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Cooperative Research Centre for Landscape Evolution & Mineral Exploration

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OPEN FILE REPORT SERIES

CRC LEME OPEN FILE REPORTS 120-143: ABSTRACTS, INDEX AND DATABASE

Covering CSIRO-AMIRA Research Project: "Geochemical Exploration in Regolith-dominated terrains, North Queensland" (P417)

I.D.M. Robertson

CRC LEME OPEN FILE REPORT 119

May 2002

(CSIRO Exploration and Mining Report 940F)

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CRC LEME is an unincorporated joint venture between CSIRO-Exploration & Mining, and Land & Water, The Australian National University, Curtin University of Technology, University of Adelaide, University of Canberra, Geoscience Australia, Bureau of Rural Sciences, Primary Industries and Resources SA, NSW Department of Mineral Resources-Geological Survey and Minerals Council of Australia.
Headquarters: CRC LEME c/o CSIRO Exploration and Mining, PO Box 1130, Bentley WA 6102, Australia

CSIRO/CRC LEME/AMIRA PROJECT P417
GEOCHEMICAL EXPLORATION IN REGOLITH-DOMINATED TERRAIN, NORTH QUEENSLAND 1994-1997

In 1994, CSIRO commenced a multi-client research project in regolith geology and geochemistry in North Queensland, supported by 11 mining companies, through the Australian Mineral Industries Research Association Limited (AMIRA). This research project, "Geochemical Exploration in Regolith-Dominated Terrain, North Queensland" had the aim of substantially improving geochemical methods of exploring for base metals and gold deposits under cover or obscured by deep weathering in selected areas within (a) the Mt Isa region and (b) the Charters Towers - North Drummond Basin region.

In July 1995, this project was incorporated into the research programs of CRC LEME, which provided an expanded staffing, not only from CSIRO but also from the Australian Geological Survey Organisation, University of Queensland and the Queensland Department of Minerals and Energy. The project, operated from nodes in Perth, Brisbane, Canberra and Sydney, was led by Dr R.R. Anand. It was commenced on 1st April 1994 and concluded in December 1997. The project involved regional mapping (three areas), district scale mapping (seven areas), local scale mapping (six areas), geochemical dispersion studies (fifteen sites) and geochronological studies (eleven sites). It carried the experience gained from the Yilgarn (see CRC LEME Open File Reports 1-75 and 86-112) across the continent and expanded upon it.

Although the confidentiality period of Project P417 expired in mid 2000, the reports have not been released previously. CRC LEME acknowledges the Australian Mineral Industries Research Association and CSIRO Division of Exploration and Mining for authority to publish these reports. It is intended that publication of the reports will be a substantial additional factor in transferring technology to aid the Australian mineral industry.

This report (CRC LEME Open File Report 119) is a first impression (first printing) and did not form part of the output of the above research project. However, it contains abstracts of reports from the above research project.

Copies of this publication can be obtained from:
The Publication Officer, c/- CRC LEME, CSIRO Exploration and Mining, P.O. Box 1130, Bentley, WA 6102, Australia.. Information on other publications in this series may be obtained from the above or from http://leme.anu.edu.au/
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PREFACE

This report presents an index of the 24 reports written for the CSIRO/LEME-AMIRA research project 'Geochemical exploration in regolith-dominated terrains, North Queensland (P417)'. The index and its contained database have been assembled to complement the re-issue of the reports from this project in the CRC LEME Open File Report series and to provide easy access to the large volume of information contained therein. It is hoped that this index will maximise the usefulness of these reports.

R.R. Anand

Project Leader

I.D.M. Robertson

Deputy Project Leader

April, 2002

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INTRODUCTION

This index covers 24 CRC LEME Open File Reports originally issued by the CSIRO-AMIRA and CRC LEME/AMIRA research project P417 'Geochemical exploration in regolith-dominated terrains, North Queensland'. This index volume provides a comprehensive and searchable guide to these reports. In addition, the data supplied on magnetic disc with individual reports has been recompiled on CD because of the limited life of magnetic media.

HISTORY

Issues addressed

Extensive, variable and, in places, thick regolith is a major impediment to mineral exploration in large areas of northern Queensland, as in many parts of Australia. Deep chemical weathering, erosion and sedimentation have concealed ore deposits in the underlying rocks. Their geological, geochemical and geophysical expression is greatly altered, weakened or buried. The Mt Isa Region and the Charters Towers - North Drummond Basin Region host numerous base-metal and gold deposits and have a long history of mineral exploration and production. These regions have been effectively explored by traditional geological methods, i.e., mapping and sampling of outcropping bedrock. Exploration is now targeting mineralisation under deeply weathered or transported cover. Regolith geochemical models, successfully used in areas lacking thick cover, are of reduced value where multiple cycles of deposition and weathering have occurred. Thus it is necessary to understand the influences that landscape evolution and weathering have had on element dispersion into the regolith, and to use this to guide geochemical exploration.

Up to the time of this research, there had been few regolith-landform investigations in the above regions, hence little to guide geochemical investigations. In the Mt Isa Region, the regolith includes saprolitic profiles, areas of cover within outcropping terrain and areas of Cambrian, Mesozoic, Tertiary and Cainozoic cover. Some Cambrian and Mesozoic sediments contain strongly anomalous element concentrations. There was difficulty in distinguishing *in situ* from transported materials and difficulties in distinguishing gossanous materials from partly dismantled duricrust. A variety of sedimentary cover sequences are widespread in the Charters Towers - North Drummond Basin Region and these had attracted considerable interest as potential sample media.

The research

To address these problems, a research project was proposed to the Australian Minerals Industry Research Association (AMIRA) by CSIRO. This was to study the regolith-landforms and the geochemical dispersion consequences of the weathering and its interaction with the landscape. The research commenced on 1st April 1994. In July 1995, this project was incorporated into the research programs of CRC LEME, which provided extended staffing, not only from CSIRO but also from the Australian Geological Survey Organisation (now Geoscience Australia), the University of Queensland and the Queensland Department of Minerals and Energy. The project operated from nodes in Perth, Brisbane, Canberra and Sydney and was concluded in December 1997 with the issue of the Final Report.

The objectives

The overall aims of this research was to substantially improve methods of exploring for base metals and gold under cover or obscured by deep weathering in selected areas within the above two regions. This was achieved by establishing sound operational procedures in the two regions from a number of case studies. From these, geochemical dispersion models were constructed and optimum geochemical sampling media were identified and characterised.

Regolith mapping methods were optimised to control exploration geochemical surveys and the research findings were transferred to the eleven sponsoring companies through the project reports indexed herein, review meetings and field excursions.

This project represented collaboration between the mineral industry and research providers in a multi-disciplinary program of geoscience research aimed at developing new and improved geological and geochemical methods for exploration in deeply weathered parts of Australia. This initiative recognised the unique opportunities, created by exploration and open-cut mining, to conduct detailed studies in the weathered zone.

Confidentiality and release of information

The Final report for P417 was issued in December 1997. Although the confidentiality period of the research project expired in mid 2000 the results have not been made public until recently. This was achieved by publishing the reports through the CRC LEME Open File Report Series. By making available the results of the research and the authors' interpretations, it is hoped that the reports will provide source data for future research and be useful for teaching. It is intended that publication of the reports will be a substantial additional factor in transferring technology to aid the Australian mineral industry. Some of this research has been and is being released as papers in various scientific journals and at conferences (see list of papers).

The reports

Of the 24 reports, the most important for obtaining an overview of the research is the final report (Open File Report 120). Useful reference information may be obtained on regolith materials from the atlas (Open File Report 136). The remaining reports cover site investigations and some general studies, which provide the scientific foundations of the atlas and final report. Two field guides, issued to sponsor representatives during well-attended field trips, assisted with technology transfer to industry. What cannot be represented here were the numerous technical presentations and workshops given to the sponsors in general.

The relationship to CRC LEME and the report numbering systems

The project was initiated by CSIRO Exploration and Mining. Early in the project, CRC LEME commenced. This project was incorporated into the research programs of CRC LEME as its broad objectives, among others, were to: -

- Establish a framework to promote greater understanding of the three dimensional evolution of the Australian landscape by integrating geomorphic, geological and geochemical processes and concepts;
- Translate this knowledge into a greatly improved ability to recognise major mineral deposits in provinces of strategic importance to the Australian mineral industry.

These CRC LEME objectives were in line with the objectives of this research project. It was proposed to the sponsoring group that CRC LEME would take over scientific management of this project, bringing with it the skills and resources of the other core parties. This was agreed to by the sponsors.

The consequence of all this were two report numbering systems, a CSIRO Exploration and Mining report numbering system for the early reports published before July 1995 and a dual CRC LEME and CSIRO report numbering system for subsequent reports.

All reports now have CRC LEME Open File Report numbers and it is this numbering system which is used throughout this index volume. The CRC LEME Open File Report series has been given a single series ISSN number (1329-4768). Individual ISBN numbers have been allocated to each report volume and another number has been allocated to sets of volumes for multi-volume reports.

Report preparation and replication
As much care as possible has been taken with this re-issue, using original material wherever possible; however, in some instances, original material could not be located so copies were used instead.

INDEX

This index volume consists of maps showing the locations of the study sites. There were two regions, one around Mt Isa and the other around Charters Towers and the North Drummond Basin. It also contains listings of the reports sorted by LEME Open File Report Number and by the various CSIRO and LEME Restricted Report numbers, by project, by author and by report type.

Maps
Maps have been prepared to show the locations of the investigation sites in the two regions, and the LEME Open File report numbers to which they refer, projected on Queensland bedrock geology (Figures 1 and 2).

Listings
Listings, sorted by LEME Open File Report Number, by CSIRO Report Number and by CRC LEME Restricted Report Number, give the report title, authors, report numbers, original issue date, LEME Open File issue date, and the approximate latitude and longitude of the study site. Brief listings have also been prepared by authors, report type (indicating atlases, final and summary reports, general studies, field guides, site studies, and specialist studies such as geochronology).

Index
An index has been prepared from a document of combined titles, authorship and abstracts. Using the full text of the reports for indexing would have been preferable but this was all that could be achieved in the time available and serves as an introduction. This index lists selected subjects by LEME Open File Report numbers.

Compilation of abstracts
A listing of abstracts is included for reference and allows the suitability of any report to be investigated further. The majority of the reports have abstracts but, where reports did not contain abstracts, the executive summary or preface has been used.

Databases and searchable files
During assembly and publication of the Open File reports, a database was produced to control the publication process. Apart from authorship, titles, report numbers, dates of original and subsequent publication, library cataloguing information and geographic coordinates, this included an abstract of each report. The original reference is also supplied. This database has been merged with the database of P240, P240A, P241, P241A, P252 and P407 and other CRC LEME Open File Reports, to give a combined database of Open File LEME regolith research. This allows more sophisticated searches than by using the index only.

The database has been supplied as a 'runtime module' that can be used independently of the user's software and may be found on the CD at the back of the volume. It was compiled in *FileMaker Pro* for both the Windows and Macintosh platforms and can be launched as any normal application. All fields in the database have been secured. The reader is advised to read the licensing agreement carefully as breaking of the seal on the CD implies the reader's agreement to its terms. A brief tutorial on the use of *FileMaker Pro* is included at the back of this report.

Geochemical data

Geochemical data have been supplied with some reports on 3.5" magnetic data discs and on CD. Data supplied on magnetic disc has a limited life of some 2-6 years. All the data supplied on 3.5" magnetic discs for Project P417 have been recompiled here and stored on the same CD as the databases and searchable files. This does *not* include data already stored on CD in the reports. The disc is written in ISO format and the data files are in DOS format (some as ASCII files) filed in directories with the appropriate CRC LEME Open File Report Number. Files are generally in tab-delimited format. Some have ReadMe files, stating the content and format.

ACKNOWLEDGEMENTS

CRC LEME acknowledges AMIRA International and CSIRO Exploration and Mining for authorisation to publish these reports. It is intended that publication of the reports will be a substantial additional factor in transferring technology to aid the Australian Mineral Industry.

Finding the original material of the 24 reports, making the necessary corrections and alterations, document replication and finishing has not been a small task and would have been impossible without the co-operation of a substantial team, apart from the numerous authors. P. Phillips and C. O'Dea located and assembled the original material and prepared it for replication. A.D. Vartesi and C.R. Steel assisted with artwork, maps and report covers. M. Sell assisted with key-wording and the supply of ISSN and ISBN numbers. Report replication and binding of the reports was by K. Clatworthy (Deluxe Colour & Digital Printing). H. Hink and G.D. Longman copied digital data. J. Forward assisted with GIS work and M. Cornelius and R.R. Anand critically reviewed the text. The Geological Survey of Queensland supplied GIS data for the maps at the end of this volume. Gordon Wilkinson-Cox of Enrich Computer Systems compiled the database into runtime modules. Distribution was by S. Game and J. Campbell. All this assistance is acknowledged with appreciation.

LIST OF REPORTS

Sorted by CRC LEME Open File Report Number

DATABASE OF CRC LEME OPEN FILE REPORTS 120-143 (AMIRA PROJECT 417) ©CRC LEME

CRC LEME O/F ReptNo	Title	Authors	Open File Date	LEME Restricted ReptNo	E&M Restricted ReptNo	Restricted Rept Date	Lats & Longs
120	Geochemical exploration in regolith dominated terrain, North Queensland (CRC LEME - AMIRA P417 Final Report)	R.R. Anand, S.J. Fraser, M.R. Jones, Li Shu, T.J. Munday, C. Phang, I.D.M. Robertson, K.M. Scott, P. Vasconcelos, J.E. Wildman, J. Wilford	February 2000	63R	447R	1997/12	Mt Isa Inlier, Drummond Basin
121	Dispersion into the Southern Cross Formation around the Scott and Cindy Lodes, Pajingo - N.E. Queensland	I.D.M. Robertson	February 2002	65R	449R	1997/12	20°32'S 146°27'E
122	Charters Towers - North Drummond Basin Field Excursion, Field Guide	K. Scott, Li Shu, S. Fraser, I.D. Campbell, R.R. Anand and I.D.M. Robertson	February 2002	11R	286R	1996/07	Drummond Basin
123	Regolith geology and soil geochemistry of the Little Eva Copper prospect, Quamby District, NW Queensland	I.D.M. Robertson, C. Phang and T.J. Munday	April 2002	-	128R	1995/06	20°08'51"S 140°08'39"E

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124	The geochemistry of transported soils and weathered bedrock at Police Creek, Drummond Basin, Queensland - A progress report	K.M. Scott	April 2002	-	157R	1995/07	21°21'30"S 147°23'20"E
125	Regolith-landscape characteristics, evolution and regional synthesis of the Mt Isa Region, Progress Report	R.R. Anand, C. Phang, J. Wilford, J.E. Wildman, Li Shu, I.D.M. Robertson and T.J. Munday	June 2002	01R	158R	1996/04	Mt Isa Inlier
126	Secondary dispersion about the Waterloo polymetallic deposit, Mt Windsor Sub-province, N.E. Queensland	K.M. Scott	April 2002	-	168R	1995/09	20°22'08"S 146°05'56"E
127	Soil, bedrock and profile geochemistry at Police Creek, Drummond Basin, Queensland	K.M. Scott	March 2002	25R	323R	1997/04	21°21'30"S 147°23'20"E

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128	The geochemical discrimination of mineralised and barren ironstones from the Selwyn Au-Cu Deposit, NW Queensland	J.E. Wildman	April 2002	35R	341R	1997/02	21°41'S 140°28'E
129	Alluvial landscapes of the Maronan area, Cloncurry - McKinlay District, Queensland	M.R. Jones	March 2002	45R	374R	1997/04	21°04'S 140°55'E
130	Alluvial landscapes of the Northern Kennedy Gap Area, Mt Isa District, Queensland	M.R. Jones	March 2002	48R	382R	1997/05	20°15'S 139°15'E
131	Regolith-landform characteristics, evolution and implications for exploration over the Selwyn Region, Mt Isa	J.R. Wilford	March 2002	44R	372R	1997/08	21°41'S 140°27'E

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133	The significance of Campaspe-dominated terrains in exploration within the Mt Windsor Sub-province, N.E. Queensland	K.M. Scott	March 2002	58R	422R	1997/09	20°30'S 146°15'E
134	Geochemical dispersion around the Maronan Cu-Au Prospect, N.E. Queensland	I.D.M. Robertson, Li Shu and J. E. Wildman	April 2002	57R	409R	1997/11	21°03'47"S 140°55'21"E
135	Surficial geology around the Eloise Cu-Au Mine and dispersion into Mesozoic cover from the Eloise mineralisation, N.E. Queensland	Li Shu and I.D.M. Robertson	April 2002	56R	405R	1997/11	20°57'30"S 140°58'40"E

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137	A regional overview of the Charters Towers - North Drummond Basin Region: Geomorphic Landform Provinces	S.J. Fraser	March 2002	39R	366R	1997/04	21°S 147°E
138	Regolith-landforms of the Mt Isa Geodynamic Transect	M.R. Dell	June 2002	67R	451R	1998/04	21°S, 139° - 141°E
139	Geochronology of weathering in the Mount Isa and Charters Towers Regions, Northern Queensland	P. Vasconcelos	April 2002	68R	452R	1998/06	Mt Isa Inlier and Drummond Basin

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140	Regolith landform relationships and geochemical dispersion around Tringadee and Brumby prospects, North Queensland	C. Phang, T.J. Munday and J.E. Wildman	April 2002	59R	429R	1997/12	21°51'S 140°49'E
141	Landscape evolution and regolith development over the Mt Coolon Area, Central East Queensland	Li Shu	April 2002	64R	448R	1998/04	21°10'S 147°10'E
142	Mt Isa Field Trip	R.R. Anand, J. Wilford, T.J. Munday, C. Phang, J.E. Wildman and K.M. Scott	April 2002	-	156R	1995/07	Mt Isa Inlier
143	Mineralogical and geochemical aspects of the regolith at the Brahman Au Prospect, Charters Towers area, N.E. Queensland	K.M. Scott and S.J. Fraser	March 2002	60R	434R	1997/12	20°05'06"S 146°01'00"E

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Note: In CSIRO Report Number field :-
1) Leading zeros have been added to facilitate sorting - they are not normally referred to.
2) Numbers without a prefix are Division of Exploration and Mining reports.
3) Numbers prefixed with EG were produced during the tenure of the Division of Exploration Geoscience and are sorted at the end.

