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OPEN FILE REPORT SERIES

REGOLITH-LANDFORM CHARACTERISTICS, EVOLUTION AND IMPLICATIONS FOR EXPLORATION OVER THE SELWYN REGION, MT ISA

J.R. Wilford

CRC LEME OPEN FILE REPORT 131

March 2002

(CSIRO Exploration and Mining Report 372R/CRC LEME Report 44R, 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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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 131) is a second impression (second printing) of CSIRO, Division of Exploration and Mining Restricted Report 372R, first issued in 1997, which formed part of the CSIRO/AMIRA Project P417.

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PREFACE

The P417 Project (Geochemical Exploration in Regolith-Dominated terrain of North Queensland) involves regolith studies of gold and base metal provinces of the Mt Isa Inlier and Charters Towers-northern Drummond Basin. The principle objective of the project is to substantially improve methods of exploration for base metals and gold in areas masked by deep weathering or beneath cover. The research includes geochemical dispersion studies, regolith mapping, regolith characterisation, dating of profiles and investigation of regolith evolution. Selwyn region is one of several district-scale investigations over the Eastern Succession of the Mt Isa Inlier. The Selwyn area was chosen for substantial study in the project because it is an example of some of the important problems of exploring regolith-dominated terrain in the Eestern Succession. The area is characterised by regolith developed on Proterozoic, Cambrian and Mesozoic rocks.

The report documents the methodology used to compile regolith maps and describes the types and distribution of regolith over the Selwyn area. The origin of different regolith materials is discussed together with a summary of landscape evolution and implication of mineral exploration. The processing and enhancement of Landsat TM imagery using principle components and band ratios for separating weathered materials at the surface over the region is also discussed. An interpretative Landsat TM image highlighting Fe oxides, clays and silica materials is provided. Regolith materials are described within a landform framework and are broadly divided into three categories - duricrusts, saprolites and sediments. These categories are further subdivided based on the major lithologies being weathered, including Proterozoic bedrock, Cambrian and Mesozoic sediments. Characteristics of representative weathering profiles are discussed.

An attempt has been made to generate a regolith 'fact map' (compiled at 1:25,000) which as far as possible is descriptively based with little or no genetic bias. The 'fact map' forms the basis of three derivative maps which highlight particular themes and interpretative models. The derivative maps have been generated from a comprehensive GIS dataset over the Selwyn study area which include; field-site descriptions, regolith and landform polygons and descriptions, processed Landsat TM imagery, landform features (e.g., palaeochannels), regolith geochemistry, images (scanned photos) and profile diagrams. One of these derivative maps is a geochemical sampling map (compiled at 1:25,000) which can be used as a tool for interpreting and planning geochemical surveys.

R.R Anand
Project Leader

I.D.M. Robertson
Deputy Project Leader

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. SUMMARY

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 40km) 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 (include; 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 may 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.

2. INTRODUCTION

2.1 Background

This report documents results from the Selwyn district which is one of several district-scale investigations over the Eastern Succession of the Mt Isa Inlier and complements regional synthesis studies of the Mt Isa Region by Anand *et al.* (1996).

The term regolith used in this report describes all weathered and/or transported material above fresh bedrock. Merrill (1897) defined regolith as the whole range of unconsolidated material that mantles the Earths surface. Although unconsolidated is used in the original definition of the regolith, indurated materials such as duricrusts and other materials formed by secondary enrichment and dehydration are now included in the definition. The word itself comes from the Greek rhegos = blanket and lithos = stone. Regolith therefore is the blanket over the rock. The regolith is seen as a barrier to mineral exploration. Understanding the nature and distribution of regolith materials in a landscape, in relation to underlying geology and mineralisation has proven critical in any comprehensive exploration program when exploring in deeply weathered or covered terrains.

Exploration problems in the Mt Isa region include:

- recognising transported and *in situ* ferruginous and siliceous materials;
- separating sedimentary cover from weathered Proterozoic bedrock;
- understanding the complex geochemical signatures arising from multiple profiles;
- correctly interpreting element concentrations in the weathered Mosozoic and Cambrian sediments overlying mineralised Proterozoic bedrock; and
- distinguishing gossans from Fe duricrusts and other ferruginous materials in the landscape.

2.2 Objective

The objective of this study is to develop an understanding of how the landscape and regolith have evolved with the aim of substantially improving geochemical exploration methods for base metals and gold. Specific objectives are to:

1) establish spatial relationships between landforms, regolith and lithology by detailed regolith-landform mapping;

2) determine mineralogical and geochemical characteristics of selected regolith types;

3) develop an understanding of weathering processes;

4) evolution of regolith- landforms; and

5) develop effective exploration strategies in different regolith-landform settings.

3. SELWYN STUDY AREA AND REGIONAL SETTING

3.1 Location

The Selwyn regolith-landform map is located approximately 140 km south southeast from Mt Isa and covers part of the Selwyn (7054) and Mt Merlin (6954) 1:100 000 map sheet areas (Figure 1). The map covers an area of approximately 40 km by 40 km and lies between the AMG coordinates of - 423000E:7622000N (top left); 466000E: 7580000N (bottom right).

3.2 Climate and vegetation

The area has a semi-arid, monsoonal climate with distinct wet and dry seasons. Most of the rainfall (approximately 375 mm) occurs in the summer months between November and March. Summer rainfall is unpredictable and droughts are common. Mean maximum and minimum temperatures range from approximately 35 and 25°C in December with corresponding winter temperatures some 10 to 15 degrees cooler (Blake *et al.*, 1983). Vegetation over the area consists largely of spinifex, acacia shrubs and scattered low eucalyptus trees.

3.3 Previous investigations

Blake *et al.* (1983) mapped the geology at 1: 100 000 scale. The Eromanga Basin sequences are described by Senior *et al.* (1978). Descriptions of the Cambrian and Ordovician rocks of the Burke River Structural Belt are provided in Shergold and Druce (1980). Noon (1976) provides an overview of mineralisation on the Duchess 1:250 000 map sheet which includes the Selwyn region. More detailed and focused studies of the mineralisation associated with the Selwyn gold-copper mine are described by Kary *et al.* (1989).

Previous information on regolith and landscape evolution in the area is sparse. Twidale (1966) provides evidence of recent uplift and drainage development immediately east of the study area. When considering the Mt Isa Inlier as a whole most of the work has focussed on bedrock investigations, particularly on the Proterozoic sequences. Exceptions to this are investigations by Senior *et al.* (1978) (Geology of the Eromanga Basin), Smart *et al.* (1980) (The Mesozoic Carpentaria Basin), Connan and Hubble (1960) (Origin of laterites), Grimes (1972 and 1979) (Mesozoic and Cainozoic geology of the Cloncurry map sheet, stratigraphic sequence of old land surfaces in North QLD and Tertiary Geology of North QLD, respectively), and Twidale and Campbell (1993) (Dedunation chronology and exhumed surfaces, Mt Isa - in Australian Landforms Structure, Process and Time). More recently, regolith-landform maps and accompanying reports (Anand *et al.*, 1996) show broad and detailed regolith characteristics over parts of the Mt Isa Inlier.

3.4 Physiography

Regolith-landform mapping is used to separate the Selwyn region into 8 major landform types. These landforms include colluvial plains and minor footslopes, alluvial plains and floodplains, pediments and erosional plains, rises, low hills, hills, escarpments and plateaux. The distribution of major landforms and their percentage cover over the Selwyn study area is shown in Figures 2 and 3.

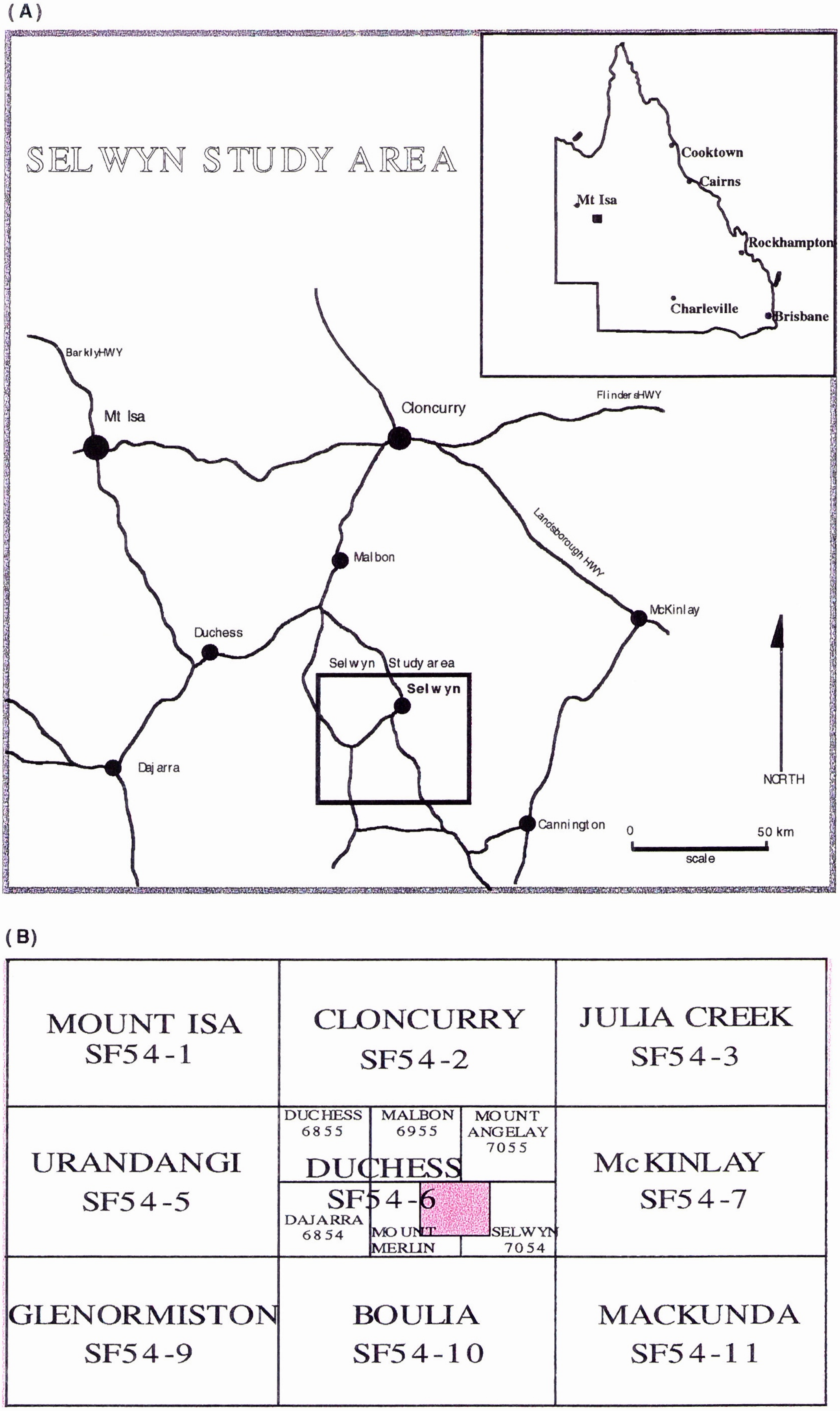


Figure 1. (a) location of the Selwyn study area and (b) index map to adjoining 1:100 000 map sheets

