Geochemistry and Mineralization of Proterozoic Volcanic Suites
Contents

Introduction ix

General Topics and Reviews

TAYLOR, S. R. Geochemical and petrological significance of the Archaean–Proterozoic boundary 3


RICKARD, D. Proterozoic volcanogenic mineralization styles 23

Early Proterozoic Volcanic Suites of the Baltic Shield

PHARAOH, T. C., WARREN, A. & WALSH, N. J. Early Proterozoic metavolcanic suites of the northernmost part of the Baltic Shield 41

HONKAMO, M. Geochemistry and tectonic setting of early Proterozoic volcanic rocks in northern Ostrobothnia, Finland 59

VIVALLO, W. & CLAESSEN, L.-Å. Intra-arc rifting and massive sulphide mineralization in an early Proterozoic volcanic arc, Skellefte district, northern Sweden 69

PARR, J. & RICKARD, D. Early Proterozoic subaerial volcanism and its relationship to Broken Hill-type mineralization in central Sweden 81

COLLEY, H. & WESTRA, L. The volcano-tectonic setting and mineralization of the early Proterozoic Kemiö-Orijärvi-Lohja Belt, SW Finland 95

Early and Middle Proterozoic Volcanic Suites of the Laurentian and North Atlantic Shields

BARAGAR, W. R. A. & SCOATES, R. F. J. Volcanic geochemistry of the northern segments of the Circum-Superior Belt of the Canadian Shield 113

ARNDT, N. T., BRÜGMANN, G. E., LEHNERT, K., CHAUVEL, C. & CHAPPELL, B. W. Geochemistry, petrogenesis and tectonic environment of Circum-Superior Belt basalts, Canada 133

LEWRY, J. F., MACDONALD, R., LIVESEY, C., MEYER, M., VAN SCHMUS, R. & BICKFORD, M. E. U-Pb geochronology of accreted terranes in the Trans-Hudson Orogen, Northern Saskatchewan, Canada 147

WATTERS, B. R. & PEARCE, J. A. Metavolcanic rocks of the La Ronge Domain in the Churchill Province, Saskatchewan: geochemical evidence for a volcanic arc origin 167

GASKARTH, J. W. & PARSLOW, G. R. Proterozoic volcanism in the Flin Flon greenstone belt, east-central Saskatchewan, Canada 183

GOWER, C. F. & RYAN, B. Two stage felsic volcanism in the Lower Proterozoic upper Aillik Group, Labrador, Canada: its relationship to syn- and postkinematic plutonism 201

CONDIE, K. C. Early Proterozoic volcanic regimes in southwestern North America 211

LECHEMINANT, A. N., MILLER, A. R. & LECHEMINANT, G. M. Early Proterozoic alkaline igneous rocks, District of Keewatin, Canada: petrogenesis and mineralization 219
Contents

RYAN, A. B., BARAGAR, W. R. A. & KONTAK, D. J. Geochemistry, tectonic setting, and mineralization of high-potassium middle Proterozoic rocks in central Labrador, Canada 241

JOHNSON, Y. A., PARK, R. G. & WINCHESTER, J. A. Geochemistry, petrogenesis and tectonic significance of the early Proterozoic Loch Maree Group amphibolites of the Lewisian Complex, NW Scotland 255

Proterozoic Volcanic Suites of the Guiana Shield

GIBBS, A. K. Proterozoic volcanic rocks of the northern Guiana Shield, South America 275

RENNER, R. & GIBBS, A. K. Geochemistry and petrology of metavolcanic rocks of the early Proterozoic Mazaruni greenstone belt, northern Guyana 289

Proterozoic Volcanic Suites of Africa

MYERS, R. E., CAWTHORN, R. G., MCCARTHY, T. S. & ANHAEUSSER, C. R. Fundamental uniformity in the trace element patterns of the volcanics of the Kaapvaal Craton from 3000 to 2100 Ma: evidence for the lithospheric origin of these continental tholeiites 315


BORG, G. & MAIDEN, K. J. Alteration of late Middle Proterozoic volcanics and its relation to stratabound copper-silver-gold mineralization along the margin of the Kalahari Craton in SWA/Namibia and Botswana 347

BREITKOPF, J. H. & MAIDEN, K. J. Geochemical patterns of metabasites in the southern part of the Damara Orogen, SWA/Namibia: applicability to the recognition of tectonic environment 355

KLEMENIC, P. M. The geochemistry of Upper Proterozoic lavas from the Red Sea Hills, NE Sudan 363

