2006

The character and genesis of pedogenic calcrete in southern Australia

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The Character and Genesis of Pedogenic Calcrete in Southern Australia

**A thesis submitted in fulfilment of the requirements for the award of the degree*

DOCTOR OF PHILOSOPHY

from

UNIVERSITY OF WOLLONGONG

by

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School of Earth and Environmental Sciences

March 2006

Certification

I, Paul Grevenitz, 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 except where otherwise acknowledged. The document has not been submitted for qualifications at any other academic institution.

Paul Grevenitz
March 2006

Abstract

Pedogenic calcrete profiles from temperate, semi-arid and arid regions of southern Australia show a diversity of forms, both in large-scale structure and texture determined in the field, and microstructures as determined by thin-section and scanning electron microscopy. Accumulations of microcrystalline calcite with varying degrees of cementation are typical of the majority of samples regardless of texture or form. Calcified filaments are prevalent at a micro-scale in the upper sections of most profiles, occurring as laminated coatings and channel infillings in hardpan calcrete, pisoliths and nodules. Organic matter occurring as filamentous and dendritic masses is commonly found associated with the calcified filaments and the formation and growth of the filaments are considered to cause the brecciated and pisolitic textures common in mature pedogenic calcrete.

Rhizogenic calcrete occurs in various host materials as taproot fragments with either dense grey micritic cement and microspar crystals which are larger adjacent to enclosed quartz grains, mottled dense micritic and microsparitic calcrete or alveolar-like fabrics. Root-formed channels are also prevalent in many indurated nodular and hardpan samples. Discrete and incipient calcrete nodules containing alveolar fabrics and microcodium grains and platy pedogenic calcrete containing fenestral microfabric were also observed. Needle-fibre calcite is present as the dominant component in some profiles, occurring as discontinuous semi-indurated channel fillings and sheets. The morphology of their occurrence suggests rhizogenic influence in their formation.

The collected samples are analysed for stable carbon and oxygen isotopic composition in order to determine if there are detectable differences across regions of different climate and host material. Many samples show within-sample variability with biogenic or rhizogenic features co-existing with micritic overgrowths and cements. In order to examine the relationship between pedogenic calcrete type and method of formation, carbon and oxygen isotopic measurements were taken from numerous sub samples within each sample to determine the extent of variation in isotopic composition within individual samples. The total spread of values is -1.0 to -12.5% and 2.0 to -10% (standard delta notation versus PDB) for carbon and oxygen isotopic composition, respectively, for all samples with large sample variation and positive co-

variation as displayed by multiple sample aliquots commonly observed. The results suggest within-sample variation caused by different and coexisting cement types, with contribution of heavy carbon by calcified filaments and carbonate precipitated through carbon dioxide degassing, and light carbon contributed by rhizogenic influences. The positive co-variation in carbon and oxygen is not depth related and indicates a simple mixing line between two end-members with differing isotopic compositions, possibly due to concomitant evaporative enrichment and carbon dioxide degassing in different carbonate cement phases. Soil organic matter carbon analysed for isotopic composition shows relative little variation across the climatic zones and no correlation with coexisting carbonate carbon isotopic composition.

Selected pedogenic calcrete samples developed in soils overlying radiogenic basement rocks from sites in arid and semi-arid western South Australia and Western Australia are analysed for 87Sr/86Sr in order to evaluate the contribution of calcium derived from silicate weathering to pedogenic calcrete. Fresh parent materials collected at the sites show 87Sr/86Sr ratios ranging from 0.7100 to 0.7993 and pedogenic calcrete 87Sr/86Sr ratios ranging from 0.7106 to 0.7198. Samples from sites in coastal and inland South Australia have 87Sr/86Sr ratios close to marine values (0.8093) indicating low calcium contribution from bedrock. Samples from Western Australia have variable and higher 87Sr/86Sr ratios indicating considerable calcium input for parent material and bedrock.

Whole rock pedogenic calcrete and host material sampled in profiles were analysed by X-ray diffraction to determine mineralogical composition and then determine relative changes in carbonate composition within the profile. Samples were further analysed by instrumental neutron activation analysis for a suite of major and trace elements and subjected to a variety of statistical tests to determine the phase relationships of the elements to each other and, in particular, calcium within the pedogenic calcrete profile. Most elements are found to be associated with residual phases such as clay, feldspar and iron oxide correlation to calcium, in some samples, and therefore are of possible interest in geochemical exploration as pathfinder elements in the search for buried ore deposits.

Acknowledgements

Certain scientific and technical aspects of this thesis would not have been possible without the expertise of the following people at the School of Earth and Environmental Sciences, University of Wollongong, Australia. As such, I wish to thank the following people for t heir assistance in developing my skills and helping me to accomplish the work that is this thesis.

David Carrie for his help and guidance in preparing samples for thin section and scanning electron microscope analysis. David Wheeler for his assistance with the stable carbon and oxygen isotopic analyses. Richard Miller for his help with drafting the diagrams and Stephen Barry for helping me learn and understand computer programming and also for assisting in other computer problems that I have so regularly experienced through the course of this thesis. Also I would like to thank Professor Allan R. Chivas for his academic guidance and for giving me direction in my research.

Outside of the University of Wollongong several people have assisted scientifically and technically. Graham Mortimer at the Australian National University spent significant effort to show me how to prepare samples and run the ICP-MS for strontium isotopic analysis and Ravi Anand from CSIRO, Kensington, Western Australia, spent time in the field showing the location of many interesting sites in the Western Australian goldfields region. An Australian Postgraduate Award, two AINSE grants and two Society of Economic Geologists Student Grants kindly granted funding for the research.

Most of all I would like to thank my long suffering partner Angela Reeves for her patience and understanding though the course of this degree.

Table of Contents

Table of Contents

List of Figures

List of Tables

List of Plates

Table of Contents

Table of Contents