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123	Regolith geology and soil geochemistry of the Little Eva Copper prospect, Quamby District, NW Queensland	I.D.M. Robertson, C. Phang and T.J. Munday	April 2002	-	128R	1995/06	20°08'51"S 140°08'39"E
124	The geochemistry of transported soils and weathered bedrock at Police Creek, Drummond Basin, Queensland - A progress report	K.M. Scott	April 2002	-	157R	1995/07	21°21'30"S 147°23'20"E
126	Secondary dispersion about the Waterloo polymetallic deposit, Mt Windsor Sub-province, N.E. Queensland	K.M. Scott	April 2002	-	168R	1995/09	20°22'08"S 146°05'56"E
142	Mt Isa Field Trip	R.R. Anand, J. Wilford, T.J. Munday, C. Phang, J.E. Wildman and K.M. Scott	April 2002	-	156R	1995/07	Mt Isa Inlier

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125	Regolith-landscape characteristics, evolution and regional synthesis of the Mt Isa Region, Progress Report	R.R. Anand, C. Phang, J. Wilford, J.E. Wildman, Li Shu, I.D.M. Robertson and T.J. Munday	June 2002	01R	158R	1996/04	Mt Isa Inlier
122	Charters Towers - North Drummond Basin Field Excursion, Field Guide	K. Scott, Li Shu, S. Fraser, I.D. Campbell, R.R. Anand and I.D.M. Robertson	February 2002	11R	286R	1996/07	Drummond Basin
127	Soil, bedrock and profile geochemistry at Police Creek, Drummond Basin, Queensland	K.M. Scott	March 2002	25R	323R	1997/04	21°21'30"S 147°23'20"E
128	The geochemical discrimination of mineralised and barren ironstones from the Selwyn Au-Cu Deposit, NW Queensland	J.E. Wildman	April 2002	35R	341R	1997/02	21°41'S 140°28'E

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CRC LEME O/F ReptNo	Title	Authors	Open File Date	LEME Restricted ReptNo	E&M Restricted ReptNo	Restricted Rept Date	Lats & Longs
137	A regional overview of the Charters Towers - North Drummond Basin Region: Geomorphic Landform Provinces	S.J. Fraser	March 2002	39R	366R	1997/04	21°S 147°E
131	Regolith-landform characteristics, evolution and implications for exploration over the Selwyn Region, Mt Isa	J.R. Wilford	March 2002	44R	372R	1997/08	21°41'S 140°27'E
129	Alluvial landscapes of the Maronan area, Cloncurry - McKinlay District, Queensland	M.R. Jones	March 2002	45R	374R	1997/04	21°04'S 140°55'E
132	Regolith-landform characteristic, evolution and implications for exploration over the Buckley River - Lady Loretta Region, Mt Isa	J.R. Wilford	March 2002	47R	407R	1997/08	20°S 139°E

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CRC LEME O/F ReptNo	Title	Authors	Open File Date	LEME Restricted ReptNo	E&M Restricted ReptNo	Restricted Rept Date	Lats & Longs
130	Alluvial landscapes of the Northern Kennedy Gap Area, Mt Isa District, Queensland	M.R. Jones	March 2002	48R	382R	1997/05	20°15'S 139°15'E
135	Surficial geology around the Eloise Cu-Au Mine and dispersion into Mesozoic cover from the Eloise mineralisation, N.E. Queensland	Li Shu and I.D.M. Robertson	April 2002	56R	405R	1997/11	20°57'30"S 140°58'40"E
134	Geochemical dispersion around the Maronan Cu-Au Prospect, N.E. Queensland	I.D.M. Robertson, Li Shu and J. E. Wildman	April 2002	57R	409R	1997/11	21°03'47"S 140°55'21"E
133	The significance of Campaspe-dominated terrains in exploration within the Mt Windsor Sub-province, N.E. Queensland	K.M. Scott	March 2002	58R	422R	1997/09	20°30'S 146°15'E

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CRC LEME O/F ReptNo	Title	Authors	Open File Date	LEME Restricted ReptNo	E&M Restricted ReptNo	Restricted Rept Date	Lats & Longs
140	Regolith landform relationships and geochemical dispersion around Tringadee and Brumby prospects, North Queensland	C. Phang, T.J. Munday and J.E. Wildman	April 2002	59R	429R	1997/12	21°51'S 140°49'E
143	Mineralogical and geochemical aspects of the regolith at the Brahman Au Prospect, Charters Towers area, N.E. Queensland	K.M. Scott and S.J. Fraser	March 2002	60R	434R	1997/12	20°05'06"S 146°01'00"E
120	Geochemical exploration in regolith dominated terrain, North Queensland (CRC LEME - AMIRA P417 Final Report)	R.R. Anand, S.J. Fraser, M.R. Jones, Li Shu, T.J. Munday, C. Phang, I.D.M. Robertson, K.M. Scott, P. Vasconcelos, J.E. Wildman, J. Wilford	February 2000	63R	447R	1997/12	Mt Isa Inlier, Drummond Basin
141	Landscape evolution and regolith development over the Mt Coolon Area, Central East Queensland	Li Shu	April 2002	64R	448R	1998/04	21°10'S 147°10'E

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CRC LEME O/F ReptNo	Title	Authors	Open File Date	LEME Restricted ReptNo	E&M Restricted ReptNo	Restricted Rept Date	Lats & Longs
121	Dispersion into the Southern Cross Formation around the Scott and Cindy Lodes, Pajingo - N.E. Queensland	I.D.M. Robertson	February 2002	65R	449R	1997/12	20°32'S 146°27'E
136	Atlas of ferruginous and siliceous materials, North Queensland	C. Phang, R.R. Anand, J.E. Wildman and I.D. M. Robertson	June 2002	66R	450R	1998/06	Mt Isa Inlier and Drummond Basin
138	Regolith-landforms of the Mt Isa Geodynamic Transect	M.R. Dell	June 2002	67R	451R	1998/04	21°S, 139° - 141°E
139	Geochronology of weathering in the Mount Isa and Charters Towers Regions, Northern Queensland	P. Vasconcelos	April 2002	68R	452R	1998/06	Mt Isa Inlier and Drummond Basin

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Both regions 120, 136, 139

ABSTRACTS

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Open File Report 120

Geochemical exploration in regolith dominated terrain, North Queensland (CRC LEME - AMIRA P417 Final Report)

R.R. Anand, S.J. Fraser, M.R. Jones, Li Shu, T.J. Munday, C. Phang, I.D.M. Robertson, K.M. Scott, P. Vasconcelos, J.E. Wildman, J. Wilford

Extensive, variable, and generally thick regolith is a major impediment to mineral exploration in parts of northern Queensland, as well as in many other parts of Australia. The Mount Isa and Charters Towers - north Drummond Basin regions host numerous base-metal and gold deposits and have a long history of mineral exploration. The well-exposed parts of these regions have been effectively explored by traditional methods. Exploration is now concentrating on areas obscured by deep weathering or by transported cover.

The main aim of this project was to develop suitable geochemical exploration methods for regolith covered areas based on an improved knowledge of the nature and evolution of the regolith and landscape. To achieve this, this project undertook regolith-geochemical dispersion studies in a variety of geomorphological and sedimentary environments with particular emphasis on distribution, characteristics and origin of the regolith. The activities of the project ranged from regional to district-scale investigations, with more detailed studies at specific sites or prospects. Sites were selected to address specific problems and, in many cases, mapping was extended to place them in their regolith-landform context. The outcomes of district-scale and specific studies are available as investigation reports. The purpose of this report is to summarise the results and to develop models, conclusions and recommendations. Regolith maps and geochemical data are available on a compact disc (Appendix III).

MT ISA REGION

Regolith

As an aid to geochemical dispersion studies, a regolith-landform framework was established for the Mt Isa region. There has been complex erosion, deposition and weathering during the Mesozoic and Cainozoic, forming complex landscapes and regoliths. Mesozoic sediments were deposited on a land surface of broad river valleys with low hills and interfluves. By the early Cainozoic most of the Mesozoic sediments had been eroded except in the southeast and north of the region studied. Field relationships and dating of Mn oxides strongly suggest that evolution of the weathering profiles spans the Tertiary, possibly extending into the Cretaceous. Weathering of Cambrian, Mesozoic and Proterozoic bedrocks left lateritic profiles capped, in places, by ferruginous or siliceous duricrust. The depth of weathering varies and is controlled largely by landscape position, bedrock, structural features and any overlying sediment at the time of weathering. Palaeoplains and topographic lows are more deeply weathered than the erosional plains and hill belts. At many locations, Proterozoic bedrocks are weathered to greater depths where overlying Cambrian or Mesozoic sediments have been removed or were never deposited. In places, remnant river channel and sheet wash deposits have been silicified and ferruginised.

Massive, fragmental and nodular duricrusts have formed *in situ* on Fe-rich weathered rocks by accumulation of ferruginous materials from mottled saprolite and were left by down-wasting of the profile as clays and soluble elements were removed. Slabby duricrust formed on lower slopes by induration of locally derived colluvium and saprolite with lateral accumulation of Fe. Slabby duricrust can be distinguished by its landscape position on plateau edges, micromorphology (platy), geochemistry (Mn and P-rich) and its goethite-rich mineralogy.

Silcretes have formed on a variety of bedrocks but are most common on siliceous materials. In places, silica has cemented alluvial sands or sheet wash sands and gravels. Silicified alluvial sands and gravels now occupy topographically higher areas, because of relief inversion since induration.

The plains feature variable thicknesses of Cainozoic and Mesozoic sediments, underlain by weathered or fresh Proterozoic bedrock. Soils have formed on fresh and weathered Mesozoic and Cainozoic sediments and Proterozoic bedrock. Lithosols are associated with resistant rocks, areas of high relief and steeper slopes. In depositional areas, the soils vary from black through brown to grey sandy clay, sands or clays and generally contain polymictic gravels. Some soils have been weathered (mottling, silicification) since their deposition. Black and brown soils have developed extensively on Cainozoic and Mesozoic sediments. Black soils were developed progressively from brown soils where the alluvium was fine, water was retained and kaolinite was transformed to smectite.

Recommendations for exploration practice

Several geochemical sample media were demonstrated to have specific application in exploration in the Mt Isa region. Appraisal of geomorphology and regolith at a district scale is an important pre-requisite for efficient exploration of a regolith-dominated terrain. Regolith-landform maps and regolith stratigraphy should guide the selection of sampling media, sample interval, sampling procedure, analytical method, element suite and data interpretation. A regolith 'fact map' is produced to describe regolith materials in a landform framework and to divide these broadly into duricrusts, saprolites and colluvium-alluvium. Each, with the exception of colluvium and alluvium, are subdivided according to their bedrock (Proterozoic and post-Proterozoic). The bedrocks have different prospectivities and require different interpretation.

Residual ferruginous materials (massive, fragmental or nodular duricrusts), where they occur, should be collected for district- to prospect-scale surveys. Data from partly transported slabby duricrust should be interpreted with care as their Fe and trace element (Cu, As) content may have been derived laterally.

Soil sampling is effective in areas of shallow overburden (1-5 m). The best materials are mottles or the soil matrix rather than clastic grains. Where Fe and/or Mn oxides have adsorbed significant quantities of indicator elements (e.g., Cu, Zn) multiple regression, followed by a residual treatment of these indicator elements would remove the effects of adsorption and draw attention to anomalies that would otherwise remain hidden.

Areas dominated by thick (>5 m) Cambrian, Mesozoic and Tertiary sediments present significant exploration problems. Coarse sediments should be collected at and just above the unconformity (interface sample) in areas of unweathered or slightly weathered Mesozoic cover to detect a near-miss when drilling a geophysical target. When sediments have been weathered, buried ferruginous bands at palaeosurfaces or at watertables may provide a continuous sampling medium. Horizontal ferruginous bands formed within sediments should be preferentially collected. These are more useful than structurally controlled sub-vertical ferruginous veins within the Mesozoic sediments.

CHARTERS TOWERS - NORTH DRUMMOND BASIN

Regolith

The landscape of the region is a product of several sedimentation and weathering episodes. The dominance of a southerly flowing river system in the early Tertiary, the formation of a large lake system in the middle Tertiary, and the reversal of the river system in the late Tertiary are the main episodes of landscape evolution in the north Drummond Basin. Deposition and erosion in the north Drummond Basin has been dictated by drainage changes. When the southerly drainage was choked during the Tertiary, rapid sedimentation formed the

Suttor Formation in the south and the Southern Cross Formation in the north. In view of their extent and fluvial nature, these were deposited over a considerable time span and were not restricted to a single event.

Deep weathering of both the fluvial sediments and the basement formed the duricrust, red earths and, to a lesser extent, yellow earths. Campaspe Formation sediments were deposited on the Southern Cross Formation. In areas where intense erosion of the Southern Cross Formation occurred, Campaspe Formation sediments were deposited in lower levels in the landscape. Yellow and grey earths with ferruginous pisoliths are developed on the Campaspe Formation.

In drill spoil, the Southern Cross Formation is more clay-rich than the Campaspe Formation and contains clasts of the basement rocks. The Campaspe Formation tends to be sand-rich and more sorted than the Southern Cross Formation. The Campaspe Formation may contain detrital nodules and pisoliths throughout the sediment, whereas most of the pisoliths and nodules in the Southern Cross Formation are concentrated near its top. There are no consistent mineralogical and geochemical criteria but hiatuses in feldspar and kaolinite abundances, rounding of quartz grains and geochemical parameters such as hiatuses in Ti/Zr ratios can be used to distinguish the Campaspe Formation from basement volcanics.

Recommendations for exploration practice

The focus of most of the geochemical studies in the Charters Towers - north Drummond Basin was on investigating dispersions in sedimentary cover. Regolith-landform procedures are similar to those described for the Mt Isa region with the exception that regolith units should be divided into Palaeozoic or post-Palaeozoic. The geochemical dispersions appear to be similar to those of the Mt Isa region, with geochemical responses where the cover is shallow (1-5 m). Here, soil sampling (including specific sampling of mottles) would be effective. The probability of hydromorphic dispersion is better in sediments that have been weathered since deposition.

