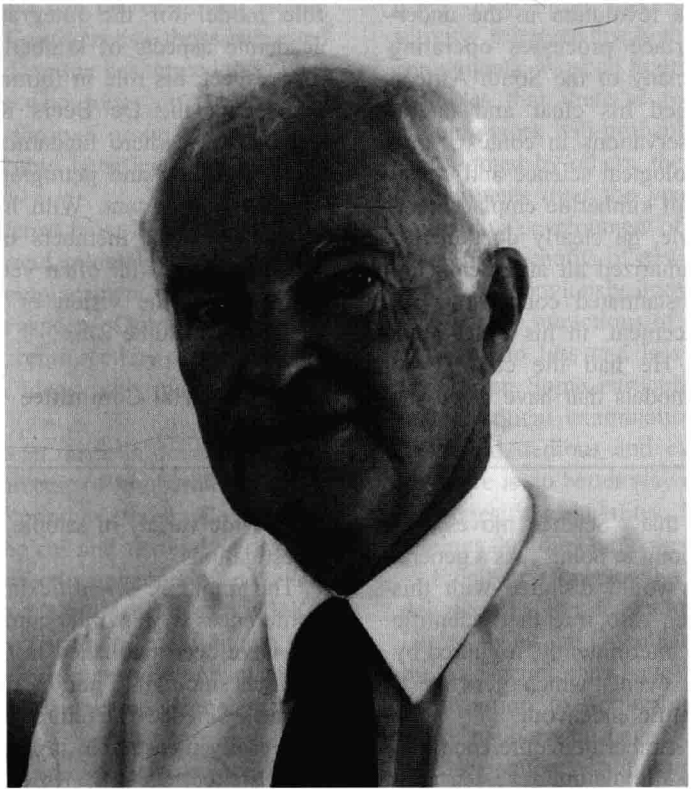
Preface



C. Roger Clement

Volume 1 of the Proceedings of the Eighth International Kimberlite Conference is dedicated to C. Roger Clement, in recognition of his outstanding studies of kimberlite geology. These studies resulted in major advances in our understanding of kimberlites and their style of emplacement.

Roger Clement has had a long and distinguished career with De Beers, commencing as a field geologist in Tanzania and concluding as President and CEO of De Beers Canada (formerly Monopros). His vast experience ranges from exploration through evaluation to mining. Decisions in his work for De Beers were always based on a sound knowledge of kimberlite geology and the recognition that this is the foundation for all aspects of the diamond industry. From 1970 to 1983, he was responsible initially for all geological work on seven major diamond mines, and subsequently, for all De Beers diamond

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mines. This position provided Roger with an unrivalled opportunity to examine kimberlites in detail. Roger did not delegate his geological work, and he personally undertook extremely thorough, careful, meticulous and typically painstaking mapping of underground exposures. In concert with petrographic studies, this enabled him to produce the first detailed three-dimensional models of kimberlite pipes. Although these investigations were undertaken primarily for economic reasons essential to the operation of the mines, they resulted in his greatest contribution to kimberlite petrology: a revolution in the understanding of the near-surface processes operating during the formation of many of the South African kimberlites. Roger applied his clear and lateral thinking to place his observations in context, integrate many aspects of geological science and consider all possible scenarios of kimberlite emplacement. Using a lucid writing style, he clearly documented his observations and summarized all arguments for, and against, his well-substantiated conclusions regarding kimberlite emplacement, in his PhD thesis and subsequent papers. He had the courage to propose innovative new models that have stood the test of time and are supported by new data from existing mines and new discoveries. His outstanding and seminal work on kimberlite intrusions has never been duplicated, and thus, is unmatched. Other benchmark papers, coauthored with his close colleague and fellow kimberlite aficionado, Mike Skinner, included a definition of kimberlite coupled with an innovative mineralogical and textural classification. In an age when there seems to be a reluctance to look at rocks, and an increased use computers rather than microscopes, Roger's work provides a role model for the integration of economic and academic aspects of kimberlite geology studies. In this respect, his role in forming, participating in and overseeing the De Beers Kimberlite Petrography Unit (KPU), where fundamental research into kimberlite geology and petrography was undertaken, is especially important. With his insightful comments on the work of members of, and visitors to, the KPU, together with often very lively debate, he put into practice the vision of Barry Hawthorne (see Preface of Volume 2).