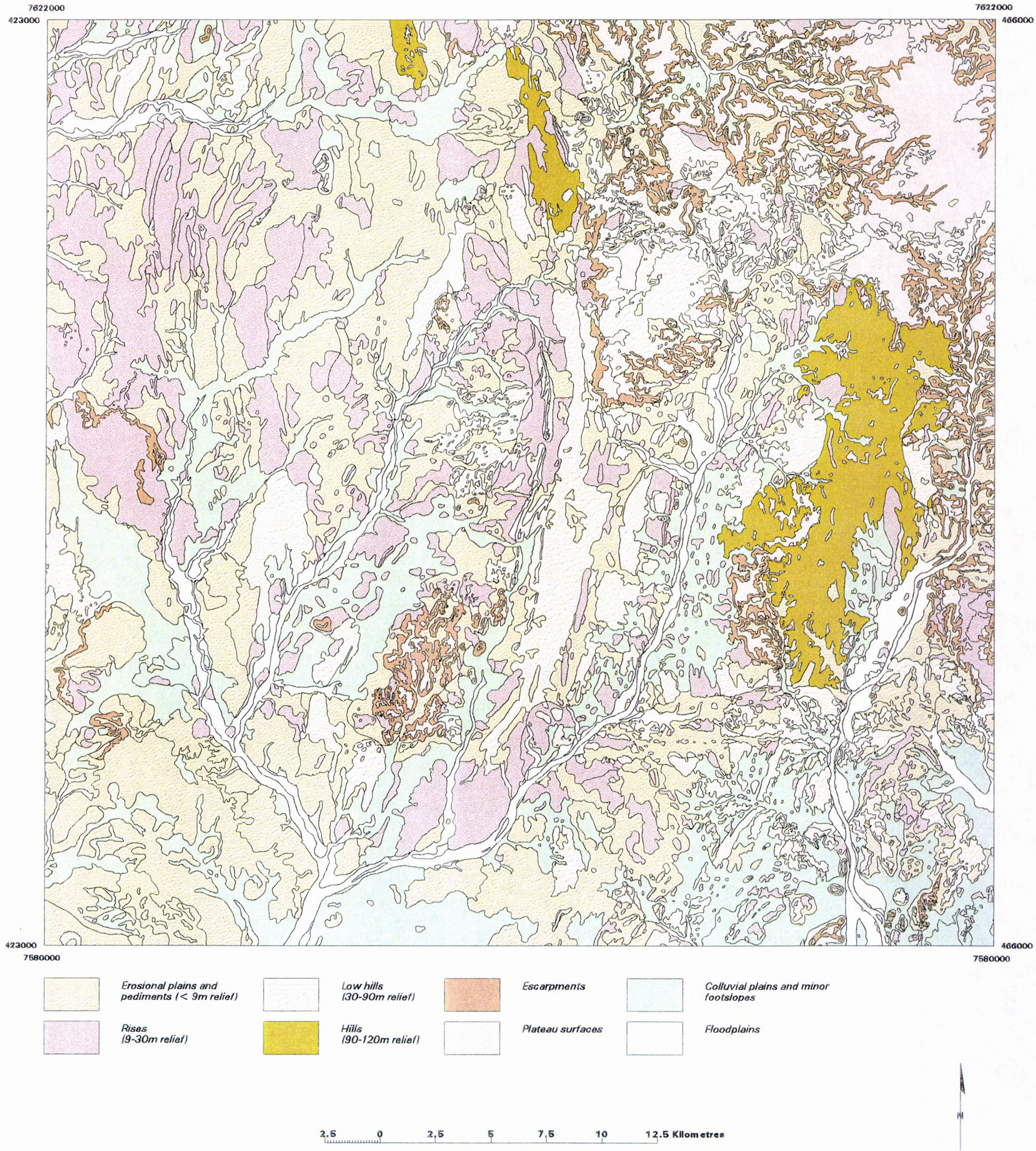


Figure 2. Major landform units over the Selwyn study area.

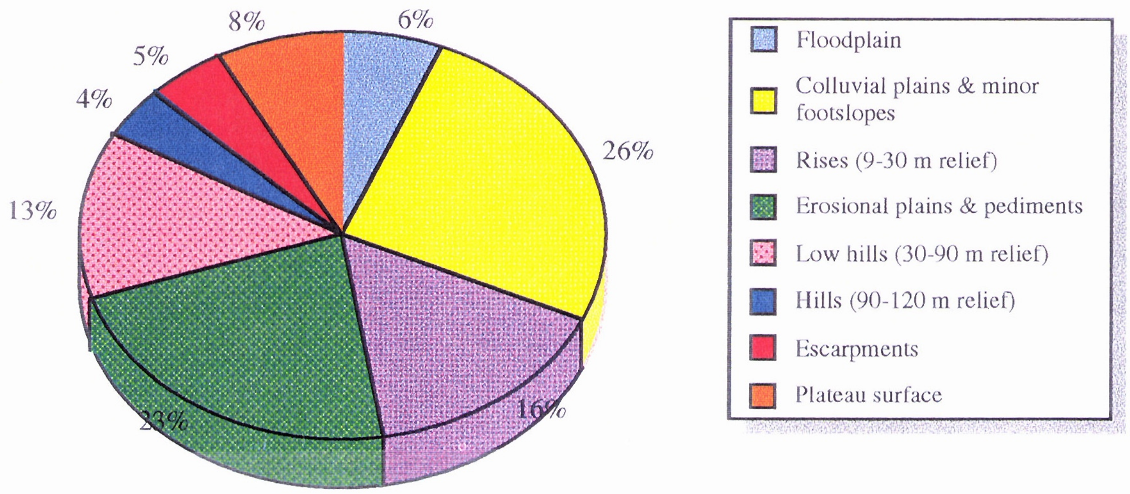


Figure 3. Pie chart showing the proportions of major landform types.

High plateaux, mesas, scarps, hills and low hills occur over the northeast corner and extend into the central part of the map sheet (Figure 2). Relief in this area ranges from 50 -130 metres and forms part of the Selwyn Range which also extends further to the north-east. The landforms are being actively eroded by moderately dense dendritic and trellis drainage channels. The trellis patterns are following predominantly north-south jointing and cleavage planes in the underlying Proterozoic bedrock. Low relief, colluvial plains, pediments and erosional plains are associated with the Mort River catchment which extends into this area of higher relief from the south (Figure 2).

Landforms along the southern edge of the map are characterised by extensive colluvial plains, erosional plains, pediments, undulating rises and minor low hills, mesas and buttes. Similar gently undulating landforms occur over the western half of the map, including; rises, pediments, erosional plains, colluvial plains, floodplains associated with major rivers and minor low hills. Well developed plateaux and associated scarps have developed largely on granitic bedrock and occur over the central part of the map sheet. Drainage patterns over these landforms are mainly dendritic with weakly developed trellis patterns following underlying bedrock structure.

The highest point, approximately 480 metres above sea level and steepest slopes occur over dissected Mesozoic plateaus at the north-east corner of the map sheet. The lowest point, approximately 240 metres above sea level is associated with floodplains of rivers draining to the south including the Mort River and Sandy Creek (a tributary of the Hamilton River).

A major divide separates rivers flowing south into the Lake Eyre basin and those draining north into the Gulf of Carpentaria (Figure 4). Sandy Creek and Little Sandy Creek are tributaries of the Hamilton River; Mort River, Mistake Creek and Limestone Creek are tributaries of the Burke River. Both the Hamilton and Burke Rivers flow into the Georgina River approximately 140 km to the south southwest. Drainages north of the divide flow into the Cloncurry River.

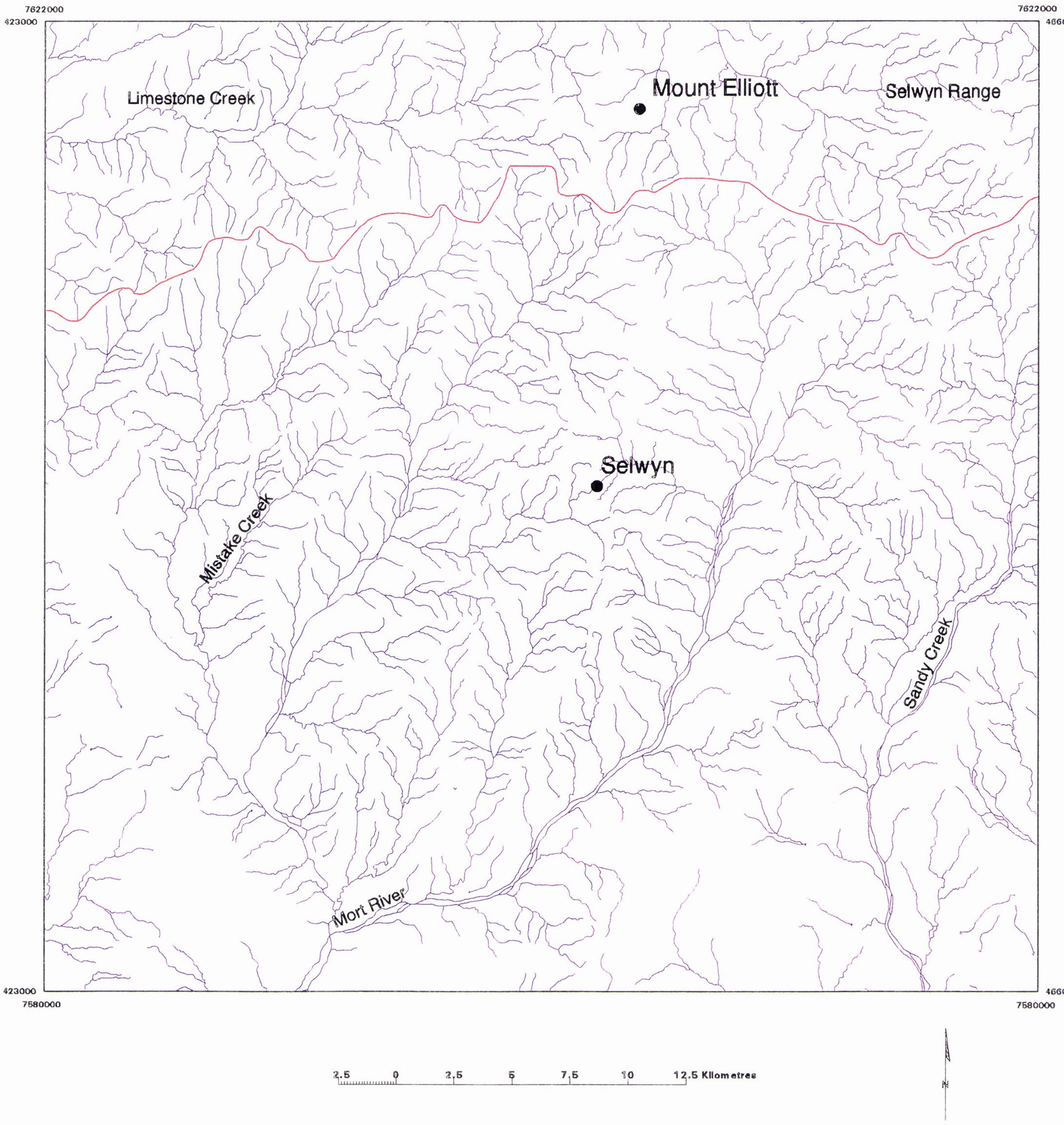


Figure 4. Major river divide (orange) and drainage over the Selwyn study area.

3.5 Regional Geological setting

The bedrock geology of the Selwyn region consists of Proterozoic rocks of the Mt Isa Inlier, Cambrian sediments of the Burke River Structural Belt and Mesozoic sediments of the Eromanga Basin (Blake *et al.*, 1983). The Proterozoic rocks consists of foliated and non-foliated granites (most common are porphyritic and non-porphyritic biotite and hornblende-biotite granite), metadolerites, metabasalts, meta-arenites, amphibolites, slate, phyllite, schist, gneiss, felsic granofels, quartzite and quartz-hematite beds (Figure 5).

The Mt Isa region, including the Selwyn area, underwent major tectonism during the early Proterozoic causing uplift and exposure of the surface to sub-aerial erosion and weathering (Blake *et al.*, 1983). Emplacement of the granites into the metamorphic sequence occurred during this time and at later tectonic events. Towards the end of the pre-Cambrian most of the landscape had been extensively eroded. During a Cambrian marine transgression shallow water sediments were laid down unconformably over the Proterozoic rocks. They consist largely of flat-lying to sub-horizontal bedded sandstones, siltstone, shale, chert, limestone, minor conglomerate and breccia. These sediments now occur mainly along the low relief western margin of the map but were once probably far more extensive over the map sheet area. Erosion and weathering of Cambrian and Proterozoic rocks then continued until an extensive cover of Mesozoic sediments were deposited. Mesozoic sediments of the Eromanga Basin are flat-lying and unconformable overlie the Proterozoic and Cambrian rocks. Mesozoic sediments consists mainly of terrestrial sandstone and conglomerate and shallow marine sandstone, siltstone and mudstone (Smart *et al.*, 1980). Since the Late Cretaceous there has been substantial weathering and erosion to the present day.