In areas dominated by a thick (>5 m) regolith on Campaspe, Southern Cross and Suttor Formations, dispersion is predominantly mechanical near the base. In places, elevated indicator elements and Au are hydromorphically dispersed with Fe oxides and dolomite-rich bands at least 10 m above the unconformity. Thus, basal sediments and ferruginous bands (redox products) should be sampled preferentially. Extensive sheets of ferruginous pisoliths, developed in the Campaspe Formation, also appear to be a promising sampling medium in the region.

Open File Report 121

Dispersion into the Southern Cross Formation around the Scott and Cindy Lodes, Pajingo - N.E. Queensland

I.D.M. Robertson

Epithermal quartz veins occur at Pajingo within relatively flat-lying andesites, tuffs, volcaniclastic sediments and sandstones. The host rocks are relatively fresh on the Mt Janet Range but are weathered and mottled on the surrounding pediment, where they are partly covered by Tertiary sediments (mottled Southern Cross and less weathered Campaspe formations) and by various more recent colluvia and alluvia.

The Tertiary sediments, exposed by mining of the Scott and Cindy lodes, were mapped and sampled. They consist of immature, clay-rich conglomerates and grits, which have drawn their detritus from a range of levels in the regolith (fresh rock, saprolite and pisolitic material). These sediments were then further weathered (weathering of fresh rock fragments and mottling).

Geochemical backgrounds, over 1 km from known mineralisation, are slightly elevated (>30 ppb) compared to 5-10 ppb more distant. The Southern Cross Formation sediments, exposed by mining at Scott Lode, are all rich in Au (>100 ppb) as their detritus was largely derived from the Scott mineralisation and its environs. Local Au anomalies of >500 ppb occur near the base and well above the base of the profile. In contrast, at Cindy, the background in the Southern Cross Formation sediments is much lower, as their detritus was derived up-slope from Cindy. A localised Au anomaly (150-5OO ppb) occurs near the base of a palaeochannel which drained the eastern side of the Cindy mineralisation. All this suggests mechanical Au dispersion together with dispersions in W and Mo. However, partial extraction, using water, potassium iodide and potassium cyanide, indicates that a proportion (about 18%) of the Au is now relatively soluble and has been relocated slightly by weathering.

Data from the exploration drilling were sifted and maximum and arithmetic mean Au contents in each drill intersection in the Southern Cross Formation sediments were determined and plotted for each study area. Gold is dispersed into these sediments at several levels and anomalies of 100-300 m occur not only at Scott and Cindy but also related to zones of numerous auriferous quartz veins, unrelated to economic mineralisation. It is necessary to understand the palaeotopography of the basement to interpret these anomalies.

Open File Report 122

Charters Towers - North Drummond Basin Field Excursion, Field Guide

K. Scott, Li Shu, S. Fraser, I.D. Campbell, R.R. Anand and I.D.M. Robertson

The principal objective of the P417 Project is to improve substantially geochemical methods of exploration for base metals and Au in areas obscured by weathering or under younger cover. The research includes geochemical dispersion studies, regolith mapping, regolith characterisation, dating of profiles and investigation of regolith evolution. The project has sites in both the Mt Isa Region and in the Charters Towers-North Drummond Basin.

Essential to this project is translation of research findings into practical exploration outcomes. Field excursions are an essential link in this technology transfer. The last excursion was in July 1995 and covered the Eastern and Western Successions of the Mt Isa Region, where research sites have deeply weathered profiles on Proterozoic and Mesozoic bedrocks and are partly overlain by variable thickness of recent sediments. This second excursion provides opportunities to examine the weathering of younger Palaeozoic rocks and their Tertiary cover sequences (Suttor, Southern Cross and Campaspe Formations) and the geomorphology of the region, all of which are important to geochemical exploration of the region.

The excursion includes visits to mineral deposits, prospects and field sites. On the first day the excursion visits Red Falls, where the Campaspe Formation can be demonstrated to overlie the Southern Cross Formation, the Featherby Walls, where the sandstones of Southern Cross Formation unconformably overlie the Ravenswood Granodiorite. At both these sites, mottling and nodules are common. In the Waterloo Area a ferruginous profile is developed in the top of the Campaspe Formation. The Waterloo Deposit has been quoted as occurring below 60 m of Campaspe Formation, however, work done in this Project indicates that the thickness of the cover has been overestimated in places and a Pb mechanical dispersion train occurs at the base of the Campaspe Formation.

The second day covers Scott Lode, the Cindy Deposit and the Wahines Prospect. Here, weathered profiles are developed on cover sequences and on the basement. Weathered components of earlier sequences have been included as detritus in later materials, implying a complex and continued weathering history. Concentrations of Fe have developed both at surface and at depth in the cover sequences, which have adsorbed pathfinder elements related to mineralisation in the basement.

The Police Creek and Wirralie prospects and profiles through the Suttor Formation are visited on the third day. Ferruginous duricrusts and silcretes are developed on the Suttor Formation.

At the Police Creek Prospect, the transported cover is generally less than 6 m thick and mottles have developed both in it and in the underlying bedrock. There appears to be both hydromorphic and mechanical dispersion in the cover. The <75 µm fraction of the soil has a more intense Au anomaly than the <180 µm fraction. Although As and Sb occur in the fine fraction, these elements are concentrated with Fe oxides of the coarse fraction with Mo.

At the Wirralie Deposit, the Au anomalies in the Suttor Formation reflect mechanical transport from the basement. Arsenic and Sb contents are generally low in the Suttor Formation, except where ferruginous sediments occur.

Open File Report 123

Regolith geology and soil geochemistry of the Little Eva Copper prospect, Quamby District, NW Queensland

I.D.M. Robertson, C. Phang and T.J. Munday

The Little Eva Cu Prospect is located 12 km north of the Dugald River Zn-Pb orebody and is situated in scapolitic granofelses of the Corella Formation and is associated with feldspar porphyry and magnetite-rich rocks. Although, in the vicinity of the Little Eva shaft, these rocks are exposed or occur under a very thin soil, the prospective rocks to the south are masked by colluvium. This prospect had been investigated intensively by CRA Exploration Pty Ltd., (CRAE), using the geochemistry of samples drilled from bedrock.

The geomorphology and regolith units were investigated on a district and on a local scale. This was to provide the setting for an orientation survey to test the effectiveness of soil sampling in areas where there is a thin layer of transported cover. South of the Little Eva Cu Prospect, detritus, from low quartzite hills and quartz veins, has been shed onto pediments gently inclined, towards Cabbage Tree Creek, to form a thin colluvial mantle of acid red earths with a quartz- and quartzite-rich lag. Near Cabbage Tree Creek, erosion has been active, etching into and through the colluvium, exposing the basement. This is largely covered by a thin, carbonate-rich lithosol, characterised by a lag rich in quartz and magnetite clasts. The magnetite is primary, although it has been partly weathered at the surface or near-surface. To the north, the area is dominated by alluvium and colluvium on which black clay soils are developed. Part of the colluvium, south of the prospect, has been almost completely dismantled, leaving an area of linear 'gilgai', occupied by dark brown, smectitic, cracking clay soils.

Soil sampling on an approximately triangular 200 m grid, shows that Cu and Au are the only indicator elements for Little Eva style mineralisation. Muted anomalies in both elements indicate the trend of the bedrock Cu anomaly, as determined by CRAE, even through the thin colluvium. The fine fraction (<75 µm) is more effective than the coarse (710-2000 µm) fraction. Iron, Co and V in the soil indicate concentrations of magnetite which may have some exploration significance.

Bioturbation by ants and termites and/or hydromorphic dispersion could have contributed to moving the Cu and Au geochemical signal in the fine fraction upward from the basement and through the colluvium. However, the low tenor of the anomalies requires that careful attention be paid to setting the correct thresholds and the use of appropriate display methods (e.g., logarithmic scales).

Open File Report 124

The geochemistry of transported soils and weathered bedrock at Police Creek, Drummond Basin, Qld - A progress report

K.M. Scott

Two distinct anomalies occur in the soils at the Police Creek epithermal gold deposit. The major geochemical anomaly occurs within transported soils overlying bedrock-hosted mineralisation. It is best defined by the occurrence of >100 ppb Au (and elevated S) in the <75 μm kaolinite-rich fraction of the soils and by As >400 ppm (and elevated Sb and Mo) in the >2 mm Fe-rich fraction of the soils. The second type of anomaly in thin residual soils directly overlying bedrock is characterised by anomalous Au, As and Sb within the >2 mm of the soils. Although use of <75 μm fraction of the soils gives a larger anomaly than the previously used <80 mesh (<180 μm) fraction, use of only that material would not identify the second type of anomaly. Thus a strategy of analysing both the fine and coarse material in soils in the region is recommended if the origin of the soils is not known.

Study of the bedrock in a number of profiles also reveals that Au is likely to be separated from pathfinders like As and Sb during weathering process. Under very acid conditions (reflected by the presence of alunite in rocks), Au is depleted but the pathfinders (As, Sb, Mo and W) are retained. However, under more alkaline conditions where near-surface dolomite is present, Au is present but pathfinder contents are low. Analysis of bedrock material for Au, As, Sb, Mo and W is thus recommended with knowledge of the mineralogy also important to understand the acidity of the environment and, hence, why different suites of elements occur.

Open File Report 125

Regolith-landscape characteristics, evolution and regional synthesis of the Mt Isa Region, Progress Report

R.R. Anand, C. Phang, J. Wilford, J.E. Wildman, Li Shu, I.D.M. Robertson and T.J. Munday

Weathering, erosion and depositional history

The Mt Isa region is characterised by a complex history of weathering and landscape development. Following marine incursion, Mesozoic sediments were deposited on a land surface of significant relief. Thus, Cretaceous sandstone, shale, claystone, siltstone, limestone, and conglomerate at that time overlay most of the Mt Isa Inlier and since has been partly eroded. Subsequent regional uplift and drainage incision has led to the development of the broad features of the present landscape, in which extensive plains surround a central hill zone. Some of the plains have been further modified by the deposition of Tertiary sediments.

Long periods of stability have favoured the development of a deep, weathered mantle, which has been differentially eroded during more active phases of erosion. Ferruginous or siliceous duricrusts can occur in the upper parts of weathered profiles. Where relatively fresh rock is exposed in erosional terrains, these are partly mantled by calcareous soils.

Regional regolith distribution and geomorphic provinces

As an aid to geochemical dispersion studies, a regolith-landform framework was established for the Mt Isa region. Mapping of an area of 84,000 km^2 (17°30'S - 22°00'S; 137°30'E - 141°OO'E) at a scale of 1:500 000, has shown the broad distribution of ferruginous materials, silcretes, soils, saprolite, Proterozoic bedrock Mesozoic sediments, colluvial-alluvial and lacustrine sediments. In the mapped area, Mesozoic sediments are more widespread in the southeast and to the north than in the centre of the Mt Isa Inlier. Lateritic duricrusts are more common in the Western Succession than in the Eastern Succession. Large areas of alluvial deposits occur west and east of the Mt Isa Inlier. Narrow corridors of coarse alluvium trend northeast across the Inlier and small areas of coarse colluvium cover the footslopes of steep hills.

In the present study, three broad geomorphic subdivisions are recognised, namely hill belts, a complex of mesas and plains, and plains. These show varying degrees of weathering, erosion and deposition and are developed on Proterozoic bedrock and Mesozoic sediments. The three major provinces were further subdivided on the basis of their dominant geology and topography.

The *hill belts* occupy the central portion of the region and consist predominantly of north-trending ridges and hills. Here, the detailed sculpturing of the land surface is intimately related to differential weathering and erosion of various lithologies. Mesozoic sediments are sporadically distributed generally capping small mesas. Not all the rocks in the hill belts are fresh and many have signs of former and present weathering that involves formation of kaolinite, smectite and pedogenic carbonates. Zones of superficial, secondary silicification are marked. The colluvium is generally less than one metre thick but reaches thickness of 12 m in places. Soils developed in colluvium are calcareous to non-calcareous.

The terrain characterised by a *complex of mesas and plains* indicates the variable distribution of former lateritic weathering. These areas are interpreted as a dissected plateau on which the original old surface forms a significant component of the landscape. This terrain occupies part of the Western and Eastern Successions. Deeply weathered profiles, with ferruginous or siliceous cappings, occur on stable parts of the landscape (mesa crests) but, even here, the total depth of weathering is variable. In contrast, relatively shallow weathering profiles occur on pediments and erosional plains. The depositional plains are mantled with shallow alluvium (1-5 m) which are underlain by deeply weathered profiles with or without a ferruginous or siliceous capping.

The *plains* feature variable thicknesses of weathered and partly eroded Cainozoic, Tertiary and Mesozoic sediments, underlain by Proterozoic bedrock.

Weathering profiles

The nature and depth of weathering profiles on Proterozoic and Mesozoic rocks are variable and are largely controlled by bedrock composition and palaeo-topography. However, the depth of weathering of the Proterozoic rocks is also controlled by the presence (or absence) of overlying Mesozoic sediments at the time of weathering. Proterozoic rocks are weathered to greater depths where Mesozoic sediments have been removed or were never deposited. Lateritic duricrust and indurated ferruginous saprolite were developed on ferruginous lithologies, with silcrete and silicified saprolite in equivalent situations on siliceous bedrock.

The 'complete' weathering profile, from top to base, has a lag of lateritic nodules and pisoliths, pockets of duricrust, indurated ferruginous saprolite, a clay zone, saprolite (silicified in part), saprock and bedrock. Lateritic duricrust and silcrete have also developed on some Mesozoic sediments. Mottled zones are common on Tertiary sediments.

The characteristics of weathering profiles reflect both past and present weathering conditions. The ferruginous and siliceous duricrust-capped weathering profiles, containing Al_2O_3, Fe_2O_3 and, probably, SiO_2 corresponds to wet climates, whereas calcrete and smectite are products of arid conditions. Calcrete and smectite are typically developed on partially weathered rocks of hill belts and on erosional plains, and are products of weathering under the present climate. Duricrust-capped, deeply weathered, kaolinised profiles on mesas are inherited from past climates.

Soils

Soils have formed on sediments (Mesozoic and Cainozoic), Proterozoic bedrock and on saprolites formed from these bedrocks. Lateritic, gravely soils have developed on lateritic profiles of the plateau erosion surface on Proterozoic and Mesozoic sediments. Red, brown and yellow earths occur on slopes and plains in erosional terrain developed below the lateritic plateau remnants. They are formed on the underlying saprolite and saprock. Yellow earths are generally associated with more siliceous Proterozoic bedrocks but, on the more ferruginous rocks, red earths occur. In places, however, these residual soils are overlain by recent fluvial deposits.

Lithosols or skeletal soils are associated with resistant rocks and areas of high relief and steeper slopes. Soils of the hill belts contain abundant pedogenic carbonates from recent weathering of underlying rocks.

In depositional plains, the soils vary from black through red to grey sandy clay, sands or clays and generally contain polymictic gravels. The nature of the soil depends on the provenance and thickness of the parent materials and on the history of post-depositional erosion. Brown and red soils are developed where the drainage is good. Hydromorphic conditions in depressions and gentle slopes favour formation of black soils. Some soils are cemented by Fe oxides and others by silica.

Ferruginous materials

These are six main categories of ferruginous materials in the Mt Isa region. These include lateritic gravels (mottles, nodules and pisoliths), lateritic duricrusts, ferricretes, indurated ferruginous saprolite, ferruginous bands and ferruginous veins; the origins of these materials vary. Mottles and nodules are residual; pisoliths have experienced local transport. The Fe-rich composition in lateritic duricrusts is the result of either or both of two processes: (1) relative concentration of Fe and Al by removal of Si and bases and landscape lowering; (2) concentration of these elements by absolute accumulation from outside sources. Duricrusts, (e.g., slabby duricrust) formed by laterally accumulated Fe were originally formed in locally derived substrates in valleys and the topography has since been inverted. Ferricretes are formed by the Fe enrichment of sediments and are not genetically related to the underlying lithologies. Where the bedrock is rich in Fe, pseudomorphic replacement of kaolinite by Fe oxides has led to strongly indurated hematite-/goethite-rich ferruginous saprolite. Ferruginous bands occur in the lower and middle part of the profile and appear related to fluctuations in the water table and texture of sediments. Ferruginous veins follow bedding planes and fault systems.

