A 56-ka Pb-isotope record from the southern hemisphere - Lynch's Crater, Queensland, Australia, and its implications for climate change

Fig. 1: Composite photo of Lynch's Crater

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Fig. 2: Damien Kelleher (ANU), the driller at work with the hollow auger drill system on Lynch's Crater.

Introduction

Lead isotopes in peat and sediment deposits are usually utilised to determine the source of lead. A study for example from Asia Pacific (Pettke et al., 2000) demonstrated that despite major weathering and climate changes over the past 12 Ma, the ultimate source of dust, and hence isotopic composition of the aeolian fraction to the north Pacific, did not change. On the other hand, several European peat deposits (e.g. Shotyk et al., 1998) have demonstrated that Holocene Pb-isotopic compositions were much less radiogenic (lower 206/207 ratios) than the Pleistocene background or pre-anthropogenic values and concluded that both climate change and anthropogenic activity changed markedly the global Pb-isotopic signature. Here we present the first Pb-isotopic record from the southern hemisphere from tropical NE-Australia covering the past 2-56 ka.

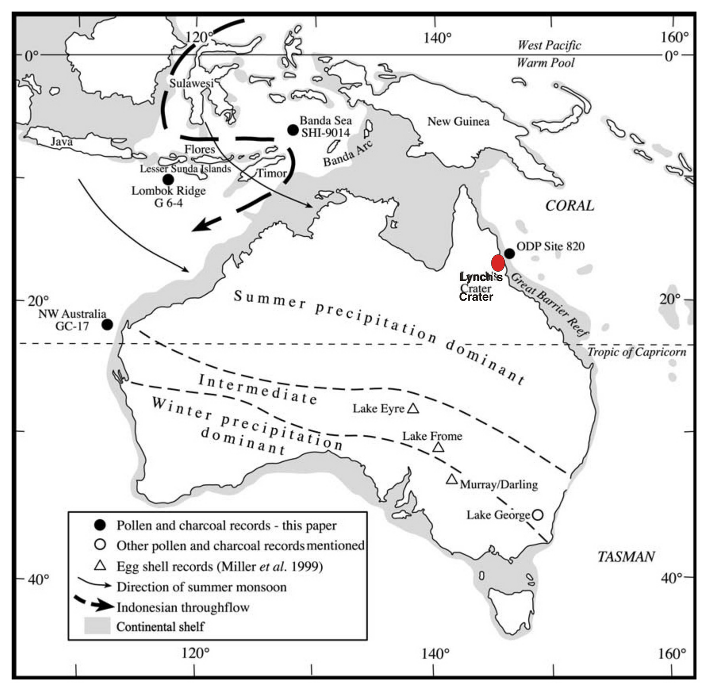

Fig. 3: Location of Lynch's Crater lake record situated in NE-Australia in relation to major geographical features (adapted from Kershaw et al., 2003).

Sample Site and Methods

Lynch's Crater (S17.36615) and E145.68824) is situated on the Atherton Tablelands in NE-Queensland, Australia. The crater is assumed to be over 200,000 years old and is filled with 64 m lake sediments and peat deposits. This study focuses on the top 13 m of the deposit (that represents about 56,000 yrs) which consist of mainly highly humified peat material with few layers with elevated loss on ignition. Sample material was collected utilising a Russian corer. Material for AMS dates was pretreated with HCl-NaOH-HCl and analysed by Accelerated Mass Spectrometry at the Australian Nuclear Sciences and Technology Institute at Lucas Heights, Australia. AMS dates were calibrated using SHCal04 (Stuiver and Reimer, 2005) for the first 10 ka and Fairbanks1204 (Fairbanks et al., 2005) for the older samples. Trace and major elements were analysed using ICP-MS and ICP-AES at the Imperial College London, whilst REEs (HF-NHO3-HClO4-digestion) and Pb-isotopes (HF-HNO3 digestion) were determined at the Natural History Museum London utilising a Q-ICP-MS and Isoprobe MC-ICP-MS, respectively.