3.6 Mineralisation

The region contains copper, cobalt, gold and minor amounts of silica flux and tungsten (Blake *et al.*, 1983). Two major Cu and minor Au mines operate in the region - Starra (Selwyn) (Lat 21.683 Long 140.472) and Mount Elliott (Lat 21.541 Long 140.500). Primary copper ore at Starra is associated with chalcopyrite, bornite, pyrite, native gold and scheelite whereas ore at Mount Elliott is associated with chalcopyrite, pyrite and pyrrhotite. Mineralisation at Starra is associated with shear zones and a multiple-veined system hosted in carbonaceous slates and metadolerite of the Kuridala Formation, and at Mount Elliott with folded and highly sheared ironstones, quartz feldspar magnetite schist and chlorite schist of the basal part of the Stavely Formation. Regional tectonism and igneous intrusions in the region are thought to be instrumental in the concentration (developing structural pathways) and providing traps (shears and veins) for mineralised fluids to concentrate. Gold and copper mineralisation associated with quartz hematite ironstones developed due to secondary processes (Blake, *et al.*, 1983) where Fe and mineralised fluids preferentially replaced existing porous strata. Comparison of mineralised and non-mineralised ironstone is described by Wildman (1997). The quartz-hematite rocks outcrop as massive resistant linear ironstone beds (Figure 6 and 11U).

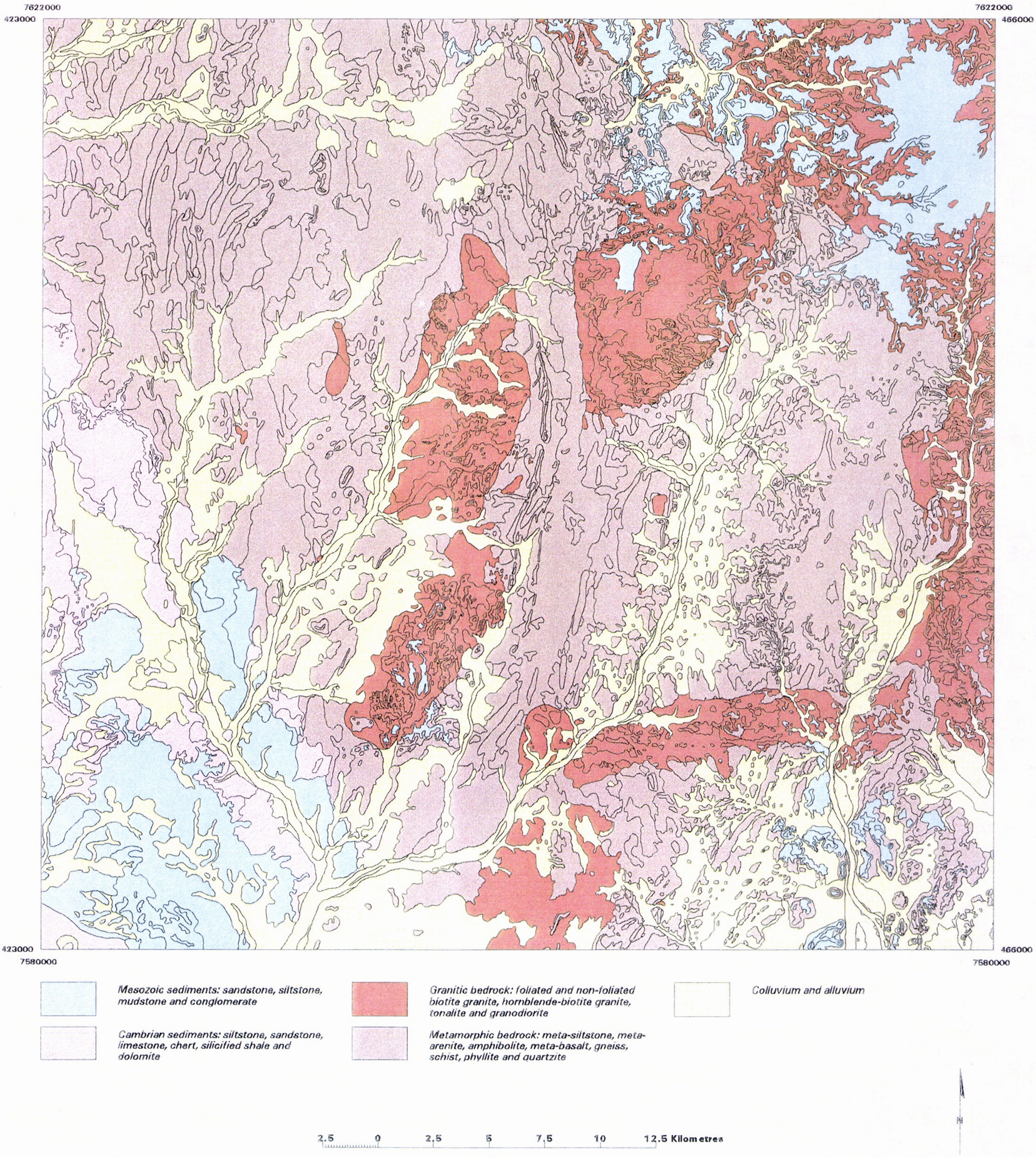


Figure 5. Simplified geological units over the Selwyn study area.

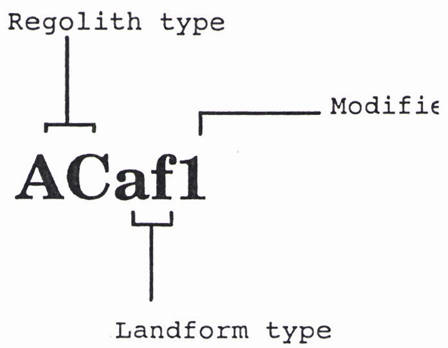
Figure 6. Distribution of mineral occurrences and massive hematitic ironstones (yellow) draped over Landsat TM band 5 which serves to highlight major structural and landform features. Regolith polygons shown in white. Copper deposits in green, Uranium in purple, Cobalt in pink and unspecified in pale blue.

4. REGOLITH MAPPING - METHODOLOGY AND DATASETS

4.1 Regolith-Landform Units

The regolith-landform unit (RLU) is the basic mapping unit and consists of areas with similar landform and regolith characteristics that can be isolated at the scale of mapping (Pain, *et al.*,1991). Due to the variability of weathered materials both spatially and compositionally, it is often difficult to map regolith directly or more importantly consistently across the map sheet. Instead, mapping units are defined mainly on the basis of landforms types (i.e. floodplain, mesa etc). Landforms can be used as a surrogate for mapping regolith because landforms and regolith are usually related both spatially and genetically. Relationships between landforms and regolith are then described within each RLU (see maps Appendix 5). Regolith-landform units, therefore, do not necessarily show uniform or pure regolith materials, but more typically associated and linked landform and regolith attributes. One landform type can have several different regolith types. Purity of regolith shown on the map is largely scale-dependent. With increasing mapping scale (i.e. 1:250,000 to 1:100,000) the higher the purity or uniformity of regolith is found within each RLU and the opposite relationship is true when decreasing map scale.

Regolith and landform types for each RLU are indicated on the Selwyn Map by a series of codes (see Appendix 5). Each RLU has either a three or four-letter code to describe its major regolith and landform types. The capital letters describe the regolith type and the lower case letters describe the landform type. For example, alluvial floodplain sediments deposited on a river floodplain would be expressed in the following manner;



The suffix 1 at the end of the RLU code is a modifier which allows the unit to be subdivided into one or more groups (i.e. suffix 1, 2, 3 etc). This is useful when wanting to show subtle but nevertheless important difference within each RLU. For example, alluvial sediments might be carbonate-rich and elsewhere carbonate poor. This difference can be shown on the map using the suffix 1 and 2 (i.e. ACaf1 and ACaf2).

Regolith and landform codes used on the maps (Appendix 5) are listed below.

Regolith codes

DF	Ferruginous duricrust
DS	Siliceous duricrust
S	Saprolite
AC	Channel deposits
AO	Overbank deposits
AA	Alluvial terrace deposits
A	Alluvial sediments undifferentiated
CH	Sheet flow sediments
CF	Footslope deposits
CF	Footslope deposits

Landform codes

ls	Plateau
ei	Pediments
ep	Erosional plain (<9m relief)
er	Rises (9-30m relief)
el	Low hills (30-90m relief)
eh	Hills (90-300m relief)
ee	Escarpment
af	Floodplain
ao	Floodout, overbank plain
ol	Alluvial terrace
fc	Colluvial fan
pd	Depositional plain
ep	Erosional plain (<9m relief)

4.2 Data collection and map compilation

The Selwyn map (Appendix 5.1) was based on approximately three weeks fieldwork with a similar amount of time for pre-fieldwork photo interpretation and image-processing. During fieldwork over 120 sites were recorded and referenced using GPS with a +/- 100 m location accuracy. The map was compiled using colour aerial photographs at a scale of 1:25 000, airborne gamma-ray imagery and Landsat Thematic Mapper imagery processed to enhance clay, iron oxides and silica (see section 5). The 1:100,000 Selwyn Special Geological map (Blake *et al.*, 1983) was used to recognise major lithological types in the region. Polygons on the map were initially drawn from landforms based on airphoto interpretation. These polygons were then in places sub-divided or modified based on the enhanced Landsat TM and airborne gamma-ray imagery. The airborne gamma-ray imagery was provided by MIM Exploration. The interpretation of Landsat TM for mapping regolith including various enhancement techniques are discussed below.

5. REMOTE SENSING TECHNIQUES FOR REGOLITH DISCRIMINATION

5.1 Interpretation of Landsat TM imagery for mapping regolith

Enhanced Landsat TM imagery proved to be particularly useful over the Selwyn area due to the relatively sparse vegetation cover and good outcrop exposure. The use of Landsat TM data for geological mapping is well known (Drury and Hunt., 1986, Abrams, *et al.*, 1984 and Podwysocki, *et al.*, 1985). However, the application of Landsat TM for regolith discrimination or, more specifically, how Landsat TM data is used in constructing a regolith-landform map is generally less well understood. A brief summary of how Landsat TM imagery was processed, interpreted and incorporated into the Selwyn regolith map is presented here.

Spectral characteristics of common surface features including vegetation, bedrock and regolith materials in the visible and near infrared part of the electromagnetic spectrum are shown in Table 1. Landsat TM bands 1,2,3 and 4 show variations in Fe oxide species (hematite and goethite) and can be used to show some separation of ferruginous materials. Band 5, due to its high reflectance of soil and rock materials, is displayed as a single band grey-scale image to highlight major landform and structural features. Band 7 provides discrimination of hydroxylated silicates, aluminosilicates and carbonates. With some prior knowledge of the regolith cover a variety of band combinations and ratio bands were found to be useful for separating different weathered materials, these are:

7 + 1 for silica-rich materials (eg. siliceous bedrock, quartz gravel lags);

5/4 for ferrous (Fe+2) iron (eg. hematite, Fe duricrust, ferruginous saprolite);

5/7 for argillic materials - clays and carbonates;

3/4 for saprolite versus vegetation;

4/2 for ferrous (Fe+2) versus non-ferrous saprolite; and

3/1 for ferric (Fe +3) iron (eg. goethitic saprolite and Fe duricrusts).

These band and ratio combinations can be displayed individually or as various three band false-colour combinations. However, one of the most effective enhancements for discriminating a range of different regolith materials is a technique called Directed Principle Component Analysis (DPCA) developed by Fraser and Green (1987). The DPCA is used to separate clays in the imagery by deriving principle components from ratio band 4/3 and 5/7. Ratio band 4/3 enhances vegetation and ratio 5/7 enhances a mixed response of vegetation and clay. The DPCA operating on these ratio bands is able to separate the vegetation from the clay response. The 'clay' band (derived from the second principle component) was then combined with ratio bands 5/4 and bands 7 + 1. Ratio 5/4 highlights ferruginous materials, and bands 7 + 1 highlights Si-rich materials. The final image was displayed as a three band composite image with clay in red, Fe oxides in green and silica in blue (see Appendix 5.3). In the three-band image (Figure 7) colluvial sheet flow deposits appeared in pale blue hues and are clearly separated from saprolitic material which appears mainly in pale red to deep red hues. Ferruginous saprolite, mottled saprolite and ferruginous gravel lags over erosional plains and rises are typically delineated in yellow. Mixtures of yellow and green indicate areas of outcropping ferruginous duricrusts together with ferruginous saprolite. Vegetation along drainage channels and water bodies appear in black or dark blue hues.

