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Reconstructing the Quaternary landscape evolution and climate history of western Flores: an environmental and chronological context for an archaeological site

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Reconstructing the Quaternary landscape evolution and climate history of western Flores: an environmental and chronological context for an archaeological site

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by

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CERTIFICATION

I, Kira E. Westaway, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Earth and Environmental Sciences, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Kira E. Westaway

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Abstract

The recent discovery of a late-surviving new human species, *Homo floresiensis*, in western Flores has accentuated our lack of understanding of the history of the genus *Homo* in Asia and of the environmental challenges that may have influenced these hominins. Western Flores contains a wealth of archaeological and palaeoanthropological material with far-reaching implications for human evolution and for Indonesian, Australian and world archaeology. But the interpretation of this evidence has been hindered by a limited Quaternary context and age control for complex stratigraphies in a region of great geological instability and widespread environmental change.

Liang Bua in western Flores is a key site in the Indonesian archaeological record, providing evidence of cave occupation by *Homo floresiensis* and *Homo sapiens*, and human evolution and dispersal on the eastern side of Wallace's Line. In this study, archaeologically-relevant information has been gleaned from an interdisciplinary approach to the analysis of this site, and has established the timing of key events, such as the first exposure of the cave and the nature of, and influences on, human occupation of the cave. This approach incorporated studies of landscape evolution, river terrace and cave development, sedimentology of cave sediments, palaeoclimate signals in speleothems, and a dating strategy utilising novel approaches to luminescence dating.

The research reported here provides a chronological and environmental backdrop to the human occupation of Liang Bua. A maximum age of cave occupation is shown to correspond to the time of cave exposure (~190 ka), which also represents a minimum age for the human habitation of the area. In addition, this study has established an age range for the occupation of the cave by *Homo floresiensis* (95–11 ka), the time of the most intensive phases of occupation (74–61 and 17–11 ka), the depositional age of the holotype skeleton (36–14 ka), and the age of the oldest human skeletal remains found on Flores (95–74 ka). Through the integration of techniques, a framework for terrace development and landscape evolution has been developed to establish the Quaternary setting in which the cave was formed and evolved. These techniques have also defined a sequence of geomorphological and sedimentological changes in the cave, enabling the reconstruction of the occupational environment. At least two zones of occupation have been identified: a zone established ~74–61 ka, and a later zone established ~18 ka.

The environmental backdrop for the arrival and dispersal of humans throughout Indonesia has been established via a palaeoclimatic and palaeoenvironmental analysis of speleothem records. These records contain evidence of multiple wet phases (110–98, 82–65, 49–39 and 17–5 ka) and a flourishing fauna. The timing of these wet phases correlate with evidence for channel and flowstone formation, episodic erosion events, and the most intensive periods of occupation in the cave. There is also evidence for a prolonged period of reduced rainfall (36–17 ka) in an organic-poor environment, the timing of which correlates with evidence of reduced erosion, pooling and less intense occupation. These correlations suggest that the occupational success of *Homo floresiensis* in this area was related to the contemporaneous environmental conditions, which, combined with the evidence for at least two volcanic events (one of which may have forced human migration), establish a link between hominids and their environment.

The results of this research indicate the value of using an interdisciplinary approach to investigate and interpret archaeological sites in Southeast Asia. By providing an environmental and chronological context for important archaeological finds, we can develop a better understanding of the prehistory of *Homo* in Asia.

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List of Abbreviations and Symbols

Luminescence

TL	Thermoluminescence
OSL	Optically stimulated luminescence
PMT	Photomultiplier tube
SA	Single-aliquot
SAR	Single-aliquot regeneration
SARA	Single-aliquot regeneration and additive dose
DAP	Dual-aliquot protocol
SG	Single-grain
CW-OSL	Continuous-wave optically stimulated luminescence
LM-OSL	Linearly-modulated optically stimulated luminescence
UV	Ultra-violet (less than 380 nm wavelength)
IR	Infrared
IRSL	Infrared stimulated luminescence
Gy	Grays (unit of absorbed dose)
nm	Nanometers (unit of measurement for wavelengths of light)
eV	Electron-volt (1 eV = 1.602 x 10^{-19} J)
mW	Milli-Watt (unit for measurement of power: 1000 mW = 1 W = 1 joule per second)
exp	Exponential
L_o	Initial sensitivity corrected luminescence measurement
L_n	Sensitivity corrected luminescence values
I_n	A point where the initial sensitivity corrected luminescence divided by the subsequent measurements (L_n/L_0) is equal to –1.
D_0	A curve fitting parameter that describes the characteristic saturation dose (⅔ saturation)
I_{max}	The saturation TL intensity
s	Escape frequency factor
s	Seconds
kc	Thousand counts
kc/s	Thousand counts per second
E	Trap depth
K	Absolute temperature using the Kelvin scale
k	Boltzmann's constant (1.380658 x 10^{-23} J/K)
±	Plus and minus an error margin
b	Detrapping probability
σ	Photoionisation cross-section
∞	Infinity (used when one side of the distribution cannot be statistically determined)
τ	Lifetime of an electron in a trap
a.u.	Arbitrary units
σ_{OD}	Over-dispersion
L	Maximum log likelihood
BIC	Bayes Information Criterion

Quaternary

ka	Thousand years (1 ka = 1000 years)
Ma	Million years (1 Ma = 1,000,000 years)
LGM	Last Glacial Maximum
MIS	Marine isotope stage
µm	Microns (unit of measurement for grain sizes)
ø	Phi (unit of measurement for grain sizes)

Palaeoclimate

SST	Sea surface temperature
IPWP	Indo-Pacific warm pool
WPWP	Western-Pacific warm pool
ITCZ	Inter-tropical convergence zone
TWT	Trade wind trough
CMT	Continental monsoon trough
OMT	Ocean monsoon trough
ENSO	El-Ninó southern oscillation
CLIMAP	Climate long-range investigation, mappings, and prediction project
PAGES	Past global change
δ	Delta – used to describe the ratio between stable isotopes e.g., $^{18}O/^{16}O$ and $^{13}C/^{12}C$
‰	Parts per thousand

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