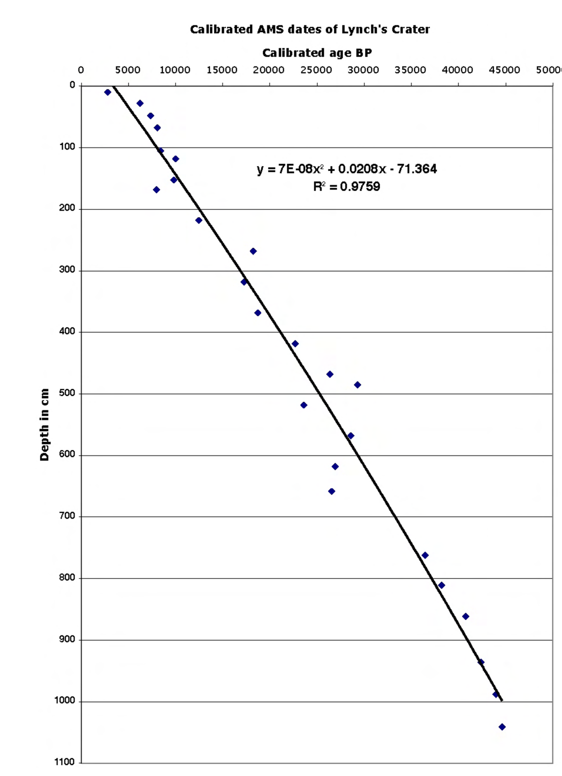

Fig. 4: Calibration curve of Lynch's Crater showing all 25 sample used. The trendline is a second order polnomial line from which the age of the material below 10 m was extrapolated.

Results & Discussion

Lynch's Crater uppermost peat deposits have distinct units based on the LOI (ash) content (A-F), three of which have low values (>38 ka - F, 17-23.5 ka - D, and 4-9 ka -B) characteristic of ombrotrophic settings (Fig. 5). The other units have LOI values of up to 53% that also show elevated Sc contents. These changes occur after H4, H2, and the Younger Dryas (YD) events, respectively. Interestingly, the LOI content and the Sc flux are directly linked to the rapid vegetational changes characterised by the pollen assembles (Kershaw et al., 1993). Between 56-38 ka, Sc and Pb flux were minimal but the PbEF was higher than the core average and the isotopic signature of 206Pb/207Pb was around 1.197, slightly below the average 206Pb/207Pb value of the core of 1.211. A rapid change with increased LOI values and higher Sc and Pb influx is contemporaneously with the observed vegetational changes based on palynological studies (Kershaw et al., 1993) from a rainforest to a mixed rainforest-sclerophyll woodland environment which may have been accompanied by an stronger seasonal climate pattern (e.g. precipitation). During this time, two marked events occurred that have the least radiogenic 206Pb/207Pb values of around 41.7 ka and 38 ka (Fig. 5, 6). Lead flux increased about 3 fold until about 24 ka. Between 24 ka and 10.8 ka Pb flux increased steadily with a culmination during the Younger Dryas event. Then, a reduced flux is followed by the modern, anthropogenic Pb-flux that can be detected in the top 5 cm of the deposit (calendar age <2.8 ka), which is about an eight-fold increase of the values during the Last Glacial Maximum. The record also shows that the Holocene values were in general less radiogenic than the Pleistocene ones, but several events occurred during the Pleistocene that led to the deposition of less radiogenic material at Lynch's Crater, one of them coincides with the timing of H4. Because hort-time climatic changes and resulting dust influx (including es in the Pb-isotopic ratios (Fig. 5, 6).

Fig. 5: Lynch's Crater top 13 m of peat deposits showing LOI, Sc, Pb, Pb/Sc, PbEF and 206Pb/207Pb ratio over the past 60 ka.