Table 1. Landsat TM spectral features

TM bands	General spectral features*	Regolith spectral responses
band 1	Ferric and ferrous iron absorption.	Fe duricrusts, ferruginous saprolite low. Hematitic iron very low. Kaolinite high.
band 2	Ferric iron absorption and ferrous iron reflection. Chlorophyll reflection peak	Fe duricrusts, ferruginous saprolite low. Kaolinite high.
band 3	Short-wavelength shoulder of ferric iron reflection. Ferrous iron absorption. Chlorophyll absorption	Moderate reflection for goethitic and hematitic iron. Kaolinite high.
band 4	Short-wavelength shoulder of ferric iron and ferrous iron absorption. Vegetation reflection peak.	Moderate reflection for goethitic and hematitic iron. Kaolinite high.
band 5	Highest reflection for most rock types. High reflection peak for hydrothermally altered rocks. Vegetation absorption.	Highly reflective for hematitic Fe duricrusts and ferruginous saprolite and clays
band 7	Absorption band for Al-O-H, H-O-H, Mg-)-H and C03 (clays, micas, carbonates, sulphates. Vegetation water absorption. Dry grass high.	Absorption associated with hydroxyl bearing minerals and carbonates (Bleached or pallid zone, secondary carbonate - calcrete and travertine) Highly reflective for hematitic Fe duricrusts and ferruginous saprolite.

General and specific regolith spectral responses associated with Landsat TM bands (excluding band 6)
(* modified from Podwyzocki *et al.*, 1985)

Processed Landsat TM imagery provides a great deal of surface information particularly on the distribution of clays and Fe oxides within different regolith-landform units. The interpretation of the image is enhanced when combined with digital elevation models. Three dimensional perspective views which integrate Landsat TM imagery and digital elevation models allow the TM response to be interpreted within a geomorphic framework (Figure 8). A map showing regolith-landform units draped over the enhanced Landsat TM imagery at 1:65 000 scale is provided in Appendix 5.3. The image response is used to describe and estimate the relatively proportion of regolith materials within each landform unit. Where required, the imagery has been used to extend or further subdivide regolith units particularly in areas of poor landform expression. Superimposing regolith polygons over the Landsat imagery also provides an estimation of the relatively purity of surface materials within each regolith unit (see Appendix 5.3).

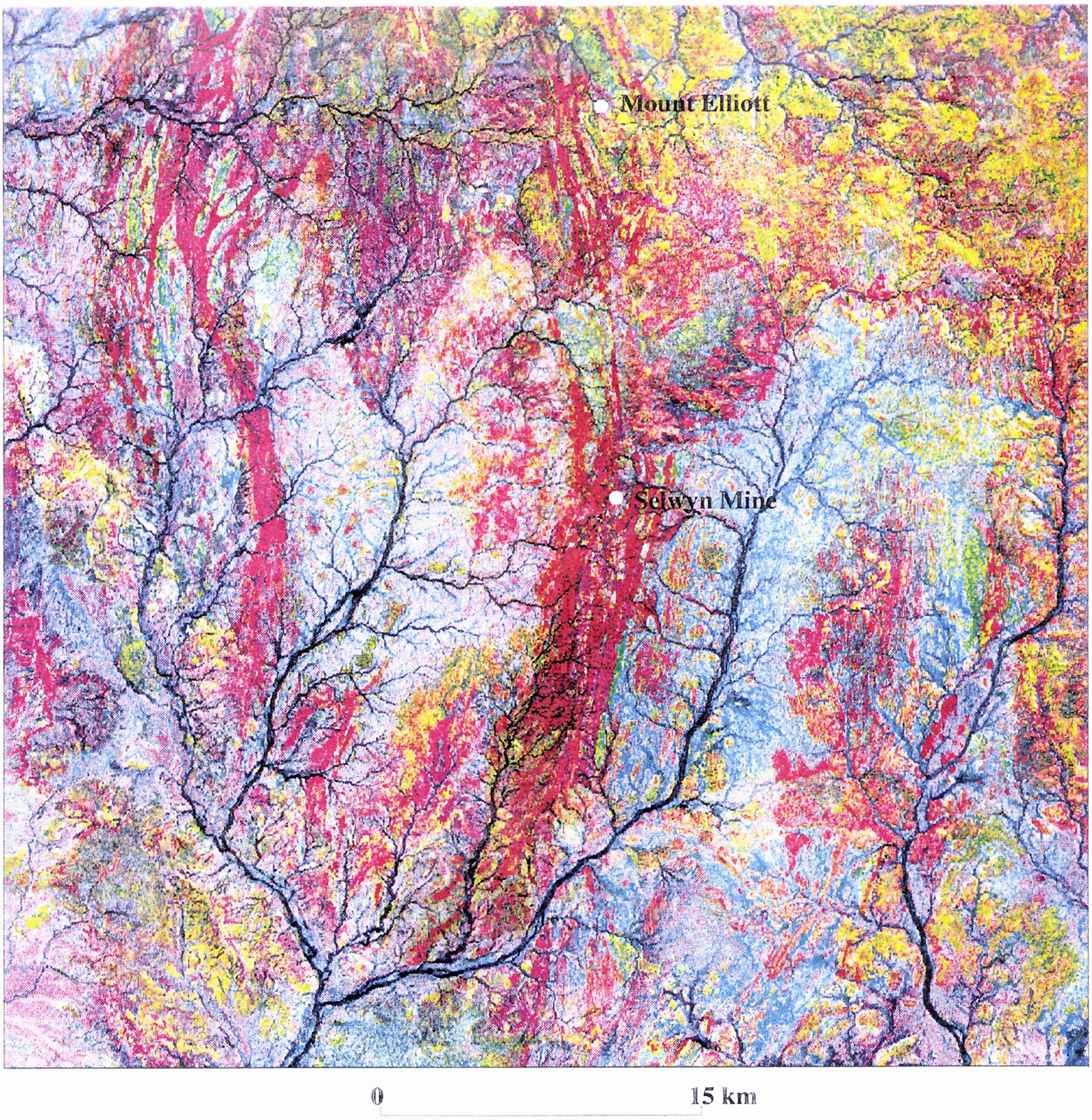
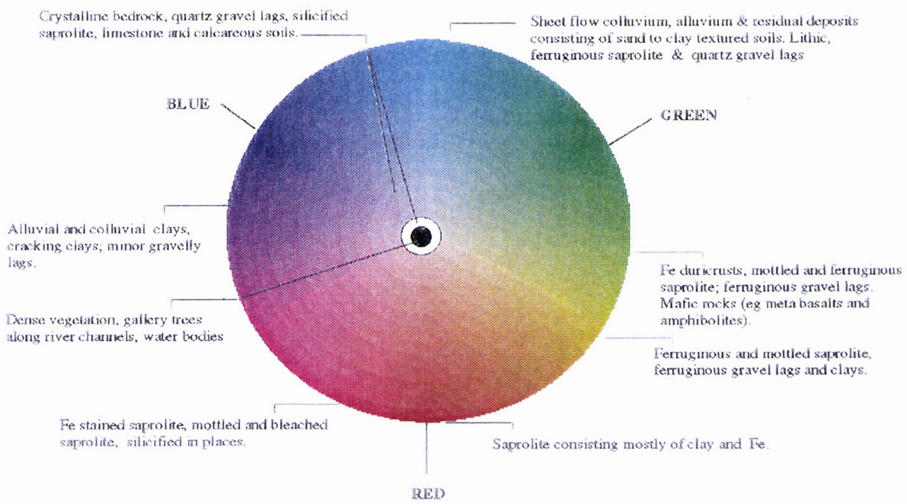


Figure 7. Three band Landsat TM image of second principle component of 4/3 and 5/7 in red, ratio 5/4 in green and the addition of bands 7 + 1 in blue. Interpretative colour wheel below.



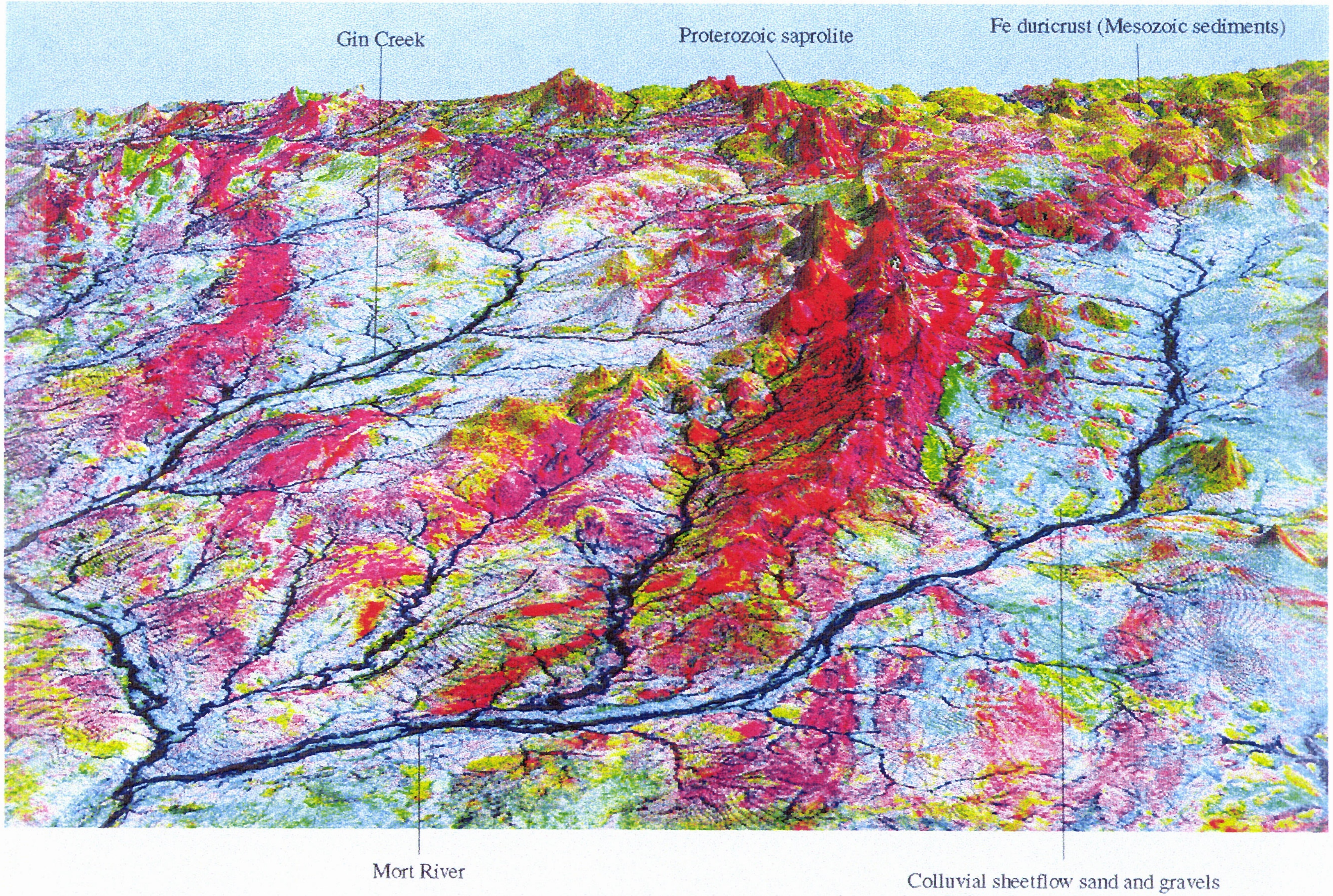


Figure 8. Three band TM image draped over a digital elevation model. Surface spectral responses can now be interpreted with a geomorphic perspective.

6. SELWYN REGOLITH-LANDFORM MAPS AND GIS

The digital regolith-landform map of the Selwyn region consists of polygons. lines. point features and raster images. Polygons define each regolith-landform unit. Lines are associated with cultural. drainage and landform features including palaeolandform slopes. palaeodrainages. erosional scarps and superimposed drainage. Points are associated with mineral occurrences. regolith geochemistry and field site descriptions.

The regolith-landform polygons were scanned. then vectorised and labelled in ArcInfo GIS. Each polygon has a number of attributes attached as items in an INFO database table. Point attributes associated with field site observations are collected using AGSOs regolith terrain site database. Field site attributes are summarised in Appendix 2. Site information is stored digitally as attributes in a point INFO table. Site INFO attributes include a description of the regolith and landform types, presence or absence of sample collection and geochemical analyses. and. in places. scanned photographs of the field site. Mineral occurrences were extracted from the Bureau of Resource Sciences (BRS) MINLOC database. Mineral localities are indicated by coloured symbols. Geo-rectified raster data includes processed Landsat TM and digital elevation model (DEM). These datasets are stored as band inter-leaved (BIL) format in the GIS.

