EARTHSCIENCES

Palaeoecology and palaeophysiology of early flowering plants from the mid Cretaceous of West Greenland

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Key words:	Cretaceous, angiosperms, climate, evolution, ecology, geochemistry, palaeobotany
Research theme(s):	• Oceanography, Climate and Palaeoenvironment • Palaeobiology and Evolution
Eligible courses for this project:	• DPhil in Earth Sciences • Environmental Research (NERC DTP) • Interdisciplinary Bioscience (BBSRC DTP)

Overview

Darwin referred to the appearance in the Cretaceous of flowering plants (angiosperms) in the fossil record as 'an abominable mystery', because it happened so long after the establishment of terrestrial floras and faunas in the late Paleozoic. Angiosperms originated in the early Cretaceous from gymnosperm ancestors that are now extinct, and diversified in the Late Cretaceous to early Cenozoic in a time interval that has been coined as the 'Angiosperm Terrestrial Revolution' (Benton et al., 2022). Today, angiosperms are the most abundant and dominant plants on the planet yet the nature and processes of their origins, diversification and geographic radiation are still poorly understood.

The Angiosperm Terrestrial Revolution was important not just in establishing the modern global floral composition but may also have impacted on carbon cycling and climate through the assumption that early angiosperms had greater net productivity and higher water use efficiency than the gymnosperms they replaced. However, the opportunity to quantify the effect of angiosperms on local ecosystems and depositional environments has generally been lacking and there have been few studies that have been able to directly compare the palaeophysiology of angiosperms and gymnosperms from the same flora.

The geochemistry and characteristics of fossils leaves (in particular their stomata) are sensitive to changes in pCO_2, climate and environment (Franks et al., 2014; Schlanser et al., 2020; Jahren and Schubert, 2024). New approaches have recently been developed that allow the quantification of palaeophysiology, productivity and characterisation of biomes from the geochemistry and traits of fossil leaves (e.g. Kipp et al., 2024; McElwain et al., 2024). Applying such techniques to both gymnosperms and angiosperms from the same stratigraphic section would allow a detailed reconstruction of the palaeoecology and

palaeoenvironment that would allow the determination of the role different plant types were playing during the early evolution of the angiosperms. This would provide a test of the different ideas about angiosperm origins and diversification.

The floras of the Cretaceous Nuussuaq Group of West Greenland have long been known for their spectacular preservation (see Dam et al., 2009 for general introduction) and for recording some of the earliest angiosperms found in the mid to high latitudes. Macrofossils and bulk rock from which cuticles can be extracted have been previously collected and are stored in Oxford, presenting an ideal opportunity to examine, in a single location, the function and effect of early angiosperms as they diversified and replaced gymnosperms.

Figure showing ~100 million year old fossil leaf from the Nuussuaq Basin, West Greenland

Methodology

This project will collect stable-isotope ($\delta^{13}C$, $\delta^{15}N$) and elemental (C, N) geochemical data from individual leaf fossils alongside measurements of stomatal and leaf characteristics. With this data it will be possible to characterise the palaeophysiology and palaeoecology of early Cretaceous angiosperms and gymnosperms and consider the role each was playing within a mid-latitude ecosystem. Training will be provided in geochemical (mainly in Oxford) and palaeobotanical (mainly in Dublin) methods. The project would suit a student with interests in palaeoenvironments, palaeobotany and palaeoclimates and with undergraduate training in botany or geosciences.

Timeline

Year 1: Introduction to sample collection, training in Oxford in geochemistry and initial training in Dublin in palaeobotanical methods.

Years 2 and 3: more extended training in Dublin and data collection.

Year 4: Data integration, thesis completion, papers for international journals/conference presentation.

Training & Skills

The student will develop skills in stable-isotope geochemistry, fossil plant preparation and imaging with fluorescence microscopy, data analysis and scientific writing.

References & Further Reading

Benton, M.J., et al., (2022), The Angiosperm Terrestrial Revolution and the origins of modern biodiversity. *New Phytol*, 233: 2017-2035. https://doi.org/10.1111/nph.17822

Dam et al., (2009), Lithostratigraphy of the Cretaceous–Paleocene Nuussuaq Group, Nuussuaq Basin, West Greenland; GEUS Monograph, https://doi.org/10.34194/geusb.v19.4886

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Jahren, A.H., Schubert, B.A. Plant response to decreasing soil moisture under rising atmospheric CO_2 levels. *Commun Earth Environ* 5, 412 (2024). https://doi.org/10.1038/s43247-024-01576-4

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McElwain, J.C., et al., (2024), Functional traits of fossil plants. New Phytol, 242: 392-423. https://doi.org/10.1111/nph.19622

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Further Information

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