

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

by

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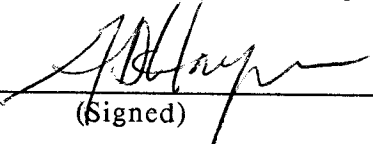
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COLLEGE OF SCIENCE AND MATHEMATICS

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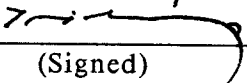
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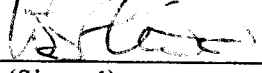
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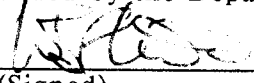


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ABSTRACT

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. $[^{87}\text{Sr}/^{86}\text{Sr}]_{\text{initial}}$ 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 $\delta^{18}\text{O}_{\text{fluid}} = +5$ 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 ($\geq 450^\circ\text{C}$) alteration with low permeability (i.e. grain-scale flow), followed by (2) a decrease in temperature (~350 to $\leq 200^\circ\text{C}$), 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

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	III
TABLE OF CONTENTS	V
LIST OF FIGURES	VIII
LIST OF TABLES	XI
LIST OF PLATES	XI
ACKNOWLEDGMENTS	XII
1.0 INTRODUCTION	1-1
1.1 Purpose of Study	1-1
1.2 Scope of Study	1-3
1.3 Format of Study	1-3
2.0 REGIONAL GEOLOGIC SETTING	2-1
2.1 General Klamath Mountains Geology	2-1
2.2 Previous Studies of the Josephine Ophiolite and Adjacent Terranes	2-4
2.2.1 Formation of the Josephine Ophiolite	2-5
2.2.2 Emplacement of the Josephine Ophiolite	2-10
2.2.3 Post-Emplacement Deformation of the Josephine Ophiolite	2-12
3.0 DETAILED DESCRIPTIONS OF VARIOUS FAULT LOCALITIES IN THE CRUSTAL SEQUENCE OF THE JOSEPHINE OPHIOLITE	3-1
3.1 Introduction	3-1
3.2 Big Bend Area.....	3-8
3.3 RH Mine Area	3-18
3.4 South Fork/Craigs Creek Area	3-23
3.5 Tyson Chrome Mine Area	3-30
3.6 Idlewild Area	3-35
3.7 Monumental Mine Area	3-41
3.8 Discussion	3-46
4.0 DIKE PROPAGATION AND EXTENSION DIRECTIONS IN THE JOSEPHINE OPHIOLITE: IMPLICATIONS FOR MELT MIGRATION AT SLOW- TO INTERMEDIATE-RATE OCEANIC SPREADING CENTERS	4-1
4.1 Introduction	4-1
4.2 Josephine Ophiolite.....	4-5
4.3 Mechanics of Dike Injection.....	4-7
4.4 Methods and Structural Data	4-15
4.5 Interpretation and Discussion	4-24
4.6 Conclusions	4-30

TABLE OF CONTENTS (Cont.)

	<u>Page</u>
5.0 MAGNETOMETER TRAVERSES AND MAGNETIC SUSCEPTIBILITY OF CRUSTAL UNITS AND OCEANIC FAULT ZONES	5-1
5.1 Introduction	5-1
5.2 Methods	5-6
5.3 Total Field Magnetometer Surveys	5-8
5.4 Magnetic Susceptibility	5-22
5.5 Discussion and Implications	5-26
5.6 Continuing Studies	5-27
6.0 THE JOSEPHINE OPHIOLITE: AN ANCIENT ANALOGUE FOR SLOW- TO INTERMEDIATE-RATE SPREADING RIDGES	6-1
6.1 Introduction	6-2
6.2 Josephine Ophiolite	6-5
6.2.1 Age and Emplacement	6-5
6.2.2 Tectonic Setting	6-7
6.2.3 Subseafloor Hydrothermal Alteration	6-7
6.3 Recognition of Oceanic Faults: Implications For Hydrothermal Circulation	6-9
6.3.1 Oceanic Faults at Slow-Spreading Centers	6-11
6.3.2 Oceanic Faults in Ophiolites	6-12
6.3.3 Oceanic Faults in the Josephine Ophiolite	6-12
6.4 Fast- Versus Slow-Spreading Centers	6-25
6.4.1 Morphology and Structure	6-25
6.4.2 Axial Magma Chambers	6-26
6.4.3 Hydrothermal Alteration	6-27
6.4.4 Seismicity	6-28
6.4.5 Crustal Thinning	6-28
6.5 Inferred Slow- to Intermediate-Spreading Origin for the Josephine Ophiolite	6-29
6.5.1 Morphology and Structure	6-30
6.5.2 Episodic Magmatism	6-38
6.5.3 Crustal Tilting	6-41
6.5.4 Discussion	6-48
6.6 Model of Structural/Amagmatic Extension in the Josephine Ophiolite ...	6-48
6.6.1 Crustal Structures	6-49
6.6.2 Upper Mantle Structures	6-57
6.6.3 Discussion	6-58
6.7 Geometry of Oceanic Structural Extension and Implications	6-58
6.8 Conclusions	6-63

TABLE OF CONTENTS (Cont.)

