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A REGIONAL OVERVIEW OF THE CHARTERS TOWERS-NORTH DRUMMOND BASIN REGION: GEOMORPHIC LANDFORM PROVINCES

S.J. Fraser

CRC LEME OPEN FILE REPORT 137

March 2002

CRCLEME

(CSIRO Exploration and Mining Report 366R/CRC LEME Report 39R, 1997.
Second impression 2002)

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, established and supported under the Australian Government's Cooperative Research Centres Program.

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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 137) is a second impression (second printing) of CSIRO, Division of Exploration and Mining Restricted Report 366R, first issued in 1997, which formed part of the CSIRO/AMIRA Project P417.

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Preface

The principal objective of the CRCLEME /AMIRA P417 Project is to improve substantially geochemical methods of exploration for base metals and Au in areas obscured by weathering or under cover. The research includes geochemical dispersion studies, regolith mapping, regolith characterization, dating of regolith and investigation of regolith-landscape evolution.

This report broadly describes the regolith and landforms of the Charters Towers - North Drummond Basin region of north-eastern Queensland This should assist better initial planning of geochemical exploration surveys and provide a framework for detailed investigations. It is our intention that digital versions of the mapped polygon units will be available upon request.

Substantial district and local-scale investigations within the area (Pajingo, Waterloo, Brahman Mt Coolon) are being reported separately.

R. R. Anand
Project Leader

I.D.M. Robertson
Deputy Project Leader

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Executive Summary

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 broadscale 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 recognized. 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 predominately 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.

1. Introduction

This study is a contribution towards an understanding of the distribution and characteristics of regolith[1] materials in the Charters Towers - North Drummond Basin region of north-eastern Queensland. More specifically, the study provides a regional framework for the nature and distribution of regolith materials based on mapped geomorphic landform units. This framework should not only assist explorationists to plan geochemical sampling strategies, but also to provide a regional setting within which more detailed regolith observations and studies can be undertaken. The results of these more detailed studies can then be placed in context and even extrapolated across the broader region. This study is part of the CRC LEME - AMIRA Project P417, Geochemical Exploration in Regolith-Dominated Terrain of North Queensland".

The nature of the area, the proposed scale of the resulting map (1:250,000), and the compromise between classification and spatial generalization resulted in the identification of geomorphic landform units, which are here termed provinces. These provinces were delineated from a mosaic of four Landsat TM scenes using traditional photo-geological methods (*i.e.*, photoform, drainage, and cover type analysis) supplemented by field observations at selected sites.

The Charters Towers - North Drummond Basin area has a history of mining activity and it is considered to be highly prospective for:

Volcanogenic Cu-Pb-Zn-Ag-Au-Ba mineralization within the Mt Windsor Volcanics of the Seventy Mile Range Group (*e.g.*, Thalanga Mine, Liontown, Highway, Reward);

Mesothermal Au mineralization consisting of narrow veins associated with quartz-carbonate alteration and base-metal sulphides (*e.g.*, Charters Towers, Rishton, Hadleigh Castle);

Permo-Carboniferous Porphyry-related Au mineralization related to intrusive complexes associated with Permian rhyolitic-to-trachytic plugs and dykes (Mt Leyshon); and,

Epithermal Au mineralization, some examples of which are localized within the sediments and volcanics of the Drummond Basin, and commonly spatially associated with porphyry systems (*e.g.*, Pajingo, Wirralie, Mt Coolon, Yandan).

1.1. Location, Climate and Vegetation

The study area extends from latitudes 20° 04' 30" to 21° 36' 30" S and longitudes 145° 57' 30" to 147° 40' 30" E, and covers parts of the Charters Towers, Bowen, Mt Coolon and Buchanan 1:250 000 scale map sheets (Figure 1).

Charters Towers, the principal population centre within the area, is situated on the Flinders Highway some 135 km southwest of Townsville. A network of station tracks and three major roads allow access throughout the study area. The Gregory Developmental Road (sealed to Belyando Crossing), which connects Charters Towers with Clermont (some 380 km south) is located within the western half of the area. The Collinsville - Mt Coolon - Belyando Road (unsealed) allows east-west access across the southern section of the area. The Mingela - Ravenswood - Burdekin Dam Road (sealed),

[1] "Regolith" is used here as a general term for the entire cover, cemented or unconsolidated, that overlies unweathered bedrock and which is formed by weathering, erosion, and sedimentary or chemical deposition.

allows north-south access east of the Burdekin River, and an unsealed track to the south (a road passes under the Burdekin Dam spillway) joins tracks that lead to Mt Coolon and Collinsville.

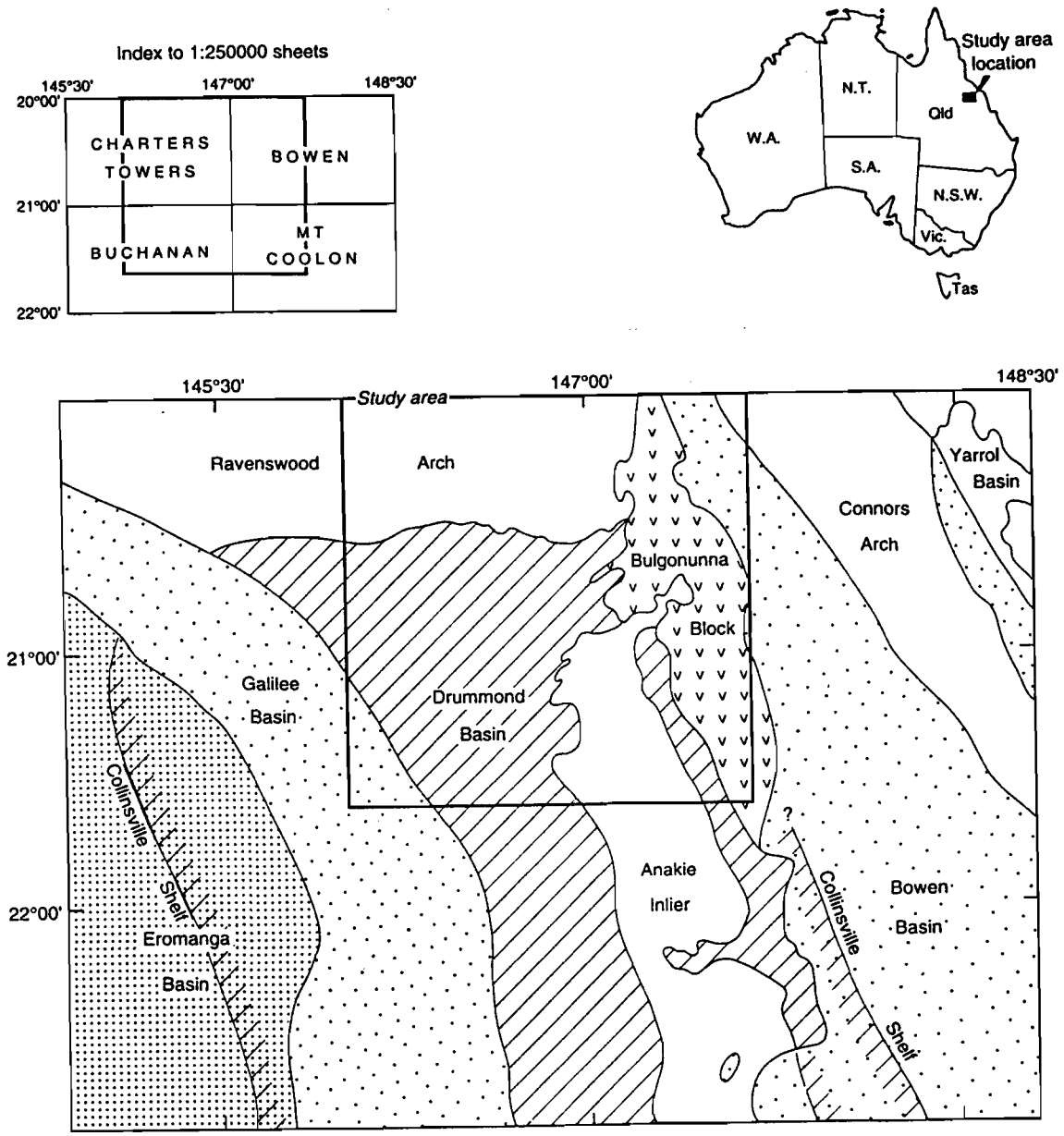


Figure 1: Location and structural setting of the Charters Towers - North Drummond Basin study area.

The climate of the area is tropical semi-arid. Annual rainfall is 550-750 mm; however, falls over the past ten years have been substantially less than normal. Most rain falls in the summer months, which is typically associated with coastal cyclonic disturbances. Daily temperatures range from 21° - 35° C in December, to 7° - 26° C in July.

The vegetation over the area consists predominately of open woodland and grassland savannah, dominated by eucalyptus, acacia and spear grass.

1.2. Generalized Geology

The bedrock (Pre-Tertiary) geology of the study area can be sub-divided into the following structural units: Ravenswood Arch, Anakie Inlier, Drummond Basin, Bulgonunna Block and the Galilee Basin (Figure 1; after Olgers, 1972). The rocks of the Anakie Inlier and Ravenswood Arch are essentially basement to the sediments of the Drummond Basin, which are in turn overlain by volcanics (Bulgonunna Block) and younger sediments (Galilee Basin).

The Anakie Inlier is a north-trending ridge of early-to-mid Palaeozoic rocks surrounded by younger strata of the Drummond and Bowen Basins. The Pre-Devonian Anakie Metamorphics (quartz-mica schists, phyllite, slate, limestone and volcanics), Mid-Devonian volcanics and sediments and Upper-Devonian intrusive granite are the main lithologies of the Inlier (Day *et al.*, 1983).

The Ravenswood Arch (Lolworth-Ravenswood Block) is an east-trending basement ridge at the northern limit of the Drummond Basin. This block consists of early Palaeozoic metamorphics, sediments and volcanics (Seventy Mile Range and Charters Towers Groups - see Hartley *et al.*, 1989), which have been extensively intruded by Mid-to-Lower Ordovician granitoid plutons. Post-granitoid igneous activity in the Carboniferous resulted in extrusion of rhyolitic lavas and pyroclastics associated with porphyry and high-level intrusive complexes (*e.g.*, Mt Leyshon Complex).

The Drummond Basin contains Late Devonian to Early Carboniferous sediments deposited in a structural remnant of a large intermontane basin (Olgers 1972). These sediments were deposited both on the west (mainly) and east of the Anakie Inlier on a basement of early-to-mid Palaeozoic metamorphics and granite (Day *et al.*, 1983). Olgers (1972) recognized three cycles of sedimentation separated by periods of volcanism. Sedimentation ceased at the onset of the Kanimblan Orogeny, during which the sequence was folded and uplifted to form a structural high shedding material into the Bowen and Galilee Basins.

