OCEANIC FAULTING AND HYDROTHERMAL CIRCULATION WITHIN THE CRUSTAL SEQUENCE OF THE JOSEPHINE OPHIOLITE, NORTHWEST CALIFORNIA AND SOUTHWEST OREGON, USA

by

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Abstract of

A Dissertation

Submitted to the State University of New York at Albany

in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

College of Science and Mathematics

Department of Geological Sciences

1992

State University of New York at Albany

COLLEGE OF SCIENCE AND MATHEMATICS

The dissertation submitted by

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under the title

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ABSTRACT

Based upon detailed (1:10 and 1:100) outcrop mapping and regional-scale (1:24,000) mapping of the Late Jurassic Josephine ophiolite's crustal sequence, a complex history of overlapping episodes of magmatic, structural and hydrothermal events has been documented using crosscutting relationships, structural analysis, petrography, geochemistry, and strontium and oxygen isotopic data. The following history is typical of the sheeted dike/gabbro transition zone: (1) crystallization of gabbro and later subvertical mafic dike injection; (2) amphibolite facies metamorphism; (3) extensional faulting and tilting of dikes; (4) continued brittle faulting, tilting and dike injection associated with retrograde metamorphism at greenschist facies conditions; (5) continued extensional faulting and tilting synchronous with the development of a variety of fault-controlled hydrothermal veins under decreasing temperature conditions and increasing fluid/rock ratios; and (6) rare subvertical injection of dikes which typically truncate all previous features (1-5). Structural analysis of crosscutting dikes generally reveals a consistent pattern: >90% of dikes dip in one direction and steep dikes typically crosscut tilted dikes, indicating that significant (~50°) tilting of the Josephine crust occurred at the paleo-spreading axis by ocean floor extensional faulting. Probable growth faulting in the extrusive sequence is also consistent with tilting at the rift axis. $[^{87}Sr/^{86}Sr]_{initial}$ ratios from recrystallized whole rocks, and from hornblende, epidote and prehnite separates from veins, display a systematic increase with relative age (from 0.7033 for variably altered gabbro and dikes to 0.7049 for prehnite cement in young oceanic fault rocks). Calculated oxygen isotope fluid compositions for the same suite of samples range from $\delta^{18}O_{fluid}$ = +5 to -1 with time, indicating a change to a seawater-dominated hydrothermal system with time, consistent with observed increased fracture permeability in outcrop (i.e. veining) due to seafloor extensional faulting. Crosscutting relationships, alteration mineral assemblages and isotopic data suggest (1) an early stage of high temperature (≥450°C) alteration with low permeability (i.e. grain-scale flow), followed by (2) a decrease in temperature (~350 to ≤200°C), an increase in permeability due to faulting, and accompanied by tectonic tilting at the rift axis. The consistency of these crosscutting relationships at similar pseudo-stratigraphic levels at different localities in the Josephine ophiolite suggests that alternating magmatic and structural extension with synchronous retrograde alteration is common in crust formed at similar rates of spreading (slow to intermediate).

"The investigator thus at the outset puts himself in cordial sympathy and in parental relations (of adoption, if not of authorship,) with every hypothesis that is at all applicable to the case under investigation. Having thus neutralized so far as may be the partialities of his emotional nature, he proceeds with a certain natural and enforced erectness of mental attitude to the inquiry, knowing well that some of his intellectual children (by birth or adoption) must needs perish before maturity, but yet with the hope that several of them may survive the ordeal of crucial research, since it often proves in the end that several agencies were conjoined in the production of the phenomena. Honors must often be divided between hypotheses."

Thomas Crowder Chamberlain, 1897

from:

The Method of Multiple Working Hypotheses,

Journal of Geology, v. 5, p. 837-848, 1897

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Acknowledgements

The logistics and scope of this study were formidable and thus the list of those who contributed significantly to this study is lengthy. I would first like to acknowledge the guidance and support that I received from Greg Harper in every aspect of the project. Greg inspired most aspects of this study and his research and publications provided the critical framework upon which my research is largely based. In addition, Greg showed me the critical need for a keen observational eye and patience, both in fieldwork and in interpretation of data, and a working motto evolved: if a piece data does not fit your existing working hypothesis, then it is probably important enough to revise your hypothesis. Greg also encouraged me to pursue my research in the mechanics of dike injection and its application to the Josephine ophiolite.

Discussions on the outcrop and also in the lab with J.R. Bowman regarding fluid/rock interactions, fluid pathways, and isotopic constraints greatly improved the research presented in this study. J.R. Bowman graciously allowed me to run the oxygen isotope samples presented in Chapter 7 of this dissertation.

The keen scrutiny of W.D. Means in discussions and in student seminars at SUNY-Albany made me realize the importance of rigorously addressing the likelihood of diachroneity in magmatic, structural and hydrothermal processes when documenting cross-cutting relationships in order to construct geologic histories. Numerous discussions with Win regarding determination of slip sense in brittle and plastic shear zones and also the brittle-plastic transition zone improved my understanding greatly.

Discussions with W.S.F. Kidd regarding the tectonics of convergent and divergent plate margins are gratefully acknowledged. In particular, Bill helped to clarify my ideas on various mechanisms (magmatic inflation and extensional faulting) which have been proposed for tilting of oceanic crust and deflection of structures at mid-ocean ridge/transform fault intersections. Bill also reminded me on a regular basis that just because something is published in a journal does not mean that it must be correct or that it is beyond critical re-evaluation.

I would also like to acknowledge a number of individuals for their assistance in collecting data and/or providing data reported in this study. Published and unpublished mapping by G.D. Harper provided the basis for (1) selecting most the localities analyzed in detail in Chapter 3, and (2) compiling geologic mapping in the Shelly Creek Ridge quadrangle (Map Plate 1). G.D. Harper also conducted two magnetometer surveys which are presented here (Big Bend Traverse #2 and the Idlewild traverse, Chapter 5) and he provided the structural data on basalt flows discussed in Chapter 6 (section 6.5). J.R. Bowman provided access to his oxygen isotope lab at the University of Utah. He also provided access to the proton-precession magnetometer and magnetic susceptibility meter used to collect the data presented in Chapter 5. A.J. Coulton graciously performed strontium analyses on the samples discussed in Chapter 7. Finally, F. Brickwedel of Crescent City, CA, provided access to data and diamond drill core of the Monumental Mine Prospect discussed in Chapter 3 (section 3.7). Numerous graduate students in the department provided constructive criticism of my work over the years, including Glenn Gaetani, Greg Norrell, Steve Schimmrich, Terry Spell and Pan Yun.

Financial assistance from the following sources is gratefully acknowledged: National Science Foundation (G.D. Harper), the State Universtiy of New York at Albany Benevolent Society, and the State University of New York at Albany Graduate Student Organization and the American Geopysical Union for Travel Grants to present research results at the Fall Meeting of the American Geophysical Union (1991).

Diane Paton (SUNY Department of Geological Sciences) was tremendously helpful with logistical support during the summer field seasons and also with administrative details during the academic year.

Finally, I would like to thank G.D. Harper, G.T. Norrell, R. Hilton, B.A. Stemper, A.J. Coulton, D.S. O'Hanley, and S. Delay for their impeccable assistance with fieldwork. Gratitude is offered to the manufacturers of hydrocortisone cream, caladryl lotion, benadryl capsules, and Burrow's solution for the reliability of their products to counteract the ubiquitous peril of Poison Oak in the Josephine's crustal sequence. Special thanks to Becky Stemper and Desiree for their unwaivering support in all aspects of my studies and research.