	<u>Page</u>
7.0 OCEANIC FAULTING AND FAULT-CONTROLLED SUBSEAFLOOR HYDROTHERMAL ALTERATION IN THE SHEETED DIKE COMPLEX OF THE JOSEPHINE OPHIOLITE	7-1
7.0 Introduction	7-1
7.1 Josephine Ophiolite	7-4
7.1.1 Age, Structure and Alteration	7-4
7.1.2 Ophiolite Emplacement	7-6
7.1.3 Recognition of Oceanic Hydrothermal Veins and Faults	7-7
7.2 Geology of the Sheeted Dike/Gabbro Transition Zone	7-8
7.2.1 Petrography, Alteration and Geochemistry	7-25
7.2.2 Orientations of Dikes and Hydrothermal Veins	7-33
7.2.3 Geometry, Fabrics and Kinematics of Oceanic Faults	7-39
7.2.4 Crosscutting Relationships	7-45
7.2.5 Generalized Evolutionary Model	7-47
7.3 Strontium and Oxygen Isotopic Data	7-49
7.3.1 Methods	7-49
7.3.2 [$^{87}\text{Sr}/^{86}\text{Sr}$] _{initial} Versus Relative Age	7-50
7.3.3 $d^{18}\text{O}$ Versus Relative Age	7-53
7.3.4 [$^{87}\text{Sr}/^{86}\text{Sr}$] _{initial} Versus $d^{18}\text{O}$	7-56
7.3.5 Discussion of Isotope Systematics	7-59
7.4 Implications For Oceanic Crust Formed at Slow- to Intermediate-Rate Spreading Centers	7-62
7.5 Conclusions	7-71
 8.0 CONCLUSIONS	 8-1
 9.0 SUGGESTIONS FOR FUTURE RESEARCH	 9-1
 APPENDIX I: Bedrock Geology of the Shelly Creek Ridge Quadrangle California/Oregon (1:24,000)	 In Map Pocket
 REFERENCES CITED	 References-1

List of Figures

	<u>Page</u>
<u>CHAPTER 2</u>	
2.1 Geologic map of the Klamath Mountains of California and Oregon	2-2
2.2 Generalized stratigraphic column of the Josephine ophiolite	2-6
2.3 Schematic model for the inferred tectonic setting of the Josephine ophiolite during formation in a backarc basin	2-7
2.4 Modern day tectonic setting for the Josephine ophiolite	2-13
2.5 Maps of the Gorda Plate showing the pattern of deformed magnetic anomalies	2-16
2.6 Schematic block diagrams of the lithosphere at the Mendocino triple junction	2-17
<u>CHAPTER 3</u>	
3.1 Map of the study area in the Josephine ophiolite and fault localities	3-2
3.2 Geologic map of the Josephine ophiolite and fault localities	3-3
3.3 Schematic diagram showing the three primary generations of faulting	3-5
3.4 Key of symbols used to plot structural features on the stereographic projections	3-9
3.5 Location map of the Big Bend and RH Mine areas	3-11
3.6 Stereographic projection of structural data for Locality 1a	3-12
3.7a Stereographic projection of structural data for Locality 1b	3-14
3.7b Stereographic projection of structural data for Locality 1c	3-15
3.8 Stereographic projection of structural data for Locality 1d	3-17
3.9 Stereographic projection of structural data for Locality 1e	3-19
3.10 Structural cross section and stereographic projection for Locality 2	3-21
3.11 Photographs of fault rocks from Locality 2	3-22
3.12 Location map of the South Fork/Craigs Creek area (Locality 3)	3-24
3.13 Stereographic projection of structural data for Locality 3a	3-26
3.14 Stereographic projection of structural data for Locality 3b	3-28
3.15 Location map of the Tyson Chrome Mine area	3-31
3.16 Structural cross section of the Tyson Chrome Mine area	3-33
3.17 Stereographic projection of structural data for Tyson Mine area	3-34
3.18 Composite structural and stratigraphic column for the Idlewild area	3-37
3.19 Outcrop map of a quartz + sulfide fault zone in the Idlewild area	3-38
3.20 Stereographic projection of structural data for the Idlewild area	3-40
3.21 Location map of the Monumental Mine area	3-42
3.22 Stereographic projection of structural data for the Monumental Mine area	3-44
<u>CHAPTER 4</u>	
4.1 Traditional paleo-stress interpretation of dikes	4-3
4.2 Photographs of discontinuous dikes with stepped margins	4-4
4.3 Geologic map of the Josephine ophiolite showing locations of dike data	4-6
4.4 Propagation paths and process zone at dike tip	4-8
4.5 Mohr diagram for state of stress during dike injection	4-11
4.6 Schematic illustration of various discontinuous dike margin structures	4-16
4.7a Stereographic projections of dike propagations for various localities	4-17
4.7b Stereographic projections of dike propagations for various localities	4-18
4.7c Stereographic projections of all dike propagations for various localities	4-19
4.8a Stereographic projections of extension directions for various localities	4-20
4.8b Stereographic projections of extension directions for various localities	4-21

