

PETROLOGIC AND EXPERIMENTAL STUDIES  
ON THE PETROGENESIS OF PAPUA NEW GUINEA OPHIOLITES

by

Alan Lynton Jaques, B.Sc. (Hons.)

Submitted in fulfillment of the requirements  
for the degree of Doctor of Philosophy.

University of Tasmania

HOBART

1980

*This thesis contains no material which has been accepted for the award of any other degree or diploma in any university, and to the best of my knowledge and belief, contains no copy or paraphrase of material previously published or written by another person, except where due reference is made in the text of this thesis.*

A handwritten signature in black ink, appearing to read 'A.L. Jaques', with a long horizontal flourish extending to the right.

A.L. Jaques

January, 1980.

<u>CONCLUSIONS</u>	212
<u>REFERENCES</u>	217
<u>APPENDIX 1.</u> ANALYTICAL TECHNIQUES	
<u>APPENDIX 2.</u> SAMPLE LOCALITY DATA	
<u>APPENDIX 3.</u> THE CONTINENT/ISLAND-ARC COLLISION IN NORTHERN PAPUA NEW GUINEA	
<u>APPENDIX 4.</u> DETERMINATION OF LIQUID COMPOSITION IN HIGH PRESSURE MELTING OF PERIDOTITE	

ABSTRACT

The late Mesozoic Marum and Papuan ophiolites of Papua New Guinea dip from the continental margin towards accreted Paleogene island-arcs and appear to represent frontal-arc basement emplaced as a result of mid-Tertiary continent/arc collision. Both ophiolites comprise thick sequences of layered ultramafic and mafic cumulates overlying tectonite peridotite and have associated basaltic pillow lavas. The petrology and geochemistry of the cumulate sequences are not consistent with an origin from common mid-ocean ridge basalts (MORB). Discrimination between mid-ocean ridge or marginal basin origins for the Papua New Guinea ophiolites is more dependent on accurate dating of the rocks rather than geochemical characteristics.

The tectonite peridotites (mainly harzburgite) are characterized by extremely refractory mineralogy and chemistry, and are believed to be the residue from large degrees of partial melting of depleted mantle peridotite at low pressure. Relic protogranular textures and mineral assemblages in the Marum harzburgites indicate a high temperature (1200-1300°C), low pressure (< 5 kb) origin followed by deformation and progressive subsolidus re-equilibration and cooling to much lower temperatures which are recorded by the different blocking temperatures of various cation exchange equilibria.

A number of cyclic units are superimposed on the gross layering (peridotite to gabbro) of the cumulate sequences which together with the igneous layering and cumulus textures indicate formation by magmatic crystallization in a large magma chamber(s) from a magma(s) of gradually evolving composition. The main cumulus phases - olivine, chrome spinel, clinopyroxene, orthopyroxene and plagioclase - show cryptic variation from highly magnesian and calcic early cumulates to more fractionated compositions. Various geothermometers and geobarometers, together with thermodynamic calculations involving silica buffers, indicate that the Marum cumulates crystallized at high temperature (1200-1300°C) and low pressure (1-2 kb) under low  $f_{O_2}$ , and subsequently re-equilibrated under subsolidus conditions and cooled. The

presence of cumulus magnesian ( $Mg_{90}$ ) orthopyroxene in the PNG ophiolites conflicts with the low pressure crystallization behaviour of MORB studied previously and with that found in an experimental study of a low-Ti olivine tholeiite basalt from a marginal basin. The cumulate sequences of these ophiolites are inferred to have accumulated from magnesian olivine-poor or quartz tholeiite parent magmas rich in Ni and Cr but poor in alkalis and other large-ion-lithophile (LIL) elements and high valence cations.

Fractionated examples of these magmas are found among the lavas directly overlying the gabbro layer in the Papuan ophiolite and, although resembling MORB in terms of their very low contents of LIL elements, mostly have lower abundances of Ti, Zr, and Y than MORB of comparable  $Mg/(Mg + \Sigma Fe)$  ratio.

Models of formation of oceanic crust based on ophiolites such as the PNG examples suggest segregation of magma from residual peridotite at shallow depth. An experimental study of the anhydrous melting behaviour of two possible upper mantle peridotite compositions at 0-15 kb pressure has been carried out to determine the composition of partial melts from peridotite at low to moderate pressure and the nature of the residual phases. Partial melts at low pressure are saturated to oversaturated in silica, magnesian olivine-poor tholeiite and quartz tholeiite, and co-exist with refractory harzburgite and dunite, consistent with the evidence from the ophiolites. Partial melts in the spinel lherzolite field are richer in normative olivine, ranging from alkali olivine basalt at low degrees of partial melting (for pyrolite) through olivine tholeiite and tholeiitic picrite to komatiitic compositions at high degrees of partial melting. It is concluded that high-alumina olivine tholeiites are not derived by segregation from harzburgite at shallow depths (< 25 km). This is consistent with crystallization studies on 'primitive' MORB and the marginal basin basalt studied here which suggest that such magmas are derived by fractionation of olivine from tholeiitic picrite parents which segregated at about 60-70 km depth.



## ACKNOWLEDGEMENTS

I wish to express my sincere thanks to my supervisor Professor D.H. Green for his constant encouragement, guidance and advice during the course of this study. I also wish to thank him and his wife Helen for their friendship, hospitality and many kindnesses extended to my family and I during our time in Hobart.

This thesis was commenced at the Research School of Earth Science (RSES), Australian National University, and I wish to acknowledge the support, both in analytical facilities and in funding of a field trip to Papua New Guinea, provided by the School. I also gratefully acknowledge receipt of an Australian Public Service Board Scholarship and the continued interest and support of my employer, the Bureau of Mineral Resources. The bulk of the mapping and sampling was carried out while I was employed by the Geological Survey of Papua New Guinea and I wish to thank the Survey and, particularly Dr. H.L. Davies, for their support and encouragement.

Because of the wide ranging nature of this thesis many people have given instruction or assistance in the various analytical techniques. I particularly wish to thank Dr. B.W. Chappell of the Department of Geology, ANU for his generous collaboration and assistance with the XRF analyses, Messrs. W.O. Hibberson and K.L. Harris for their assistance with the experimental work and fellow student Mr. B.J. Griffin for his generous contribution in automating the energy-dispersive probe at Hobart. I am grateful to Dr. S.R. Taylor (RSES) for access to his laboratory and wish to thank him and Ms. P. Muir and Mr. M. Shelley for instruction and assistance in operation of the MS7. I also wish to thank Mr. N.G. Ware, Dr. A. McKee and Mr. B. Griffin for assistance and instruction with the microprobe work, Messrs. P. Beazely, R. Freeman, E. Kiss, P. Robinson and J. Wasik for assistance with XRF, AAS and wet chemical analyses, and Dr. R.W. Page for the isotopic analyses. Drs. J. Walshe, M. Owen, A. Glikson

and Mr. R.J. Ryburn kindly gave assistance with computing and data processing.

I have benefited from discussions with a number of people on various aspects of this work - Dr. R. Arculus, Mr. C.M. Brown, Dr. H.L. Davies, Dr. D.J. Ellis, Mr. J. Foden, Dr. F.A. Frey, Mr. B.J. Griffin, Mr. K.L. Harris, Mr. G. Jenner, Dr. R.W. Johnson, Dr. T. Mori, Mr. C.J. Pigram, Dr. G.P. Robinson, Dr. S.R. Taylor, and Dr. R. Varne.

I would finally like to thank my wife Barbara for her patience and understanding during the course of this study and her care and endurance in typing the thesis.