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Preface

Chemical and physical processes affecting element mobility from the slab to the surface

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8 The understanding of the physicochemical processes attending and resulting from both prograde and retro-9 grade metamorphism of subducted plates is conceptually 10 advancing. However, the accuracy with which we can 11 model processes at the PT conditions attending slab 1213 metamorphism and the ensuing fate of slab components 14is hindered by a lack of detailed understanding of element mobility during devolatilization and concomitant 15mass transfer between the slab and the volatile phase(s), 16the chemical evolution of the volatile(s) during reactive 17 18 ascent, metamorphic recrystallization of the slab, and punctuated differentiation of ascending melt(s). 19

20For the 15th annual V.M. Goldschmidt conference held at the University of Idaho, the guest editors con-21 22vened two symposia entitled "Subduction zone metamorphism. 1. Processing of geochemical tracers" and 23"Subduction zone metamorphism. 2. Fluids from the 24slab to the surface". In an effort to bring together a 25diverse group of scientists, the sessions focused on the 2627entire range of physical and chemical processes which affect recycling in subduction zone environments and 28the record by which these processes are revealed. The 2930 first session focused broadly on the geochemistry of metamorphic subduction zone complexes, xenoliths and 3132 arc volcanic rocks as used to reconstruct the relative proportions of various oceanic lithologies within the 33 integrated subduction component returned to the arc as a 3435 means to infer recycling processes within subduction zones. Recent research has shown that pre-subduction 36 geochemical compositions may be modified strongly by 37 metamorphic processing deep within subduction zones, 38 suggesting that direct geochemical comparison of sea-3940 floor inputs to arc outputs to establish a mass balance is 41 not realistic. The need to quantify metamorphic modi-

fication of geochemical tracers is fundamental to fur-42 thering our understanding of arc evolution and mantle 43 dynamics. Contributors presented analytical, experi-44 mental, and theoretical constraints on reactions and 45processes that address the complex geochemical evolu-46tion of subducted materials during subduction-zone 47 metamorphism. The second session focused broadly on 48 the physicochemical mechanisms which may result in 49the fractionation and transport of elements in the 50magmatic plumbing system which extends from shal-51low-level geothermal systems to mid-crustal magmatic-52hydrothermal systems to the devolatilization of sub-53ducting slabs and the subsequent flux-melting of the 54mantle wedge and overlying crust. These physically 55distinct regions are now recognized as sharing a chemi-56cal genetic link through the process of element redis-57tribution via volatile and melt fluxes that transport 58elements from depths of possibly 200 km in down-going 59slabs to the surface. Contributors presented data from 60 studies of natural samples and experiments in analogue 61 systems to model and decipher fluid evolution in Earth's 62 upper mantle and crust. Together, the two sessions pro-63 vided a good mix of field, experimental and theoretical 64 science. The 10 papers in this special issue represent 65extensions of work presented in the symposia as well as 66 contributions from scientists who could not attend. 67

The first two papers provide reviews of the global 68 water budget and fluid migration pathways in the sub-69 duction zone-mantle wedge environment, respectively. 70In an effort to constrain the recycling of water in the 71subduction zone factory, Iwamori (2007) presents and 72discusses geological and seismological observations, 73 focusing largely on the Japan arcs. He models dehy-74dration of the slab and the effects of this buoyant gas 75

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phase on the overlying mantle wedge and finds that 76 77 serpentine and chlorite act as mediating phases con-78 trolling the mass transfer of water between the slab and 79the overlying volcanic front such that a significant 80 quantity of H₂O may be transported into the deep mantle in this hydrated buffer zone. Zack and John (2007) 81 82 discuss how fluid channelization and fluid-rock reac-83 tion rates affect element mobility in the slab environ-84 ment. Geochemical tracers such as LILEs, LREEs, HREES and HFSEs display decreasing degrees of mo-85 86 bilization and their redistribution appears to be veincontrolled, rather than by porous-media flow. They 87 conclude that accurate modeling of the modification of 88 89 the trace element signature of ascending fluids (aqueous and silicate) and the wall rock must include kinetic 90 parameters as well as the traditional use of simple 91Nernst-type partition coefficients. 92

There is general agreement that the ability of aqueous 93 94fluids to migrate via porous-media flow through sub-95ducted ocean crust is minimal. In an effort to quantify 96 fluid flow pathways, Ague (2007) uses field evidence 97 from Syros and Tinos, Cyclades, Greece to model fluid 98 flow in mélange matrices which contain blocks of sub-99ducted oceanic crust. He concludes that the higher relative permeability of mélange zones acts to control fluid 100flow around the included blocks, rather than within low-101 permeability ocean crust. The position of the block with 102respect to surrounding mélange fabric controls the mag-103104nitude of fluid-rock reaction and, in turn, this has im-105portant implications for the total flux of fluid through both the block and mélange as well as the resulting 106 chemical signature of both units. 107