Ferruginous materials in the Mt Isa region have formed in a variety of substrates derived from Proterozoic bedrock, Mesozoic, Tertiary and recent sediments. However, the degree of development of the ferruginous horizon depends upon the nature of the parent material. The ferruginous horizon on Tertiary sediments is limited to mottles; duricrust is not developed.

Silcrete

Silicification has affected a range of regolith materials. Well-developed silcretes on plateau remnants are interpreted as a landscape near equivalent of the lateritic duricrust. Silcrete is not only developed on bedrock but is also developed in alluvium, sand and gravel sediments of valleys, many of which have since undergone topographic inversion.

Erosional surfaces

No reliable indication of age can be obtained from the morphology, chemistry and mineralogy of duricrusts as similar ranges of weathering and ferruginous and siliceous duricrusts occur at different levels. Variation in altitude of duricrusts may result from differential erosion of a single, broadly undulating, deeply weathered land surface and to variations in local geology and groundwater conditions. The variable Fe oxide mineralogy of lateritic duricrusts suggests that they have formed in differing hydrological environments. Duricrusts dominated by hematite may be older than those dominated by goethite. The variety of ferruginous and siliceous materials suggests that formation of land surfaces in the Mt Isa region has been complex. It would be unwise to ascribe a single age to the regolith or imply a single extensive surface of planation, since different parts of the surface may have formed at different times.

Pilot studies

Five pilot studies of areas characterised by base metal geochemical anomalies (Python, Lady Loretta, Drifter, Blinder, Tringadee) are summarised within their district-scale regolith-landform settings. Common regolith-landform situations and their implications to exploration, particularly in relation to geochemical sampling media and data interpretation, are discussed.

The Python Cu Prospect (Buckley River - Grey Ghost district) has a Cu, Sb, As and Pb anomaly restricted to slabby duricrust and lateritic nodules and pisoliths. There are three sources of Fe and trace elements at the Python Prospect, namely pyritic units in the Proterozoic bedrock, a fault that cuts through the duricrust-capped hill and absolute accumulation from outside sources. The fault is rich in Pb, Au and Sb and is probably related to underlying mineralisation. Dispersion from the fault has caused a broad anomaly in the slabby duricrusts and lateritic nodules and pisoliths.

At the Lady Loretta Deposit, patchily developed nodular duricrust is widely enriched in As, Sb, Mo, W, Pb and Zn and is related to underlying Pb-Zn-Ag mineralisation. The duricrusts are located on a mesa which is strongly dissected. This confirms that analysis of even widely-spaced duricrust may reveal base metal mineralisation below a deeply weathered lateritic surface.

A cherty breccia (Cambrian unconformity) and soils at the Drifter Prospect are anomalous in Cu, Zn and Pb without any known underlying significant mineralisation. Copper and Zn anomalies in the cherty breccia appear to be related to leakage from the Proterozoic Drifter Fault into the overlying Cambrian. These elements exhibit similar dispersion characteristics and have strong affinities for Fe and Mn oxides, implying hydromorphic dispersion. Iron in the cherty breccia is derived from several sources, including the fault and the underlying Proterozoic bedrock. The high concentrations of Pb and Sb in soils imply a nearby source, since Pb and Sb are relatively immobile. However, the source may be minor.

At the Blinder Prospect there are significant Zn and Pb anomalies in the Mt Hendry Formation but no mineralisation has been found by drilling. The Fe oxides that host the anomaly in conglomerate (Mt Hendry Formation) are not derived from the underlying Paradise Creek Formation or from the overlying Cambrian. Bedding in the Mt Hendry Formation suggests a fluvial environment that has transported the anomalous Fe-rich material into place before burial by the Cambrian.

At the Tringadee Prospect there is a widespread Zn anomaly in the Mesozoic cover. The Zn anomaly is associated with accumulated Fe and Mn oxides, probably related to fluctuating water tables and fractures in the Mesozoic cover. The latter appear to have conducted Fe-rich fluids from external sources. The source of these anomalies could be nearby deposits such as Cannington and Pegmont.

Regolith-landform mapping

Application of an interpretive or derivative mapping scheme established for parts of the Yilgarn Craton (colloquially referred to as the 'RED mapping scheme') is assessed for the Mt Isa region. An interpretative scheme for the Mt Isa region is proposed. This is now open for comment and other interpretative schemes are being considered.

Open File Report 126

Secondary dispersion about the Waterloo polymetallic deposit, Mt Windsor Sub-province, N.E. Queensland

K.M. Scott

Zinc-rich polymetallic mineralization occurs as steeply dipping lenses at a number of locations within the Cambro-Ordovician Trooper Creek Formation of the Mt Windsor Sub-province, south of Charters Towers. Such mineralization is, however, often obscured by regolith, especially the arenites of the flat-lying Upper Tertiary Campaspe Formation. At the Waterloo deposit a dispersion halo has been reported within the Campaspe Formation. Because of the implications for exploration, the significance of this halo has been critically investigated by studying the mineralogy and geochemistry of profiles through the Campaspe Formation into the underlying volcanics.

Along Line 4 at Waterloo a 20-25 m thick sequence of feldspar- and smectite-bearing sandstone overlies a 20 m interval where feldspar is absent and kaolinite is the dominant clay. Bands of dolomite and Fe oxides are also present immediately beneath the feldspar-bearing rocks. Below ~45 m, relatively fresh volcanics with feldspar, chlorite $\pm$ pyrite are present. The presence of a feldspar-bearing unit above a highly weathered feldspar-depleted band suggests a lithological break at that contact. Supplementary geochemical data (Ce, Cl, Zr and Ti/Zr) also suggest that the base of the plagioclase-bearing material represents a major compositional break.

These results suggest that 20-25 m of Campaspe Formation overlies a sequence of weathered volcanics with the Fe-rich horizon representing the near surface Fe enrichment of a lateritic profile. The presence of the dolomite horizon at or above the Fe-rich horizon would thus represent pedogenic or secondary dolomite formation prior to the deposition of the feldspar-bearing Campaspe Formation. It is suggested that the anomalous levels of Pb and Ba occurring immediately beneath the feldspar-bearing Campaspe Formation represent the occurrence of secondary minerals (Pb-bearing alunite type minerals and barite) mechanically transported from secondary mineralization which cropped out prior to deposition of the Campaspe Formation. It is also possible that the Pb could be at least partly residually accumulated or hydromorphically dispersed and concentrated in the Fe-rich horizon. Whatever its genesis, the presence of the Pb halo in a predictable position within the regolith profile makes its use in exploration more viable. Copper and Zn are hydromorphically dispersed within the weathered volcanics but not into the Campaspe Formation.

Open File Report 127

Soil, bedrock and profile geochemistry at Police Creek, Drummond Basin, Queensland

K.M. Scott

Anomalies within residual soils along the 20300E traverse at Police Creek are defined by both the >2 mm and <75 µm fractions. Although Au, As and Sb are anomalous in both soil fractions, Au is preferentially concentrated in the fine fraction and As and Sb in the coarse fraction. Significant Mo may also be present, especially in the coarse fraction in anomalous areas. Gold >40 ppb in the fine fraction and As >100 ppm in the coarse fraction define an anomaly at least 1 km x 600 m (southern anomaly) in alluvium and residual soil. As in the previous survey at 20050E, a second anomaly was found to the north of the major geochemical anomaly and again identified by anomalous Au, As and Sb contents in both soil fractions. Arsenic >100 ppm defines the 400 x 150 m northern anomaly in residual soil. Comparison of results from residual soils and adjacent outcrop reveals that the fine fraction of the soils concentrate Au with respect to the rock. These features indicate that the soils at Police Creek are a good sample medium whether they are transported or residual.

The effect of weathering on three distinctive profiles have been observed. Highly mineralized samples with illite, adularia and kaolinite associated with arsenical pyrite (up to 7.3% As, 2.3% Sb and 0.4% Hg) weather to illite, kaolinite, jarosite and Fe oxides. In less mineralized samples, chlorite and calcite occur with adularia and illite, with the latter two minerals retained in outcrop with neoformed kaolinite. Areas of argillic alteration contain dickite and pyrophyllite, with the former being retained in outcrop. Such mineralogical and consequent geochemical variation in the feldspar and phyllosilicate stabilities/abundances could be defined by PIMA and radiometric survey of outcrop (or shallow drill spoil) to provide vectors to the most altered areas during exploration.

Open File Report 128

The geochemical discrimination of mineralised and barren ironstones from the Selwyn Au-Cu Deposit, NW Queensland

J.E. Wildman

Recent exploration for Au-Cu deposits in the Eastern Succession of the Mt Isa Inlier has concentrated on the type of magnetic ironstones found at Selwyn. Aerial magnetics are used to find the larger occurrences of magnetite but they cannot distinguish between mineralised and barren magnetite bodies. Samples of mineralised and barren ironstones were used to geochemically differentiate the two types of ironstone. Comparisons were also made between the unoxidised sulphide ore and its weathered equivalent found at the surface.

Samples of mineralised and barren ironstones were analysed for 38 elements by XRF and INAA. Photomicrographs and backscattered electron images were used to describe the mineralogy and textures of selected samples. Those elements that distinguish mineralised from barren ironstones have been displayed using several methods of plotting the data.

The mineralised samples are distinguished by Au and W and the barren samples by Ba and Mn. Copper is high in the mineralised samples but there is a large overlap of concentrations with the barren samples.

The SEM investigation shows that Au, W, Sn and Cu can be preserved in hematite derived from the magnetite. This hematite may then be a source of local stream sediment anomalies at surface in the case of Selwyn or at a palaeosurface where the ironstones are buried by Mesozoic or recent sediments.

Open File Report 129

Alluvial landscapes of the Maronan area, Cloncurry - McKinlay District, Queensland

M.R. Jones

Location

The Maronan area extends approximately 70 km northwest of McKinlay and includes the slopes of the Selwyn Range and the adjacent plains to the east. In the north, drainage is provided by the Williams and Fullarton Rivers, which have upper catchments incised in the Selwyn Range. Most of the numerous minor streams in the south only drain the foothills along the range's eastern margin. The McKinlay River and its tributary, Boorama Creek, are the other major streams in the south. Braided channels are common on the plains.

Known minerals in the area include copper, gold, lead, and zinc, and most are found in outcrops of steeply dipping metamorphics along the eastern flank of the Selwyn Range. The area contains the Eloise copper-gold mine, and the Maronan lead-zinc prospect. The Proterozoic rocks are considered the most likely hosts for mineralisation in the region.

The Proterozoic rocks form most of the Selwyn Range, but, except for a few small outcrops, are concealed beneath the plains east of the foothills. There is very little *in-situ* regolith over Proterozoic bedrock. The largely unconsolidated sediments on the plains are inferred to be of Tertiary and Quaternary age. This regolith cover is primarily thin alluvium which occurs as a blanket mainly less than 10 m thick over Cretaceous rocks. The Cretaceous rocks are as much as 100 m thick, and cover the Proterozoic basement.

Landscape Studies
Field investigations involved inspections at 73 sites across the plains and foothills. Many of the sites were in stream channels where good sections of the regolith were exposed in the banks. The field observations were given a regional context by relating them to geology maps and to a Landsat TM image of the area.

Geomorphology and Landscape Evolution
The main geomorphic units are:

Isa Highlands - the Selwyn Range.

Cloncurry Plain - the narrow foothills zone along the base of the Selwyn Range.

Wondoola Plain - the extensive plain east of the ranges and north of the McKinlay River.

Julia Plain - the plain southeast of the McKinlay River; this plain is slightly higher than the Wondoola Plain.

The Isa Highlands have been a long-term source of sediments for the eastward flowing streams. Weathering products have been eroded from the bedrock and transported onto and across the plains to the east and northeast. Fluctuations in sediment supply from the upper catchments have caused cycles of accretion and erosion on the plains. Here the surficial deposits comprise interfluve sediments and channel floor deposits. The interfluves contain fluvial deposits which accumulated during earlier cycles of catchment accretion. The channel floor deposits are very coarse sands and gravels washed from the upper catchments and are now in transit to downstream areas.

Former accretionary cycles built up the plains to form the once extensive Julia Plain. However with more recent diminishing supply from the upper catchments, the plains have entered an erosional phase. Erosion has developed the Cloncurry Plain as a partially denuded pediment along the front of the Selwyn Range. The sediments from the Cloncurry Plain now extend downstream in the braided channels that have incised the Wondoola Plain. A large but thin store of sediment exists on the plains, mainly as alluvial interfluves. Erosional remnants from the southward retreat of the Julia Plain are found in the McKinlay River flood corridor.

Age and distribution of regolith
In this study, no laboratory determinations of the age of the regolith were made. The ages referred to are estimations, based on the degree of consolidation and on soil profile development.

Implications for Mineral Exploration
Hydromorphic dispersion of trace elements.

Hydromorphic dispersion of trace elements into the regolith is likely to produce a detectable geochemical halo if the regolith is undisturbed for a long time. However, in the Maronan area, the *in situ* regolith on the Proterozoic rocks is generally quite thin. Most has been eroded from the Selwyn Range and transported on to the plains where it has been reworked intermittently. The oldest, and likely to be the least disturbed of the interfluves are on the Wondoola Plain and on the Julia Plain. Iron staining in some of these deposits may have continued, following deposition, due to the breakdown of minerals such as mica. The chemical activity provides further opportunities for hydromorphic dispersion in these transported deposits. However, the thick sequence of Cretaceous sediments beneath much of the alluvial plains probably forms a barrier to upward hydromorphic dispersion from the Proterozoic rocks. Such dispersion may produce geochemical haloes in the Cretaceous rocks more readily than in the younger surficial deposits.

In the upper catchment, the *in situ* regolith on Proterozoic bedrock is thin and is mostly alluvium, subject to frequent overturning. Overall, the prospects for finding geochemical haloes in the Quaternary regolith appear to be poor.

Mechanical dispersion of trace elements

Diffusion of geochemical tracers by mechanical processes should be discernible by stream sediment geochemistry. Most of the sand and gravel supplied from the upper catchments is confined to the flood corridors crossing the plains, rather than being dispersed widely. Hence, sources in the upper catchment may be detectable by sampling in the channels on the plains. Further downstream, trace elements from sources in the Proterozoic rocks would become too diffuse for detection. Windows of Proterozoic bedrock such as at Kevin Downs could be investigated for trace elements and compared with Selwyn Range samples to determine regional variability between Proterozoic rocks in the ranges and beneath the plains.

Interpretations

The regional structure of the bedrock in the Selwyn Range is discernible on TM images. For the most part, the bedrock consists of steeply dipping metamorphics having a north-south strike, approximately parallel to the boundary between the plains and the ranges. The known mineral localities enable along-strike extrapolation of potentially prospective horizons between the Fullarton and Williams Rivers. The bedrock strike curves to the northeast, and it can be inferred that this general trend continues beneath the plains. Amalg Resources NL have achieved some encouraging results by prospecting along strike from known mineral occurrences such as Fairmile.

In the area to the south of Fullarton River, it is difficult to infer the type of Proterozoic bedrock as there is no along-strike exposure. Mineral exploration is made more difficult by the limited knowledge of the Proterozoic bedrock concealed beneath the plains.

Open File Report 130

Alluvial landscapes of the Northern Kennedy Gap Area, Mt Isa District, Queensland
M.R. Jones

Quaternary landscape evolution has been investigated in an area located mid-way between Mt Isa and Camooweal, on the Kennedy Gap 1:100 000 sheet. Here, Proterozoic bedrock forms prominent ridges having a general north-south orientation and rising up to 180 m above the surrounding plains. Drainage is provided by streams, whose upper catchments are confined by bedrock ridges. The area extends only marginally onto the plains that continue from the base of the Mt Isa Inlier to the south and west. Despite the arid environment, the principal agents of landscape evolution are the rivers and creeks which carry away the products of weathering in the high country and distribute these sediments across the lowlands. The study area lies across the divide separating northward drainage to the sea and southward drainage to central Australia.

