

Canopy change through the Cenozoic in South Eastern Australia

Thesis submitted in accordance with the requirements of the University of
Adelaide for an Honours Degree in Geology

Benjamin James Birch

November 2015



THE UNIVERSITY
of ADELAIDE

CANOPY CHANGE THROUGH THE CENOZOIC IN SOUTH EASTERN AUSTRALIA

CENOZOIC CANOPY CHANGE

ABSTRACT

Reconstructing canopy closure is difficult, and has up until recently only been done through interpretation of cuticular morphology. However, along with the morphology, isotope characteristics preserved in the leaves have enabled the deduction of the “canopy effect”, and thus the able to reconstruct the closure of ancient forests. Australia has had rich and unique development since its separation from Antarctica and its flora has developed from closed canopy tropical rainforests, of the Eocene, to its open arid hummock grasslands of the present day. To assess the canopy change from the Eocene through to the Miocene, we employed the carbon isotopic data from leaf fragments from two sites, Anglesea (Victoria) from the Eocene, and Kiandra (New South Wales) from the Miocene, and compared them to present day carbon isotopic data of open and closed canopy forests. There were two assessments conducted on the sites, and individual leaf and a dispersed cuticle, to validate whether dispersed cuticle is reflective of single leaf specimens for the deposit. The mean individual leaf values of the fossil sites show that they are significantly more depleted in ^{13}C , resulting in the larger Δ_{leaf} values. Anglesea has a larger mean value at $28.01 \pm 0.52\text{‰}$, with Kiandra having a lower value of $27.45 \pm 0.51\text{‰}$. The range of isotopic values, for the two sites are 6.10‰ and 6.2%. An additional test in Anglesea showed that there is a large influence in the dispersed cuticle from gymnosperms. In Modern closed canopy, tropical rainforests have mean isotopic ranges of approximately 5.8‰, with mean values of 22.59‰. Whereas modern open canopy temperate forests have isotopic ranges of approximately 4.8‰, with mean values of 21.08‰. So, upon inspection the Anglesea and Kiandra sites are both similar to tropical rainforests. An additional study was conducted of dispersed cuticle, across the Eocene-Miocene interval, for 13 sites. The results varied, showing a decrease in canopy structure during the Oligocene from the Eocene, followed by the closed canopy Miocene.

KEYWORDS

Canopy closure, Australia, Cenozoic, Anglesea, Kiandra, Stable isotope geochemistry

TABLE OF CONTENTS

| | |
|--|----|
| Canopy change through the Cenozoic in South Eastern Australia..... | i |
| Cenozoic Canopy change..... | i |
| Abstract..... | i |
| Keywords..... | i |
| List of Figures and Tables..... | 3 |
| Introduction..... | 5 |
| Previous Geological and Palaeobotanical studies..... | 13 |
| Methods..... | 17 |
| Sampling method..... | 17 |
| Isotopic analysis..... | 18 |
| Carbon discrimination..... | 19 |
| Atmospheric CO ₂ δ ¹³ C reconstructions..... | 20 |
| Results..... | 20 |
| Individual leaf measurements..... | 20 |
| Dispersed cuticle measurements..... | 25 |
| Acidification test..... | 28 |
| Discussion..... | 29 |
| Individual leaf..... | 29 |
| Dispersed cuticle..... | 33 |
| Conclusions..... | 37 |
| Acknowledgments..... | 38 |
| References..... | 38 |
| Appendix A: Supplementary Data..... | 43 |
| Anglesea..... | 43 |
| Kiandra..... | 45 |
| Nelly Creek <i>Myrt</i> TEst..... | 47 |
| Dispersed cuticle..... | 48 |
| Appendix C: Complete Procedure..... | 49 |
| Pilot study..... | 49 |
| Anglesea experiment..... | 50 |
| Kiandra experiment..... | 51 |
| Dispersed cuticle experiment..... | 52 |