The Bulgonunna Block consists of Bulgonunna Volcanics, which unconformably overlie the Drummond Basin, east of the Anakie Inlier. The Volcanics have a regional dip to the east and consist of porphyritic rhyolitic-to-dacitic flows with pyroclastics, minor andesite, lithic siltstones and sandstone. The Volcanics are attributed a Late Carboniferous to Early Permian age.

The Late Carboniferous to Mid Triassic Galilee Basin formed as a large, shallow intracratonic basin to the west (and south) of the Drummond Basin. The Basin received mainly fluviatile sediments; however they are now mostly covered by later sediments of the Eromanga Basin, with only the northeastern margin (against the Drummond Basin) exposed.

Two Cainozoic sediment systems are developed within the study area; an older system represented by the Southern Cross Formation and its southern correlative, the Suttor Formation; and, a younger system represented by the Campaspe Formation.

The Southern Cross and Suttor Formations generally outcrops as flat-lying caps on mesa and upland areas. The sub-surface extent and distribution of these units beneath "younger" sediments is not established. However, the widespread nature of these "younger" sediments would suggest that the Southern Cross Formation (and possibly the Suttor Formation) potentially have a widespread sub-surface distribution. The Southern Cross and Suttor Formations consist predominately of fluviatile and lacustrine sandstones and siltstones. Henderson (1996) suggests that the provenance for the sequence was a well-weathered landscape, based on the quartz-rich nature of the sandstones and the presence of kaolinitic clays. Henderson (*ibid.*) also suggests a Palaeocene age for the system, based on a 53 Ma basalt that overlies Suttor Formation at Mt Dalrymple.

The Campaspe Formation consists of poorly sorted, clay cemented sandstones and siltstones with minor conglomerate. Henderson (1996) notes that the general coincidence of the top of the Campaspe Formation with the contemporary landscape leads to the conclusion that the unit essentially has been unmodified since its deposition. Henderson (*ibid.*) also suggests a Pliocene/Pleistocene age for the Campaspe Formation based on its stratigraphic relationship between two basalt flows with isotopic ages of 3.8 and 1.35 Ma .

At least two periods of extensive weathering have occurred in the Tertiary The presence of ferruginous duricrust and weathering profiles on currently exposed Southern Cross (Suttor) and Campaspe Formation sediments is evidence for a post-Campaspe weathering episode. The evidence for a "pre-Campaspe" weathering episode is based on the exposure at Red Falls where ferruginous nodules and pisoliths are developed within and upon the Southern Cross Formation sediments, which are in turn overlain by Campaspe Formation sediments (which themselves have ferruginous nodules developed towards the top of the sequence).

2. Methodology

2.1. Landsat TM Data

Landsat TM data were compiled, rectified and processed over an area that extends from Charters Towers in the north, to Mt Coolon in the south. The study area covers parts of four TM scenes:

094/074
094/075
095/074
095/075.

The ERMapper™ software package was used for the image-processing, although display and annotation procedures were undertaken using TNTMips ™ ([1]) .

Each scene was geo-referenced and warped to the relevant 1:100,000 map sheet using nearest-neighbour-resampling before then being processed as follows:

1) Dark pixel corrections based on analysis of scattergrams (Raw TM#7,#4,#1 (RGB) colour composite produced);

2) Log residual calculations using statistics from non-water, non-cloud, and non-irrigated crops to avoid spectral extremes (Inverted TM#7,#3,#1(RGB) log residual colour composites produced);

3) LSFit calculation for TM#7 with statistics as in (2); and

4) CSIRO-REG (ratio) images produced using the dark-pixel corrected data, with the LSFit "clay" image (LSFitTM#7, TM#4/TM#7, TM#4/TM#2 - RGB, colour composite produced)

Colour-composite images of the above data were contrast-balanced for each TM scene before being merged into mosaics over the study area. To further enhance the "Raw 741" Landsat image for "landform-analysis", a high-pass filter was applied to highlight geomorphic effects (edge-enhancement).

While it was apparent that the log residual and CSIRO-REG images were displaying useful information on surficial materials at detailed scales (>1:80,000), these images did not retain enough "spatial" information to make them sufficiently useful for the regional broad-scale landform interpretation that was being undertaken here (1:250,000 scale). Hence the most useful image for this interpretation (at this scale) was the edge-enhanced, "Raw TM #7,#4,#1" colour composite.

2.2. Vector Interpretation

[1] The use of product names does not constitute official endorsement by either the author or his employers

A variety of methods was used to produce vector overlays of the interpretation in digital form. For the initial interpretation, 1:100,000 scale images of the TM scenes were produced as poster-layouts using TNTMips™. Transparent overlays were then annotated with linework, which was then digitized (using ArcInfo™). These maps had their vector topology verified using ArcInfo™, and these coverages were then imported as vector lines and polygons into TNTMips™ .

For subsequent editing and refinements, all modifications were performed in TNTMips™ using "heads-up" digitizing (onscreen) directly over the raster-image base with vector topology and attribute management controlled by TNTMips™ as well.

3. Geomorphic Provinces

3.1. Description of the Mapped Geomorphic Provinces

The map detailing the geomorphic provinces for the Charters Towers - North Drummond Basin area is shown in Figure 2; and the Landsat mosaic from which the interpretation is based is shown in Figure 3 (with vector-polygons). The provinces were defined primarily on the basis of drainage texture and photo-form which, when combined, represent landform. The map presented here is a broad-scale representation of the landscape and the mapped provinces are certainly not homogenous. Aerial photographs were not used in this interpretation and field work has been primarily of a reconnaissance nature. Table 1 gives a brief description of the interpreted geomorphic province units and their associated regolith characteristics.

In the following sections the geomorphic units have been grouped into three broad categories: "Duricrust Dominated", "Saprolite Dominated" and "Colluvium and Alluvium Dominated". The groupings are an attempt to "classify" the mapped units in terms of their "degree or likelihood to preserve weathering profile material". This grouping has some similarities with the RED scheme (Anand *et al.*, 1993), which was devised as a regolith-landscape classification scheme for the Yilgarn in Western Australia. However, the RED scheme was not designed for more complicated landscapes, with multiple weathering events affecting basement lithologies and overlying Tertiary and Quaternary sediments.[1] The landscape in the Charters Towers - North Drummond region contains possible evidence for a Pre-Cainozoic weathering event, and definite evidence for at least two major weathering episodes which have affected the Tertiary sediments (post Southern Cross deposition and post Campaspe deposition).

[1] Anand et al. (1996) proposed a modification to the RED scheme to accommodate the increased complexity of the Charters Towers - North Drummond and Mt Isa terrains. The "Duricrust," "Saprolite," and "Alluvium and Colluvium Dominated" scheme used in this study evolved from that earlier work

Table 1 : Geomorphic Descriptions and Regolith Characteristics for the Mapped Geomorphic Units belonging to the Duricrust, Saprolite, and Alluvium and Colluvium Dominated Terrains

Duricrust Dominated Terrains

Province	Geomorphic Description	Regolith Observations
UPS	Undulating plateau surfaces, with moderate elevation, commonly bounded by scarps	Ferruginous duricrust present; some residual sand developed on mesas, plateaux, backslopes. (Southern Cross or Suttor Formations)
RSm	Remnant sedimentary mesas and benches, typically with flat plateau tops, bounded by steep scarps	Mesas commonly with preserved weathering profiles, but not everywhere; (may be related to either Campaspe or Southern Cross Formation)
RSc	Remnant sedimentary cover, level or sloping with low mesas and/or their dissected remains	Dissected sedimentary cover, may contain partially preserved weathering profiles; (may be related to either Campaspe or Southern Cross Formation)
UFP	Undulating flat plains of sediments (perhaps Tertiary Campaspe Formation); now being re-worked by cross-cutting streams and encroaching catchment expansion; sheetwash and bedload re-working of pre-existing sediments	Extensive plains, with surficial sheetwash and soil development. Field work has shown that, at a number of places, these deposits include a layer of ferruginous nodules that overlie a buried, weathered profile. The extent of this layer needs to be evaluated further. (Campaspe Formation ?)
Sil	Mesa(s) cappings on elevated terrain	Silcrete preserved as capping on elevated "granitic" ? terrain

Saprolite Dominated Terrains

Province	Geomorphic Description	Regolith Observations
MRR	Moderate-to-high relief, rugged terrain; strike-ridges evident.	Minor lithosols and colluvium on slopes, alluvium in valleys is removed with little accumulation, rate of sediment production approx. equals rate of sediment removal
FeI	Strongly dissected low terrain	Strongly weathered mafic intrusives, ferruginous soils and ferruginous saprolite preserved (?)
UCLG	Undulating country, consisting of strongly dissected (eroded) granitic terrain	Some preservation of saprolite on hills and topographically higher areas, thin lithosols.
LRSH	Moderate relief terrain, with linear strike ridges	Thin lithosols and colluvium on ridges and slopes; alluvium in valleys. Basement structural trends are evident. Remnant outliers of weathered basement preserved?
SUH1	Strongly undulating, rounded, hilly terrain, low-to-moderate relief with exposed basement	Lithosols and colluvium on slopes, alluvial material in valleys; rate of sediment production exceeds rate of removal. Remnant outliers of weathered basement preserved?
TSBS_L	Thin soils on basement sediments; low relief; strike-ridges	Lithosols and colluvium on slopes; Thin cover as basement structural trends evident. Remnant outliers of weathered basement preserved?
SEDS	Slightly elevated, dissected sediments with trellis drainage patterns; flat-lying (inlier within UFP unit)	Lithosols and colluvium on slopes, alluvium in valleys; rate of sediment production approximately equals rate of removal

Alluvium and Colluvium Dominated Terrains

Province	Geomorphic Description	Regolith Observations
A/F	Alluvial plains associated with present day drainages, some sediment re-working	Detritus derived from erosion of Palaeozoic, Mesozoic and Cainozoic lithologies
SW/SS	Moderate-to-steep terrain; sheet wash areas.	Areas with active erosion and detritus throughput; unlikely that weathered profile materials have survived
CDA	Rolleston River Catchment : complex landscape.	Recent alluvial and colluvial material; sediment production exceeds rate of removal; sediments derived from erosion of Tertiary sediments
EUP	Slightly elevated, undulating plains, commonly bounded by scarps,	Areas of black soil with gilgai development, - possibly remnant lake deposits, (caused by ponding within drainages)
UC	Relatively flat, undulating areas with low rises/hills.	Predominately recent alluvium and colluvium covering basement and overlying sedimentary units (Suttor /Southern Cross/Campaspe Formations)

LEGEND

Geomorphic Provinces

Duricrust Dominated

UPS
Undulating plateau surface, with moderate elevation, bounded by steep scarps

UFP
Undulating flat plains of sediments (Tertiary Campaspe Fm ?); now being reworked(sheetwash and bedload re-working of pre-existing sediments

RSm
Remnant sedimentary mesas, typically with plateau tops, bounded by scarps unless they abut higher ground (partially dissected UPS unit)

Sil
Silcrete developed as capping on granitic terrain

RSc
Remnant sedimentary cover, level or sloping terrain with low mesas or their dissected remains (strongly dissected UPS)

Saprolite Dominated

MRR
High-to-moderate relief, rugged terrain; bedrock characteristics evident

SUH1
Strongly undulating, rounded hilly terrain, low-to-moderate relief, exposed basement.