6.1 Regolith-landform and GIS thematic maps

Regolith-landform and various thematic maps at 1:65 000 scale were produced using the GIS to extract or emphasise different attributes within the database (Appendix 5). Information shown on each of the maps are summarised on the map face keys below. Numbers 1-7 refer to the position of elements on the map face (Figure 9).

Map face key

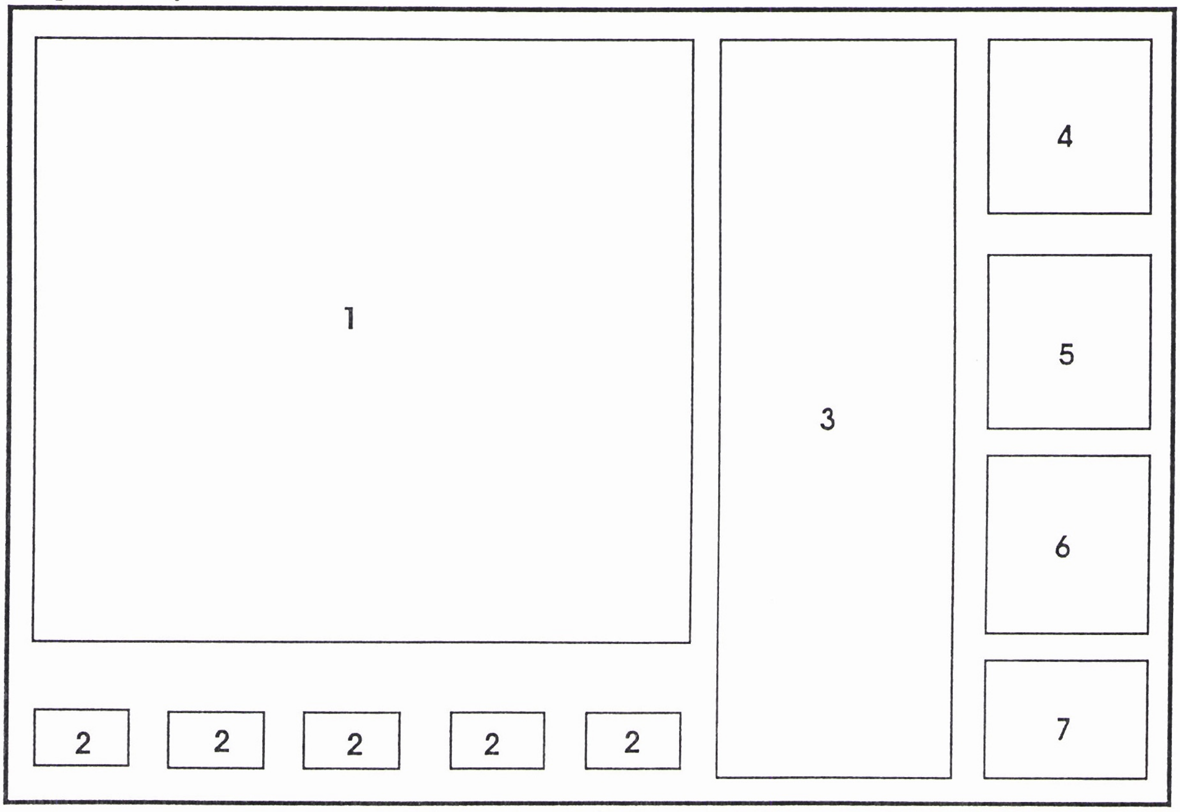


Figure 9. Map face diagram showing the layout of map elements on the regolith-landform and GIS thematic maps in appendix 5.

6.1.1 Regolith-Landforms (Appendix 5.1)

1. Regolith-landform units, palaeodrainage lines, erosional scarps, palaeoslope drainage, mineral occurrences and major roads.
2. Slides showing representative regolith-landform features with accompanying descriptions.
3. Purely descriptive reference of regolith and landform features.
4. Simplified geological units. Divided into Metamorphic, granite, Cambrian, Mesozoic bedrock and transported materials (alluvium and colluvium)
5. Landform units over Landsat TM image
6. Three band Landsat TM image enhanced for separating regolith materials.
7. Map logos, acknowledgments, credits, copyright, location and index maps.

6.1.2 Deeply weathered Regolith over Landsat TM (Appendix 5.2)

1. Relict indurated and very highly weathered units highlighted and draped over band 5 of Landsat TM. Also shown are palaeodrainage lines, erosional scarps, palaeoslope, mineral occurrences and major roads.
2. Slides showing representative regolith landform features with accompanying descriptions.
3. Reference with relict and very highly weathered units highlighted.
4. Simplified geological units. Divided into Metamorphic, granite, Cambrian, Mesozoic bedrock and transported materials (alluvium and colluvium).
5. 3-D image showing Fe duricrust and bleached/silicified saprolite associated with palaeo channel.
6. Three band Landsat TM image enhanced for clays in red, Fe oxides in green and silica in blue.
7. Map logos, acknowledgments, credits, copyright, location and index maps.

6.1.3 Regolith-landform Units over 3-Band Landsat TM image (Appendix 5.3)

1. Regolith-landform units, palaeodrainage lines, erosional scarps, palaeoslopes, drainage, mineral occurrences and major roads draped over a 3 band Landsat TM image.
2. Slides showing representative regolith landform features with accompanying descriptions.
3. Full reference including description of units and regolith codes. Reference not coloured.
4. Simplified geological units. Divided into Metamorphic, granite, Cambrian, Mesozoic bedrock and transported materials (alluvium and colluvium)
5. Landsat TM draped over a digital elevation model.
6. Landsat TM interpretative key. Shows the associated of image colours with surface materials.
7. Map logos, acknowledgments, credits, copyright, location and index maps.

6.1.4 Interpretative Geochemical Sampling Strategy Map (Appendix 5.4)

1. Interpretative map indicating the degree of masking or dilution of regolith materials to underlying bedrock. Also indicates palaeodrainage lines, erosional scarps, palaeoslopes, drainage, mineral occurrences and major roads.
2. Slides showing representative regolith landform features with accompanying descriptions.
3. Simplified sample strategy reference. Regolith/geochemical profiles and transects.
4. Simplified geological units. Divided into Metamorphic, granite, Cambrian, Mesozoic bedrock and transported materials (alluvium and colluvium)
5. Regolith-Landform units showing indurated materials, very highly weathered bedrock, highly weathered bedrock, moderately weathered bedrock, alluvium and colluvium.
6. Three band Landsat TM image enhanced for separating surface materials including clays, Fe oxides and silicates.
7. Map logos, acknowledgments, credits, copyright, location and index maps.

7. REGOLITH-LANDFORM UNITS (RLU)

Regolith-landform units have been divided into four principle groups, they include duricrusts, saprolite and alluvial and colluvial materials. Distinction between these groups are largely based on descriptive differences rather than form of classification or hierarchical system. The legend on the regolith-landform map (Appendix 5.1) shows these four major groups, whereas the other maps (Appendix 5.2 and 5.4) are in part interpretative. A brief description of the regolith-landforms features within these four groups is provided. Major characteristics of each regolith-landform unit including regolith type, soils and lags, landform types, lithology and induration style are summarised in Appendix 3.

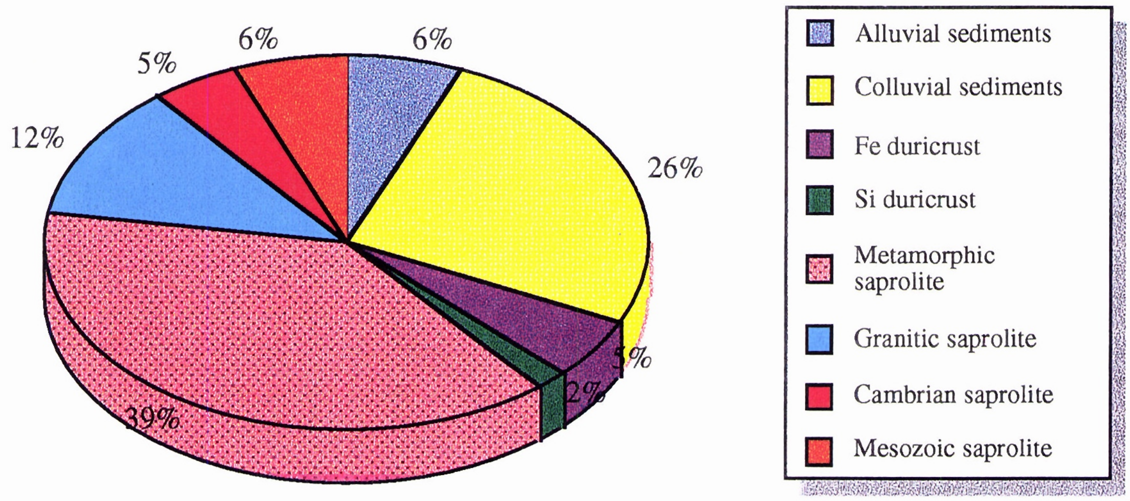


Figure 10. Pie chart of the proportions of major regolith materials.

7.1 Duricrust

The term duricrust is used to describe a mass of hard material formed within the regolith by either relative or absolute accumulations of natural cements in sediment or saprolite. Ferruginous and siliceous duricrusts occur in the Selwyn region. Although duricrusts form only a small part of the Selwyn map (7%, Figure 10) they are significant when understanding and reconstructing landscape regolith evolution (see section 9). Duricrusts are generally preserved on relict parts of the landscape including mesas, buttes, plateaux and dissected plateaux.

7.1.1 Ferruginous duricrusts (DFls1, DFls2, DFls3, DFls4 and DFls5)

There are five regolith-landform units in this category - DFls1, DFls2, DFls3, DFls4 and DFls5. The first three refer to regolith-landform units on Proterozoic bedrock, and the last two units occur on Mesozoic sedimentary rock. Regolith associated with these units consists of massive and in places slabby ferruginous duricrust over ferruginous, mottled and bleached saprolite (Figure 11D). The surface is typically mantled by a veneer of gravel lags consisting of ferruginous saprolite fragments, ferruginous duricrust and pisoliths. Well developed iron segregations are common in the upper part of the mottled zone. Silicification of the saprolite is also common and typically extends into the bleached zone beneath the mottled zone.

DFls2 forms flat-topped hills and minor plateaux surfaces over prominent stratigraphic quartz-hematitic beds. RFls2 consists of ferruginous duricrusts and localised re-cemented ferruginous duricrust colluvial gravels. Unconsolidated ferruginous gravels form footslope deposits immediately down slope from the stratigraphic hematite ridges.

DFls4 and DFls5 consists of extensive plateaux landforms over the northeast corner of the map sheet. They consist of massive ferruginous duricrust and highly ferruginous saprolite over mottled (irregular to mega sub-circular) and in places bleached bedrock. Silicification of the saprolite is common and in places silcrete caps rather than ferruginous duricrust have developed (Figure 11N). The underlying Proterozoic bedrock is typically very highly weathered, mottled, bleached and silicified.

7.1.2 Siliceous duricrusts (DSls1 and DSls2)

Regolith-landform units Dsls1 and DSls2 refer to weathering on granitic and Cambrian rocks. DSls1 consist of mottled silcrete, silicified Fe-stained saprolite over bleached bedrock. Most of the primary minerals, particularly in the upper part of the weathering profile have been weathered to clay (kaolinite) and Fe oxides. Silicification commonly extends into the underlying bleached zone. Ferruginous duricrust and highly ferruginous saprolite can also occur at the top of the weathering profile but are usually thin and patchy. The most distinguishing feature of this regolith unit is the silicification and intense bleaching of the underlying saprolite which commonly extends several 10s of metres below the surface (Figure 11B,F and M). Silicification commonly overprints ferruginous and mottled saprolite within the profile. In places, cemented quartz pebbles in the silcrete indicate that the upper part of the weathering profile is transported (Figure 11O).

DSls2 forms isolated mesas on the western side of the map sheet and consists of silicified, ferruginous and mottled Cambrian rocks. The top of the profile commonly consists of re-cemented ferruginous and siliceous saprolite with a breccia fabric (Figure 11E).

