Late-Pleistocene Climate Evolution of the Southern Sub-Equatorial Tropics from East-Indonesian Speleothems

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Statement of Originality

I declare this thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying subject to the provisions of the Copyright Act 1968.

Acknowledgement of Collaboration

I hereby certify that the work embodied in this thesis has been done in collaboration with other researchers, or carried out in other institution. Below I have outlined the extent of collaboration, with whom and under what auspices.

Linda Ayliffe and Michael Gagan, from the Australian National University, helped out with the stable isotope measurements presented in Chapter 2. Jian-xin Zhao, from the University of Queensland, and John Hellstrom, from the University of Melbourne, helped carry out U/Th dating presented in all chapters. Hubert Vonhof provided on-site training for the fluid-inclusion analysis carried out at Vrije Universiteit, Amsterdam; results from this are presented in Chapter 3. Ian Cartwright, from Monash University, carried out stable isotope analyses of rainwater samples presented in Chapters 2 and 3.

Acknowledgement of Authorship

I hereby certify that the work embodied in this thesis contains a published paper/s/scholarly work of which I am a joint author. I have included as part of the thesis a written statement, endorsed by my supervisor, attesting to my contribution to the joint publication/s/scholarly work.

I, Michael Griffiths, was the primary investigator and lead author of all papers presented in this thesis.

(Russell Neil Drysdale)

(Michael Lindgren Griffiths)

Dedication

To Jill and my parents for their unwavering support

Acknowledgements

Table of Contents

List of Figures

List of Tables

Publications arising from this thesis

Peer-reviewed Publications

Griffiths, M.L., R.N. Drysdale, M.K. Gagan, J.C. Hellstrom, W.S. Hantoro, L.K. Ayliffe, S. Frisia, B.W. Suwargadi, *in preparation*. Abrupt Indo-Pacific climate response to high-latitude warming during MIS 5a/b. *Nature Geoscience*.

Griffiths, M.L., R. N. Drysdale, H.B. Vonhof, M.K. Gagan, J-x. Zhao, L.K. Ayliffe, W.S. Hantoro, J.C. Hellstrom, I. Cartwright, S. Frisia, B.W. Suwargadi, 2010. Younger Dryas-Holocene temperature and rainfall history of southern Indonesia from δ^{18}O in speleothem calcite and fluid inclusions. *Earth and Planetary Science Letters* 295, 30-36.

Griffiths, M.L., R.N. Drysdale, M.K. Gagan, L.K. Ayliffe, S. Frisia, J.-x. Zhao, J.C. Hellstrom, M.J. Fischer, W.S. Hantoro, Y.-x. Feng, B.W. Suwargadi, 2010. Evidence for Holocene changes in Australian-Indonesian monsoon rainfall from stalagmite trace element and stable isotope ratios. *Earth and Planetary Science Letters* 292, 27-38.

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Griffiths, M.L., R. Drysdale, M. Gagan, L. Ayliffe, J. X- Zhao, E. St Pierre, W. Hantoro, B. Suwargadi. A 12,800 year palaeomonsoon record from a stalagmite in Flores, Indonesia. *XVII INQUA CONGRESS, Cairns, Australia, Jul. 28 – Aug. 3, 2007.*

Abstract

The climate evolution of the southern sub-equatorial tropics during marine isotope stage (MIS) 5a/b and the Holocene is explored using geochemical tracers from speleothems on Flores island, Indonesia. Oxygen isotope measurements from two precisely-dated stalagmites reveal that the Australian-Indonesian monsoon increased during the Younger Dryas (YD) cooling event, when Atlantic meridional overturning circulation was relatively weak. Monsoon precipitation intensified even more rapidly from 11 to 7 ka ago, when the Indonesian continental shelf was flooded by global sea-level rise.

Analysis of oxygen (δ^{18}O) and hydrogen (δD) isotope ratios from speleothem fluid inclusions shows that inclusion-δ^{18}O values vary in phase with speleothem calcite δ^{18}O during the Holocene, confirming that calcite δ^{18}O primarily reflects variations in the δ^{18}O of meteoric rainfall. Cave drip-water temperatures, reconstructed from coupled measurements of δ^{18}O in speleothem calcite and fluid inclusions, remained relatively constant through the Holocene but were significantly cooler during the YD, consistent with the high northern latitudes.

To help confirm the stable isotope records, trace elements were used to reconstruct the position of the austral summer inter-tropical convergence zone and east Indonesian rainfall variability during the Holocene. Mg/Ca and Sr/Ca ratios correlate significantly with one another, and with δ^{18}O and δ^{13}C, throughout the record suggesting that the trace element ratios were dominated by prior calcite precipitation, a process whereby degassing in the vadose zone during periods of low recharge causes deposition of calcite and disproportionate loss of Ca^{2+} ions (relative to Mg^{2+} and Sr^{2+}) 'upstream' of the stalagmite. Comparison of speleothem δ^{18}O time-series from Flores and Borneo shows that they vary in unison for much of the Holocene. However, there is an exception during the mid-Holocene when a distinct anomaly in δ^{18}O in the Borneo record, possibly caused by a change in the circulation of the Australian-Indonesian summer monsoon (AISM) in response to a period of positive IOD-like conditions in the eastern Indian Ocean, occurred between the two regions.

A stalagmite reconstruction of Indo-Pacific climate through the interval 84 - 91 ka shows that the lower-frequency oxygen isotope trend indicates that the AISM was largely controlled by local summer insolation during this time, while the carbon isotopes show a pattern that is closer linked with northern polar-latitude ice-core records. Most notably, an abrupt decrease in the temperature-controlled δ^{13}C values at the MIS 5a/b transition occurs in parallel with GIS 21 in the GISP2 δ^{18}O and CH_4 records highlighting the strong connection between the IPWP and North Atlantic during the last glacial period.