FeI
Strongly dissected low terrain with iron staining; mafic intrusives(?)

TSBS_L
Thin soils on basement sediments; low relief. (structure).

UCLG
Undulating, strongly dissected granitic terrain

SEDS
Slightly elevated, dissected sediments with trellis drainage patterns; flat-lying inlier

LRSH
Thin soils on basement sediments, moderate relief,strike ridges. (structure)

Alluvium and Colluvium Dominated

A_F
Alluvial plains associated with present day drainages; some sediment re-working

UC
Relatively flat undulating plains with low rises/hills, predominately relict transported surficial detritus, now being reworked

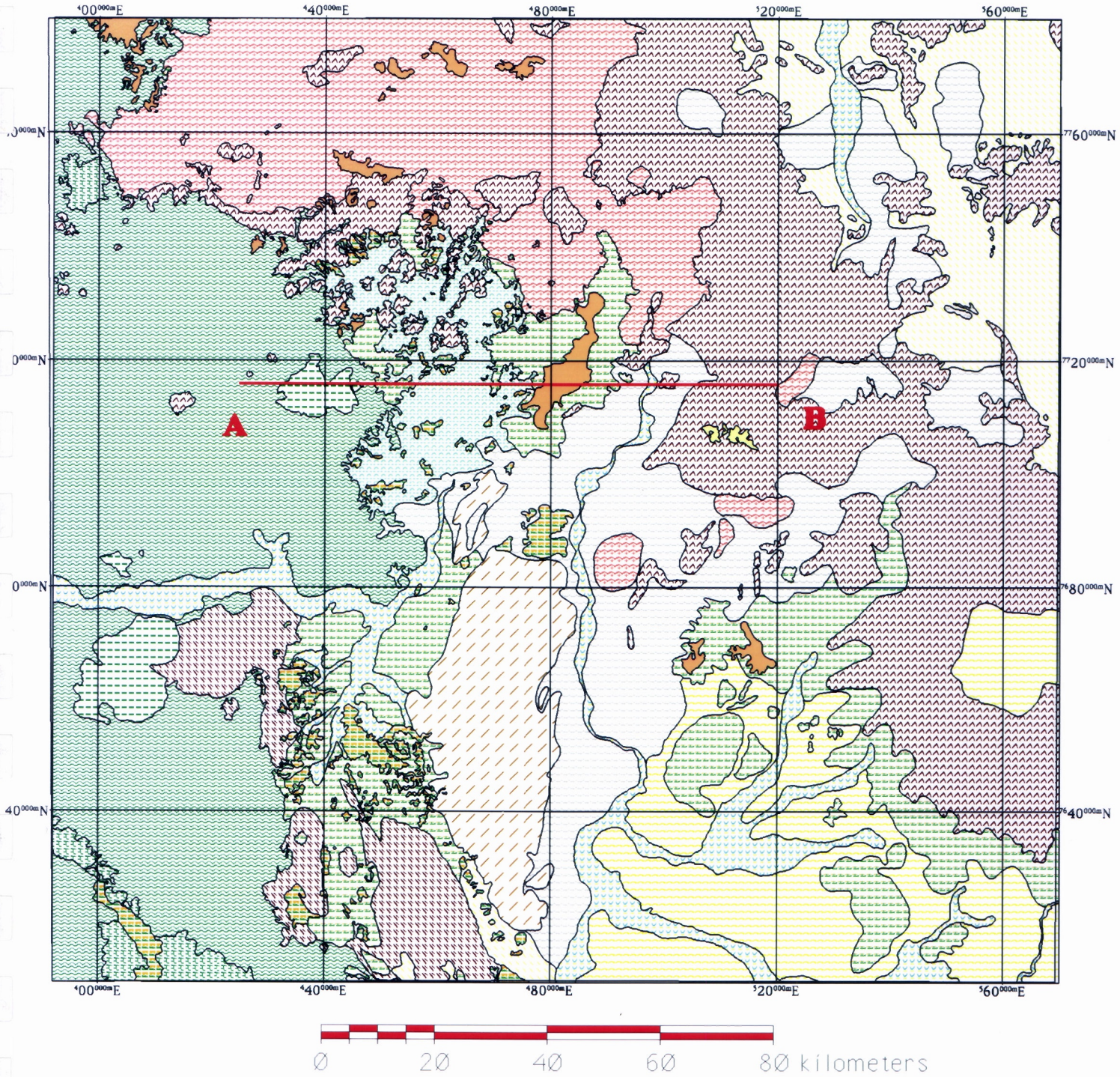
CDA
Rolleston River Catchment: an almost choked catchment with detritus derived from erosion of Tertiary sediments.

Sw_SS
Moderate to steep terrain; sheet wash areas & colluvium

EUP
Slightly elevated undulating plains, bounded by scarp margins

Figure 2: Geomorphic Provinces Charters Towers - North Drummond Area. Section A-B indicates the location the cross-section depicted in Figure 4

Charters Towers - North Drummond Geomorphic Province Map



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Charters Towers - North Drummond Geomorphic Province Map

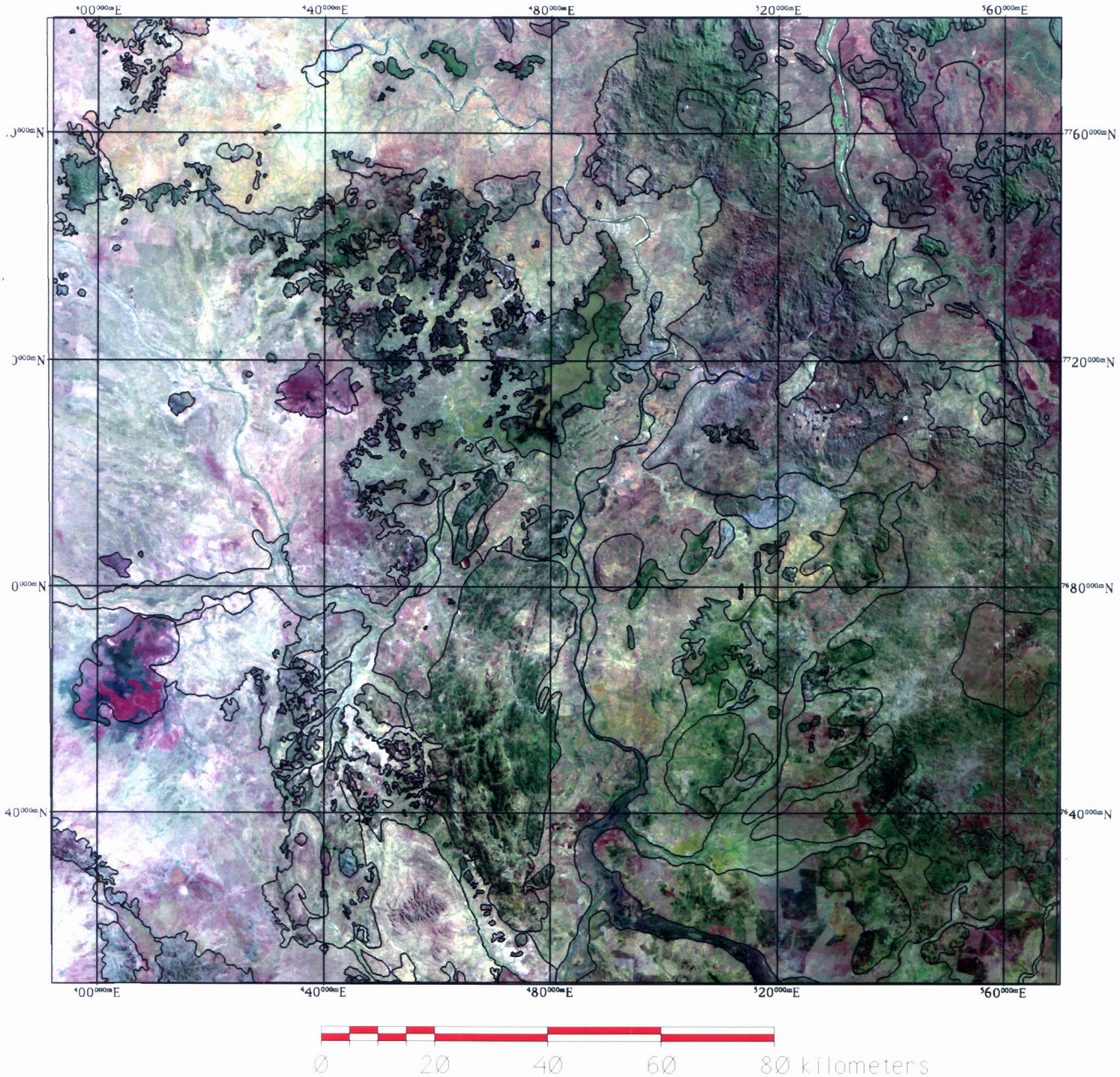


Figure 3: Mosaic of Landsat TM bands used in our analysis, Charters Towers - North Drummond Area.

3.1.1. Duricrust Dominated Terrain

The mapped geomorphic province units UPS, RSm, RSc, UFP and Sil all appear to have substantial remnants of the weathering products preserved, often with duricrust present.

Based on the interpretation of the Landsat imagery and observations from reconnaissance field work, there is little evidence for widespread development of duricrust on "basement" lithologies (with the exception of the silcrete unit, Sil).

Units UPS and UFP represent landscapes where (nearly) intact weathering profiles are preserved on Southern Cross (Suttor) and Campaspe Formation sediments, respectively. These areas are typically mesas, plateaux, benches or plains. Units RSm and RSc represent landscape units that have been more severely eroded and dissected than UPS and UFP, but there is a strong suggestion that duricrust material is locally preserved. While it is relatively easy to determine that RSm and RSc are associated predominately with Tertiary sediments (either Southern Cross or Campaspe), it is difficult from the Landsat imagery to determine specifically to which Tertiary sedimentary system they belong. Southern Cross and Campaspe sediments could well both be present in some areas. Duricrust capped basement lithologies are also known to occur within these units, but their extent is limited.

Unit Sil represents a silcrete, which has been preserved as mesas capping granitic lithologies in rugged dissected terrain south of the Burdekin Dam. The distribution of this unit is limited. During field work other silcretes were located near the Suttor River and Rosetta Creek, but these have restricted size in outcrop and are not discernible on the imagery.