7.2 Saprolite units

This category includes all units dominanted by saprolite or weathered bedrock which are actively being eroded. Saprolite is defined as weathered bedrock which has formed largely in place (*in situ*) without any significant change in volume (see glossary for more complete discussion - Appendix 1). Saprolite occurs over erosional landforms and although it may be partly covered by residual soils and lags, it is the major feature within the RLU. Saprolitic units are divided by the type of lithology being weathered (e.g. granite, metamorphics). Saprolite units on some of the interpretative regolith-landform maps have been subdivided on the relative degree of weathering. The degree of weathering is described in terms of three classes; very highly, highly and moderately weathered bedrock. This subdivision is based on the degree to which the original minerals, textures and structures of the bedrock are retained based from field observations. Brief definitions of the degree of weathering classifications are describe in Appendix 1.

7.2.1 Metamorphic bedrock (Sls1, Sel2, Sep3, Sep4, Sep5, Sep6, Ser7, Sel8, Seh9, See10, Sel11, Ser12 and Sel13)

Sls1 consist of silicified iron stained and bleached saprolite which form low hills, plateaux and dissected plateaux. Sel2 and Sep3 consists of ferruginous, mottled and bleached bedrock. The bleached zone can be thick (> 10 metres) and is in places silicified and diffusely mottled. Unit sel2 is partly covered by lithosols consisting of ferruginous/bleached lithic fragments, gravels and minor ferruginous duricrust fragments, nodules and pisoliths. Unit Sep3 is largely covered by a veneer of residual soils gravel lags of ferruginous and silicified saprolite, quartz and lithic fragments.

Sep4, Sep5 and Sep6 consists of erosional plains where saprolite is largely covered by extensive veneers of residual gravel soils, residual clays and lags consisting of ferruginous saprolite fragments, quartz, lithic fragments, minor ferruginous pisoliths and ferruginous granules (Figure 11H). Narrow tracts of alluvium occur along some stream channels. Unit Sep6 in comparison is more ferruginous, consisting of ferruginous-duricrust and ferruginous lithic gravel lags and red clay soils with minor ferruginous nodules. These materials develop on Fe rich lithologies including amphibolites and meta-basalts.

Unit Ser7 and Sel8 consists of rises and low hills which consists of mottled and ferruginous bedrock partly covered by lithosols and lithic lags. The lags consists of ferruginous lithic fragments, quartz gravels with a red silt/clay matrix. Seh9 consists of saprock partly covered by lithosols and colluvium flanking steep hills. Unit See10 forms escarpments and consist of saprock partly covered by scree and lithosols. The upper part of the scarp maybe highly weathered with bleached and silicified saprolite.

Unit Ser12 consists of rises and low hills, and develops over Fe-rich bedrock (ie. meta-basalt). It consists of highly weathered ferruginous and diffusely mottled bedrock which is partly covered by highly ferruginous lithic gravel lags and reddish-orange clays and fine sands. There are locally developed ferruginous duricrusts and Fe segregations. Unit Sel13 is associated with stratigraphic quartz-hematitic beds which form low hills and prominent ridges (Figure 11U). Its saprolite is partly covered by Fe gravel lags, lithosols and pockets of red clay soil over massive diffusely mottled ironstone.

7.2.2 Granitic bedrock (Sls14, Sel15,Ser16,Sep17, Sep18,Ser19,Sel20 and Sec21)

Regolith units Sls14, Sel15 and Ser16 consists of plateaux surfaces, mesas low hills, rises and minor scarps. Regolith includes ferruginous, mottled, bleached and silicified saprolite. Most of the primary minerals have been weathered leaving resistant quartz and secondary Fe oxides and clays (mainly kaolinite). In places, silicification of the saprolite extends into the bleached zone (Figure 11 C, I and P). The saprolite is partly covered by a veneer of gravel lags and soils consisting of; quartz, ferruginous pisoliths, lithic fragments and residual clays.

Figure 11. Descriptions and representative photographs of regolith materials.

(A) Slabby ferruginous duricrust with clearly visible horizontal to sub-horizontal layering. The duricrust overlies mottled and silicified bleached saprolite (456200E:7601300N).

(B) Slabby ferruginous duricrust and ferruginous saprolite over silicified mottled and bleached saprolite (schist and phyllite). Intense bleaching and silicification is thought to be associated with palaeo-channels (now relief inverted) (456200E:7601300N).

(C) Deep weathering profile developed on granite. The profile consist of massive ferruginous duricrust overlying (not seen) mottled, bleached and non-bleached saprock. Although the granite underlying the duricrust still retains its original structure most of the primary minerals have been altered to kaolinite and goethite. (463911E:7596416) (see section 8 Figure 11A).

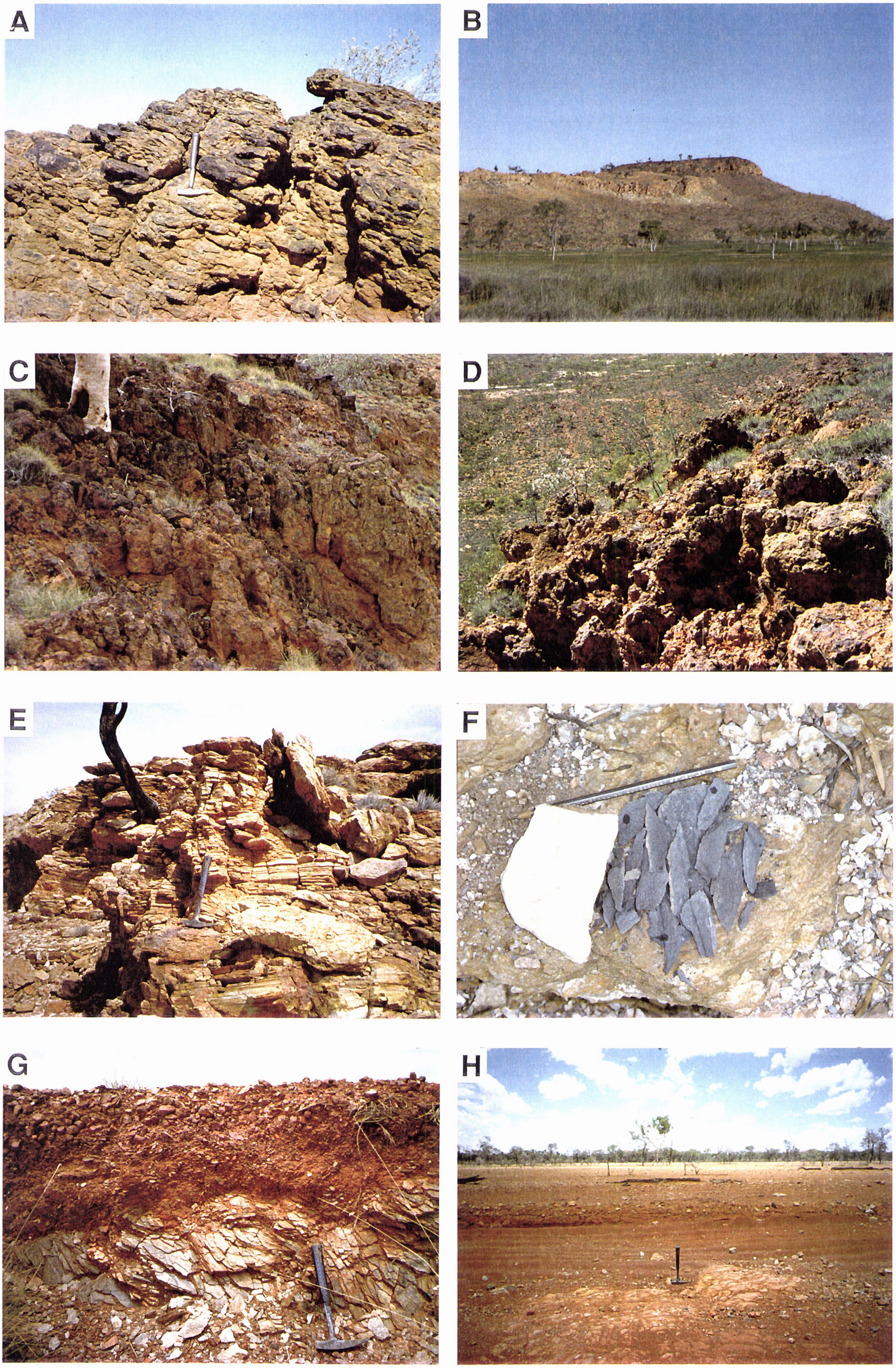
(D) Massive ferruginous duricrust forming the top of a deeply weathered zoned profile. Ferruginous duricrust overlies mottled and bleached saprolite. The ferruginous duricrust has formed from the segregation of Fe in the mottle zone. Further weathering and erosion has cemented and exposed the Fe segregations together to form massive duricrust at the surface (458695E:7599384N).

(E) Silicified and ferruginous Cambrian sediments (shales and siltstones) forming local rises. Surface bedrock is typically brecciated and partly re-cemented by Si and Fe oxides (424487E:7608250N).

(F) Comparision between bleached and partly silicified Proterozoic shale and non-bleached shale. The bleached shales occur immediately below silicified and ferruginous Mesozoic sediments. Bleached shales grade into non-bleached saprock at 20-30 metres below the Mesozoic contact (448271E:7614489N).

(G) Colluvial and residual clays and gravels consisting of ferruginous saprolite and lithic fragments overlying highly weathered and mottled Proterozoic saprolite (427416E:7607328N).

(H) Veneer of residual and colluvial sheet flow clays, sands and gravels over highly weathered and mottled saprolite. Lags consist of ferruginous saprolite, lithic and quartz gravels (451634E:7602207N).


A
B
C
D
E
F
G
H

(I) Silicified mesas and rises developed in granitic saprolite, lithosols and gravel lags occur over surrounding erosional plains (442000E:760100N).

(J) Ferruginous and mottled Mesozoic sediments (sandstone, siltstone and mudstone). Massive ferruginous duricrust forms a capping to the mesa (450528E:7617986).

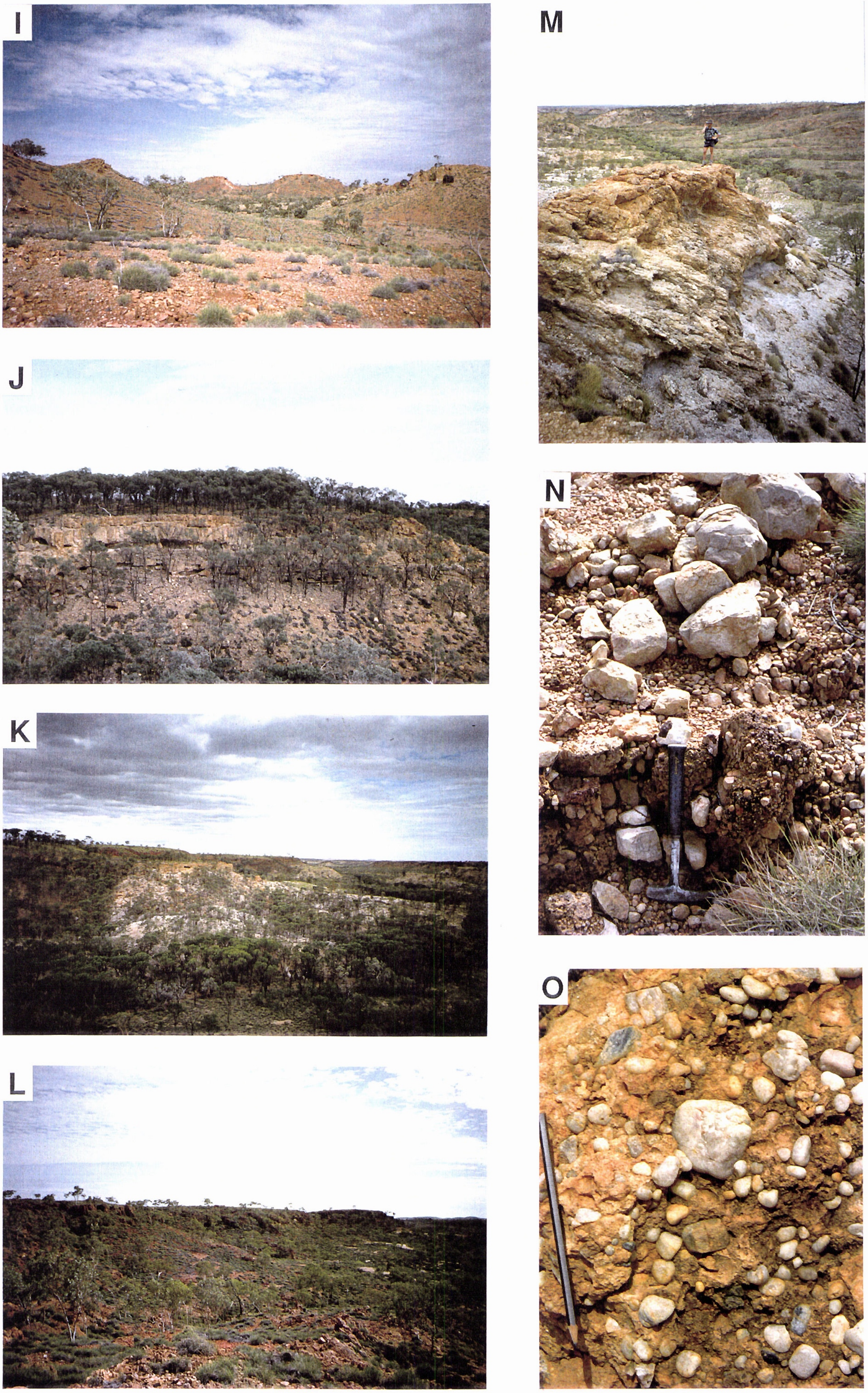
(K) An example of pre-Cretaceous weathering (white areas) developed in Proterozoic bedrock. Softer Mesozoic sediments have been largely eroded leaving an exhumed deeply weathered landsurface (448540E:7614766N).