LIST OF FIGURES AND TABLES

| | |
|--|----|
| Table 1: Definitions for the different climate variable found in the text, adapted from Macphail (2007). | 13 |
| Table 2: Summary of literature for the sites used in this study, including species found (both angiosperm and gymnosperm), deposit description, elevation above seawater, depositional environment. * indicates that the age of the site was identified through palynology means. ** indicates that the age of the site was identified through isotopic (K-Ar) dates for an overlying basalt or igneous event. The symbols for each of the sites correspond to the dispersed cuticles figures..... | 14 |
| Table 3: Summary of literature for the sites used in this study, regarding the flora of the. Notes: percent of gymnosperm taxa, uses the palynology of microfossils not macrofossil,, reproduced from Macphail, (2007). The symbols and colour for each of the sites correspond to the dispersed cuticle sites for all figures..... | 15 |
| Figure 3: The fossil sites, from oldest to youngest, the colours correspond to the sites list both here and in tables 2 and 3. Ages produced from either radiometric dating from overlying basalts, or through biostratigraphy (palynology) dating. | 16 |
| Table 5: showing the t-test results between the different samples. Significance is at $P < 0.05$. Anglesea Angiosperms (AA), Anglesea Gymnosperms (AG), Anglesea Dispersed Cuticle (AC), Kiandra Angiosperms (KA), Kiandra Dispersed Cuticle (KC), Nelly Creek Angiosperms (NCA) percentage of gymnosperm taxa (%G), dispersed cuticle sites (DC)..... | 22 |
| Figure 6: Both individual leaf Δ_{leaf} for angiosperms, gymnosperms as well as Δ_{leaf} for dispersed cuticle, Anglesea and Kiandra. The Anglesea angiosperms and gymnosperms reflect the offsets shown in modern day angiosperms and gymnosperms shown by (Diefendorf et al., 2010). Dispersed cuticle samples, for Anglesea and Kiandra, have a sample size of 10, with Anglesea and Kiandra angiosperms have samples ~50 each, with Anglesea gymnosperms having a size of 20. The fossil sites represent the mean $\delta^{13}C_{leaf}$ value for the benthic foraminifera atmospheric proxies. The mean Δ_{leaf} values of two modern day forests, seasonal and tropical, reproduced from Graham et al (2014). These two forests represent the different canopy structures; the seasonal characterizes the open canopy forests, with the tropical the closed forest, reproduced from the Graham et al (2014) model for the sample size of 50. Diefendorf et al (2010) forest biome types are also include, which range from tropical rainforest (TRF), evergreen warm moist forest (EWMF), tropical seasonal forest (TSF), and cool cold deciduous forest (CCDF). These forests show possible modern day analogues, for the different forest types. | 23 |
| Figure 7: Isotopic ranges, the modern day forests, tropical and seasonal, (Graham et al, 2014) returned by 2000 iterations of the resampling model for the discrete sample size of 50, expressed as a boxplot, for maximum and minimum values, generated by the Graham et al (2014) model. The fossil sites have not been resampled, and are expressed as mean lines. Anglesea gymnosperms have a sample size of 20, the other sample, types have sample sizes of 50. Figure is arranged from the recent sites, the seasonal and tropical forests, to the Eocene, Anglesea, and finally the Miocene site, Kiandra. | 24 |
| Figure 8: The percentage of gymnosperm taxa of each site, shown in table 3, observed in the literature compared to the corresponding Δ_{leaf} values. The colours indicate site, also shown in tables 2 and 3. The symbols indicate whether the values recorded from palaeobotanical studies or calculated using equation 2. The squares symbols are for the two fossil sites: Anglesea and Kiandra, which had the gymnosperm abundances calculated; the diamonds are the palaeobotanical. | 25 |
| Figure 9: The fossil sites span 52Ma (Eocene) to approximately 16Ma (Miocene), with each of the colours representing the different sites, shown in table 2 and 3. The dashed line indicates an inferred trend the data follows. (a) Shows the mean dispersed cuticle Δ_{leaf} values across the ages span. The benthic foraminifera was used for the atmospheric reconstruction in the Δ_{leaf} values, range of the age indicates the possible ages of each site, whereas the Δ_{leaf} range shows the atmospheric variability in the reconstruction across the age. (b) Shows the percentage of gymnosperm taxa change also shown in table 3. The percentages of gymnosperms taxa, reproduced from (Macphail, | |

2007), is hard to distinguish as some fossil sites have very low abundances of gymnosperms. (c) Shows the estimated temperature from the dispersed cuticle sites, described in tables 1 and 3. These estimates are placed into categories, from microthermal to megathermal (for definitions see table 1), and represent the error in the temperature. Most of the dispersed cuticle sites have an estimated climate associated with them, see table 3 (Macphail, 2007)..... 27

Figure 10: Comparison of acidic treated and untreated *Myrtaceae* leaves from Eocene leaves in Nelly Creek. The blue indicates treated, and the orange represents the untreated. Each sample represents one lead that has been measured for bulk carbon twice, once treated with acid and once without, this was to remove any morphological / taxa bias, used to assess possible contamination in fossil leaves..... 28