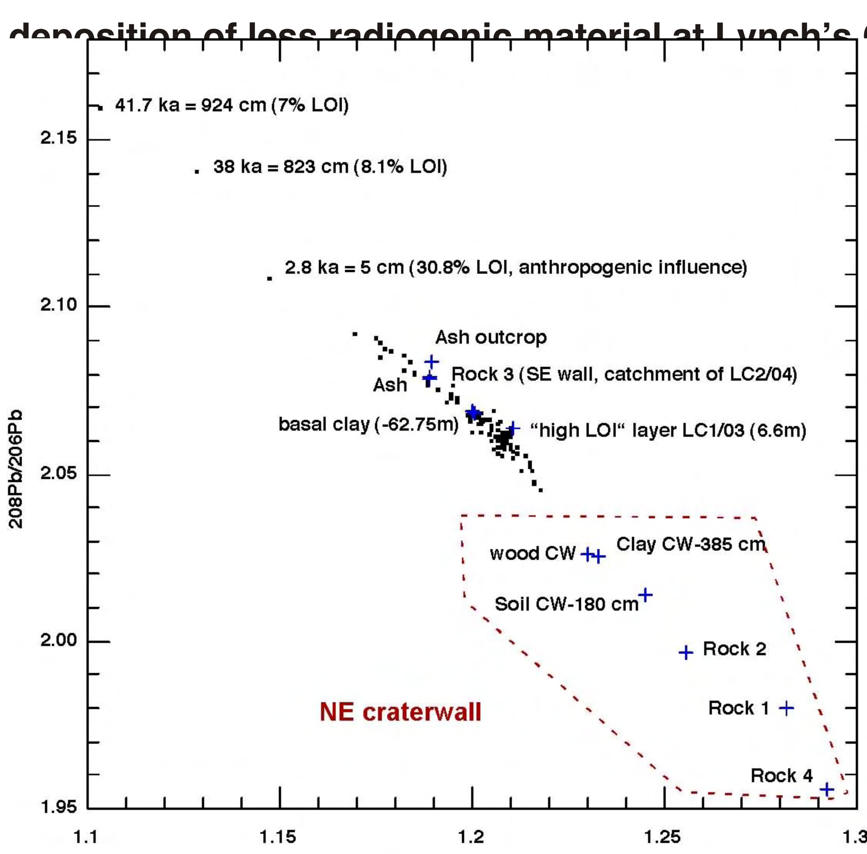

Fig. 6: 206Pb/207Pb ratio vs 208Pb/206Pb ratio of sample material from Lynch's Crater.

The Pb-isotopes show that several events led to the accumulation of peat with a less radiogenic signature in particular during the time between 56 and about 35 ka. Three other marked events occurred around 21.5 ka, 7.8 ka and the value of the uppermost sample (2.8 ka). All these values are less radiogenic than the average or most likely "background" value. Comparisons with analysis of rocks from the vicinity and volcanic ash outcrops demonstrated that rocks from the NE craterwall did not contribute much to the peat deposits, while the southeastern rock outcrops, the ashes and the basal clays (-62.75 m) match the Pb-isotopic signature of the peats. Hence, the influx of the NE part of the crater has been minimal in the past 56 ka. None of the soils or rock outcrops do match, however, the less radiogenic peaks described above and it is hypothesised that an external source is responsible for those fingerprints.

In general, the ratios of 206Pb/207Pb in Lynch's Crater's peat material varies over the last 56 ka mainly between 1.175 to 1.215. These values are comparable to the mid Holocene values from Europe (Shotyk et al., 1998). Several very low radiogenic peaks occur in the deposits which could be due to a strong aeolian contribution. The anthropogenic values of Europe (1.1307) (Shotyk et al., 1998) are, however, very close to the value of the uppermost samples at 5 cm depth (1.147). In conclusion, Pb-isotopic signatures of the peat deposits of Lynch's Crater demonstrate that dust influx and composition changes were most likely the result of changes in regional precipitation and thus vegetation coverage in combination with regional (NE-Queensland, SE-Asia) volcanism. These changes may have been the result of global events that influenced regional precipitation patterns and seasonality.

Comparison with the EPICA ice core record

Comparison with the EPICA ice core record (Vallelonga et al., 2005) demonstrates that the Antarctic dust and the Lynch's Crater peat have a very similar Pb-isotopic composition (Fig. 7). All ice core values over the last 220 ka are within close range to the values of the peat deposits. Again, the least radiogenic peat samples (41,7 ka, 38 ka, 2.8 ka) and the rocks from the NE crater wall show significant differences. In general, the Lynch's Crater Pb-isotope record shows similar values as Antarctica between 56 and 21 ka (Fig. 8). The Antarctic record shows a more radiogenic value around 18 ka during the LGM whilst the Lynch's Crater record remains constant. However, a direct comparison may be difficult because of the large discrepancies of resolution between the two records. In conclusion, both records show similar Pleistocene background values and local climatic events (dust and volcanism) may have contributed to the mixture of the records.