There are six major streams present, each with distinctive drainage patterns associated with different levels of erosional activity. The most active of the streams is the northward-flowing Judenan Creek, which has a highly channelled catchment. The stream is continuing a long-term trend for expansion to the west and south along erosion scarps in bedrock. Weathered Eastern Creek Volcanics in the Judenan Creek catchment are susceptible to erosion, and the numerous channels ensure that the weathered mantle is readily removed. The sediments produced are derived from a wide area of bedrock, and are predominantly "new" sediments. In contrast, the adjoining Cattle Creek catchment to the west contains a mixture of older alluvial deposits now being reworked, and only minor "new" sediments derived from low lying bedrock outcrops.

Other catchments in the area include the bedrock-confined and aligned Gidya Creek, which drains to the north, and Buckley River, which flows westwards across the strike of the bedrock. In the south, Johnson and Wilfred Creeks are conduits for westward moving sediments produced in their upper catchments. Johnson and Cattle Creeks join Buckley River, and contribute to the drainage towards central Australia.

The sediments are derived from the area within 2-5 km of the drainage divides between the upper catchments. For the most part, the surficial sediments are thin and young. There is no evidence of widespread thick sequences of transported deposits overlying an incised and back filled bedrock surface. Rather, the alluvial deposits are mainly confined to narrow corridors along the valley floors. The alluvial deposits form a blanket which protects the shallow underlying bedrock from significant erosion.

The alluvial deposits are only a proportion of the total sediment throughput during the evolution of the landscape to its present form. The blanketing unconsolidated sediments are in transit to distant depositional areas. It is unlikely that these deposits would remain in place long enough for geochemical haloes to develop from underlying mineral deposits. Overall, the processes of erosion, transport and deposition are diffusive for indicator minerals. However, there is the potential for stream bed concentrations of heavy minerals which could be related to up-catchment sources.

The differences between the catchments are related to the confining geology that determines the lateral limits of catchment development, and the underlying geology that determines the erodability of the catchment substrate. Judenan Creek is the main catchment where erosional processes are most active. In part, this can be related to Judenan Creek having a steeper slope to its base level (Gulf of Carpentaria) in comparison with the other streams draining to the west and south towards Lake Eyre. The Judenan Creek catchment may also contain more erodable bedrock than in neighbouring streams. The erodability could be related to deep weathering and or fracturing of the bedrock allowing surface or near-surface chemical concentrations indicating underlying mineral deposits. The Judenan Creek catchment contains known occurrences of copper and uranium mineralisation. This catchment may need further evaluation of its potential to contain economic mineral deposits.

The Eastern Creek Volcanics also underlie parts of the Gidya Creek catchment, which may warrant investigation for anomalies in the regolith. Stream sediment geochemistry could assist exploration in the Judenan and Gidya Creek catchments.

Iron-rich pisoliths and nodules have proved to be useful sampling media for geochemical exploration in Western Australia. In the Kennedy Gap area, iron pisoliths and nodules are abundant. Hematitic and goethitic pisoliths and nodules occur *in-situ* in weathering profiles, and also in transported deposits where secondary goethitic cementation has occurred. Geochemical analyses of goethitic cutans and hematitic centres of iron pisoliths are expected to give different results. Careful interpretation of the environment of deposition is required before selecting samples for analysis. This is essential if geochemical anomalies are to be successfully related to source areas.

Open File Report 131

Regolith-landform characteristics, evolution and implications for exploration over the Selwyn Region, Mt Isa

J.R. Wilford

A regolith-landform map and a series of thematic maps based on fieldwork, 1:25 000 colour air photography, enhanced Landsat TM imagery and airborne radiometrics have been produced over the Selwyn region (40 x 40 km) approximately 140 km south-southeast from Mt Isa. The maps show the distribution of regolith and landform types, relationships between regolith materials and Landsat TM imagery, associations between known mineral deposits, regolith materials and landform features such as palaeochannels and erosional scarps. An interpretative geochemical sampling map has been generated which can be used as an aid in the interpretation of surface geochemistry and drill samples.

The maps show a complex history of landscape evolution. A combination of a long weathering history and variable degrees of stripping and exhumation has resulted in a landscape of variable regolith. Rocks exposed at the surface reflect weathering processes which operated from the Jurassic to the present day. Regolith consists of duricrusts (7% map sheet area) which may reflect both local and transported derivations, saprolite (62% map sheet area includes bedrock) and sediments (32% map sheet area).

Duricrusts and saprolite

Duricrusts typically form the top of deeply weathered, zoned profiles which include ferruginous mottled and bleached saprolite at depth. These highly weathered materials are associated with exhumed landforms and relict parts of the landscape including plateaux and mesas. Duricrusts reflect a long history of weathering from sub-aerial exposure in the Late Cretaceous to the present day. Some of the most intensely weathered bedrock is associated with palaeochannels which were probably established during the Jurassic or perhaps earlier.

Three types of ferruginous duricrust are recognised including; massive, brecciated and slabby duricrust. In places, silcrete and silicified saprolite develop instead of iron duricrusts - particularly where the underlying bedrock is siliceous. Veneers of sheet wash gravels, residual sand and clay overlying mottled saprolite are common in areas of relatively low relief (including rises, erosional and pediments). Lithosols lying directly on bedrock or saprock occur on steeper slopes. These areas of high relief and geomophic activity include mountains, hills and low hills.

Sediments

Alluvium consisting of variable proportions of gravel, sand and clay is associated with channel, flood plain and sheet flow deposits. In many places, rivers are superimposed over the predominantly north-south structure of the underlying Proterozoic rocks. Silica or iron commonly cements alluvium to form 'creek rock' or alluvial hardpan along river floors. Small areas of colluvium occur as coarse footslope deposits below steeper hill slopes.

Implication for exploration

Massive and brecciated duricrusts and ferruginous saprolite have developed largely *in situ* and can be sampled to detect mineralisation at depth. Valley silcretes (some of which are now relief inverted) and slabby iron duricrusts are thought to be largely formed from lateral movement of silica and iron. Nevertheless, they can be used to give broad geochemical indicators.

Several regolith-landforms should be assessed carefully when interpreting surface and drill hole geochemistry, these include:

1) Exhumed components of the landscape which expose in places very highly weathered kaolinised Proterozoic bedrock due to possible pre-Cretaceous weathering. Metal concentrations in these kaolinised zones are low relative to surrounding bedrock.

2) Regolith developed on Mesozoic and Cambrian lithologies are unlikely to directly relate to mineralisation at depth. Reworked Proterozoic bedrock and metals precipitated from groundwaters in the sedimentary sequence can give false anomalies.

3) Deep weathering and leaching beneath palaeochannels, some of which are now relief inverted. Metal concentration within these leached zones are anomalously low.

4) Slabby ferruginous duricrusts may give false anomalies due to lateral movement of iron oxides. However, slabby duricrusts can be used to give broad geochemical indicators.

Open File Report 132

Regolith-landform characteristic, evolution and implications for exploration over the Buckley River - Lady Loretta Region, Mt Isa

J.R. Wilford

A regolith-landform map and a series of thematic maps based on fieldwork, 1:25 000 colour air photography, enhanced Landsat TM imagery and airborne radiometrics have been produced over the Buckley River - Lady Loretta region (92 x 35 km) approximately 40 km north-northwest of Mt Isa. The maps show the distribution of regolith and landform types, relationships between regolith materials and Landsat TM imagery, associations between known mineral deposits, regolith materials and landform features such as palaeochannels and erosional scarps. In addition, a geochemical sampling strategy map has been generated which can be used as an aid in the interpretation of surface geochemistry and drill-hole samples.

The maps reveal a complex history of landscape evolution. A combination of a long weathering history and variable degrees of stripping has resulted in a landscape of highly variable regolith. Rocks exposed at the surface reflect weathering processes which operated from the Jurassic to the present day. Regolith consists of duricrusts (5% map sheet area) which may reflect both local and transported derivations, saprolite (67% map sheet area, includes bedrock) and sediments (28% map sheet area).

Duricrusts and saprolite

Duricrusts typically cap deeply weathered, zoned profiles which include ferruginous, mottled and bleached saprolite at depth. These highly weathered materials are associated with relict parts of the landscape, including palaeoplains, plateaux and mesas.

Three types of ferruginous duricrust are recognised including massive, fragmental, nodular and slabby duricrust. Ferruginous duricrusts are commonly associated with Fe-rich lithologies (e.g., shales, basalt and dolomitic siltstones). Siliceous materials include massive microcrystalline silcrete, silicified sands and gravels and siliceous saprolite (typically cementing the mottled and bleached zones). Silcretes are associated with palaeo-lows in the landscape (e.g., river channels) and with siliceous bedrock lithologies (e.g., siltstones). Veneers of sheet wash gravels, residual sand and clay overlying mottled saprolite are common in areas of relatively low relief (rises, erosional plains and pediments). Lithosols lying directly on bedrock or saprock occur on steeper slopes are most common over the higher relief and geomorphologically active eastern half of the study area.

Sediments

Alluvial gravel, sand and clay are associated with river channels, terraces and alluvial plains. Colluvial sands, gravels, clays and lags form sheet flow and footslope deposits. Extensive blankets of sheet flow deposits occur over the central western part of the study area where they overlie deeply weathered saprolite. Major rivers at the southern end of the map sheet are superimposed over the predominantly north-south structure of the underlying Proterozoic rocks. In places these rivers have been captured and their flow redirected to the north. Silica or Fe commonly cements alluvium to form 'creek rock' or alluvial hardpan along river floors. Small areas of colluvium occur as coarse footslope deposits below steeper hill slopes.

Implications for exploration

Some regolith-landforms should be assessed carefully when interpreting surface and drill hole geochemistry, these include:

1) Exhumed landscapes, which have largely removed Cambrian sediments exposing ferruginous and mottled Proterozoic bedrock. In many places not all the Cambrian has been completely removed, leaving behind pockets or veneers of Cambrian sediments in the form of cherty breccia or gravel lags. These patches of Cambrian can give false geochemical anomalies.

2) Regolith developed on Mesozoic and Cambrian lithologies are unlikely to directly relate to mineralisation at depth. Re-worked Proterozoic bedrock and metals precipitated from groundwaters in the Mesozoic sediments may give false anomalies.

3) Bedrocks below palaeoplains are commonly deeply weathered and leached. Metal concentration within these highly weathered zones are typically low.

4) Massive, fragmental and nodular duricrusts and ferruginous saprolite have developed largely *in situ*. These materials can be sampled to detect mineralisation at depth.

5) Slabby iron duricrusts are thought to be largely formed from lateral movement of iron and, as a result, may give false anomalies. Nevertheless, they can be used to give broad geochemical indicators.

6) Mottling and Fe granules derived from the mottles in silcretes and silicified saprolite may be useful sampling media in highly siliceous terrains.

Open File Report 133

The significance of Campaspe-dominated terrains in exploration within the Mt Windsor Sub-province, N.E. Queensland

K.M. Scott

Weathered altered volcanics associated with mineralisation within the Mt Windsor Sub-province are characterised by very kaolinitic assemblages (sometimes with alunite-jarosite minerals and barite) derived from alteration of the feldspars. The younger Campaspe Formation is generally characterised by feldspar-bearing assemblages and is not strongly kaolinitic. Thus, the units are easily distinguished on the basis of their kaolinite and feldspar contents. However, where the volcanics are unaltered, feldspars are retained and other criteria must be used to distinguish them from the overlying Campaspe Formation sediments. If the volcanics are intermediate to basic in composition, their lower Si, Cl and higher Al and Ti/Zr relative to the Campaspe Formation can be used to discriminate. Unfortunately, if the volcanics are felsic (as at Thalanga) the geochemical parameters, e.g. Ti/Zr do not discriminate between the two units. In these cases, although the unconformity between the two units is commonly associated with Fe oxide enrichment in both units, to accurately define the boundary, the degree of rounding of the quartz grains may be the only reliable parameter for discrimination.

Chalcophile elements (Ba, Cu, Pb and Zn) may be dispersed by mechanical means into the basal 10 m of the Campaspe Formation at Waterloo and Thalanga East. The distribution of Cu, Pb and Zn within thick sequences of the Campaspe Formation at Waterloo reveals that the dispersion of Zn (and Cu) is more restricted (600 m x 300 m) than that of Pb. The usually mobile elements (viz. Zn and Cu) may be stabilised by being associated with dolomite (i.e. an alkaline environment). At Brittania, quartz -rich 'sand' occurs directly over mineralised volcanics. Despite its location there is no dispersion observed in this unit, probably because there is no suitable host to immobilise chalcophile elements.

Open File Report 134

Geochemical dispersion around the Maronan Cu-Au Prospect, N.E. Queensland
I.D.M. Robertson, Li Shu and J. E. Wildman

The area around Maronan homestead is on the margin of the Eromanga Basin where the Proterozoic metamorphic rocks of the Mt Isa Inlier have been partly covered with Mesozoic, Tertiary and Quaternary sediments. This has presented a considerable challenge to geochemical exploration in the region. To date, exploration in the Eromanga and Carpentaria basins has been by investigation of geophysical targets by drilling.

There has been a complex history of erosion and deposition during the Mesozoic and Tertiary. In the late Jurassic and early Cretaceous, fluvial and deltaic sediments of the Gilbert River Formation were deposited in broad valleys which later became mesas on the Proterozoic basement at the headwaters of the Cloncurry, Bustard and Fullarton rivers to the southwest of the study area. Subsidence of the Eromanga Basin and marine transgression in the Cretaceous covered the Eloise area with mudstones and limestones 50-150 m thick concealing mineralisation in the Proterozoic basement.

The ancestral Fullarton River later deposited 5 to 8 m of Tertiary fluvial sediments on the Mesozoic. Since the early Cretaceous, incision has created erosional terraces, plains, higher river terraces and lower river terraces. The Tertiary fluvial sediments were slightly ferruginised and mottled and brown soil was developed on them.

There were no indications of mechanical dispersion of mineralised material from the Maronan mineralisation into the alluvium, the only geochemical indications were restricted to the saprolite in the single drillhole investigated. Consequently there were no geochemical indications in the soil over the prospect.

Thick Tertiary alluvial cover at Eloise presents an effective barrier to geochemical exploration. Dispersions within the saprolite would seem to be the best geochemical target, these are likely to be limited.

Open File Report 135

Surficial geology around the Eloise Cu-Au Mine and dispersion into Mesozoic cover from the Eloise mineralisation, N.E. Queensland

Li Shu and I.D.M. Robertson

The area around Eloise is on the margin of the Eromanga Basin where the Proterozoic metamorphic rocks of the Mt Isa Inlier have been partly covered with Mesozoic and Cainozoic sediments. This has presented a considerable challenge to geochemical exploration in the region. To date, exploration in the Eromanga and Carpentaria basins has been by investigation of geophysical targets by drilling. The intent of this study was to determine the geomorphic and linked sedimentary history of this region and, using this framework, to investigate a number of opportunities for using geochemistry in this difficult environment.

There has been a complex history of erosion and deposition during the Mesozoic and Tertiary. In the Late Jurassic and Early Cretaceous, fluvial and deltaic sediments of the Gilbert River Formation were deposited in broad valleys which later became mesas on the Proterozoic basement in the catchments of the Cloncurry, Bustard and Fullarton rivers to the southwest of the study area. Subsidence of the Eromanga Basin and marine transgression in the Cretaceous covered the Eloise area with mudstones and limestones 50-150 m thick, concealing the mineralisation in the Proterozoic basement.

The ancestral Fullarton River later deposited 5-8 m of Tertiary fluvial sediments on the Mesozoic. Since the Early Cretaceous, incision has created erosional terraces, plains, higher river terraces and lower river terraces. The Tertiary fluvial sediments were slightly ferruginised and mottled and brown soil was developed on them. Kaolinite of the brown soil has been partially converted to smectite, forming patches of black soil on the higher terrace, where the fine-grained sediments are water retentive. Black soil has developed on the lower river terrace, forming extensive black soil plains.