List of Figures (cont.)

	<u>Page</u>
<u>CHAPTER 4 (cont.)</u>	
4.9 Stereographic projections of oceanic fault sets and dike propagation directions for the Big Bend area	4-25
4.10 Schematic structural and stratigraphic model for the Josephine ophiolite	4-26
4.11 Schematic model for variations in dike propagation directions with pseudo-stratigraphic depth	4-28
4.12 Perspective diagram of dike propagation at an oceanic spreading center and influence of stress field	4-32
<u>CHAPTER 5</u>	
5.1 Primary magnetic minerals in the ternary system FeO-Fe ₂ O ₃ -TiO ₂	5-3
5.2 Oceanic crust basement magnetization model of Kidd (1977)	5-4
5.3 Map showing locations of magnetometer traverses	5-9
5.4 Map of Big Bend areas showing locations of magnetometer traverses	5-11
5.5 Magnetometer traverses #1, #2 and #3 in the Big Bend area	5-12
5.6 Magnetometer traverses #4 and #5 in the Big Bend area	5-15
5.7 Magnetometer traverse in the Patrick Creek area	5-17
5.8 Magnetometer traverse in the Cook Road/Oregon Mtn. area	5-19
5.9 Magnetometer traverse in the Idlewild area	5-21
5.10 Histograms of magnetic susceptibility of rocks and fault rocks in the Josephine ophiolite	5-23
5.11 Histograms of magnetic susceptibility of rocks and fault rocks in the Big Bend area	5-24
<u>CHAPTER 6</u>	
6.1 Geologic map of the Late Jurassic Josephine ophiolite	6-6
6.2 Tectonic setting for the formation of the Josephine ophiolite	6-8
6.3 Recharge and discharge alteration patterns in the Josephine ophiolite	6-10
6.4 Schematic diagram of characteristics of Josephine oceanic faults	6-14
6.5a Photograph and cross section of an outcrop of the dike complex	6-15
6.5b Crosscutting relationships, relative ages and structural data for the same outcrop of the dike complex	6-16
6.6 Photographs of gabbro hand samples showing crosscutting relationships of several types of oceanic hydrothermal veins	6-18
6.7 Photographs of epidote- and prehnite-cemented cataclastic oceanic fault rocks	6-19
6.8 Photograph of a hydrothermally-cemented breccia at a fault step	6-22
6.9a Schematic sketch of outcrop setting of screens in the dike complex	6-32
6.9b Photographs of a heterolithic sedimentary breccia screen and a pillow screen in the dike complex	6-33
6.10a Cross section and structural data for the RH Mine area	6-36
6.10b Photograph of bent layering in cumulate gabbro in footwall of a fault ..	6-37
6.11 Schematic diagram of structural and stratigraphic relations during alternating phases of amagmatic and magmatic extension	6-40
6.12 Photograph of layered gabbro with a high-T plastic shear zone	6-42
6.13 Structural data and stratigraphic column showing growth faulting in the extrusive sequence	6-47
6.14 Structural and stratigraphic model for amagmatic extension in the Josephine ophiolite	6-50

List of Figures (cont.)