Examples:

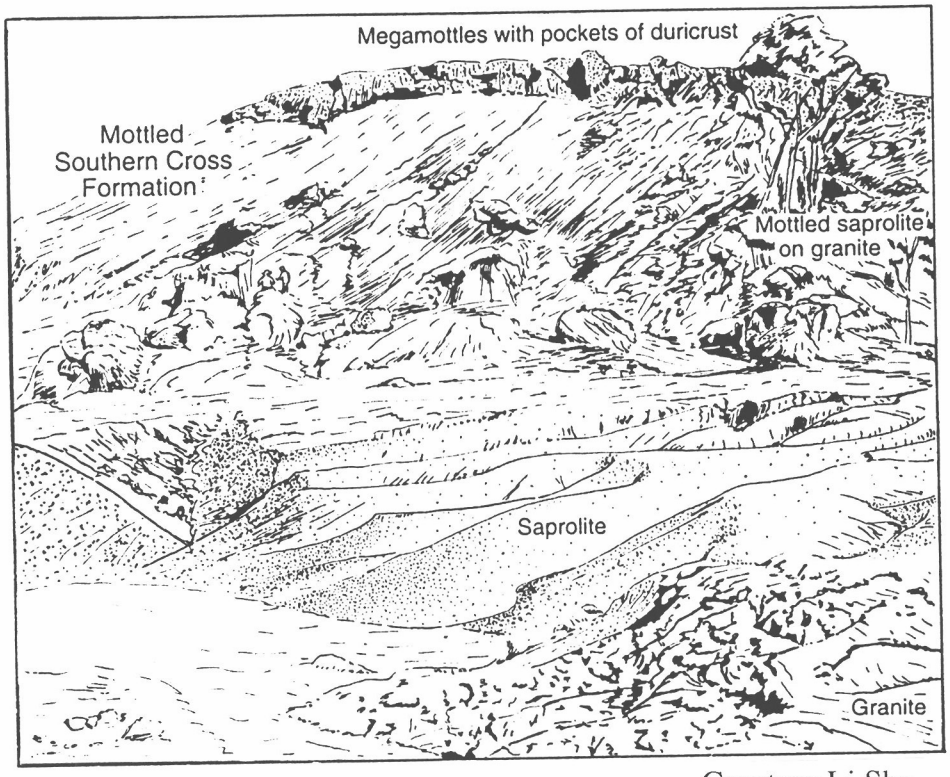
Featherby Wall (modified after Scott *et al.*, 1996)

Location:	411579E 7774720N, (northern side of Charters Towers Hughenden Rd)
Mapped Province:	UPS
Geology:	Southern Cross Formation, Ravenswood Granodiorite
Landform:	Mesa and breakaway
Regolith	Megamottles, lateritic pisoliths and nodules, saprolite

Featherby Walls is an elongate mesa and breakaway, rising some 25m above the surrounding pediment. The site is an example of weathering profile development on Southern Cross Formation sediments and Ravenswood Granodiorite (Figure 4). The mesa itself is composite, consisting of both sedimentary and granitic materials. Mottled duricrust is preserved on the Southern Cross Formation and the granitic materials on the mesa as well. The hardness of the granitic saprolite would suggest that it also has been silicified.

The sediments consist of flat-lying, weakly bedded sandstones, siltstones and mudstones (Southern Cross Formation), which exhibit graded-bedding in parts. A notable feature of these sediments is their strong red (ferruginous) colouration. These sediments overlie mottled granitic saprolite. Ferruginous pisoliths and nodules occur within mottled siltstones and mudstones just above the contact with the granite, near the base of the mesa. Towards the top of the mesa (upper 3m) there is a zone of ferruginous duricrust associated with megamottle development. Segregation of iron oxides, removal of clay material (eluviation) and subsequent erosion (collapse) of the profile are factors which have contributed to megamottle formation. These megamottles form a distinctive pock-marked "jacuzzi" surface on the top of the mesa; however, despite an abundance of iron oxide material, there is no evidence of ferruginous pisolith or nodule lag on this upper surface. These sediments outcrop on the southern and western sides of the mesa.

there is no evidence of ferruginous pisolith or nodule lag on this upper surface. These sediments outcrop on the southern and western sides of the mesa.



Courtesy Li Shu

Figure 4: General view of a mesa forming part of Featherby Wall, west of Charters Towers, showing fresh bedrock of granite, saprolite, mottled saprolite, mottled Southern Cross Formation and a duricrust cap

Towards the north-eastern side of the mesa, there is a gradation into granitic saprolite. Near the top of the mesa in the granite "zone", a distinctive "mini tower" landform has formed as a result of the megamottling (iron and silica (?) re-mobilization).

It appears unlikely that the mesa was covered by Campaspe Formation, which leads one to postulate that the weathering profile has resulted from two periods of weathering (A weathering episode post Southern Cross deposition, followed by another weathering episode post Campaspe deposition. These periods of weathering could have combined into a "protracted - event", as weathering would have continued on a basement-high during deposition of the Campaspe sediments..) The underlying Ravenswood granite may have also been subjected to a pre-Cainozoic period of weathering, and it is very likely that the weathering episodes that affected the overlying Southern Cross also affected the underlying "granitic" lithologies.

Mapped Province:	UPS
Geology:	Southern Cross Formation, andesitic volcanics
Landform:	Mesa, bench and breakaway
Regolith	Megamottles, iron duricrust, iron pisoliths and nodules, mottled saprolite

The Scott Lode area is complex in its geology, geomorphology and landscape evolution. The lode occurs in the Mt Janet Ranges, with the line-of-lode partially covered by Southern Cross sediments. It is highly likely that the elevated basement lithologies on the Mt Janet Ranges remained as basement "islands" during deposition of both the Southern Cross and Campaspe Formations, while a skirt of Southern Cross sediments also remained above the level of deposition of Campaspe sediments. Some areas of basement lithologies have potentially been exposed to weathering since pre-Cainozoic times; whereas, the Southern Cross sediments that skirt Mt Janet above the level of the surrounding plains, have probably been exposed since early-mid Tertiary times

Localized remnants of weathering profiles are preserved within the basement volcanics, as evidenced by an iron-rich pisolitic duricrust in the Mt Janet Ranges. This duricrust is dominately hematite, with some goethite, kaolinite and gibbsite cementing the pisoliths. This unit was distinguished from duricrust developed over sediments, on the basis of lack of cobbles (which occur within the Southern Cross Formation). The possibility of extensive weathering of the basement before the deposition of Southern Cross sediments is difficult to assess; but some weathering almost certainly did occur. Most surficial outcrops of volcanics within the Mt Janet Ranges contain relatively unweathered materials, so a degree of stripping has occurred. In the Scott Pit, mottling is intensely developed on the volcanic saprolitic substrate, beneath the Southern Cross sediments, with kaolinitic clays and hematite and goethite mottles.

The weathering profile on the Southern Cross Formation is variable. Massive-to-weakly pisolitic duricrust is preserved on plateaux and bench landforms, although pisolitic gravels can be found at lower elevations as a consequence of profile erosion. Ferruginous nodule and pisolith development appears to be restricted to the top of the profile. In the Scott Pit, the Southern Cross Formation sediments exhibit a substantial weathering profile with mottling and ferruginization present throughout. Cobbles of volcanics and quartz vein material have been incorporated into the Southern Cross sediments; an indication that proximally-derived material from elevated basement highs has contributed to the Southern Cross sedimentary package.

Red Falls (modified after Scott *et al.,* 1996)

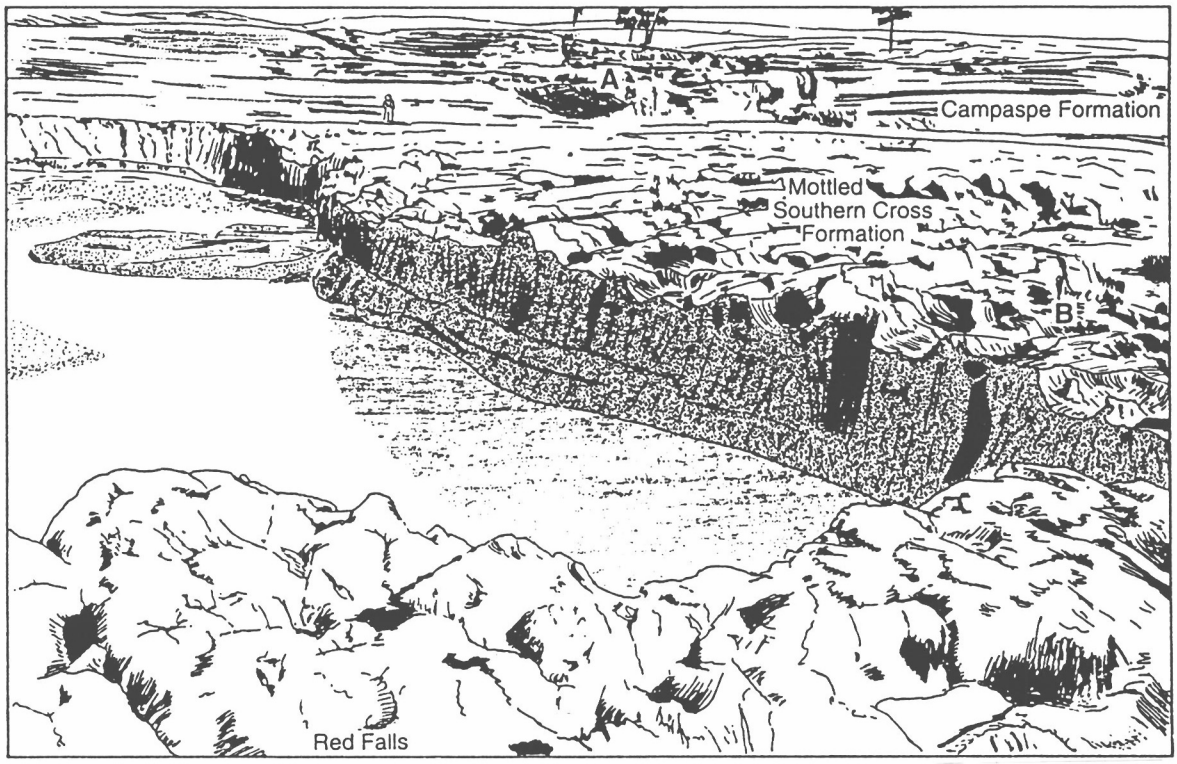
Location:	367751E, 775918N
Mapped Province:	Not within mapped area (UFP and RSc)
Geology:	Campaspe Formation, Southern Cross Formation
Landform:	Knick point and breakaway
Regolith:	Ferruginous profiles on Southern Cross and Campaspe Formations, mottled and ferruginous duricrusts, nodular calcrete.