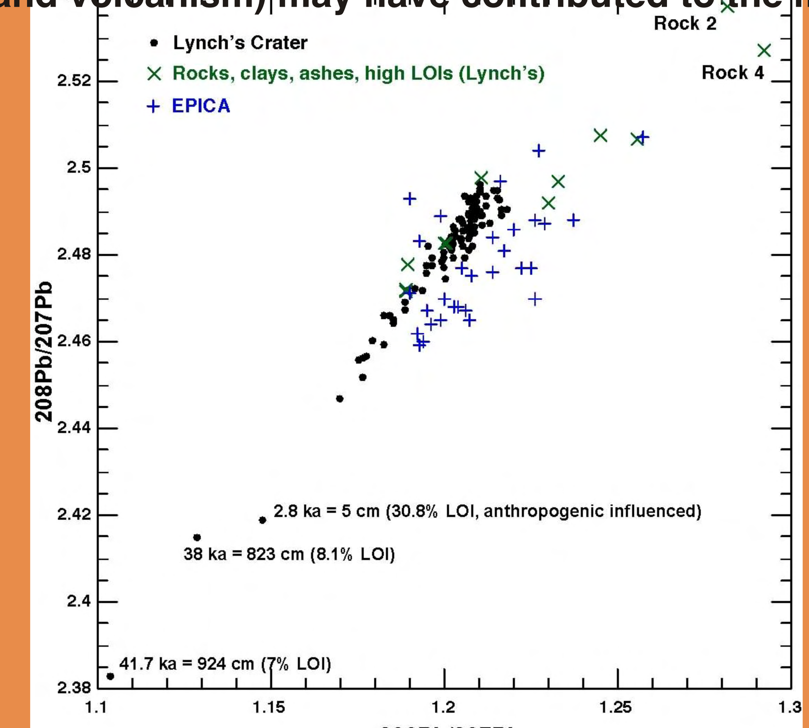

Fig. 7: 206Pb/207Pb ratio vs 208Pb/206Pb ratio of sample material from Lynch's Crater compared with the EPICA ice core record.

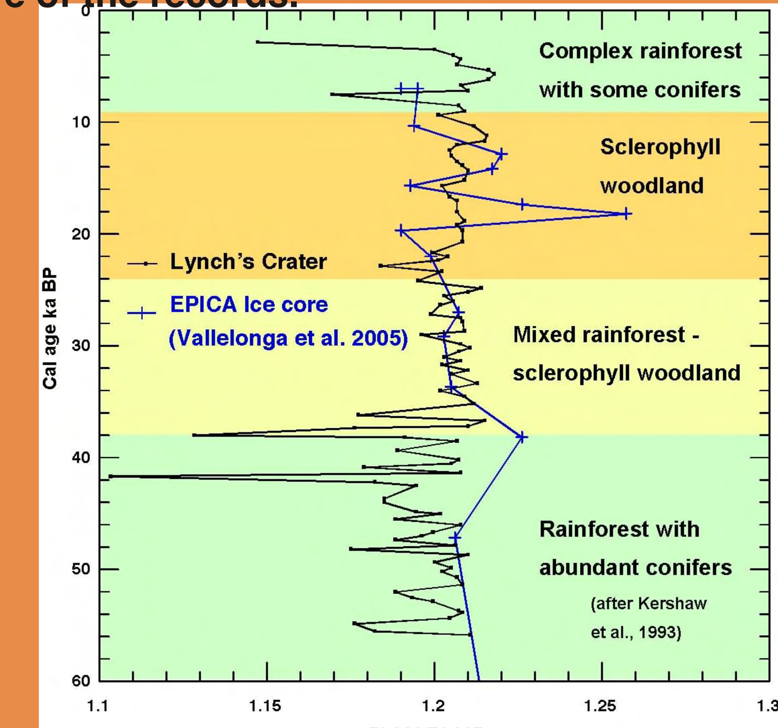

Fig. 8: 206Pb/207Pb ratio vs age of sample material from Lynch's Crater compared with the EPICA ice core record.

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