Thick Cretaceous cover at Eloise presents an effective barrier to geochemical exploration. Apart from the mineralisation, the most promising geochemical target at Eloise is the Proterozoic-Cretaceous unconformity. This consists of a thin and probably discontinuous layer of coarse sediments developed on and from erosion of the basement which might retain a mechanical or hydromorphic dispersion from the Eloise mineralisation. The palaeotopography of the unconformity was reconstructed from distant water bores and near mine drilling. Sampling of the decline and geotechnical and water bore drilling indicated no dispersion into the Mesozoic but there were indications of mechanical down-slope dispersion along the unconformity. Mechanical dispersion at the unconformity around Eloise may have extended about 100 m from the mineralisation or from mineralised faults. Drilling 3 km distant from the mine indicated some small anomalies, notably just above the unconformity. This site appears to have been located directly down the palaeo-slope from Eloise and early sediments infilling this area were, therefore, slightly anomalous.

Investigation of mechanical dispersions of Cu, Au, As and Sb in coarse sediments at the Proterozoic-Mesozoic unconformity seems to be a valid prospecting method in areas of unweathered or slightly weathered Mesozoic cover. The form of the palaeolandscape governs dispersion directions so this needs to be thoroughly understood.

Open File Report 136

Atlas of ferruginous and siliceous materials, North Queensland
C. Phang, R.R. Anand, J.E. Wildman and I.D.M. Robertson

This Atlas fulfils one of the specific objectives of the P417 project, that is to determine a field scheme for the identification and classification of sample types for use with exploration drilling and surface sampling. The Atlas depicts ferruginous and siliceous regolith materials that are found in the Mount Isa and Charters Towers - north Drummond Basin regions in North Queensland. Each group of regolith materials is subdivided into different regolith types and sub-types. The classification is based on field relationships and morphology of sliced hand specimens. Wherever feasible, regolith types are related to photographically illustrated geomorphological settings.

Open File Report 137

A regional overview of the Charters Towers - North Drummond Basin Region: Geomorphic Landform Provinces

S.J. Fraser

A regional-scale map (1:250 000 scale) of interpreted geomorphic provinces has been produced over the Charters Towers - North Drummond Basin area. The area has substantial mineral potential, but Tertiary sediments conceal prospective lithologies. For explorationists, the map is intended as a guide, to assist in area-selection and in formulating exploration strategies. For regolith mappers and researchers, the map provides a framework for more detailed studies. A digital version of the mapped polygons is available upon request.

The landscape evolution and weathering history of the region since the Mesozoic is complex. Erosional processes currently dominate; however, the landscape retains evidence of a complex history of at least two cycles of deposition, weathering and erosion.

The area has been subdivided on the basis of landform into seventeen geomorphic provinces, each of which contains particular regolith characteristics. These geomorphic-regolith provinces were delineated using photoform, drainage and other textural features identified on processed Landsat TM imagery. The resulting interpretation is a broad scale regional subdivision of the landscape. For planning geochemical surveys at tenement or prospect scales, a more detailed subdivision of the landscape would be required than that presented here.

Because the nature of the land's surface is critical in determining an appropriate geochemical exploration strategy, the mapped geomorphic-regolith provinces were grouped into regolith-terrain classes, which broadly convey information regarding the nature of the surface, and the state of preservation of weathering profile material. Three terrain types have been identified: Duricrust Dominated Terrain, Saprolite Dominated Terrain and Alluvium and Colluvium Dominated Terrain.

In provinces belonging to the Duricrust Dominated Terrains, ferruginous weathering products could be useful geochemical sampling media because Au and other pathfinder elements such as As, Cu and Bi are generally trapped in secondary iron oxides, which are in turn, the main components of ferruginous materials. Such samples should be most informative in those areas with duricrust preservation on basement lithologies, however, extensive areas of duricrust development on basement have not been recognised. Areas of duricrust are commonly found on outcrops of Tertiary sediments, which belong to the Southern Cross (Suttor) and Campaspe Formations. Despite these sediments being predominantly fluviatile, their associated secondary ferruginous weathering materials could contain trace-element concentrations indicative of underlying mineralization. Both clastic (mechanical) and hydromorphic geochemical dispersal mechanisms have possibly operated. Of particular significance for mineral exploration is the development of a widespread, though not continuous layer of weakly cemented ferruginous nodules towards the top of weathering profiles associated with the Campaspe Formation (unit UFP) on the western side of the study area. The possibility that these ferruginous nodules may contain subtle geochemical anomalies indicative of basement mineralization needs to be investigated further.

In those provinces belonging to the Saprolite Dominated Terrains, secondary ferruginous materials, if available, should be sampled wherever possible. However, these will need to be supplemented with more traditional, geochemical samples, such as stream sediment, rock chip, and soil samples, in areas where saprolite has been removed.

For those provinces in the Alluvium and Colluvium Dominated Terrains, there are two geochemical strategies. In areas of colluvium, traditional geochemical sampling methods should be appropriate. Areas with a high contribution of alluvial material probably will require drilling and subsurface sampling. And if buried weathering profiles are intersected during drilling, ferruginous materials if available, should be preferentially sampled.

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Regolith-landforms of the Mt Isa Geodynamic Transect
M.R. Dell

In March 1994 the Australian Geodynamics CRC (AGCRC) and the Australian Geological Survey Organisation (AGSO) conducted a seismic survey across the Proterozoic Mt Isa Inlier in Northern Queensland. The objectives of that study were to determine the regional and local structure of the Mt Isa region, particularly the nature of its boundaries and internal structure. The survey resulted in some 1200 seismic shot holes being drilled along the full extent of the transect. Coincident with this study, the CRC for Landscape Evolution and Mineral Exploration (CRCLEME) in collaboration with the CRC for Australian Mineral Exploration Technologies (CRCAMET), initiated an AMIRA Project (P417) which was concerned with developing our understanding of the nature and evolution of the regolith and landscape of the Mt Isa region.

The large number of seismic shot holes along the seismic transect presented a unique opportunity to study the nature of regolith materials and regolith stratigraphy associated with the principal lithologies and tectonic units of the Inlier and adjoining basins. To that end, the three CRCs entered into a collaborative arrangement whereby the lifts from each shot hole were logged from a regolith perspective. The observed regolith stratigraphic relationships were placed in context by mapping the regolith landforms along a 5 km swath for the length of the transect. This report presents the results from this study and represents a successful outcome from that collaboration.

Weathering Characteristics
The complex geology observed within the drill spoil along the Geodynamic Transect is reflected in the development of a highly variable, complex regolith profile. The observed complexities are related to a varied tectonic history, complex boundary relationships, sudden changes in lithology the steep dip and gradational metamorphic grade.

The rocks observed along the Geodynamic Transect and in particular across the Inlier itself are characterised by relatively thin regolith profiles. The nature of the present-day regolith and more notably the thin profiles can be attributed to the present erosive geomorphic phase, which has persisted through the late Tertiary and Quaternary (Blake, 1987). This regime coupled with the present climate in the study area is not favourable for deep (>50 metres) regolith development or the preservation of older weathering profiles.

The removal of the regolith mantle is facilitated by the relatively high relief of the inlier, coupled with heavy seasonal rains which act to prevent the 'blanket' lateritic profiles which have developed within similar aged rocks in areas of western and south-eastern Australia.

Remnant mantles of black soils and patches of ferruginous alluvium and colluvium elevated above the present basin and are interpreted as being indicative of past stable landscapes are observed being actively eroded from the Proterozoic rocks of the inlier. The removal of this material is aided by the development of active new drainage networks, which have captured older drainage systems.

Evidence for past deep weathering episodes are preserved within mesa structures, developed over Proterozoic and Mesozoic rocks and within the basinal sedimentary assemblages present within the Eromonga and Georgina basins. Other more fragmental evidence for past deep weathering events is present beneath isolated siliceous, ferruginous caps, Tertiary sediments or alluvial soil profiles along the Geodynamic Transect. At these locations the relatively resistant materials have preserved a more complete weathering profile with deeper saprolite development than surrounding rock units and the development of mottling, strong iron staining and silicification of the upper profile.

Thick regolith profiles are generally restricted to areas of subdued relief; unconsolidated or poorly consolidated sediments, where shearing or faulting is present or where significant permeability contrasts along bedrock contacts are present. In these situations regolith thickness exceeds 40 metres.

Silicification

Silicification is observed in numerous locations and geomorphic settings along the Geodynamic Transect. It occurs as laterally extensive siliceous duricrusts capping Mesozoic sedimentary successions and Proterozoic basement, and as variably silicified horizons within saprolite, saprock, bedrock, alluvial or colluvial profiles. The silicification of the rocks observed within the inlier can be attributed to intrusion of igneous bodies and associated contact metamorphism and metasomatic fluids, regional scale metamorphism and to groundwater and weathering processes. Silicification resulting from groundwater and weathering processes is commonly spatially related to ferruginisation. Silicic horizons are both overlain, or in places underlain by iron enriched or cemented material. The spatial relationship of ferruginisation and silicification suggests that siliceous and ferruginous duricrusts can form in similar settings.

In areas where there has been considerable stripping of weathered material these siliceous mantles are elevated in respect to the rest of the landscape. This phenomenon is best illustrated by the mesas to the south east of Cloncurry and by the silicic capped metasedimentary successions south east of Mt Isa which rise up to 200 metres above the undulating granitic and porphyritic plains below.

Siliceous mantles are observed within the poorly consolidated sediments of the Georgina Basin. These silicified saprolitic sandstones and siltstones and silicified and ferruginised alluvium are observed continuously for over 1 km at thicknesses up to 10 metres beneath a thin cover of saprolitic clays, iron-rich colluvium and black soils. These inclined siliceous mantles sit within the saprolite below the lower slope of a low hill. This setting has been suggested as being a favourable sight for the formation of both siliceous and ferruginous duricrusts.

Ferruginisation

Ferruginisation or more particularly the development of iron-rich regolith profiles is greatest within the more mafic volcanic, schistose and iron-rich sedimentary lithologies. However, some degree of ferruginisation in the form of iron staining or iron-rich veining is observed within all rock types. Ferruginisation occurs as pervasive staining, micro and large-scale veining and spotting and in more concentrated forms as goethitic and hematite rich ferruginised saprolites and mottled zones and iron cemented alluvium. Sub-metallic hematitic accumulations and segregations as early stage mottling were observed within metasedimentary units and less frequently within metabasalts, mafic schists. Within the Sybella granites a very well developed mottled zone up to 10 metres thick is preserved beneath a hard resistant cap of silicified and ferruginised saprolites.

Iron-rich lags of ferruginous granules, pisoliths, ironstone fragments and ferruginised bedrock fragments are common over mafic lithologies and where ferruginous saprolites are exposed at surface. Iron cemented bedrock fragments and lag occur within drainage depressions or depositional slopes adjacent to iron-rich lithologies or ferruginous weathering mantles.

The lack of extensive iron-rich lithologies and ultramafic units across the inlier has restricted the formation of the deeply weathered lateritic profiles capped by a hardened ferruginous mantle or 'duricrust', underlain by mottled saprolitic clays, pallid zone, saprock and bedrock which are observed in Western and South Eastern Australia.

Calcification

Calcification and the calcareous enrichment of the regolith profile and underlying rocks is observed as late stage pedogenic calcretes, calcareous nodules and as pervasive calcareous veining and coatings. Calcretes are preferentially developed within the calc-silicate units of the Corella Formation and Corella Group rocks. Pedogenic carbonates are also observed adjacent to creeks, rivers and other drainage depressions or poorly drained areas of the landscape. Contemporary processes have led to the development of calcareous root casts. These have developed beneath native grasses and are observed within recent unconsolidated sediments at station 3532. Gypsiferous crystals and calcification of the upper profile within sediments of the Eromonga Basin is attributed to present groundwater processes.

Implications for Exploration

Geochemical exploration strategies over much of the Mt Isa Block are relatively simple due to the extensive outcrop of unweathered or partially weathered bedrock and skeletal soils. Soil and stream sediment sampling strategies can be employed over these areas, with numerous ephemeral streams and creeks providing fresh sample media after each wet season. Care must be taken to identify colluvial and alluvial materials, which will dilute or mask the geochemical signal of the underlying rocks. The Geomorphic domains map shows the distribution of skeletal soils, colluvium and alluvium across the study area.

Regional studies undertaken by the CSIRO within the Yilgarn Craton and the Mt Isa Block and localised studies of the Lady Loretta and Python Prospects have found that ferruginous upper profiles, mottled zone and calcretes provide favourable sampling media for metalliferous mineral exploration. Both these media would be effective tools for mineral exploration within the Inlier.

The historically economically important sedimentary and metasedimentary units of the Urqhart Shales and Mt Isa group rocks show strong bleaching and deep saprolite development to depths in excess of 40 metres. In these areas deep drilling below the bleaching is recommended as weathering may have leached the pathfinder elements. Iron-rich sedimentary sequences within these units are expressed surficially by the presence of iron-rich segregations, granules, ferruginous duricrusts or gossan like features. These massive iron accumulations effectively scavenge ore related elements and provide a very useful sampling medium.

The sedimentary dominated areas at the Eastern and Western Extents of the study area provide the most difficult exploration environments. Geophysical technologies are proving the most useful tools in these environments, with supplementary redox front or ferruginous interface zone sampling. Further work is required on the definitions and development of effective geochemical strategies in these environments.

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Geochronology of weathering in the Mount Isa and Charters Towers Regions, Northern Queensland

P. Vasconcelos

Weathering geochronology of the Mount Isa region

This project is the most comprehensive weathering geochronology study ever undertaken in a single region. More than 103 $^{40}Ar/^{39}Ar$ laser step-heating and 11 K-Ar analyses provide a substantial geochronology database which permits answering some surficial geochemistry and landscape evolution questions for the region.

The Mn oxide results indicate that the evolution of weathering profiles in the Mount Isa Region spans the whole of the Tertiary, possibly extending back into the Cretaceous. The $^{40}Ar/^{39}Ar$ results obtained for the jarosite samples also indicate that weathering-related mineral precipitation continued until the Quaternary. However, these weathering reactions are driven by groundwater with little recrystallization of Mn oxides at the surface.

A remarkable feature is the concordance in the ages from similar geomorphic provinces, even where samples were from chemically different and spatially separated profiles. The ages of the Mount Isa Mines gossans (14.5-21 Ma, with 20.9 Ma as the most probable) and gossans exposed at Lake Moondarra (17-24 Ma, with 19.5 or 20.7 Ma as the most probable) indicate that the Mn oxide minerals in the dissected part of the landscape were precipitated in the early Miocene. The results for the Kennedy Gap area are also very consistent. Manganese oxides from the Mesa I and the Gunpowder Creek Road site yield ages ranging from 30-40 Ma, with best estimates at 32, 35, and 37 Ma. Finally, samples from the Selwyn, Pegmont, and Tringadee prospects are concordant with the weathering ages (12-13 Ma) for the Cannington Region. Geomorphological provinces with more complete and stratified weathering profiles (Overhang, Selwyn, and Kennedy Gap) are older; the most dissected parts of the landscape yield the youngest weathering ages (Century).

The weathering geochronology implies that the Mount Isa region has seen some very wet periods, when dissolution, redistribution and reprecipitation of elements within weathering profiles was facilitated by an abundance of meteoric water. These periods were probably the late Cretaceous to early Palaeocene, the early to middle Oligocene, and the early to middle Miocene.

The geochronology is significant because it may be combined with mineral chemistry to suggest mechanisms, pathways and rates of element migration in the past that may, in turn, help explain patterns of surficial geochemical anomalies. A complete explanation of this is given by Vasconcelos (1997). Some important issues are summarised below.

The Mn oxides overlying the Mount Isa deposit are rich in Pb, Zn, and Ba. In addition to cryptomelane (KMn_8O_{16}), coronadite ($PbMn_8O_{16}$), chalcophanite ($ZnMn_3O_7.3H_2O$), hollandite ($BaMn_8O_{16}$) and barite are present, suggesting large-scale migration of Pb, Zn and Ba in solution between 14-21 Ma.

The Mn oxides of the Century profiles host coronadite, chalcophanite and plumbogummite ($PbAI_3(PO_4)2OH5.H_2O$). The high concentrations of Pb and Zn suggest that these elements were derived from a nearby source, and did not precipitate at the Cambrian-Proterozoic unconformity by long-range transport in the groundwater system. The most likely source for Mn, Zn, Pb, Ba and K in the Mn oxide outcrops is the weathering Century mineralization.