Red Falls is an important location as there is definite evidence for two periods of weathering after deposition of Southern Cross sediments, separated by deposition of Campaspe sediments. It also is a location where Campaspe sediments actually overlie Southern Cross sediments.

Approximately 14m of relatively mature, white-to-buff, quartz-rich fluvial sandstones and siltstones of the Campaspe Formation overlie ferruginized Southern Cross sediments. The Campaspe sandstones show graded, and cross-bedding structures. Weak iron staining is associated with the formation of ferruginous nodules and pisoliths near the top of the sequence. Nind (1988) reported the presence of nodular calcrete, 1.8m from the surface.

The clay rich, ferruginized, siltstones and sandstones of the Southern Cross Formation display an incomplete weathering profile at this location. Mottling results in a pock-marked surface (which is

The clay rich, ferruginized, siltstones and sandstones of the Southern Cross Formation display an incomplete weathering profile at this location. Mottling results in a pock-marked surface (which is almost "mini-jacuzzi" like), and a layer of cemented iron-rich clasts, nodules and transported pisoliths with goethitic cutans is exposed in the creek bank and floor. The nature of the clasts and the presence of detridal quartz grains would suggest that some of this material has been transported. Some bleaching and mottling appears related to iron reduction associated with root casts. There is a strong probability that the upper part of this weathering profile was eroded prior to deposition of the Campaspe sediments.



Courtesy Li Shu

Figure 5 : Red Falls on Lolworth Creek, northwest of Charters Towers. The Southern Cross Formation has been deeply weathered and ferruginized, forming the channel bed and waterfall. The Campaspe Formation is exposed in the valley wall.

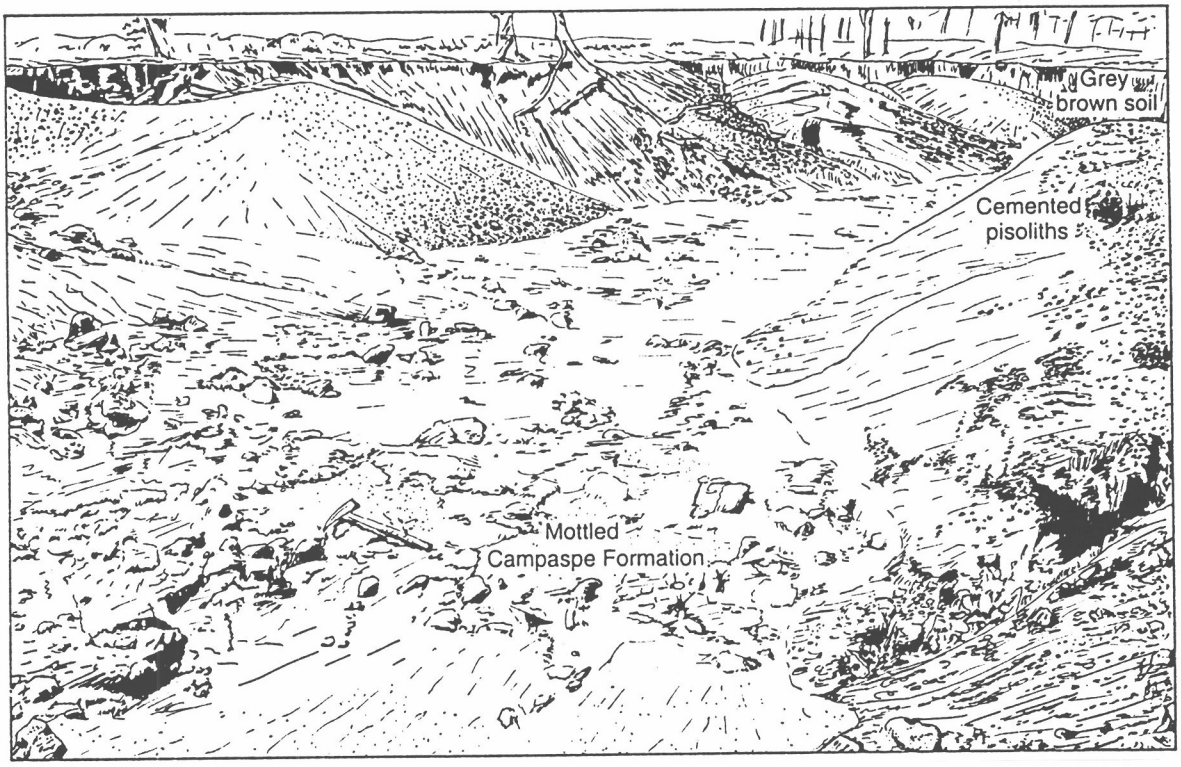
Waterloo Erosion Gully (modified after Scott *et al.*, 1996)

Location:	405400E, 7746516N
Mapped Province:	UFP
Geology:	Campaspe Formation, Mount Windsor Volcanics/Trooper Creek Formation
Landform:	erosion gully, gently sloping plain

Regolith: Grey-brown soil, weakly cemented pisoliths and ferruginous gravels

Thin grey-brown soils (0.3m thick) overlie approximately 0.5 m of nodular iron gravel which has a gradational contact with underlying saprolitic, lithic-rich sediments of the Campaspe Formation. The ferruginous gravels are typically goethitic in character, with a goethitic cement. The Campaspe sediments have been described as a conglomeratic greywacke with angular to sub-rounded quartz clasts and grains at this location (Scott *et al.*, 1996).

The weakly-cemented, ferruginous nodular layer has most likely resulted from the erosion (collapse) of a more complete weathering profile, which had developed on Campaspe sediments.



Courtesy Li Shu

Figure 6 : Erosion Gully at Waterloo Prospect. The sketch shows soil, pisoliths, cemented pisoliths and mottled Campaspe Formation.

3.1.2 Saprolite Dominated Terrain

The Saprolite Dominated Terrain grouping consists of the following mapped geomorphic province units: MRR, FeI, UCLG, LRSH, SUH1, TSBS_L and SEDS. All of which have had their weathering profiles eroded or stripped to various levels.

localized vestiges of saprolite remaining. Minor iron staining and clay development are typical mineralogical changes on weathered surfaces.

Provinces FeI and UCLG represent the other extreme of this "Saprolite Dominated Terrain" grouping. These units are typically developed on "granitic" lithologies, in which the upper parts of pre-existing weathering profiles have been removed. The most common feature of these units is the conversion of feldspar and plagioclase to "clays"; however patches of nearly unweathered material do occur. These "fresher" outcrops are considered to be more siliceous phases, perhaps related to silicification (weak silcretization?).

Provinces LRSH, SUH1 and TSBS_L tend to occur over "basement" lithologies, which also have had their weathering profiles stripped to various degrees. In all of these three provinces there is a strong probability that remnant saprolitic material could be preserved. The LRSH and TSBS_L provinces occur over meta-sediments, and various basement structural features are evident on the Landsat imagery. The difference between the two units is that LRSH is more elevated terrain, and dominated by near parallel, linear strike ridges; whereas TSBS_L has lower relief and shows complex fold structures. Bedding trends are less well preserved in province SUH1, and its undulating, rounded appearance suggests that it is more eroded and stripped than either LRSH or TSBS_L. Bedrock is covered by shallow colluvium and lithosols on ridges and slopes, and alluvium conceals bedrock in the valleys.

The SEDS province represents Mesozoic sediments, which occur as inliers on the western side of the study area. The current-day drainage has incised these areas (trellis pattern), and they are actively eroding.

Examples:

Waypoint 005

Location:	417948E, 7774378N
Mapped Province:	UCLG
Geology:	Ravenswood Granodiorite
Landform:	Gently sloping plain, (costean - gravel pit)
Regolith:	Red-brown soil, 0.1 - 0.5m thick overlying granitic saprolite.

Thin red-brown in-situ soils (0.1 to 0.5 m), overlying 2-3 m (+?) of iron-stained granitic saprolite. No fresher material was evident at the base of the costean, so the weathering profile could extend to greater depths beneath the floor of the costean. There is no indication of mottling or bleaching, with the main features being plagioclase and feldspar weathering to clays and the release of iron oxides through biotite weathering, which results in red (hematitic) iron staining.

Waypoint 023

Location:	417948E, 7774378N
Mapped Province:	MMR
Geology:	Star of Hope Formation, Lower Carboniferous tuffs sandstones, volcanoclastics
Landform:	Rugged, elevated hills and valleys
Regolith:	Lithosols and colluvium with minor iron staining on surfaces and along joints

Thin lithosols and colluvium cover rocky outcrops. This is an area of fairly active erosion and eroded materials are quickly transported away from the area. Iron oxide staining is common on exposed weathered surfaces and along joints.

3.1.3. Colluvium and Alluvium Dominated Terrain

Provinces A/F, SW/SS, CDA, EUP and UC form the Alluvium and Colluvium Dominated Terrain group. The units represent terrain types where Quaternary sediments have been deposited over older units. These more recent sediments are derived from the erosion of Southern Cross, Campaspe and basement lithologies

Province CDA covers the complex landscape present within the Rolleston River catchment. Although this unit is dominated by alluvial and colluvial materials, areas within it are representative of provinces belonging to the "Duricrust Dominated" (UPS, UFP, RSm, RSc) and "Saprolite Dominated" (SUH1, TSBS_L) Terrain groups. It was decided to "bundle" the whole of this catchment into a particular province type rather than show all of these units, which ideally would have required a more detailed scale map. This catchment is undergoing active erosion in its headwaters; however, the rate of sediment production appears to exceed the drainage's capacity to transport these erosional products downstream.

Several areas of black soil have been identified as province EUP. These are slightly elevated regions with a gilgai surface, commonly bounded by scarps. The black soils are considered to be Quaternary deposits, probably associated with localized lake formation and/or ponding within drainages. Whereas the map shows this province as a younger feature lying upon province UFP, several other less extensive occurrences of "black soil" are known to occur throughout the region (not shown on the map). In some cases these deposits occur at lower elevations in the landscape and they seem to be "perched" or relict deposits associated with episodes of localized stream ponding.

The UC province consists of alluvial plains associated with the convergence of Rosetta and Police Creeks, and the Suttor and Belyando Rivers. In parts, a grey soil has developed on these plains. These plains currently contain Quaternary materials which possibly conceal Tertiary sediments such as a unit equivalent to the Campaspe Formation (Scott *et al.,* 1996), overlying Suttor Formation sediments, which in turn would overlie basement (Anakie Inlier lithologies?) Alluvium associated with current drainage systems and areas covered with extensive scree or sheet wash have been assigned to provinces A/F and SW/SS respectively. Only the more spatially significant flood-plains and areas of scree and sheet wash have been annotated on the map.