(L) Flat top concordant summits of the Selwyn region (northeast of Selwyn mine).

(M) Ferruginous breccia consisting of angular lithic fragments cemented by Fe and Si which grades over several meters into highly bleached structured saprolite. The bleached zone then grades over several meters into non-bleached (not seen) schist and phyllite at about 30 metres below the top of the breccia zone (see section 8 Figure 11B) (448394E:7614340N).

(N) Silcrete pods and gravels cemented in a ferruginous earthy matrix. The silcrete pod consist of micro-crystalline Si and have developed in Mesozoic sediments (sandstone and siltstone) (450615E:7618443N). (see section 8 - Figure 11H).

(O) Silicified river channel sands and gravels overlying highly weathered, mottled and partly silicified granitic saprolite. The channel sediments are relief inverted and now from sinuous disconnected mesas (441207E:7595801N).


I
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(P) Granite tors - surrounded and partly buried by colluvial and residual feldspathic and quartz sands (461552E:7590887N).

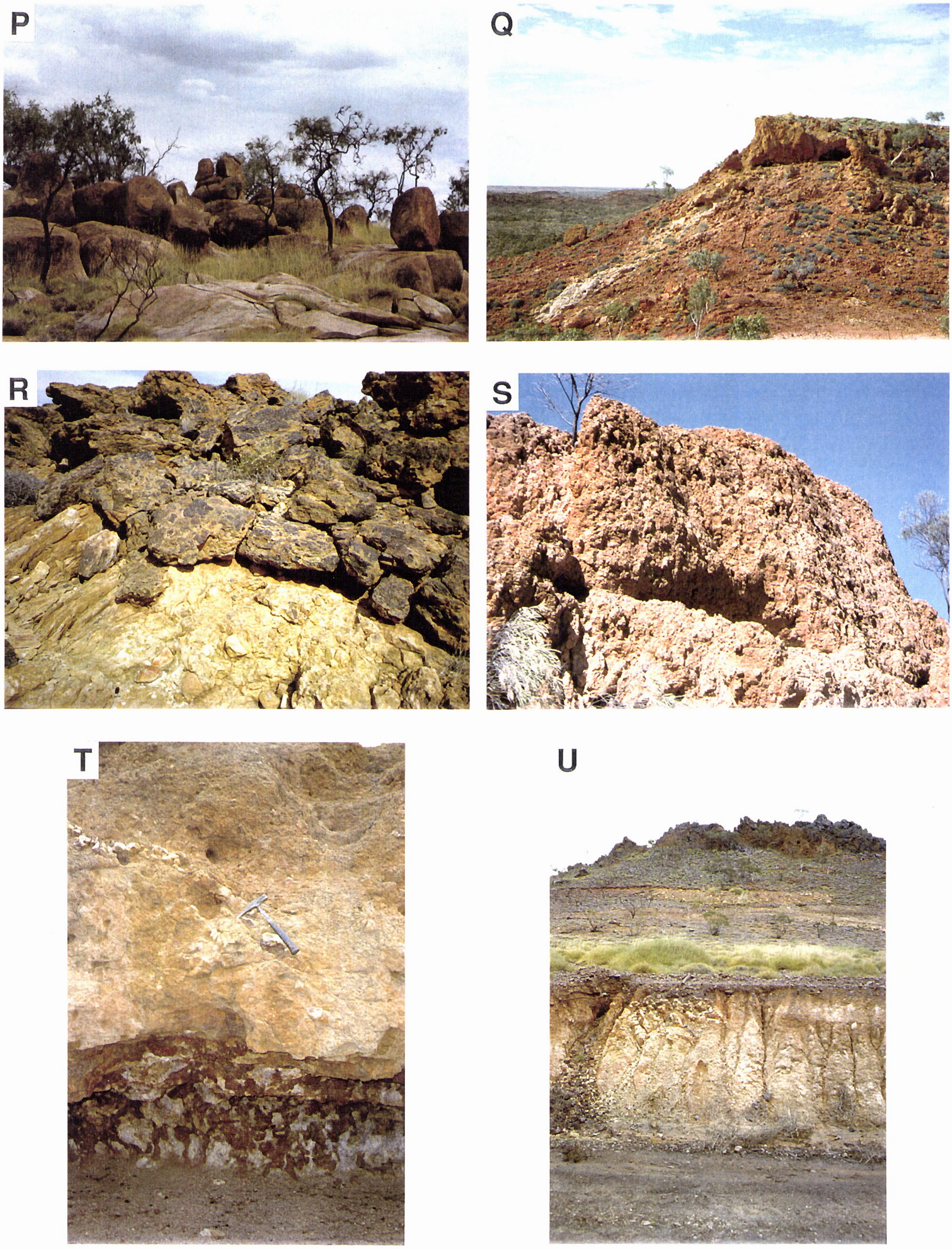
(Q) Mesas over granite bedrock. The mesa surface is silicified and diffusely stained by Fe. Rises between the mesas consist of ferruginous and bleached saprolite partly covered by gravel lags and lithosols (440947E:7595707N).

(R) Slabbly ferruginous duricrust and silicified conglomerate (Mesozoic ?) unconformably overlie weakly mottled, bleached Proterozoic saprolite. The slabby duricrust exhibits sub-horizontal layering and consists of Fe cemented sands and pebbles (see section 8 Figure 11D) (455427E:7586354N).

(S) Collasped ferruginous breccia consisting of angular lithic fragments cemented by Fe and Si forming bluffs. The breccia overlies mottled and bleached saprolite (447615E:7613120N).

(T) Ferruginous breccia consisting of angular lithic fragments cemented by Fe and Si overlying a well developed mega mottled zone. Quartz veining indicates that the profile has formed *in situ* (447676E:7613534N) (see section 8 - Figure 11C).

(U) Thin colluvial Fe stone scree down slope from massive stratigraphic, hematitic ironstone ridges. Colluvial scree partly covers highly weathered koalinised and mottled saprolite (445562E:7601717N).


P
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Regolith units Sep17 and Sep18 consists of low-relief erosional plains and consists of bleached bedrock, partly covered by extensive veneers (generally < 1.0 m) of residual sands and gravel lags. The sands and gravels consist of mica, quartz, feldspar grains, siliceous, ferruginous and bleached lithic gravels, minor ferruginous duricrust fragments, pisoliths and nodules. Narrow tracts of alluvial sediments are associated with low order streams. Unit Ser19 and Sel20 consists of rises and low hills, respectively. They consist of ferruginous and mottled (reddish orange) granitic bedrock which is partly covered by a veneer of residual sand and gravel lags. About half of the primary minerals are weathered to clays and Fe oxides.

See21 consists of escarpments and consists of diffusely mottled granite partly covered by rocky scree and lithosols. Primary rock fabric is clearly visible. Saprolite on the upper part of the scarp edge is commonly silicified, bleached (kaolinised) and mottled. Bedrock at the base of the scarp is typically only slightly weathered.

7.2.3 Mesozoic sediments (Sep22, Ser23, Sep24, Sel25,and See26)

Units Sep22 and Sep24 consists of erosional plains. Sep22 consists of ferruginous sediments covered by a veneer of residual sand, clay and gravel lag. Lags consist of highly ferruginous saprolite, lithic fragments and minor siliceous saprolite gravels. Sep24 consists of extensive sheets of residual soils and lags which cover ferruginous, mottled and in places silicified saprolite. Lags consist of ferruginous lithic and ferruginous duricrust fragments, quartz pebbles and silcrete gravels in a reddish orange sandy to silty soil matrix. Sel25 consists of low hills and consists of highly weathered ferruginous, mottled and bleached sediments. In places, the saprolite is silicified. Ser23 is a similar to Sel25 but occurs on rises where the saprolite is largely obscured by gravelly lags, lithosols and generally thin residual soils. Unit See26 consists of Fe-stained diffusely mottled sediments developed on escarpments.

7.2.4 Cambrian sediments (Sep27, Sel28, Sep29 , Sep30, Sep31, Ser32 and See33)

Unit Sel28 forms low hills and consists of highly weathered ferruginous, mottled and in places silicified sediments. The saprolite is partly covered by gravelly lithosols. Similar weathering patterns are associated with unit Ser32 over rises (9-30 metres relief). Lags and soils are more extensively developed over unit Ser32 - consist of ferruginous saprolite gravels, lithic, chert and silcrete fragments, residual clays and fine sands. Units Sep27, Sep29, Sep30 and Sep31 consists of low relief erosional plains and pediments. Unit Sep27 occurs over highly dissected erosional plains (<9m relief) and consists of highly ferruginous and mottled sediments. Here the saprolite is partly covered by thin lithic lags and lithosols. Unit Sep29 also occurs on erosional plains and is generally characterised by extensive sheets of gravel lags, consisting of ferruginous lithic and ferruginous duricrust fragments, quartz pebbles, silcrete gravels and residual reddish orange sandy soils. Unit Sep30 consists of light grey to brown silty residual clays with minor calcareous lithic and chert lags. Unit Sep31 consists of hard-setting dull green to reddish brown residual clays and swelling gilgai soils. Scattered float consists of ferruginous lithic fragments, ferruginous pisoliths and in places carbonate nodules. Unit See33 consists of ferruginous and mottled saprolite partly covered by lithosols over escarpments.

7.3 SEDIMENTS

7.3.1 Alluvial sediments

Alluvial sediments deposited on floodplains, alluvial plains and alluvial terraces occupy about 6% of the study area (Figure 3). Sediments consists of varying proportions of sand, gravel, clay, silt and minor cobbles. The sediments are weathered to varying degrees depending largely on their age (i.e. recent and older alluvial terraces). The sediments can be up to 20 metres thick along major river channels but in most places are less than 10 metres thick.

Unit ACaf occurs on floodplains along and adjacent to major river channels, and consists of recent river channel sediments of unconsolidated interbedded gravels, sand, clay with local lens of cobble conglomerates. In places, alluvium is partly cemented by either clay, Fe or Si. Soils consist of reddish brown and grey sandy earths.

Overbank deposits AOao are formed by floodout overflow channels from major rivers, and consist mainly of alluvial sands, clay and minor gravels, typically overlying residual sands, clays and saprolite.

Alluvial sediments (AAol) developed on terraces and benches consists of interbedded sand, clay and gravel. In places truncated palaeosols indicate several cycles of deposition, erosion and weathering. Soils consist of reddish brown mottled earths and duplex soils.

Undifferentiated channel and overbank alluvium (Aaf) consist of variable proportions of clay, sand and gravel. Alluvial channels forms narrow tracts between rises, low hills and hills. Alluvial sediments are typically intermixed with minor colluvial footslope deposits adjacent to scarps, low hills and hills.

7.3.2 Colluvial sediments

Colluvial sediments are extensive and cover approximately 26% of the map sheet (Figure 10). The sediments occur beneath erosional plains, pediments, depositional plains and minor footslopes. They consist of unconsolidated polymictic gravel and gravel lags with various proportions of sand and clay. The underlying bedrock is generally very highly weathered and mottled . Sediment thickness range from 0.1 to 4 m. The sediments can have a proximal or distal source.