Proterozoic Volcanic Suites of Australia

WYBORN, L. A. I., PAGE, R. W. & PARKER, A. J. Geochemical and geochronological signatures in Australian Proterozoic igneous rocks 377

JAMES, S. D., PEARCE, J. A. & OLIVER, R. A. The geochemistry of the Lower Proterozoic Willyama Complex volcanics, Broken Hill Block, New South Wales 395

WILSON, I. H. Geochemistry of Proterozoic volcanics, Mount Isa Inlier, Australia 409

WYBORN, L. A. I. The petrology and geochemistry of alteration assemblages in the Eastern Creek volcanics, as a guide to copper and uranium mobility associated with regional metamorphism and deformation, Mount Isa, Queensland 425

Proterozoic Volcanic Suites of Asia

JIA CHENGZAO. Geochemistry and tectonics of the Xionger Group in the eastern Qinling Mountains of China—a mid Proterozoic volcanic arc related to plate subduction 437

Middle to Late Proterozoic Volcanic Suites of the North Atlantic Borderlands

SMITH, T. E. & HOLM, P. E. The trace element geochemistry of metavolcanic and dykes from the Central Metasedimentary Belt of the Grenville Province, southeastern Ontario, Canada 453
Contents

BREWER, T. S. & ATKIN, B. P. Geochemical and tectonic evolution of the Proterozoic Telemark supracrustals, southern Norway 471

WINCHESTER, J. A., MAX, M. D. & LONG, C. B. Trace element geochemical correlation in the reworked Proterozoic Dalradian metavolcanic suites of the western Ox Mountains and NW Mayo Inliers, Ireland 489


CABANIS, B., CHANTRAINE, J. & RABU, D. Geochemical study of the Brioverian (late Proterozoic) volcanic rocks in the northern Armorican Massif, France. Implications for geodynamic evolution during the Cadomian 525

PHARAOH, T. C., WEBB, P. C., THORPE, R. S. & BECKINSALE, R. D. Geochemical evidence for the tectonic setting of late Proterozoic volcanic suites in central England 541

Index 553
Introduction

The Proterozoic eon spans about half of recorded earth history from 2500 to c. 550 Ma. Volcanic rocks can provide useful information on the evolution of the crust and mantle during this long period of time. The desirability of a scientific meeting specifically to address the nature of Proterozoic volcanism came to us in the Spring of 1984. Financial support for the meeting was provided by the Royal Society and the Geological Society of London. At an early stage of planning, sponsorship was received from the International Lithosphere Program and the newly created Project 217 (Proterozoic Geochemistry) of the International Geological Correlation Programme. In April 1986, 120 geochemists and geologists from eighteen countries attended the special meeting of the Geological Society convened at the Keyworth headquarters of the British Geological Survey (BGS). Sixty-five papers, representing all the continents (except Antarctica) were presented during the four days of the international symposium. Many of these papers are published in this special volume. Field excursions to late Proterozoic terranes in Britain and France gave the participants time for active discussions ‘on the rocks’. A report of the conference and excursion activities has been published in Episodes, the Journal of the International Union of Geological Sciences, in September 1986.

This volume does not attempt to provide a complete survey of Proterozoic volcanic geochemistry and mineralization. The reader will notice an inevitable bias towards coverage of the comparatively well explored Precambrian shields of Europe and North America. It is hoped that the scarcity of information on Proterozoic volcanic suites of Africa, Asia and South America can be remedied by the end of Project 217, which had been running for less than a year at the time of the meeting. The new geochemical data published in this volume will provide a basis for discussion at subsequent meetings of the project. Due to shortage of space it has not proved possible to publish all of the data depicted in the variation diagrams. Many of the authors have however contributed full data listings and it is hoped that these can be incorporated in a computer database at a later date.

Investigators of Proterozoic volcanic suites face three major problems which are usually less significant in younger volcanic suites. First and foremost is the problem of alteration and metamorphism. The enormously long crustal residence times (up to 2500 Ma) of Proterozoic rocks means that metamorphism is potentially a very significant problem. Fortunately, most of the suites described here have suffered little deformation subsequent to the initial phase of cratonization. Primary volcanic textures and even primary mineralogy may be well preserved (e.g. see LeCheminant et al., this volume). However, as with volcanic suites of any age, original compositions are usually more or less altered by deuteric reactions with surface-derived water. This is especially true of the rocks associated with volcanicogenic ore deposits, which may show extreme compositions. It thus seems advisable that the interpretation and comparison of Proterozoic volcanic suites should be based on the abundance of elements which are known to be less mobile during alteration and metamorphic processes.

