PHYSICS AND CHEMISTRY OF PARTIALLY MOLTEN ROCKS

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Physics and Chemistry of Partially Molten Rocks

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Cover illustration:
Secondary electron photographs of fracture surfaces of quartzites synthesized in the presence of small volume fractions of various fluids. ***a*** Quartzite containing≈0.2 vol. % of hydrous granitic melt ($\theta = 14°$; P-T-t conditions are 900 °C - 1GPa-159 hr; from Laporte et al., 1997, Fig. 7): melt forms an interconnected network of grain-edge channels (edges along which the glass has been destroyed during sample preparation appear rounded).

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Preface

Nickolai S. BAGDASSAROV, Didier LAPORTE and Alan B. THOMPSON

This special volume contains papers presented at the symposium "Physics and chemistry of partially molten systems" of the EUG 9th meeting, held in Strasbourg, France, from March 23-27, 1997. This symposium grew out of a realisation that there has been a significant amount of interest and activity on the topic of partially molten rocks over the past few years. The main reason for this interest is that partial melting occurs in a variety of geological environments, from granitic partial melts in the continental crust, to basaltic or carbonate partial melts in the upper mantle. Also, partial melting is the first stage of magmatism and therefore plays a role of primary importance in the chemical differentiation of the Earth and in the transport of heat to the Earth surface.

The special volume is intended to provide a current understanding of the physics of partial melting and melt segregation. Although some aspects of these topics are discussed in many special volumes or monographs, a book encompassing the different aspects of partial melting is not available. The monographs most closely related to our special volume are: *The structure and dynamics of partially solidified systems* (D. E. Loper, ed., 1987, Kluwer Academic Publishers), which is primarily devoted to cooling of man-made systems in which the volume fraction of liquid is high; *Melting and melt movement in the Earth* (Cox K. G., McKenzie D., White R. S., eds., 1993, Philosophical Transactions of the Royal Society of London, series A, vol. 342, 1-191), which focuses on the problems of partial melting and melt migration in the Earth mantle and the isotope chemistry of basalts; and *Deformation-enhanced fluid transport in the Earth's crust and mantle* (M. B. Holness, ed., 1997, Chapman & Hall, London) whose focus is on the effect of deformation and stresses on the mobility of geological fluids (including partial melts).

This special volume comprises four sections of two chapters:

(1) The first section is devoted to the rheology of partially molten rocks. In chapter 1, **D.L. Kohlstedt, Q. Bai, Z.-C. Wang and S. Mei** review constitutive equations for the rock rheology accounting the effects of temperature, melt fraction, stresses, grain size, activity of oxygen and water. Special attention is paid to reconcile the results on crystal-melt aggregate creep at small (0.1 MPa) and high (300 MPa) confining pressures. Effect of the activity of oxygen, water and pyroxenes has been demonstrated in creep experiment on olivine-basalt aggregates. Comparison of rheology of olivine melt-free aggregates with aggregates containing 3 vol% of basalt melt demonstrates moderate decrease of the viscosity by a factor 3 - 5. In chapter 2, **N. Bagdassarov** experimentally demonstrates the effect of transient rheology and frequency dependent elastic properties of partially molten rocks in oscillatory torsion deformation. New laboratory results on the internal friction spectroscopy at seismic frequencies have been obtained on partially molten gabbro, spinel lherzolite, Hawaiian basalt and Mount St. Helens dacite. These data outline the fundamental difference in transient rheology of rocks, having moderate degree (< 20 vol%) of partial melting and magmatic suspensions, having signifdicant degree (> 40%) of melt phase. Analysis of the frequency exponent in the internal friction of partially molten rocks and lavas reveals the continuous change from anelastic type stress relaxation to viscoelastic behaviour of rocks at high temperatures.

(2) The second section is devoted to the topology of partial melt and its effect on physical properties such as permeability and seismic velocity. In chapter 3, **U. Faul** describes the effects of surface energy anisotropy and grain growth on melt topology in the olivine-basalt system. He shows that the permeability of olivine aggregates at very low melt fractions may be three to four orders of magnitude lower than previously anticipated. In chapter 4, **D. Laporte** and **A. Provost** make a review of the theoretical and experimental studies on the grain-scale distribution of silicate, carbonate and metallosulfide partial

melts and discuss the implications for the movement of low melt fractions

(3) The modelling of melting processes and crustal assimilation is considered in the third section. In chapter 5, **H. Schmeling** develops a model of partial melting and melt segregation in a convecting mantle. He concludes that, for current estimates of mantle temperatures and state of stress, many regions of the asthenosphere may be partly molten but that melt migration is restricted. The most successful environments where melt production is succeeded by volcanism are related to mantle plumes and hot spots. In chapter 6, **L. Matile**, **A. B. Thompson** and **P. Ulmer** present a fractionation model for differentiation of hydrous mantle magma. They show that various thermal evolution paths are possible depending upon the evolution of the heat budget during crystallisation and that primitive magmas (e.g, picrite) can assimilate up to 80 % of fertile country rocks, whereas basalt can assimilate about 30 to 40%.

(4) The scope of the fourth section are "natural examples of partial melting". In Chapter 7, **A. Hobson**, **F. Bussy** and **J. Hernandez** describe felsic melts produced by anatexis of gabbroic rocks with the heat source from ocean island magmas and participation of magmatic metasomatising fluids. Regional scale deformation aided the anatexis and melt collection.In Chapter 8, **R. Wirth** and **L. Franz** deduce the early stages of the melting history of mantle-derived xenoliths from observations on intergranular glassy layers. Melt compositions are locally different in micron-sized films compared to more homogeneous melt pools, permitting the diffusion process of melt homogenisation to be quantified.

Finally, we would like to thank all the authors for their chapters and the external reviewers for their efforts which contributed to the improvement and the shaping of this book.

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