	<u>Page</u>
<u>CHAPTER 6 (cont.)</u>	
6.15 Structural data and stratigraphic column of oceanic faults in the upper sheeted dike complex and lower extrusive rocks	6-51
6.16 Outcrop sketch of a thin dike with complex offsets on faults with opposite dip directions	6-54
6.17 Photograph of a dike crosscutting igneous layers at an inclined angle	6-56
6.18 Schematic diagram showing three hypotheses for the nature of the oceanic Moho	6-62
<u>CHAPTER 7</u>	
7.1 Geologic map of the Gasquet area, California	7-5
7.2a Photograph of water-polished outcrop of tilted sheeted dike complex which is crosscut by a thick subvertical Fe-Ti dike	7-9
7.2b Photograph of dike-parallel epidote veins with epidote halos.....	7-10
7.2c Photograph of an epidote vein crosscut by a prehnite vein, and both veins crosscut by a fine-grained dike	7-11
7.2d Photograph of a dike-parallel epidote-cemented cataclasite.....	7-12
7.2e Photograph of a multiply reactivated fault zone breccia at a fault step with older cement of epidote + quartz and later prehnite + quartz cement	7-13
7.2f Photograph of a dike-parallel epidote vein crosscut by a prehnite vein	7-14
7.2g Photograph of a dike-parallel prehnite + quartz cemented cataclasite	7-15
7.2h Photograph of subvertical chilled dike margin which truncates older tilted dikes, gabbro screens, and epidote and prehnite veins	7-16
7.2i Photograph of dike-parallel, multiply reactivated cataclasite with cements of early epidote + quartz disrupted and recemented by quartz + sulfide + chlorite	7-17
7.3a Photograph of amphibolite facies isotropic gabbro intruded by several subparallel dikes	7-18
7.3b Photograph of fine-grained gabbro crosscut by two generations of dikes with a step and hanging bridge	7-19
7.3c Photograph of late plagiogranite dike intruding an oceanic strike-slip (transfer) fault zone and crosscut by epidote and prehnite T-veins	7-20
7.3d Photograph of an oceanic fault intersection and intense brecciation and veining at corner	7-21
7.3e Photograph of slickenstriae on an oblique-slip (transfer) fault	7-22
7.3f Photograph of an orthogonal network of quartz + sulfide veins with normal offsets similar to an adjacent prehnite cataclasite	7-23
7.4 Geologic map of a small area of a large outcrop of the dike complex	7-24
7.5 Plot Cr versus Y values for several ophiolite dikes in the outcrop	7-30
7.6a Cross section of the same outcrop, showing some sample and photograph locations and also angular relations of dikes and fault zones	7-31
7.6b Relative ages of features in the outcrop based on crosscutting relations ...	7-32
7.7 Stereographic projection of poles to sheeted dikes and model for tilting.....	7-34
7.8 Schematic diagram showing orientations of sheeted dikes and oceanic faults and orientations and relative ages of oceanic hydrothermal veins	7-40
7.9 Geometry of secondary fractures in faults and principal stress directions..	7-42
7.10 Stereographic projection of poles to oceanic faults and slip vectors	7-44
7.11 Schematic evolutionary model of Josephine sheeted dike complex	7-48
7.12 Strontium isotopic data plotted as a function of relative age	7-52
7.13 Oxygen isotopic data plotted as a function of relative age	7-54

List of Figures (cont.)

	<u>Page</u>
<u>CHAPTER 7 (cont.)</u>	
7.14 Strontium ratios plotted against calculated oxygen values for fluids	7-57
7.15 Fault valve model for episodic venting of hydrothermal fluids along brittle fault zones	7-63
7.16 Schematic model for styles of hydrothermal circulation during phases of magmatic and structural extension	7-68

List of Tables

	<u>Page</u>
<u>CHAPTER 6</u>	
Table 1 Characteristics of Slow- and Fast-Spreading Centers and Corresponding Features in the Josephine Ophiolite	7-29
<u>CHAPTER 7</u>	
Table 1 Selected Analyses of Dikes and a Gabbro Screen and a Cataclasite From the Sheeted Dike/Gabbro Transition Zone	7-37
Table 2 Estimates of Temperatures for Hydrothermal Veins and Alteration in the Sheeted Dike/Gabbro Transition Zone	7-38
Table 3 Isotopic Data For Rocks and Veins in the Sheeted Dike Complex	
Table 4 Mineral-Fluid and Rock-Fluid Oxygen Fractionation Factors	7-51

List of Plates
(In Map Pocket)

1. Bedrock Geologic Map of the 7.5 Minute Shelly Creek Ridge Quadrangle, California/Oregon (1:24,000)

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