8IKC Editorial Committee

Tennyson once wrote that "Science moves, but slowly, creeping on from point to point". As a general axiom, few geoscientists would disagree with this observation. It is, however, also true that scientific progress often takes place intermittently, triggered by specific developments or events which generate a flurry of interest and scientific endeavour.

The First International Kimberlite Conference was a fundamental trigger in stimulating research into kimberlites, diamonds and the Earth's upper mantle. Subsequent conferences, taking place at intervals of approximately four years, have provided outstanding opportunities to assess research progress, review research directions and build a growing body of data pertinent to an ever-increasing understanding of kimberlites and the mantle. Each of the eight Conferences held to date has provided participants with a wealth of new data, concepts and ideas. Each Conference has provided an excellent forum for formal and informal discussion and debate. Each Conference has offered delegates unrivalled opportunities to collect a wide variety of sample material for subsequent investigations.

The immense scientific impact of the Kimberlite Conferences is, in part, documented by the 586 papers that have been published in Conference Proceedings Volumes since 1IKC and by many other contributions to Earth Science Literature during the last 30 years. Less easily measurable in a quantitative sense is the scientific enthusiasm, which each Conference has generated—rekindled, perhaps, in the case of the "Old Hands" but, importantly, stimulating bright young geoscientists to focus their minds on old problems and new challenges.

In the Preface to Volume 2 of these Proceedings, Barry Hawthorne has summarised the main reasons for the success of the Kimberlite Conferences. Paramount among these are the opportunities afforded to delegates to examine and extensively sample a variety of kimberlites and associated upper-mantle-derived rocks and minerals. In this respect, the cooperation and willing participation of companies involved in exploring for

and mining diamonds on several continents has been a critical factor. Without access to their operations, much less scientific progress would have been achieved.

Assured access to unique geological material has led to the attendance at these Conferences of an outstanding mix of delegates, reflecting a wide range of interrelated disciplines. It must be rare for so many eminent scientists from respected academic institutions around the world to have joined forces with exploration and mining experts to undertake such extensive collaborative research—research that is ongoing. Broadly speaking, two groups of people can be recognised among delegates to Kimberlite Conferences—those interested primarily in what Barry Dawson has termed the "kimberlite bus" and those who focus on the "mantle passengers". Together, the two groups have formed an informal but remarkably beneficial and cohesive scientific association.

My own areas of interest have largely focused on kimberlite petrography and mineralogy and the processes involved in the emplacement of these unusual rocks. Working on these aspects of kimberlite has been a rewarding experience, reinforced by opportunities to exchange and discuss ideas with many dedicated researchers.

Great strides have been made in documenting the remarkably diverse character of kimberlites. Prior to 1IKC, kimberlites were poorly defined petrologically, and the many mineralogical and textural variants of these rocks were imperfectly understood and inadequately classified. Most early workers (pre-1IKC) regarded kimberlite as a variety of peridotite or mica peridotite, based on the presence of abundant olivine associated with other mafic minerals. Since then, much progress has been made.

Detailed petrographic studies have led to kimberlite being properly defined. Systematic mineralogical classification of kimberlites has been established, based on primary mineral content, but allowing for the extensive alteration of primary minerals that is often evident. Many textural variants of kimberlite have been recognised, competently described and formally classified. New discoveries of kimberlite, notably in Saskatchewan, Canada, and in the Arkhangelsk region of Russia, which differ substantially from the classic South African occurrences, have resulted in modifications or extensions to mineralogical and textural classification systems that are currently in use. As further discoveries are made, additional petrological information will no doubt lead to further refinements in the systematic documentation of the kimberlite family of rocks.

One of the great benefits of a vastly improved petrographic understanding of kimberlites is that a solid platform has been established for studying the origins of kimberlite pipes. In this area of research, some division still exists between researchers favouring phreatomagmatism as the driving force of near-surface pipe formation and those who believe that the pipes reflect high-level brecciation and explosive activity, triggered by high-pressure juvenile volatile components. Work in South Africa and Saskatchewan indicates that there is room for both views, and ongoing work will probably confirm this.