3.2. Distribution of the Mapped Geomorphic Provinces

The distribution of the mapped provinces is predominately related to the current drainage systems. There are several major catchments that dominate the landscape of the study area, all of which are part of the Burdekin River system. The Burdekin and Campaspe Rivers are in the north; the Cape River is in the west; and the Belyando and Suttor Rivers are in the south. These rivers show the area to be dominantly erosional, with progressive lowering of base-level, and sediment transport towards the east and north-east.

For convenience, the map has been sub-divided into three broad zones as shown on Figure 7 .

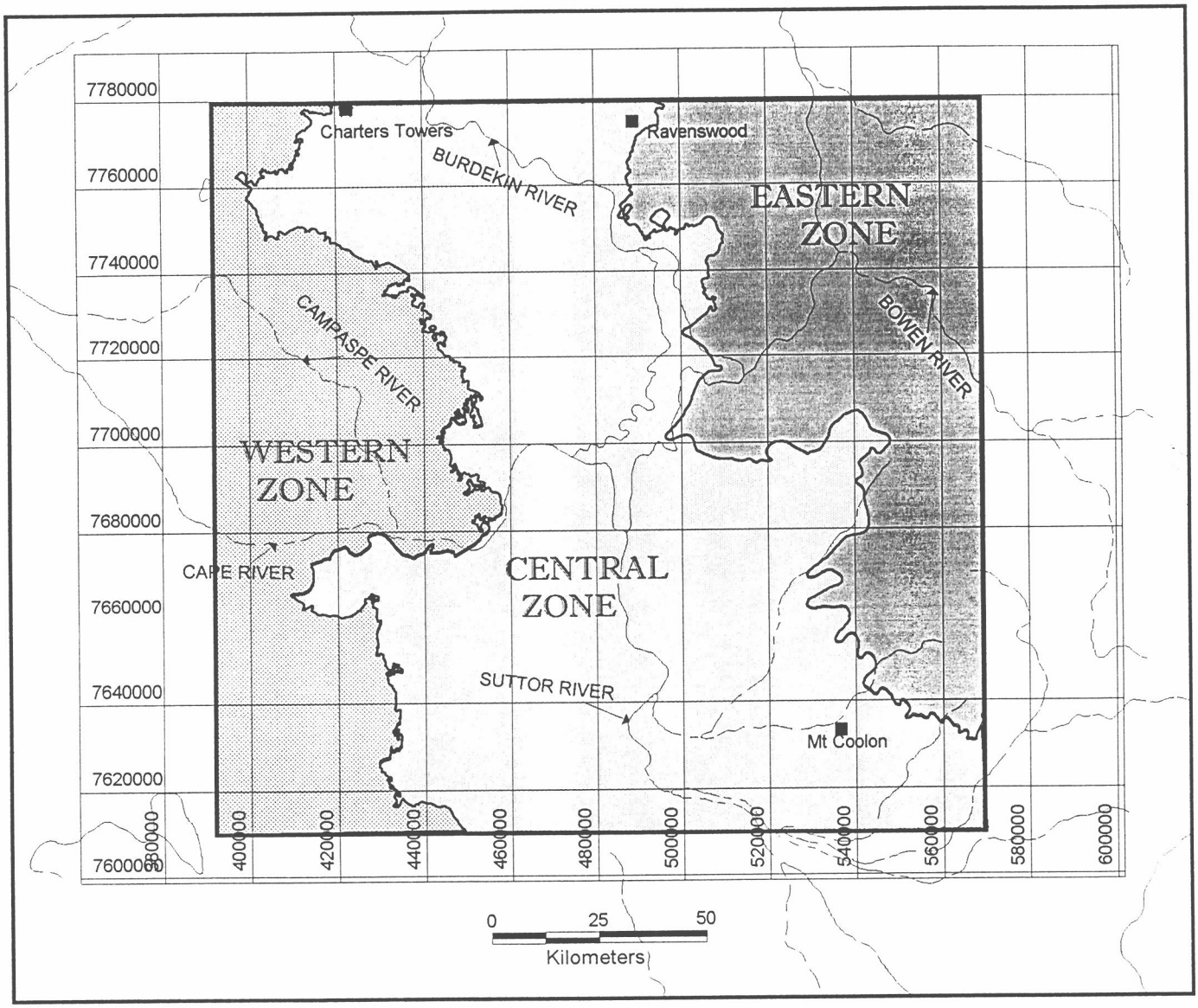


Figure 7: Map showing sub division of the study area into Eastern, Central and Western Zones, along with major rivers and towns.

3.2.1 Eastern Margin of the Study Area

The north-eastern part of the study area contains the lower reaches of the Burdekin River as it dissects its way through elevated and rugged terrain towards the coast. A zone of moderate-to-high relief, with rugged terrain (unit MRR), forms the western boundary of this zone. Further to the east, are some areas of eroded and stripped basement outcrop (unit SUH1), but most areas are dominated by colluvial and alluvial materials (unit SW_SS).

Previous weathering profiles and materials have been extensively stripped away from the MRR and SUH1 units (assuming there was widespread development there in the first place). Field work, however, has indicated that silcretes (unit Sil) are preserved over some granitic lithologies within unit MRR, but overall the silcrete's extent is restricted. No evidence for preservation of iron duricrusts in the MRR was found, however some localized occurrences of iron-stained saprolitic material were

located in units MRR and SUH1 during field work. The presence of silcretes suggests that conditions for widespread deep weathering have existed in the past, but the association between silcrete and granite appears to be very specific and perhaps worthy of further investigation.

3.2.2. Central Zone of the Study Area

A zone of complex landforms occurs in the central portion of the study area. This zone has been subdivided into a number of geomorphic units, based on landform and inferred erosional activity. There are extensive areas of basement lithologies (pre-Tertiary) along with a variable distribution of landforms associated with Tertiary sediments (units UPS, RSm, RSc). Without field work, it is generally difficult to assign these sedimentary landforms specifically to one of the Tertiary sediment systems (either Campaspe or Southern Cross Formations). However, most mesas (unit UPS) appear to be remnant of the older Southern Cross Formation.

In the north-central region of the area, there has been extensive stripping of weathering profiles, from the Ravenswood Complex (unit UCLG), with preservation of some Tertiary sedimentary outliers (some possibly Quaternary) as mesas (unit UPS). Granitic saprolite is common.

The Rolleston River Catchment (unit CDA) is a particularly active drainage system (probably reactivated through base level lowering to the east), which is currently encroaching (through headwater retreat) into more stable terrain to its west. Some remnant mesas in this vicinity could belong to the Campaspe Formation (unit UFP). The Rolleston Catchment appears to be almost choked with more recent sediments, leading to a complex, mixed landscape of eroded basement, eroded Tertiary sediments and deposits of Quaternary alluvium and colluvium.

In the south-central part of the study area (Blowhard Creek), the complexities of the Rolleston River Catchment are repeated on a broader-scale. Areas of outcropping basement (folded sediments and volcanics) are covered by partially eroded Tertiary sequences in various states of truncation and preservation, which are in turn covered by more recent locally-derived sediments.

In the Suttor River Catchment (including both Police and Rosetta Creeks), Tertiary sediments (units UPS, RSm and RSc) on the western flanks of the MRR unit have been assigned to the Suttor Formation (*i.e.,* equivalent to the Southern Cross Formation to the north). These Tertiary sediments and older basement lithologies, have been eroded in part, to form extensive areas of flat, undulating terrain (unit UC). At some localities, the older "source" Tertiary sediments are most likely covered by their younger erosional products, which form the undulating plains (i.e., unit UC).

3.2.3. The Western Zone of the Study Area

The western part of the study area appears to be a more mature landscape, which is now being encroached by drainage catchments of the "central zone". In this western region there is an extensive plain (units EUP and UFP) which is considered to consist of Tertiary sediments of the Campaspe Formation, with smaller elevated inliers of flat-lying 'older' Gaililee Basin sediments (unit SEDS) forming basement-highs and ridges.

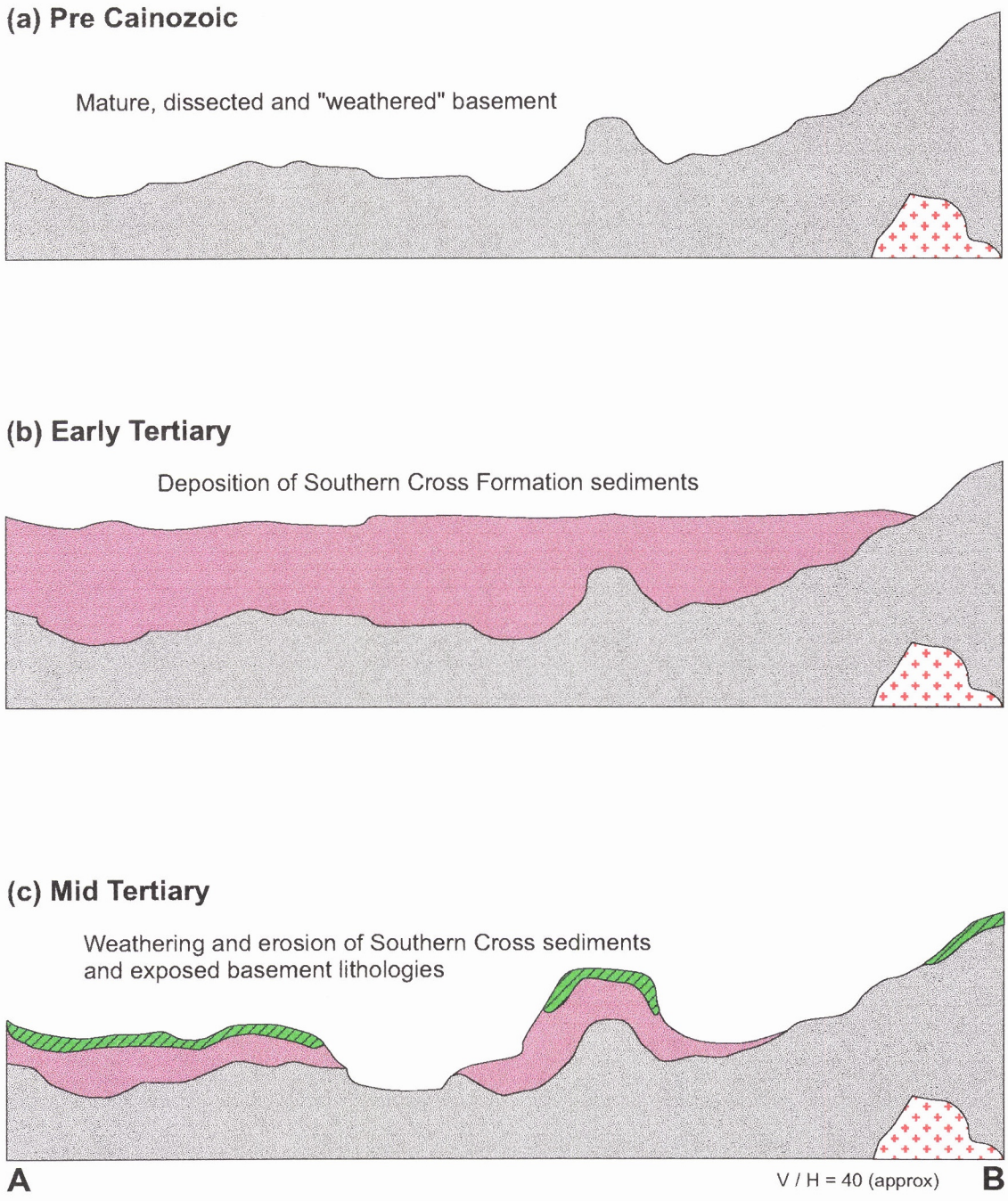
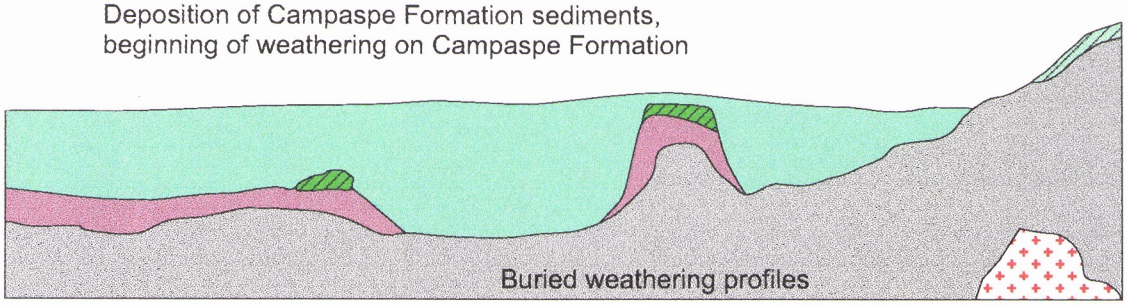


