WATER AND MAGMA GENESIS

Proceedings of a symposium held on the occasion of the joint annual meetings of the MINERALOGICAL ASSOCIATION OF CANADA, GEOLOGICAL ASSOCIATION OF CANADA, GEOLOGICAL SOCIETY OF AMERICA (north-central section), NATIONAL ASSOCIATION OF GEOLOGY TEACHERS (east-central section), PALEONTOLOGICAL SOCIETY (north-central section), and the PANDER SOCIETY at the University of Waterloo, Waterloo, Ontario, May 15 - 17, 1975.

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PREFACE

Water is the most important volatile constituent in virtually all igneous rocks and its importance in the genetic development of these rocks has long been recognized. In his classical treatise on "The Evolution of the Igneous Rocks" published in 1928, N. L. Bowen cautioned petrologists not to regard a volatile component as a Maxwell demon, which does exactly what one wishes to do with it (Bowen 1928, p. 282). In the past 50 years our knowledge of the role of water, as well as that of other volatiles, has increased immensely although the sources of water, particularly in problems involved in calc-alkaline magmatism, are still a subject of debate and controversy. This increase in our knowledge of the role of water has been due to careful laboratory studies employing a wide variety of techniques. One example of such a technique is the use of oxygen isotope ratios to determine the extent of groundwater contamination in basic and ultrabasic rocks (Taylor & Epstein 1968).

Aside from the problems of the sources of water for magmatic processes in both the crust and mantle, we know approximately the effect of water on the viscosities of silicate melts (*c.f.* Friedman *et al.* 1963; Shaw 1963, 1969; Bottinga & Weill 1972; Scarfe 1973). Diffusion of water in silicate liquids probably occurs as (OH) molecules (Burnham & Jahns 1962; Hamilton *et al.* 1964). In silicate liquids or glasses, both H_2O and H_2 may react with Si-O-Si bondings which replace the bridging oxygen bonds by 2OH. This replacement may eventually lower the viscosity of the silicate liquid.

The solubility of water in silicate liquids depends on the temperature, pressure and composition of the melt (*c.f.* Burnham *et al.* 1969; Burnham & Davis 1971; Hamilton *et al.* 1964). The melting points of magmas will be affected greatly by the solubility of water. Whether these are lowered (under conditions of, or approaching, water saturation in the silicate liquid, ($P_{H_2O} = P_{total}$) or raised (under conditions of water undersaturation in the silicate liquid, $P_{H_2O} < P_{total}$) may have profound influence on any petrogenetic theory as well as affecting the use of geobarometers and geothermometers. Examples of difficulties in using geothermometers and geobarometers as well as calculating water fugacities from thermodynamic data without knowledge of the relationship between P_{H_2O} and P_{total} are given in Carmichael *et al.* (1974). A review of the role of water in magmas has been given by Burnham (1967).

Under mantle and deep crustal conditions, water plays an important role in partial melting of source materials to produce a host of derivative magmas. In the past 15 years many high-pressure experimental studies on rock–water systems have been done in laboratories throughout the world. A review of these experimental studies is given by Wyllie (1971, 1973). On the basis of these studies, Green (1970, 1971, 1972) has proposed a petrogenetic grid for basaltic magmas generated in the upper mantle. This grid relates temperature, depth, amount of partial melting, and percentage of water in the melt to the type of basalt produced.

During 1974 the Mineralogical Association of Canada asked W. S. Fyfe of the University of Western Ontario if he and his colleagues could organize a symposium on a topic incorporating experimental and chemical petrology, to be presented at the May 1975 joint meeting of the Mineralogical Association of Canada, the Geological Association of Canada and other societies to be held at the University of Waterloo. The wide ranges covered by both experimental and chemical petrology suggested to us that we should try to narrow the topic to cover aspects both current and controversial. In addition, it was thought advisable to stress igneous rather than metamorphic petrology, which had been the subject of a similar symposium held the previous year at the 1974 meeting. After considerable discussion the topic of the role of water in the genesis of magmas was proposed, and "Water and Magma Genesis" became the official title of the symposium.

The organizers felt that a combination of "invited" speakers and "contributed" papers would provide the most stimulating meeting. The "invited" speakers were chosen on the basis of their outstanding contributions in experimental and chemical petrology, and for the controversies they had stimulated. In addition we tried to achieve a balance between predominantly field-oriented and laboratory-oriented petrologists.

The following papers represent some of the contributions presented at the Water and Magma Genesis symposium, Waterloo. Unfortunately some of the speakers were unable to provide a manuscript, but some of those contributions have already been published and hopefully others will eventually be published elsewhere. In this special issue the various roles of water in the processes of formation and alteration of magmatic rocks under conditions ranging from deep in the mantle (e.g. the article of D. H. Green) to the oceanic floor (e.g. the article of F. Aumento, W. S. Mitchell & M. Fratta) are considered. The majority of the papers are concerned with various aspects of magmatism in the island-arc continental-margin tectonic regime (e.g. the articles of A. R. McBirney, L. W. Younker & T. A. Vogel, D. H. Green) which indicates the perplexed problems of genesis of these magmas. The role of water in the genesis of hypersolvus and subsolvus granites is discussed by R. F. Martin & B. Bonin and indicates that the granite controversy is still alive and well. The paper by D. M. Francis describes how the *P-T* conditions of formation of fragments of the base of the crust can be approximated.

Hopefully this collection of papers shows that although water is not the Maxwell demon that Bowen cautioned petrologists to be aware of, its role in the genesis of magmas is much greater than imagined even a few years ago. Studies published recently indicate the importance of carbon dioxide and other volatile constituents in the genesis of magmas, particularly under mantle conditions. Perhaps future symposia sponsored by the Mineralogical Association of Canada can be devoted to the roles of those volatiles.

Finally, I wish to thank authors of the papers for their prompt submission of manuscripts, the speakers at the Waterloo Symposium for their contributions, my colleagues at the University of Western Ontario, and the National Research Council for a Conference Grant which defrayed speakers' expenses. I am grateful to the officers of the Mineralogical Association of Canada and particularly to Dr. John Jambor for bringing this volume to fruition.

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