As noted by others, the success of the Kimberlite Conferences over the years is, in part, due to the continuous development of high-tech analytical equipment. The benefits of new or refined analytical technology are obviously immense. There is, however, a risk that the attractions of new analytical instruments will lead to less and less optical microscopy being undertaken. Some, particularly younger scientists, may regard optical examination of thin sections as old fashioned, tedious and extremely time consuming, but there is no better way of getting to grips with the mysteries of kimberlites. Proper evaluation of rocks requires that they be looked at properly!

Finally, on a personal note, I am both humbled and delighted by the dedication of this volume. I would like to thank the Organising Committee of 8IKC for the recognition they have accorded me. However, my contribution to kimberlite geology owes much to many people who have been responsible for general encouragement, stimulating discussion and critical comment. In particular, I would like to thank my long-term colleagues EMW (Mike) Skinner and Barbara Scott Smith, whose enthusiasm for kimberlites is unmatched. I have learnt much from the perceptive petrological work of Barry Dawson and Roger Mitchell. Lastly, my pleasure at the dedication of this volume has been enhanced by the dedication of Volume (2) to Barry Hawthorne, friend and colleague for many years.

Roger Clement
Knysna, South Africa

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The geology of kimberlite pipes of the Ekati property, Northwest Territories, Canada

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Abstract

This paper reviews key characteristics of kimberlites on the Ekati property, NWT, Canada. To date 150 kimberlites have been discovered on the property, five of which are mined for diamonds. The kimberlites intrude Archean basement of the central Slave craton. Numerous Proterozoic diabase dykes intrude the area. The Precambrian rocks are overlain by Quaternary glacial sediments. No Phanerozoic rocks are present. However, mudstone xenoliths and disaggregated sediment within the kimberlites indicate that late-Cretaceous and Tertiary cover (likely <200 m) was present at the time of emplacement. The Ekati kimberlites range in age from 45 to 75 Ma. They are mostly small pipe-like bodies (surface area mostly <3 ha but up to 20 ha) that typically extend to projected depths of 400–600 m below current surface. Pipe morphologies are strongly controlled by joints and faults. The kimberlites consist primarily of variably bedded volcaniclastic kimberlite (VK). This is dominated by juvenile constituents (olivine and lesser kimberlitic ash) and variable amounts of exotic sediment (primarily mud), with minor amounts of xenolithic wall-rock material (generally <5%). Kimberlite types include: mud-rich resedimented VK (mRVK); olivine-rich VK (oVK); sedimentary kimberlite; primary VK (PVK); tuffisitic kimberlite (TK) and magmatic kimberlite (MK). The presence and arrangement of these rock types varies widely. The majority of bodies are dominated by oVK and mRVK, but PVK is prominent in the lower portions of certain kimberlites. TK is rare. MK occurs primarily as precursor dykes but, in a few cases, forms pipe-filling intrusions. The internal geology of the kimberlites ranges from simple single-phase pipes (RVK or MK), to complex bodies with multiple, distinct units of VK. The latter include pipes infilled with steep, irregular VK blocks/wedges and at least one case in which the pipe is occupied by well-defined sub-horizontal VK phases, including a unique, 100-m-thick graded sequence. The whole-rock compositions of VK samples suggest significant loss of kimberlitic fines during eruption followed by variable dilution by surface sediment and concurrent incorporation of kimberlitic ash. Diamond distribution within the kimberlites reflects the amount and nature of mantle material sampled by individual kimberlite phases, but is modified considerably by eruption and depositional processes. The characteristics of the Ekati kimberlites are consistent with a two-stage emplacement process: (1) explosive eruption/s causing vent clearing followed by formation of a significant tephra rim/cone of highly fragmented, olivine-enriched juvenile material with varying amounts of kimberlitic ash and surface sediments (predominantly mud); and (2) infilling of the vent by direct deposition from the eruption column and/or resedimentation of crater rim materials. The

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