Figure 8: Stylized series of sections illustrating the landscape evolution from Pre-Cainozoic (a) through to Present Day (e), for the section A-B shown on Figure 2. See text for details.

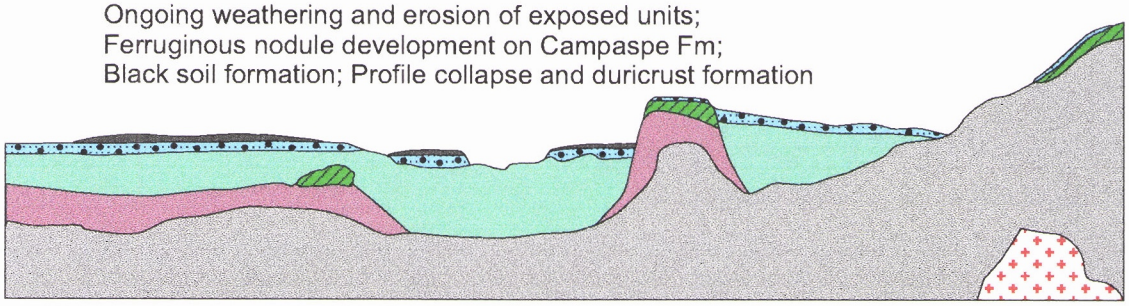
(d) Late Tertiary

Deposition of Campaspe Formation sediments,
beginning of weathering on Campaspe Formation



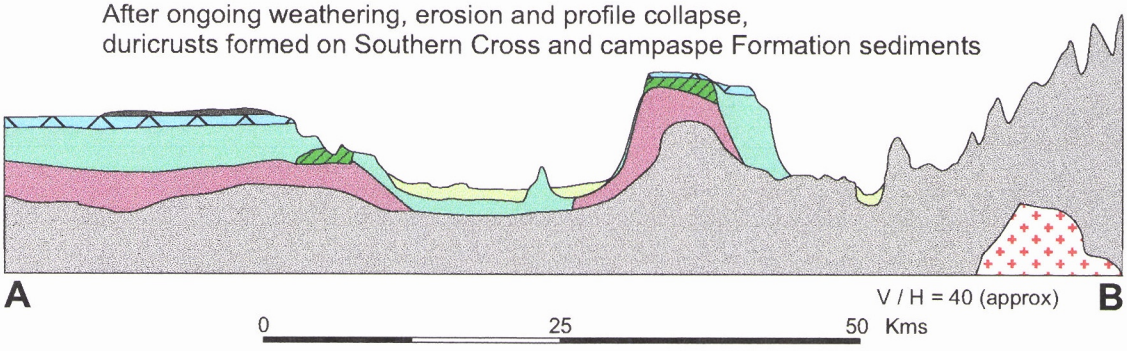
(e) Mid Quaternary

Ongoing weathering and erosion of exposed units;
Ferruginous nodule development on Campaspe Fm;
Black soil formation; Profile collapse and duricrust formation



(f) Present Day

After ongoing weathering, erosion and profile collapse,
duricrusts formed on Southern Cross and campaspe Formation sediments



3.3. Regolith History and Evolution

The area retains evidence of a complex history of weathering, erosion and deposition, since the Mesozoic. Figure 8 depicts a schematic series of cross-sections which illustrates the Cainozoic landscape evolution for section A-B, shown on Figure 2.

Towards the end of the Pre-Cainozoic, the landscape was characterized by a gently undulating dissected basement of Paleozoic rocks (Figure 8a). Although not shown on the cross-section, there is evidence of Mesozoic sedimentation (deposits on the western margins of the study area) and further isolated sequences could well be preserved beneath the Tertiary deposits elsewhere. Both the Palaeozoic and Mesozoic rocks that were exposed would almost certainly be weathered to some degree.

During the early Tertiary (Paleocene), an extensive blanket of continental fluvial sediments was deposited over the land surface (Figure 8b). These sediments are now known as the Southern Cross (Suttor) sedimentary system. The dissected basement was "flooded" by a substantial mass of transported sediments. As the uneven basement topography was "drowned" in a rising tide of fluvial material, locally-derived, colluvial detritus from topographically elevated basement was also incorporated into the sequence. Cobbles of vein material at Pajingo were incorporated into the Southern Cross sediments at this stage. Some of the basement hills and ridges probably remained as "island-inliers", standing above the maximum level of sediment in-fill and so were not covered by these sediments.

The next stage of the evolution is problematic. Almost certainly the sediments of the Southern Cross system were extensively eroded, dissected and weathered (Figure 8c), before the Campaspe sedimentary package was deposited in late Tertiary times. The exact details and timing of events during this 40(+) m.y. period are unknown. The Southern Cross sediments were probably partially dissected, then subjected to an extensive period of prolonged deep weathering. The Southern Cross Formation is a unit with variable thickness, which consistently shows a high degree of weathering and ferruginous coloration. The fluvial and lacustrine, sandstones and siltstones of the Southern Cross Formation are clay-rich and they contain clasts of basement material (cobbles and pebbles), some of which are exotic, some locally derived. Sediments of Southern Cross Formation typically occur as mesa cappings in the current landscape (unit UPS).

In the north of the study area, during the late Tertiary, the Campaspe sediments were deposited in a fashion similar to that of the earlier Southern Cross sediments: the dissected pre-Campaspe land surface was "flooded" by distally, and proximally-derived, fluvial sediments (Figure 8d). These materials covered an undulating, dissected, pre-existing land surface, consisting of sediments of the Southern Cross Formation and older Mesozoic and Paleozoic lithologies. Topographically elevated portions of this pre-Campaspe land surface probably stood above the maximum level of sediment infill and remained as inliers. Because the Campaspe Formation sediments are more quartz-rich and better sorted than those of the Southern Cross Formation, it is likely that the Campaspe Formation consists of a substantial contribution of re-worked Southern Cross. Since its deposition, the Campaspe has been dissected and weathered, and it currently forms an extensive plain on the western side of the study area (unit UFP).

Towards the top of the Campaspe Formation, there is widespread development of ferruginous nodules, which locally can be cemented to form a nodular ferricrete. The origin of this layer is debatable. One school of thought would favour these deposits as colluvium derived from proximal Southern Cross Formation. Another school, would suggest that this material results from a locally-developed weathering profile within the Campaspe itself. At Red Falls (to the north of the mapped area), and on the track into the Waterloo Prospect, there is definite evidence for the development of a weathering profile (ferruginous nodules and mottling) within Campaspe Formation sediments. These observations would suggest a locally-developed, rather than an inherited-transported origin for this ferruginous material. The iron may have been sourced form either weathering of minerals within the Campaspe sediments or derived laterally from either "ferruginous Southern Cross" sediments or weathered (?) basement lithologies. Localized re-working, and profile collapse during post-Campaspe times, could then result in the formation of the nodular ferricrete.

In the south of the study area, within the drainage catchment of the Suttor River and its tributaries, there is little evidence for an equivalent sedimentary sequence to the Campaspe Formation. If such a sequence was deposited, it has since been stripped, or its remnants have not as yet been recognized.

"Black soils" are present within the landscape (Figure 8e). At several localities these "black soils" are preserved as slightly elevated rises (EUP), above the level of the surrounding plains (UFP), which suggest they are "relict" landforms, which are being eroded by the current processes of landscape modification. These soils generally appear to be thin "deposits", which exhibit a sharp boundary with underlying units. Because of these characteristics, and their predominately smectitic nature, as opposed to the kaolinitic nature of the materials they are deposited on, it is considered that they are related to palaeo-lake deposits. Since the deposition of the Campaspe Formation, the whole area has been subjected to widespread erosion and on-going weathering, with most lithologies being dissected to various degrees (Figure 8f). The deposition and formation of these "black soils", could well be related to localized ponding of drainages, perhaps related to intermittent phases of catchment choking (rate of sediment production greater than rate of sediment removal).

4. Implications for Exploration and Recommendations

Whereas the map produced during this study gives an overview of the area's geomorphology, a more detailed interpretation of regolith materials is needed to control exploration geochemical sampling at the tenement scale. The landscape geomorphic provinces defined on the map are not homogeneous regolith units, and some variability is expected because of scale limitations. In the following, the exploration significance of the findings of this study are discussed.

Duricrust Dominated Terrains

In the Duricrust Dominated Terrains, two situations are significant for explorationists: duricrust development on basement lithologies and duricrust development on Tertiary sediments overlying basement.

This study did not identify extensive areas of ferruginous duricrust development on basement lithologies. Field work has shown that localized areas of duricrust development on basement lithologies do exist; but their outcrop size and characteristics are such that they could not be uniquely mapped in this study. Elsewhere, if such areas exist they most likely have been incorporated into mapped units UPS, RSm, RSc and UFP. Where it can be demonstrated that the duricrust on these basement lithologies has essentially developed in-situ, ferruginous weathering materials (iron-rich mottles, nodules and pisoliths) should be favoured sampling media. This situation is analogous to the use of ferruginous materials in the Yilgarn.