108 A series of contributions next utilize experimental techniques to explore element redistribution at the PT 109 conditions attending slab devolatilization. Spandler 110et al. (2007) used data from piston-cylinder experi-111 ments producing aqueous fluid equilibrated with a 112pelite assemblage at 2.2 GPa and 600 to 750 °C to 113suggest that the mass transfer of LILE, REE and HFSE 114 115to an aqueous fluid is minimal up to at least eclogite-116 facies conditions; however, their data do suggest that sub-solidus volatiles may effectively fractionate, albeit 117 not significantly, the LILE from both REE and HFSE, 118119the latter two element suites being retained in the slab. Their conclusion that the slab remains nearly isoche-120121mical at sub-eclogite grade has important implications for element recycling in the subduction zone environ-122123ment. Feineman et al. (2007) quantified the partitioning of the REEs, Rb, Ba, Th, U, Nb, Ta, Pb, Sr between 124125zoisite and aqueous fluid at 2 GPa and 750 to 900 °C 126and combined their data with extant mineral/fluid 127Nernst-type partition coefficients for garnet, clinopyr-

oxene, rutile and phengite to explore geochemical 128signatures of specific clinozoisite-consuming reactions 129as well as signals expressed by fluids equilibrated with 130bulk eclogite. Their results suggest that zoisite stability 131affects significantly the mass transfer of both Sr and Pb 132from the eclogite to an exsolved volatile phase. in-133dicating that the Sr and Pb concentrations in arc basalts 134may be used to infer PT conditions of slab degassing 135beneath the arc. Mayanovic et al. (2007) performed 136 experiments in the hydrothermal diamond anvil 137cell (Bassett et al. 1993) using synchrotron X-ray 138 spectroscopy to elucidate the state of REE-complexes 139in aqueous solutions at pressures up to 480 MPa and 140temperatures from 25 to 500 °C. Specifically, they used 141aqueous fluids with different compositions to quantify 142 the aqueous speciation of Gd^{3+} . They demonstrate that 143REE-H₂O association plays an important role in REE 144transport in aqueous fluids at all temperatures; 145however, the solubility of Gd, and other REEs by 146inference, as a REE-Cl complex is more significant 147than REE-H₂O at temperatures above 300 °C. 148

The next two papers focus on the Catalina Schist 149(California, U.S.A.). Bebout et al. (2007) use trace 150element data from porphyroblasts in the Catalina Schist 151to elucidate the significance of varying prograde P-T 152paths on element mobility. They demonstrate that min-153eralogy plays an important role in element mobility 154owing to element preference for certain solid phases 155(e.g., B and Rb for white mica and Li for chlorite) and 156that mineral abundance affects strongly whole-rock 157geochemistry. Their results further support models 158where reactions involving specific trace-element min-159eral hosts may be used reliably to interpret the mobility 160 of key tracers in the subducting section, rather than 161 reliance upon bulk geochemistry of subducting litho-162logic components. King et al. (2007) use B and Pb 163isotopic data to elucidate the effect of prograde me-164tamorphism on element redistribution in a mélange-165slab-mantle wedge environment. Their results suggest 166that metasomatic reactions accommodating mixing of 167diverse components (i.e., peridotite, basalt, sediment) 168along the slab-mantle interface can develop B and Pb 169isotopic signatures not easily predicted from the known 170compositions of pre-subduction seafloor rocks. King 171et al. compare their new data to published B-Pb isotope 172compositions of arc volcanics to demonstrate how fluids 173derived from such hybridized zones along the slab-174mantle interface are compatible with modern across-arc 175isotopic trends. 176

Marschall et al. (2007) combine data from natural 177 mineral assemblages and experiments to calculate mineral/fluid Nernst-type partition coefficients for Li, Be 179

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and B as well as fractionation of $\delta^{11}B$. They use the 180 partition coefficients to develop a model tracking the 181 182mass transfer of Li, Be and B from a subducted metabasite to exsolved aqueous fluids, suggesting that the 183concentration of Be in the slab is unaffected during 184degassing whereas an exsolved gas phase may effec-185tively scavenge on the order of one-half of the Li present 186 187 originally in the slab. Retention of B in the slab is 188 correlated positively with the modal abundance of white mica and, perhaps most significant, that $\delta^{11}B$ values 189 depend strongly on the modal abundance of white mica. 190Usui et al. (2007) present major and trace-element 191 192data from a coesite-bearing, lawsonite-eclogite (Color-193ado Plateau, U.S.A.), inferred to represent a fragment of subducted Farallon ocean crust, suggesting that garnet 194195efficiently sequesters HREEs whereas LREEs and Sr are incorporated preferentially into lawsonite. Based on 196197 contrasting concentrations of Sr in garnet-hosted law-198sonite inclusions and ground-mass lawsonite, they postulate the presence of allanite which decomposed and 199liberated LREEs, the latter then being sequestered by the 200201 matrix lawsonite. These data imply that prograde metamorphism through the lawsonite-eclogite facies field 202203does not necessarily result in a decrease of the REEs or Sr in the residual mineral assemblage. 204

The guest editors express their sincere gratitude to all 205the authors for their contributions to this special issue 206 and especially for the patience of many of you who have 207208eagerly awaited the print edition. We also thank the 209many scientists who provided timely and highly constructive reviews of each manuscript. We feel that the 210breadth of science included here advances significantly 211243

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our understanding of physicochemical processes in the 212subduction zone environment and stimulates greatly 213future research. 214

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