Since solubility and oxidation-reduction constraints would prevent large-scale migration of Pb, Zn and Mn in solution by oxidising surface waters, the precipitation of the Mn-rich "false gossans" at Century most likely occurred in a shallow subsurface environment. Lead, Zn and Mn, derived from weathering of the Century mineralization, migrated in solution and were precipitated at the chemical barrier imposed by the basal Cambrian limestone. Erosion of 5-50 m of overburden in the past 5 Ma is implied.

The Mn oxides (coronadite and chalcophanite) from Pegmont and Cowie are also significantly enriched in Pb and Zn, respectively, indicating association with nearby Pb and Zn mineralization.

The Mn oxides at Tick Hill and Selwyn are different from those associated with Pb-Zn deposits in that they are enriched in Co and Zn (~0.5 wt%) with negligible Pb contents.

Manganese oxides from the Tringadee prospect are devoid of Pb, contain only moderate Zn contents (~0.5 wt%), and are enriched in Co which is consistent with association with Cu-Au or Au mineralization.

Manganese oxides on the Pilgrim Fault in the Tick Hill area replace silcretes. Given the extreme cation-depleted (except for Si and Ti) nature of the silcretes it is unlikely that the cations in the Mn oxides (Mn, K, Ca, Ba, Na, Co) were precipitated from descending groundwaters. The most likely source of these oxides is mineralised groundwater ascending along the Pilgrim Fault. The geochemical anomalies associated with these manganese "breccias" may reflect leaching of elements from distal sources (100's to 1000's of m) and are unlikely to be from nearby or underlying mineralization.

Weathering geochronology of the Drummond Basin

The deep weathering profiles exposed at the Scott Lode gold deposit were sampled in detail (Vasconcelos, 1997 (452R)). Manganese oxides and K-bearing sulphates (alunite and jarosite) occur throughout but only selected benches could be sampled due to safety reasons. No mineral suitable to $^{40}Ar/^{39}Ar$ geochronology occurred in the ferruginous channel deposits (Southern Cross Formation) overlying the mineralised volcanic rocks so only weathering of the underlying volcanic bedrock could be investigated. Manganese oxide samples were collected along the mine access road bench and at approximately 20 m and 60 m below the mine access road level. Thirty-eight grains from 13 Mn oxide samples were analysed by the 40Ar/39Ar laser-heating method and four grains from 2 jarosite hand specimens from approximately 20 m below the mine access road level.

Remarkably reproducible results were produced from the 13 Mn oxide samples analysed (in excess of 500 individual analyses). Plateau ages ranged from 3.9 $\pm$ 0.1 Ma at the bottom of the pit to 16.2 $\pm$ 0.2 Ma at the uppermost part of the weathering profile at the western edge of the pit. The ages from jarosite were also remarkably reproducible. Only one jarosite grain yielded a plateau age (4.5 $\pm$ 0.1 Ma); the other three grains displayed a plateau-like series of steps at low temperatures, but the ages were unreasonably great at high temperature. The climbing spectra suggest that the jarosite grains are intermixed with unweathered or partially weathered hypogene silicates.

One Mn oxide sample from the Scott Lode was also dated by the K-Ar bulk method. The age (39.5 $\pm$ 2 Ma) is drastically different from the $^{40}Ar/^{39}Ar$ ages. The only explanation for the discrepancy is the presence of contaminants.

Weathering profiles overlying the Mount Leyshon and Kidston ore deposits were dated by K-Ar analysis of alunite. The results for Kidston (1.85 $\pm$ 0.04, 1.61 $\pm$ 0.04, 1.52 $\pm$ 0.03, 3.91 $\pm$ 0.07, 4.1 $\pm$ 0.2 Ma) and Mount Leyshon (3.1 $\pm$ 0.2 and 4.1 $\pm$ 0.1 Ma) indicate Plio-Pleistocene ages, surprising given the long history of weathering in the region. The $^{40}Ar/^{39}Ar$ ages for jarosite samples of this study (plateau age of 4.5 $\pm$ 0.1 Ma and plateau-like steps at 3.2 $\pm$ 0.1 and 2.7 $\pm$ 0.1 Ma) are consistent with these young ages.

However, Mn oxide $^{40}Ar/^{39}Ar$ ages indicate a longer history of weathering than suggested by $^{40}Ar/^{39}Ar$ jarosite or alunite ages. The Mn oxides dated in this study fill cavities and desiccation cracks in kaolinised volcanic rocks, indicating that the host sequence was already strongly weathered at the onset of Mn oxide precipitation, at approximately 17 Ma. It is significant that Mn oxide ages are greater (10-17 Ma) at shallower horizons and younger precipitation ages are recorded at the bottom of the profile (4-6 Ma), indicating a downward propagation of the weathering front.

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Regolith landform relationships and geochemical dispersion around Tringadee and Brumby prospects, North Queensland

C. Phang, T.J. Munday and J.E. Wildman

The purpose of this study is to investigate the origin of a Zn anomaly (up to 1000 ppm) in Mesozoic cover at Tringadee prospect. In the Brumby prospect, ferruginous materials developed in Mesozoic cover at the surface or subsurface were studied to find any indication of concealed mineralisation. District scale regolith mapping of approximately 550 km2 was carried out to provide a framework for a geochemical dispersion study of the two prospects. Stratigraphic relationships of the main regolith units were also established to provide constraints for the interpretation of the regolith geochemistry.

Three major geomorphic environments can be delineated in the Tringadee area. These are i) the low hills and mesas developed in Mesozoic sediments in the central zone, ii) the low hills and mesas developed on the Proterozoic basement in the north and west and iii) the depositional plains with brown and well-developed 'black' clay soils over recent alluvial materials to the south and southeast. Contrasting lithologies combined with erosion, deposition, ferruginisation and silicification are important factors contributing to the variation in regolith materials and landforms observed in the area.

At the Tringadee Prospect, the Zn anomaly in the Mesozoic sediments appears to be associated with accumulated Fe and Mn oxides. The area is interpreted to have remained in a low part of the landscape before, during and after deposition of the Mesozoic sediments. Iron, Mn and Zn appear to have derived from external sources and have migrated laterally along permeable layers, precipitating at redox fronts within the sediment pile. This probably occurred after deposition, but contemporaneous accumulation of the metals with the sediments is possible. It is considered that the source of the Zn is external and that it has been scavenged by Fe-Mn oxide precipitates, now represented by ferruginous bands. There is, thus, no relationship between Zn anomalies in the sedimentary cover and potential base metal mineralisation in the basement.

The Brumby prospect has subvertical ferruginous veins in the Mesozoic, probably associated with faulting of the underlying Proterozoic and appear to form remnants of conduits for fluids rich in Fe. The ferruginous veins give no indication of mineralisation. In contrast, the subhorizontal ferruginous bands associated with redox zones or permeability layers within the sediment pile are preferentially sampled.

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Landscape evolution and regolith development over the Mt Coolon Area, Central East Queensland

Li Shu

The Mount Coolon area has a complicated history of regolith development and landscape evolution. The dominance of a southerly flowing river system in the early Tertiary, the formation of a large lake system in the middle Tertiary, and the reversal of the river system in the late Tertiary make up the main episodes.

The Eastern Highlands of Australia in central Queensland divide the coastal plains to the east and the inland lowlands and hills to the west. To the west of the Highlands, a southerly drainage once existed as shown by the Burdekin, Cape, and Campaspe rivers as well as the upper reaches of the Suttor River and its tributaries such as Police Creek and Rosetta Creek. Tertiary sediments are found on the ancestral southerly flowing rivers.

Eruption of a large volume of basalt around Clermont in the south disrupted the southerly drainage. Tertiary basalts, extruded from fissures and circular vents over a large area during the Tertiary, filled in valleys and blanketed sub-basaltic topography. A palaeovalley under the basalt is evident from bore hole data from various companies. As a consequence of basalt eruption in the south, the southerly flowing Burdekin River system was choked, and a large lake was subsequently formed. With ongoing deposition in the Tertiary lake, flood waters in the Burdekin River rose to a level high enough to find a new course along a gap through the Eastern Highlands and divert the river to the east. With a large catchment and high erosional energy, the Burdekin River incised the Highlands and formed a conspicuous gorge and, as a result, a northerly flowing drainage was developed.

Deposition and erosion in the north Drummond Basin has been dictated by drainage changes. During the period when the southerly drainage was blocked, sedimentation took place at a rapid rate, giving rise to the Suttor Formation in the south and the Southern Cross Formation in the north. With the formation of the Burdekin Gorge, the base level of erosion for the Burdekin River was lowered rapidly, renewing erosion energy within the river system. As a result of rapid erosion, the Southern Cross and Suttor Formations were dissected and largely removed.

Once the easterly drainage system was established, sediments were deposited on the Suttor Formation and its equivalent where less affected by the major change from the southerly to the easterly drainage. New floodplains were built up again where intensive erosion of the Suttor Formation occurred. These late sediments are termed the Campaspe Formation in the Charters Towers region.

Along with landscape evolution, both Palaeozoic rocks of the Anakie Inlier and Tertiary sediments of the Suttor Formation have been deeply weathered in the area. Saprolites are common in the Anakie Inlier and the Drummond Basin sequence, and, in most cases, are mottled, bleached or silicified. Late Carboniferous volcanics, mainly rhyolites and ignimbrites, are less weathered and crop out as saprock. Sediments of the Suttor Formation are ferruginised and silicified, giving rise to the formation of ferruginous duricrusts and silcretes. Lateritic duricrust forms mesa-cappings predominantly on Tertiary sediments, but it is also found on Palaeozoic rocks. Based on field observations, a regolith-landform map of the area (25 x 49 km) is prepared to a scale of 1:50,000.

This study suggests that ferruginous duricrust, nodules and pisoliths on saprolite of basement, are likely to be indicators of geochemistry at depth. Stream sediment sampling may be an alternative approach to explore erosional terrains. Alluvial material, including the Suttor Formation and soils on alluvial plains, is not suitable for geochemical exploration. However, where the cover is less than five metres thick, soil sampling, including specific sampling of mottles, would be effective. The probability of hydromorphic dispersion is better in sediments that have been weathered since deposition.

Open File Report 142

Mt Isa Field Trip

R.R. Anand, J. Wilford, T.J. Munday, C. Phang, J.E. Wildman and K.M. Scott

8:00 Bus leaves Verona Motel, travel to Tringadee

STOP 1

Cowie Prospect - Pb, Zn, Ag gossan, implications for exploration.

STOP 2

Relationships between the base of the Mesozoic and ferruginisation;

implications for exploration.

STOP 3

Weathering and ferruginisation over a Proterozoic granitoid; implications for exploration.

STOP 4

Brumby Prospect - relationships between ferruginised fracture zones in Mesozoic cover and mineralisation; implications for exploration.

STOP 5

Black soils

STOP 6

Tringadee Prospect - relationship between anomalous Zn in Mesozoic cover rocks, ferruginisation and pathfinder elements; implications for exploration.

STOP 7

A Mesozoic lateritic weathering profile - relationships between ferruginisation, mottling, collapse breccias and silicification - implications for exploration.

17:00 Travel to McKinley

7:30 Bus leaves Walkabout Hotel, travel to seismic line and Mt. Isa

11:30 Arrive Mt. Isa

Open File Report 143

Mineralogical and geochemical aspects of the regolith at the Brahman Au Prospect, Charters Towers area, N.E. Queensland

K.M. Scott and S.J. Fraser

The regolith at the Brahman Au prospect, is characterised by the presence of ferruginous pisoliths above mottled transported sandstone (Campaspe Formation) which unconformably overlies residual clay and saprolitic granite. Within the profile, Au is laterally dispersed for up to several hundred metres at the top and bottom of the saprolite as well as in the surficial pisoliths. Arsenic, Cu and Pb contents are also elevated in the ferruginous pisoliths. Zones of lateral dispersion of Au with a zone of depletion beneath the surficial anomaly are similar to those commonly observed in the Yilgarn Craton of Western Australia. However, at Brahman, the Au-enriched pisolitic unit and Au-depleted mottled zone are developed in transported material, i.e., Au has been hydromorphically dispersed into the overlying sediments. Manganese oxides and associated elements (Ce, Co, La and Zn) are well developed in the clay zone of the profile, but are also present in transported material suggesting that they are also dispersed late in the history of regolith development.

Despite their probable development in transported material, the ferruginous pisoliths represent a good sampling medium. Orientation results suggest that low level Au, As, Cu end Pb halos at least 700 x 500 m are present even in five metre composite samples that include a large component of non-ferruginous material. More intense anomalies, with better signal-to-noise ratios, would be expected with purer pisolitic samples which have not been diluted with depleted material. The development of such extensive hydromorphic dispersion over minor mineralisation is encouraging for exploration within the Charters Towers region. Anomalous Th (+U) with the pisoliths suggest that airborne radiometrics may be a useful method to assist in the planning a regional pisolith sampling programme.

INDEX

Indexed by CRC LEME Open File Report Number

Notes:-

1). This index has been taken from the abstracts.
2). Refer to the listing of abstracts above to obtain context before reading the report itself.
3). See also the small index in Open File Report 125 'Regolith-landscape characteristics, evolution and regional synthesis of the Mt Isa Region - Progress Report.

M

N

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P

LIST OF PAPERS

Papers published, at least in part, as a result of these CRC LEME/AMIRA Studies

At the date of this publication, the following papers have been published or are in press: -

Feng, Y.X. and Vasconcelos, P.M. 2001 Quaternary Continental Weathering Geochronology by Laser-Heating $^{40}Ar/^{39}Ar$ Analysis of Supergene Cryptomelane. Geology, 29(7): 635-638.

Li, J.W. and Vasconcelos, P.M. 2002 Cenozoic continental weathering and its implications for paleoclimatic: evidence from $^{40}Ar/^{39}Ar$ geochronology of supergene K-Mn oxides in Mt. Tabor, central Queensland, Australia. Earth and Planetary Science Letters. 6209: 1-52.

Robertson, I.D.M. 2002. Dispersion into the Tertiary Southern Cross Formation sediments from the Scott and Cindy lodes, Pajingo - N.E. Queensland, Australia. Geochemistry: Exploration, Environment, Analysis. In press

Vasconcelos P.M. 1999 $^{40}Ar/^{39}Ar$ Geochronology of Supergene Processes in Ore Deposits. Reviews in Economic Geology. 12: 73-113.

Vasconcelos P.M. 1999 K-Ar and $^{40}Ar/^{39}Ar$ Geochronology of Weathering Processes. Annu. Rev. Earth Planet. Sci. 27:183-229.

Vasconcelos, P. and Conroy, M. 2002 Geochronology of weathering and landscape evolution, Dugald River, NW Queensland, Australia. Geochimica et Cosmochimica Acta. In press.

The following papers are available in abstract: -

Feng, Y.X. and Vasconcelos, P.M. 2000. Quaternary Geochronology by Incremental Heating $^{40}Ar/^{39}Ar$ Analysis of Supergene Cryptomelane, Geological Society of America Annual Meeting, Reno Geological Society of America Annual Meeting, Reno, GSA Abstracts with Programs. 32(7) Abstract 51704.

Vasconcelos, P. 2001 Geocronologia de intemperismo e a evolução geomorfológica e pleoclimática do Nordeste da Austrália. In: VI Congresso de Geoquímica dos Países de Língua Portuguesa & XII Semana de Geoquímica, Faro, 2001. Actas, Conferência Plenária. 748-750.

Vasconcelos, P.M. 2000 Supergene Enrichment of Ore Deposits in Lateritic Systems, Geological Society of America Annual Meeting, Reno, GSA Abstracts with Programs,V. 32, No. 7, Abstract 51411.

Vasconcelos, P.M. 2001 K-Ar and $^{40}Ar/^{39}Ar$ geochronology of weathering processes, Exploring the Earth: a Celebration of Four Journeys, Australian National University, Research School of Earth Sciences, p. 31.

Vasconcelos, P.M., Feng, Y.X., Conroy, M. and Newberry, T. 2000 The Suitability of Alunite-Group Supergene Sulfates to $^{40}Ar/^{39}Ar$ Geochronology, Geological Society of America Annual Meeting, Reno, Geological Society of America Annual Meeting, Reno, GSA Abstracts with Programs,V. 32, No. 7, Abstract 51725.

