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Reconstructing climate change of the last 55 kyr: The Lynch's Crater peat mire record, NE-QLD, Australia

Thesis submitted by

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in September 2006

for the degree of Doctor of Philosophy

in the School of Earth Sciences,

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Declaration

I declare that this thesis is my own work and has not been submitted in any other form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

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Statement of Contribution by Others

This thesis has benefited greatly from the contribution of others to the formulation of ideas, the development of research approaches, and the interpretation and critical review of data. Acknowledgement of many of these contributors is made at the conclusion of relevant chapters, but is here due to several individuals.

Raphael Wüst was instrumental in providing the initial momentum to investigate geochemistry at Lynch's Crater and he secured the funding through an Australian Research Council Discovery Grant. Raphael Wüst has also contributed to acquisition and interpretation of data herein. The importance of his contribution to this research is apparent in his status as co-author to published or manuscripts submitted for publication, however, he recognises this authors role as chief investigator in these studies, and as having acquired the majority of the data, formulating the bulk of the interpretations, preparing drafts, and refining the manuscripts.

Dominik Weiss, Malin Kylander and Antonio-Martinez-Cortizas provided analytical and interpretive expertise. The contribution of these individuals is recognised by their status as co-authors on the manuscripts presented herein and all recognise this authors role as chief investigator in this particular avenue of research. This project would not have been possible without primary funding from the Australian Research Council (DP0456515) and the Australian Institute of Nuclear Sciences and Engineering (PGR8/03).

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ABSTRACT

This study provides new information on past climate conditions in equatorial regions through the application of geochemical proxies to an uncharacteristically long (55 kyr) peat record of Lynch's Crater in the Southern Hemisphere. Lynch's Crater is an extinct volcanic crater (>200 kyr) within the basaltic field of the Atherton Tablelands, NE Australia, from which a 13 m peat record was extracted. The peats consist of 1.5 m of ombrotrophic peat underlain by a minerotrophic peat. The ombrotrophic section has low ash yield (<5%) and low pH (~4-5), while the minerotrophic section has low to high ash yield (often <8%) and a more neutral pH (~7). Geochemical analyses were used to identify local, regional and global signals of environmental change over the past 55 kyr.

Principal component analyses (PCA) of trace, major and rare earth elements identified the crater wall (basaltic and schist bedrock) as the primary source of the peat's inorganic constituents. The PCA of the geochemical data are used to differentiate pathways and processes of elements that occur within the peat deposit and the information is used to interpret climate changes such as changes in precipitation, weathering and dust influx. Two distinct sources (local and long range) have contributed to the lithogenic and chalcophile elemental composition throughout the deposit. Most of the inorganic fractions have the same geochemical signatures as the rocks and sediments of the crater wall, with low As and high Al, Ti and Sc concentrations. From 55-35 kyr BP, low inorganics (<7%) and elemental concentrations coincide with rainforest vegetation in the vicinity of the crater, which reduced catchment soil erosion. The low catchment influx allows a long-range dust signature to be distinguished in this section of the deposit, as indicated

by increased As and V concentrations. Leading up to the Holocene (~35,000-10,000 kyr) the influence of dust may be still present but local sources become more dominant. During the Holocene lithogenic and chalcophile influx decreases significantly and coincides with the lowest ash values (~4%) indicating that little weathering of the catchment soils occurred during this period. This interpretation is supported by previous pollen studies that show established rainforest vegetation at this time.

Within the minerotrophic section of Lynch's Crater, several layers with abundant sponge spicules, diatom fragments and detrital quartz occur indicating high algal and protista productivity that signal high water tables and standing water. These layers are characterised by high (up to 50%) ash yield that further indicate persistent flooding of Lynch's Crater deposits and signal a change in the precipitation regime in North Queensland, Australia. High ash yield layers are synchronous with high biogenic silica, high Si/Al ratios, high Cyperaceae/Poaceae ratios, heavier $\delta^{15}N$ isotopes and low C and O concentrations. These intervals span the following periods: 34-37 kyr, 28-30 kyr, 22-25 kyr, 14.5-16 kyr, 12.5-13.5 kyr and 8.5 kyr which are contemporaneous with Heinrich events, the Younger Dryas and the 8.2 kyr event, all of which are characterised in the Northern Hemisphere as abrupt climate events. These layers also provide evidence for an extended southward migration of the Intertropical Convergence Zone (ITCZ) in the Southern Hemisphere Pacific region during major climate perturbations of the last 55 kyr. This interpretation is supported by a general circulation model (GCM), which shows a southward propagation of the ITCZ in response to a Heinrich like simulation where freshwater forcing is applied in the North Atlantic. The record provides insight into climate shifts in the Southern Hemisphere and more specifically the western Pacific Ocean during these millennial-scale climate perturbations in the low latitudes.

Post-depositional remobilisation of elements occurs within the peat deposit and provides evidence of previous environmental conditions of the peat ecosystem. Concentration profiles of Ca, Mg, Sr, Fe and S show a change between high values in the minerotrophic and low values in the ombrotrophic section of the mire, this is primarily a result of groundwater influence in the minerotrophic deposits. In addition small enrichments are associated with some of the interpreted wet events and indicate increased input of Ca, Mg, Sr, Fe and S cations from the catchment. The study also shows post-depositional diagenetic response of Mn that is regulated by Eh-pH conditions and results in increasing Mn concentrations with depth, where conditions generally become more anoxic and alkaline.

To date, research into historical distribution of halogens in peat has been limited, yet some studies have assumed Cl to be conservative in peat thereby reflecting changes in the halogen concentrations of rainwater. The present study also suggests that Cl variations in Lynch's Crater reflect a high-resolution record of precipitation change over the past 55 kyr. At Lynch's Crater the Cl concentration profile shows a remarkable similarity to the vegetation and precipitation phases suggested by pollen analysis from the area. Stable C isotope values show some similarity to that of the Cl record and indicate changes within the soil moisture regime. Lynch's Crater shows similarities to other Australian paleo-precipitation records, for example increased Cl values coincide with the early Holocene and also possible periods of intense monsoon activity between 42-55 kyr. During most of the late Pleistocene (~18-30 kyr) however, low Cl concentrations indicate dry conditions across the Tablelands and possibly throughout NE Australia. It is possible that the Cl record shows increased precipitation in the tropics associated with warm periods know as Dansgaard-Oeschger cycles generally recorded in high northern latitudes. Here a detrended Cl concentration profile displays a remarkable resemblance to the oxygen isotope records from the Greenland Ice Core Project, implying the presence of a global climate signature in the Southern Hemisphere tropics.

The initial geochemistry investigation of the Lynch's Crater peat cores has uncovered important information on past climate change in the equatorial Southern Hemisphere. Future work would benefit from improved dating techniques allowing better correlation of the deposit with other paleorecords. This may provide answers to important paleoclimate questions, such as 'what is a feedback and what is a trigger of abrupt climate change?'. In addition, geochemical analysis should be undertaken on more samples to obtain higher resolution records for past climatic interpretation and more time must be spent on individual elements that are poorly understood. This is a unique opportunity to study past climate dynamics in an area of the world that is poorly constrained by paleorecords.

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