The usefulness of sampling ferruginous weathered materials in areas with extensive duricrust development on Tertiary sediments, is questionable. However the possibility that these materials could contain broad geochemical haloes indicative of underlying mineralization should not be dismissed. Selective sampling of weathered materials combined with appropriate analytical and interpretation methods could produce trace-element geochemical patterns indicative of underlying mineralization. Despite the fact that the sediments of both the Southern Cross (Suttor) and Campaspe Formations are predominately fluvial, there are factors that could assist in the transfer of trace elements from basement mineralization into the overlying sediments.

- Firstly, mechanical dispersion can be important, especially the incorporation of locally-derived materials near basement highs etc., as demonstrated at the Scott Lode, with mineralized vein-material incorporated into the overlying Southern Cross Formation. This material could then form the basis of an even larger hydromorphic dispersion cell within the younger sediments as weathering proceeds.

- Secondly, because the area has essentially been subjected to continental conditions throughout the Cainozoic, lithologies within the area have potentially been subjected to prolonged periods of weathering. It would be feasible to expect that weathering fronts could extend to great depths, perhaps into bedrock beneath the overlying sediments; and that water-table fluctuations could well result in concentration of trace elements into secondary ferruginous materials in the weathering profile.

Whereas the above discussion would suggest that duricrusts and ferruginous materials developed within weathering profiles on the older Southern Cross and Suttor Formations (unit UPS) are to be favoured for geochemical sampling, much of the area is now covered by duricrust development on younger Campaspe sediments (unit UFP). Field work suggests that there is a widespread, though non-continuous, preservation of a ferruginous nodular layer associated with a weathering profile within the Campaspe Formation sediments (unit UFP). It could be argued that the Campaspe sediments are not particularly suited for regolith sampling (e.g., because they are fluvial, they are stratigraphically younger than the "underlying", Southern Cross Formation, and they may be derived, at least partially, from reworked Southern Cross Formation). However, the Campaspe Formation can occur both marginally to, and at lower topographic elevations than the Southern Cross

Formation, so Campaspe sediments could, at some localities, directly overlie basement lithologies. Hence, geochemical dispersion from underlying mineralization may be evident in secondary ferruginous materials within the Campaspe Formation.

Further work is needed to assess the exploration significance of the nodular duricrust within the Campaspe Formation and the subsurface extent of the Southern Cross Formation. The significance of mechanical dispersion as a tool to vector mineralization should be recognized and investigations into the basement topography and palaeo-channels within the Southern Cross (Suttor) and Campaspe Formations could assist explorationists to interpret surface and subsurface geochemical haloes and dispersion trails.

Saprolite Dominated Terrains

In areas with exposed basement landforms and preserved saprolitic material (units TSBS, SUH, UCLG, & FeI), ferruginous weathering materials, especially mottles and nodules, may be useful sampling media. Care is needed to determine the nature of these ferruginous samples and their geochemical significance. In areas of saprolite that are clay-rich and iron poor, traditional stream, soil and rock sampling methods may need to be employed. Optimal exploration sampling strategies for these landscapes will most likely result in a combination of traditional geochemical (stream sediment, soil and rock chip sampling) and specialized "ferruginous" samples being collected.

In those basement areas with moderate-to-steep terrain and with minor saprolite preservation (units MRR and LRSH), traditional geochemical prospecting techniques (stream sediment, soil and rock chip sampling) should be appropriate. However, if the opportunity arises, samples of ferruginous mottles and nodules should also be collected and assayed.

Colluvium and Alluvium Dominated Terrains

Some of the rugged, higher relief, basement areas are dominated by colluvial deposits. However, these materials are usually locally derived and moved through the area fairly rapidly. In these areas, traditional geochemical methods should still be effective for exploration purposes. It is only after there is a contribution from alluvial material that other, more invasive techniques, such as drilling and trenching may be required.

Areas covered by recent alluvium and sheetwash derived from the erosion of Tertiary and older materials (units, A/F, CDA, UC) may require extensive investigation. The nature and thickness of these Quaternary materials needs to be determined, as they mask the underlying geology and geochemistry. Drilling and sub-surface sampling will be necessary.

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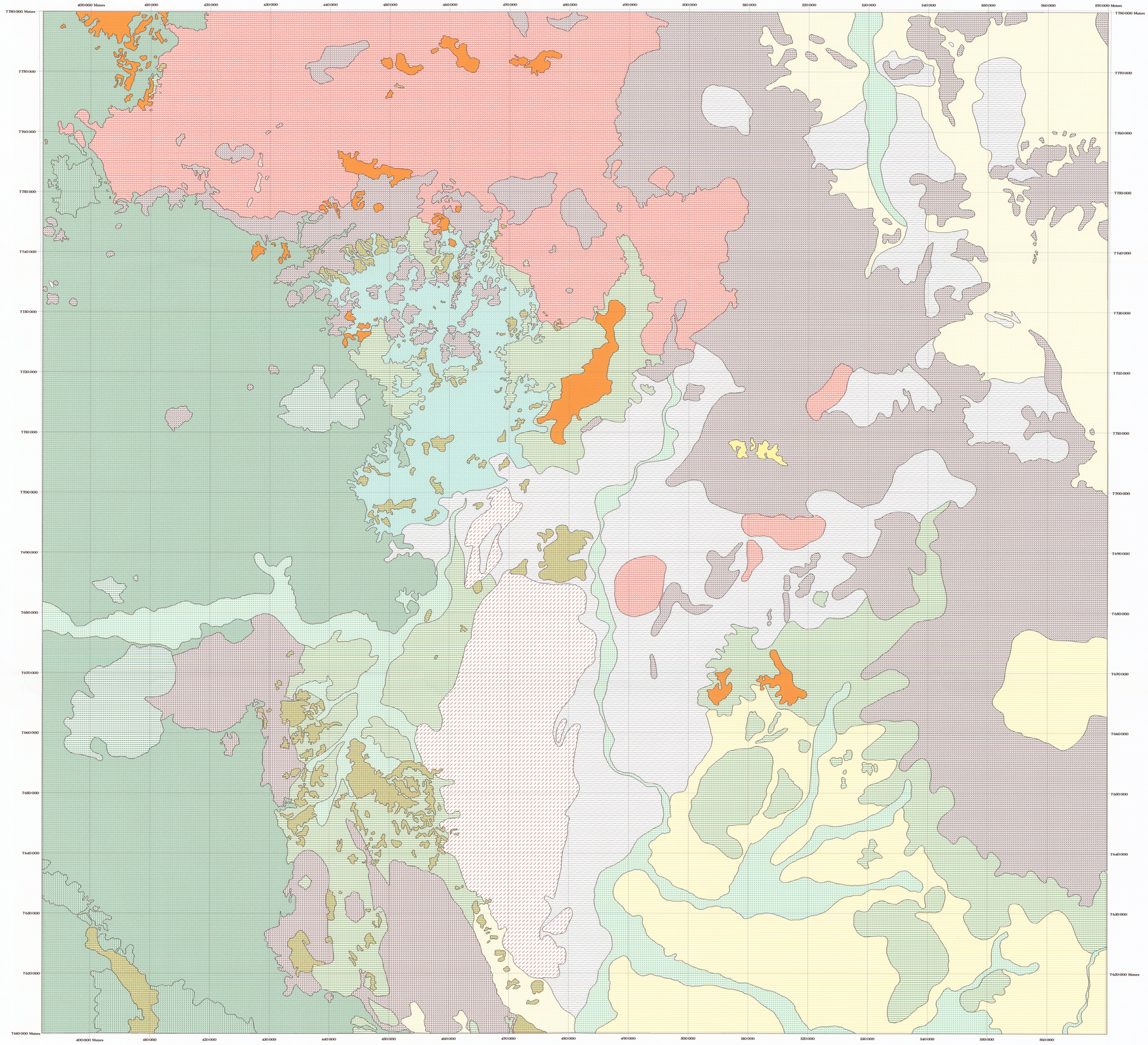
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Appendix I

Geomorphic Provinces of the Charters Towers - North Drummond Basin Area (1:250,000)

GEOMORPHIC PROVINCES
CHARTERS TOWERS - NORTH DRUMMOND



AMIRA

Australian Mineral Industries Research Association Limited ACN 004 448 266

0 10 20 30 40 50 Kms

1:250,000

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It is recommended that this map be referred to as:

Fraser S.J. 1997 - Geomorphic Provinces. Charters Towers-North Drummond (1:250,000 map scale). Cooperative Research Centre for Landscape Evolution and Mineral Exploration (CRC LEME) Brisbane.

The regolith map is based on interpretation of a mosaic of four Landsat TM scenes over the Charters Towers-North Drummond region. This map provides a broad overview of landforms around the Charters Towers-North Drummond region. Boundaries and polygon descriptions are generalized to show main regolith and landform types.

CRC LEME does not warrant that this map is definitive, nor free from error and does not accept liability for the loss caused or arising from reliance upon information provided herein.

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LEGEND

Duricrust Dominated

- UPS — Undulating plateau surface, with moderate elevation, bounded by steep scarps
- UFP — Undulating flat plains of sediments (Tertiary Campaspe Fm ?); now being reworked(sheetwash and bedload re-working of pre-existing sediments
- RSm — Remnant sedimentary mesas, typically with plateau tops, bounded by scarps unless they abut higher ground (partially dissected UPS unit)
- Sil — Silcrete developed as capping on granitic terrain
- RSc — Remnant sedimentary cover, level or sloping terrain with low mesas or their dissected remains (strongly dissected UPS)

Saprolite Dominated

- MRR — High-to-moderate relief, rugged terrain; bedrock characteristics evident
- SUH1 — Strongly undulating, rounded hilly terrain, low-to-moderate relief, exposed basement.
- FeI — Strongly dissected low terrain with iron staining; mafic intrusives(?)
- TSBS_L — Thin soils on basement sediments; low relief. (structure).
- UCLG — Undulating, strongly dissected granitic terrain
- SEDS — Slightly elevated, dissected sediments with trellis drainage patterns; flat-lying inlier
- LRSH — Thin soils on basement sediments, moderate relief,strike ridges. (structure)

Alluvium and Colluvium Dominated

- A_F — Alluvial plains associated with present day drainages; some sediment re-working
- UC — Relatively flat undulating plains with low rises/hills, predominately relict transported surficial detritus, now being reworked
- CDA — Rolleston River Catchment: an almost choked catchment with detritus derived from erosion of Tertiary sediments.
- Sw_SS — Moderate to steep terrain; sheet wash areas & colluvium
- EUP — Slightly elevated undulating plains, bounded by scarp margins

This map is a supplement to CRC LEME Restricted Report 39R / CSIRO Exploration and Mining Report 366R