A number of case histories, covered by research under P417, will be published shortly as part of two CRC LEME thematic volumes. These thematic volumes will be: -

1) Regolith expression of Australian ore systems
2) Regolith-landscape evolution across Australia

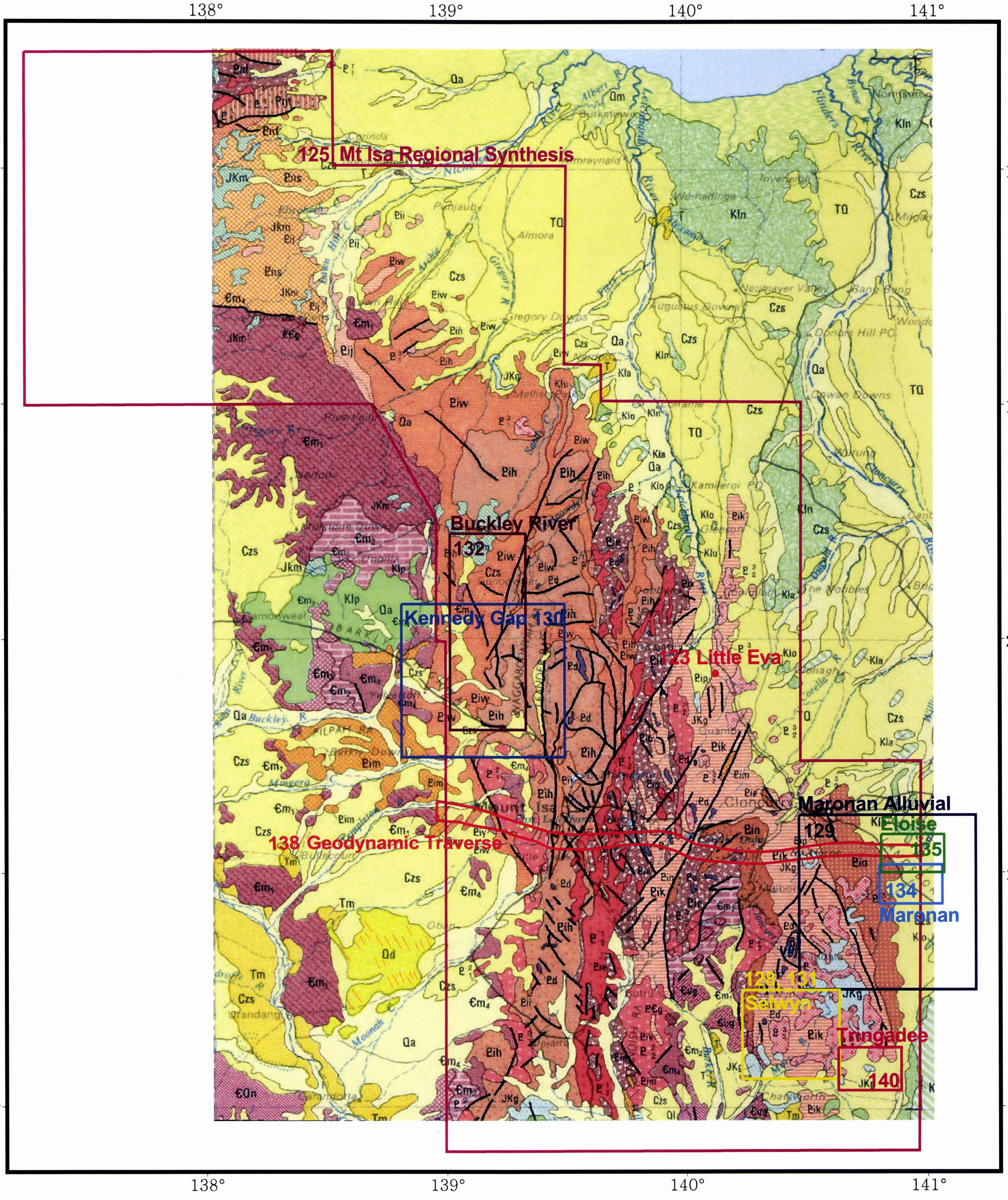

Figure 1. Western Region: Investigation sites and mapped areas with CRC LEME Open File report numbers superimposed on Queensland geology. Mapped areas as rectangles with report number. Study sites as dots with report number. Geology courtesy Queensland Department of Natural Resources and Mines.

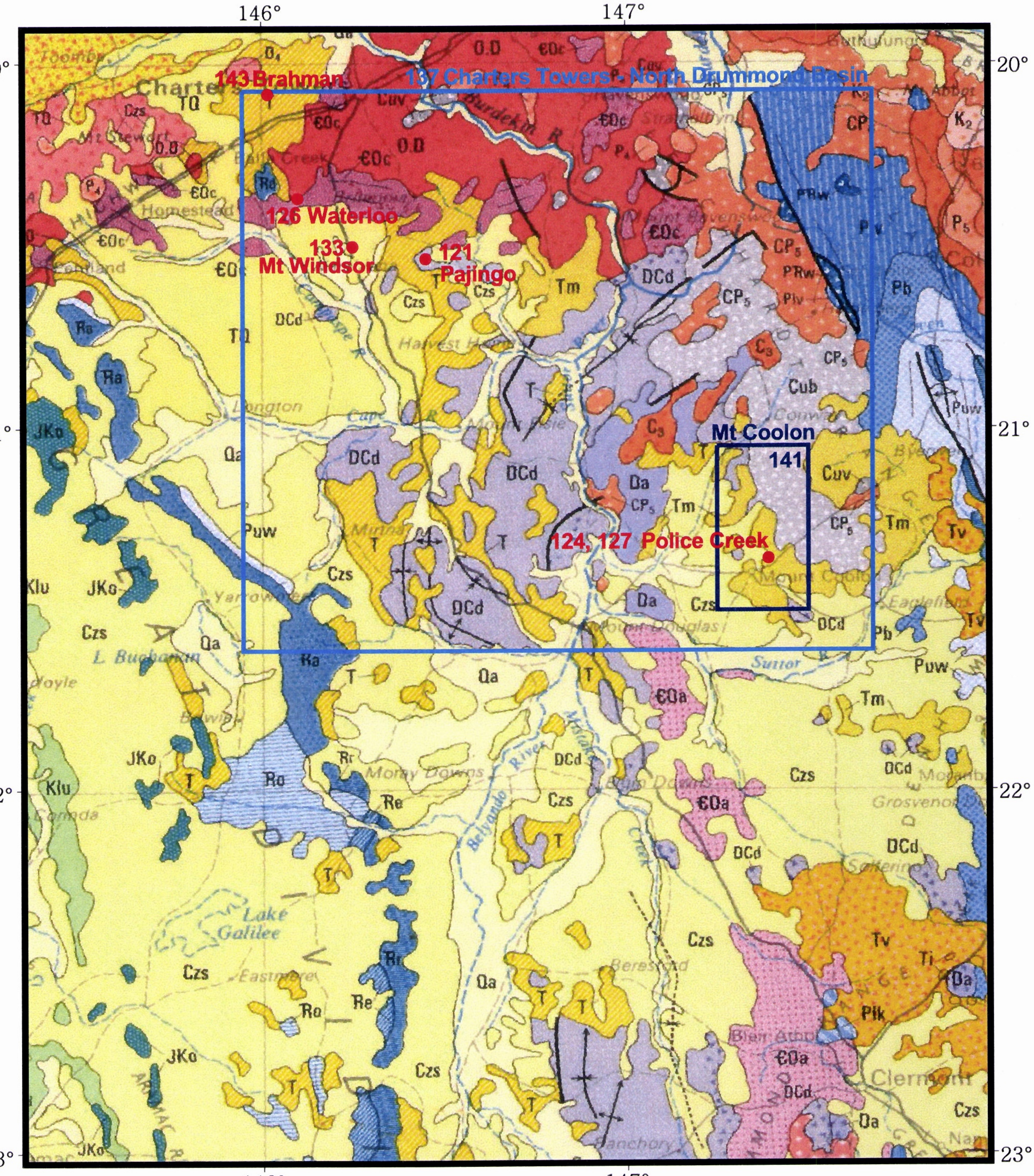

Figure 2. Eastern Region: Investigation sites and mapped areas with CRC LEME Open File report numbers superimposed on Queensland geology. Mapped areas as rectangles with report number. Study sites as dots with report number. Geology courtesy Queensland Department of Natural Resources and Mines.

FileMaker Pro Tutorial

This brief tutorial will allow you to use the basics of the run-time 'FileMaker Pro' Database, which is stored on the CD in the back of this volume. For more elaborate operation of a FileMaker Pro database, see Hester (1998)[1].

There are two database versions; *S417.FP3* for those using the MS Windows platform and *S417.MAC* for the Macintosh platform. These databases are runtime modules and contain all the software you require. Ownership of FileMakerPro software is unnecessary. First, read the license agreement on the last page of this volume. Provided you accept this agreement, you may copy the appropriate files to your hard disc and launch it as you would any normal application. A splash screen with the license agreement appears. On accepting the terms of the license, the data may be accessed. All the data in these databases has been secured. However, in the extremely unlikely event of file corruption, reload the file from the CD.

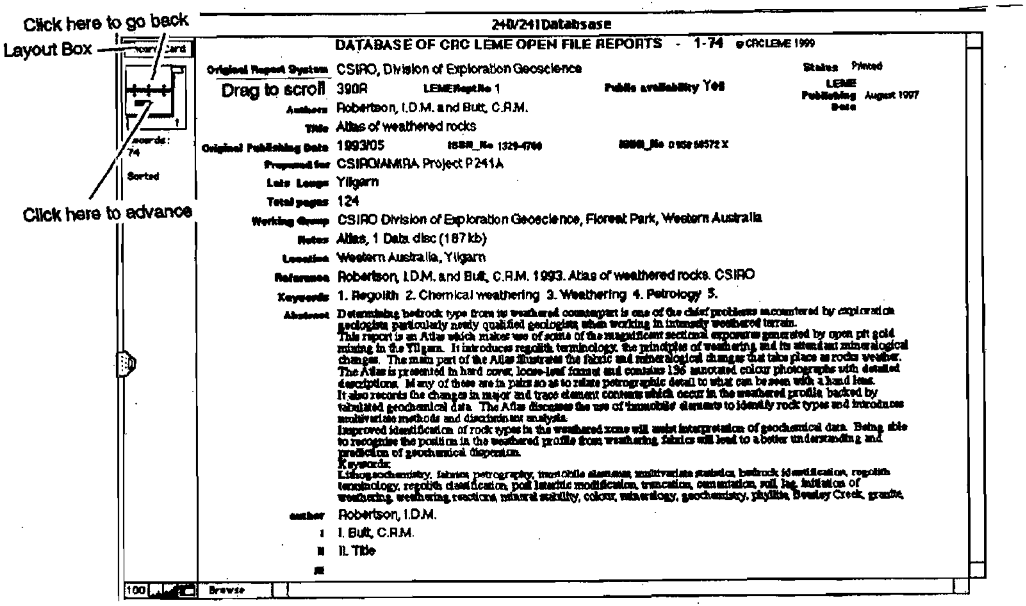

Figure 1. The appearance of the Record Card layout. Stepping through the database is achieved with the booklet icon and scroll bar in the top left.

Layouts and getting around

The first layout is the Record Card layout as in Figure 1. In the top left is a booklet icon on edge with a mini-scroll bar. The number of records is stated (141 in this database) and the database is sorted according to LEME Open File Report Numbers. You may scroll up and down the database, report by report, by clicking on the upper or lower pages of the booklet icon or by dragging the scroll bar for gross changes.

Three other layouts may be accessed by selecting from a menu activated by clicking on the Layout box. These other layouts are Bibliographic, Index Listing and Reference. The Index Listing is a similar layout to the listings given elsewhere in this volume. The Reference layout is used for a list of the *original* references; this will require editing to suit the required format. The Bibliographic layout contains information that might be required by librarians.

[1] Hester, N. 1998. FileMaker Pro for Windows and Macintosh. Peachpit Press. Website http://www.peachpit.com. This quickstart guide gives details of the full implimentation of FileMaker Pro.

Note that, in the Record Card layout, some fields contain more information than their field initially shows. Click on the field to read all its contained information. Click and drag in the Abstract field to read large abstracts.

Searching
Select **Find** from the **Mode** menu. Click in the Abstract box, type the word 'calcrete' and click the **Find** button. This will search all abstracts for the word 'calcrete'. There are 26 reports with this specification. Step through them with the book icon.

A more complex search can be achieved by typing different criteria into different boxes before initiating the **Find**. In this case, the search will find only those records that match all these criteria. To include an extra search criterion (where *either* one *or* the other (or both) will be met) select **New Request** from the **Mode** menu for the second or subsequent criterion before starting the **Find**. A * may be used as a wild-card for zero or more unknown characters. In numeric fields (only the number of pages and the Open File Report Number are numeric fields) <, or > etc may be used to set criteria. See Hester (1998) for details of more sophisticated searches.

To return to *all* the records, select **Find All** from the **Select** menu.

Sorting
The **Sort** command is found in the **Mode** menu. Select the required sort fields and **>>Move>>** them from the LH menu to the RH menu and click **Sort**.

Printing
Print from your chosen layout using the **Print** command in the **File** menu. It may be necessary to scale the size of the printed output, using the **Page Setup or Printer Setup**, to suit your printer and paper size.

Exporting
Exporting of selected records is achieved by selecting **Import/Export** from the **File** menu and selecting **Export Records** *but read and ensure compliance with the license agreement before doing this*. Give the export file a name and, under **Type**, select the export file format required. Be aware of the severe limitations in field sizes imposed by Excel and MS Access if the abstracts are to be exported. ASCII text is selected as comma-delimited text or tab-delimited text. Output to Excel may be achieved with SYLK. Select the fields to be exported from the LH Menu and **>>Move>>** these to the RH menu. Click **Export** to write the file in the chosen format.

In general, basic operation of this secure database is easy and intuitive but more complex use will require a little reading.

CONTENTS OF COMPACT DISC

This is a multi-session disc with a Macintosh part (MAC_VOL) and a Windows part (WIN_VOL). Only the appropriate part can be seen by either platform. The contents of the disc are as follows: -

***WIN_VOL** - for Windows computers*
Copy the contents of this volume to a directory of your choice. Its contents are given below.

OFDATABASE This contains the Filemaker Pro runtime module with supporting files. Launch the executable file (LEMEOREPT.EXE) in the usual way and the database will run. *N.B. This database contains information on all CRC LEME Open File Reports (1-143) and is not restricted to the produce of AMIRA P417.*

FMPTUTOR This is a brief FileMaker Pro tutorial as a PDF file. Please note there are some slight differences with the runtime module that was compiled in a more recent version.

GEOCHEM This contains a number of directories (by CRC LEME Report Number) each of which contain a compilation of all the geochemistry of P417 recorded on magnetic disc in the relevant Open File report. In some cases, individual Readme files are provided to give content and format.

LICAGREE.PDF The License Agreement in PDF[2] format.

ABSTRACT This contains the Abstracts in Word, PDF and text format.

INSTALL_INSTRUC.DOC Notes on accessing the database in Word format.

***MAC_VOL** - for Apple Macintosh Computers*
Copy the contents of this volume to a folder of your choice. Its contents are given below.

O_File_Database This folder contains the Filemaker Pro runtime module with supporting files and a directory of extensions. Launch the runtime module (LEME Open Report) by double clicking.

FMPTUTOR This is a brief FileMaker Pro tutorial as a PDF file. Please note there are some slight differences with the runtime module that was compiled in a more recent version.

GEOCHEM Copy This contains a number of directories (by CRC LEME Report Number) each of which contain a compilation of all the geochemistry of P417 recorded on magnetic disc in the relevant Open File report. In some cases, individual Readme files are provided to give content and format.

LICAGREE.PDF The License Agreement in PDF[3] format.

ABSTRACT This contains the Abstracts in Word, PDF and text format.

Installation Instructions Notes on accessing the database in Word format.

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[2] Readable by Adobe Acrobat Reader downloadable free through http://www.adobe.com/
[3] Readable by Adobe Acrobat Reader downloadable free through http://www.adobe.com/