The second problem is that the age of eruption of many Proterozoic volcanic suites is not known with great precision. Lack of palaeontological control in Proterozoic sequences results in absence of the stratigraphic precision available for many Phanerozoic successions. Analytical errors are compounded by lack of rigorous geological control in complex volcanic environments. The isotopic systems may have suffered a long and complex history with little certainty about which event is recorded. Unfortunately, Phanerozoic earth history clearly demonstrates that an ocean can open and close again within the duration of the analytical uncertainties for early Proterozoic volcanic rocks using routine isotopic techniques. Thus analytical techniques with much greater precision must be applied rigorously before we can fully appreciate the age relationship of different volcanic suites within individual orogeneric terranes. It is encouraging to see that significant progress is already being made along these lines using U-Pb mineral dating in Scandinavia and North America (e.g. see Lewry et al., this volume).

Finally, there is the question of the validity of the uniformitarian approach for volcanic rocks between 550 and 2500 Ma old. As the reader will very soon appreciate, the interpretations of the tectonic environment of Proterozoic volcanic rocks which follow are to a large degree dependent on discrimination diagrams with fields defined using the chemical composition of Phanerozoic volcanic rocks. Just how far back into earth history such an approach can be validly applied is currently the subject of much discussion, and is not easily resolved. The existence of volcanic rock types unique to the Proterozoic cannot be ruled out although these differences may be more apparent than real. A case in point is the
recognition that komatiitic magmas, distinctly less magnesian than their Archaean antecedents, were erupted in a number of shields in the early Proterozoic, but are apparently absent by the end of the Proterozoic.

The evidence outlined in this volume suggests that by the early Proterozoic, large areas of the earth's crust (the cratons stabilized by the end of the Archaean) had begun to behave as internally rigid units similar to modern continental lithospheric plates, albeit rather smaller in size. The cratons were capable of supporting and preserving spatially diverse volcanosedimentary supracrustal sequences of considerable lateral extent. The diversity of chemical composition, sedimentary facies and ore associations suggest that these volcanic sequences were generated in a variety of tectonic environments, although the identification of the latter is still open to debate. Such diversity contrasts strongly with the repetitive and predictable style of volcanism characteristic of Archaean greenstone belts.

The widespread occurrence since the early Proterozoic of volcanic suites exhibiting the characteristic geochemical signature of subduction magmatism implies the destruction of oceanic lithosphere by processes akin to those of modern plate tectonics. The location of such arc volcanic suites along the margins of cratons within the Baltic and Laurentian shields reflects the overwhelming importance of lateral accretion in the growth of the continental crust since the early Proterozoic. The Trans-Hudson and Svecofjord Orogenic Belts exhibit a number of similarities in their evolution, as shown for example by studies of U-Pb isotopes (e.g. see Lewry et al., this volume) and by their volcanic and sedimentary sulphide ore deposits. The latter may mark the scar of an early Wilson cycle affecting a belt extending from Finland to Arizona (Rickard, this volume). This is not to say that evidence of subduction is to be found everywhere in the Proterozoic. In some shields, e.g. Australia (Wyborn et al., this volume), volcanism is dominantly of intra-plate type, with little evidence for subduction magmatism. This might be expected if the Proterozoic cratons were arranged as a 'supercontinent' as proposed by Piper on palaeomagnetic evidence. Assuming no change in the radius of the earth since the Archaean, it follows that any such supercontinent must have been bordered by an equally impressive Proterozoic 'super ocean'. Perhaps the Proterozoic shield areas containing abundant evidence of subduction magmatism and lateral accretion, e.g. the Laurentian and Baltic Shields, lay at the margin of this supercontinent which at least from time to time formed a Pacific type margin, involving subduction of oceanic lithosphere. The interior of the supercontinent might be expected to reflect purely intra-plate magmatism.

The papers in this volume are grouped into sections geographically. Each section is preceded by a simplified geological map at 1:25M scale to assist the reader in establishing the spatial relationship of the volcanic suites described in the text. The maps are based on the 1:10M maps from the UNESCO Geological World Atlas augmented by data from the papers in this volume. Standard ornaments are used to depict the Proterozoic volcanic suites (highlighted in black), the Archaean shield nuclei (random dashed ornament, fine where concealed), major Proterozoic batholithic complexes (crosses) and Proterozoic metasedimentary sequences (dots). The latter may also include substantial amounts of gneissose metamorphic rock, granite and migmatite.

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Tim Pharaoh Robert Beckinsale David Rickard

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