Unit CHpd1 is typically thicker (> 1.5 m) than CHpd2 (generally < 1.5 m). Both units include sheet flow deposits consisting of silty clay loams, clays, sands and local areas of cracking clay soils (gilgai micro-relief) which have accumulated over extensive depositional and erosional plains. The sediments overlie very highly weathered and mottled bedrock at depth (Figure 11G). The surface is partly covered by lags - consisting of ferruginous saprolite, lithic fragments and quartz with minor ferruginous duricrust fragments and Fe pisoliths. Local narrow tracts of alluvium occur along stream channels. Saprolite protrudes in places as well as patches of residual sand and clay. Unit CFfc1 comprises colluvial fan deposits consisting of quartz, ferruginous saprolite and lithic fragments in a coarse sandy to gravelly earthy matrix. Polymictic gravel lags of quartz, ferruginous saprolite and lithic fragments are common over the surface. Unit CFfc2 includes colluvial fan deposits of highly ferruginous saprolite, ferruginous duricrust, ferruginous pisoliths and lithic fragments in a ferruginous earthy matrix. Polymictic gravel lags of quartz, ferruginous saprolite, ferruginous duricrust and lithic fragments typically form a surface veneer.

CHei3, CHei4, CHei5 and CHei6 form gently sloping erosional plains and pediments(Figure 11H). CHei3 consists of sheet flow colluvial and minor alluvial deposits forming a veneer (generally < 1m thick) of sand, clay and gravel over mottled and typically bleached bedrock (mainly metamorphic). Gravelly lags are common and consist of ferruginous saprolite, quartz and lithic fragments. Sheet flow sediments associated with CHei4 are locally derived from granite and are developed on erosional plains and pediments (Figure 11 I). They consists of quartzose/feldspathic sand, clay and gravels (generally < 1m thick). Residual sand, gruss, clay and protruding granite tors are common (Figure 11 P). Gravelly lags consist of siliceous, ferruginous and bleached saprolite fragments, quartz and ferruginous duricrust fragments. Minor alluvium occurs along river channels. CHei5 comprises colluvial and alluvial clay, sand and gravel over ferruginous and mottled saprolite. CHei6 consists of sheetflow sands and lags consisting of lithic fragments and ferruginous gravels over highly weathered Cambrian sediments (typically mottled and ferruginous). Minor amounts of sand and gravel are associated with narrow river channels.

8. WEATHERING PROFILES AND GEOCHEMISTRY

Ferruginous or siliceous duricrusts typically form the top of the most deeply weathered profiles in the Selwyn region. The duricrusts commonly overlie zoned weathering profiles. The weathering zones below the duricrust consist of mottled saprolite, bleached saprolite (kaolinised), saprock and fresh bedrock. The mottled and bleached zones are often silicified. However, in different parts of the landscape, one or more of the underlying weathering zones may be poorly developed or absent. Representatives of these deeply weathered profiles over different lithologies have been summarised into a series of profile diagrams (Figure 12 A-H). Some of these profiles have been sampled and analysed for major and trace elements by XRF and mineralogy by XRD. Selected major and trace elements for these profiles are shown on the right hand side of the regolith profile. A complete geochemical analysis of the samples are located in Appendix 4.

8.1 Proterozoic bedrock

Weathering of Proterozoic bedrock is variable - ranging from moderately weathered to completely weathered saprolite. The duricrusts have either massive, brecciated or slabby fabric.

Massive ferruginous duricrust developed on granite are shown on the regolith-landform maps (appendix 5) as unit DFls3. The duricrust and underlying profile (Figure 11A and Figure 12A) has developed *in situ*, although Fe and Si cements are likely to be derived laterally as well as from below the weathering profile. The profile develops on plateaux and is typically massive ferruginous duricrust, although in places it may have a weakly developed slabby or vuggy appearance. A mottled saprolite zone underlies the duricrust. The upper part of the mottled saprolite is characterised by well developed Fe segregations which are commonly silicified. The vugs in the duricrust are typically infilled with ferruginous gritty sands derived from the duricrust and cemented by Fe oxides. The mottled zone has a gradual contact over several metres to a well developed bleached zone which is typically silicified and diffusely iron stained. Bleached saprolite has a gradual irregular contact to non bleached saprock.

The duricrust consists largely of hematite and goethite. Clay in the mottled zone is dominated by kaolinite; other minerals include quartz and mica with hematite and goethite in the mottles. The bleached zone consists largely of kaolinite, quartz, secondary silica with minor amounts of mica and goethite. Saprock consists of quartz, feldspars, kaolinite and minor goethite. The mineralogy is consistent with whole rock geochemistry (Figure 12A).

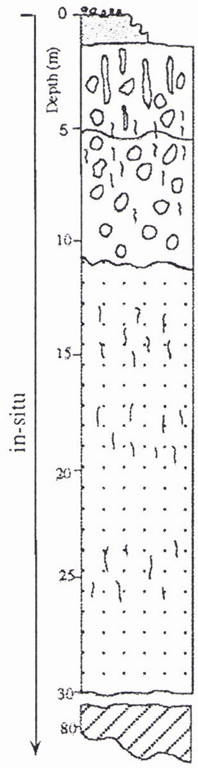
Iron and Si are inversely related - with Fe increasing towards the top of the profile as Si decreases. Copper, Cr, Zn and Ni have strong affinities with Fe and are concentrated in the duricrust relative to the mottled, bleached and saprock zone. Rubidium, Ba, K and Sr are lost from the upper part of the profile as micas weathers to clays. Aluminium Al and Ga are low in the ferruginous duricrust and have similar trends in the mottled, bleached and saprock zones where they are likely to be associated with kaolinite and feldspars.

Highly ferruginous brecciated duricrusts consist of saprolitic fragments (typically angular) cemented by hematite and goethite. This brecciated fabric typically overlies a well developed mottled zone (Figure 11T and Figure 12B). Mega mottling and silicification in the upper part of the mottled zone is common. The mottled zone grades over several metres into a bleached saprolite which is diffusely mottled and in places silicified. The bleached zone grades at depth into saprock. The profile has developed *in situ* as evident from quartz veining to the surface. The degree of ferruginisation in the breccia zone is variable. The breccia zone in profiles shown in Figure 11M and 12C are largely siliceous with Fe staining throughout, whereas profiles shown in Figure 11T and 12B consist mostly of Fe. Geochemical trends associated with these profiles differ as a result of the variable Fe content in the upper part of the profile. The breccia zone in profile shown in Figure 11T is relatively high in Cu, Cr, Zn and vanadium (V) due to scavenging by iron oxides. Rubidium, Ba, K and Sr increase down the profile (Figure 12B) and are largely associated with micas.

Slabby duricrust developed on Proterozoic bedrock are typically underlain by mottled and bleached saprolite (Figure 11A and B) and form cappings to rises, low hills and mesas. A slabby duricrust profile has been reconstructed from samples along a eastwest traverse (see section 9, Figure 12 D). The profile from the top to bottom consists of slabby ferruginous duricrust, Fe segregations, mottled zone, bleached and silicified zone, and Fe saprock (non -bleached , Fe rich schist). Clay in the mottled and bleached zone is largely kaolinite. Copper, Ni and Zn have strong affinities with Fe and are concentrated in the duricrust relative to the bleached zone. Aluminium is associated with clays in the bleached zone and with feldspars in the saprock. Potassium generally increases with depth and is largely associated with K-mica within the schist. Lead is largely immobile with uniform concentrations throughout the profile.

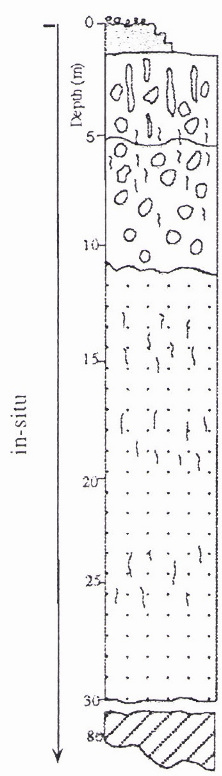
Slabby ferruginous duricrust developed on transported sediments (Mesozoic sediments ?) is shown in Figure 11R and 12E . The profile from top to bottom includes slabby ferruginous duricrust with a sharp contact to a mottled and silicified cobble conglomerate which rests unconformably over mottled, bleached and slightly weathered Proterozoic schist/sandstone. The duricrust consists mainly of hematite and goethite. Elevated Cu, Cr and V concentrations are a result of scavenging by Fe oxides in the ferruginous duricrust. Barium, Rb and K are very low in the re-worked sediments and are comparatively high in the weathered schist where they are likely to be associated with micas.

463911E 7596416N - Ferruginous duricrust over mottled and bleached Proterozoic granite



Regolith	Mineralogy	SiO2	Al2O3	Fe2O3	CaO	MgO	MnO	K2C
		Elements in %						
Lag of iron nodules, pisoliths and lithic fragments	Hm, Gt, Qtz	6.56	3.06	77.34	.01	.05	.006	.03
Massive duricrust -slabby in places contains quartz grit and gravels. Partly silicified.		71.37	18.4	1.11	.06	.05	.005	.33
Iron segregations. Elongated and circular hematite-rich mega-mottles.	Kao, Qtz, Mi	69.5	19.99	1.36	.05	.06	.008	.55
Gradual contact to: Mottled and kaolinised saprolite. Upper part commonly silicified								
Bleached saprolite with diffuse iron staining, partly silicified in places		67.42	19.81	1.34	.04	.13	.011	3.8
	Qtz, Kao, Mi, Gt, Fp							
Gradual and irregular contact to saprock.		76.36	13.38	.45	.08	.08	.003	4.58

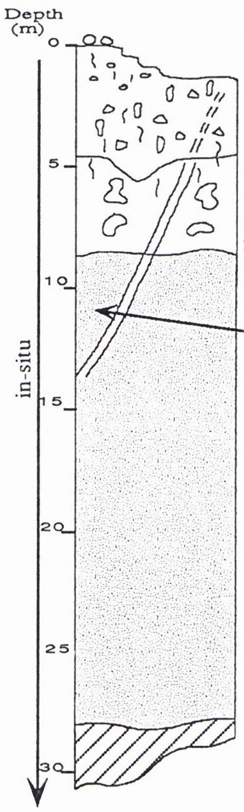
Hm Hematite
Gt Goethite
Kao Kaolinite
Sm Smectite
Ca Calcite
Qtz Quartz
Fp Feldspar
Mi Mica



Regolith	Mineralogy	Cu	Zn	Ni	Pb	Cr	V	Zr
		Elements ppm						
Lag of iron nodules, pisoliths and lithic fragments		6.56	3.06	77.34	.01	.05	.006	.03
Massive duricrust - slabby in places, contains quartz grit and gravels.		14	4	9	18	7	37	354
Partly silicified Iron segregations. Elongated and circular hematite-rich mega-mottles.		14	7	62	18	7	44	431
Gradual contact to: Mottled and kaolinised saprolite. Upper part commonly silicified								
Bleached saprolite with diffuse iron staining, partly silicified in places		14	6	13	22	3	66	359
Gradual and irregular contact to saprock.		463	119	30	17	170	421	119

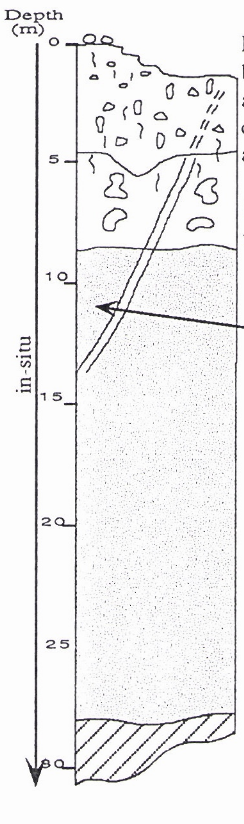
Figure 12A. Vertical distribution of major minerals and some major and trace elements in the weathering profile over granite (porphyritic biotite/hornblende-biotite granite). Profile developed on plateaux and mesas.

447615E 7613120N - Ferruginous breccia and mottled saprolite over Proterozoic bedrock (Phyllite)



Regolith	Mineralogy	SiO2	Al2O3	Fe2O3	CaO	MgO	MnO	K2O
		Elements in %						
Ferruginous saprolitic breccia, consisting of angular lithic fragments cemented by iron and silica	Gt, Ht, Kao	12.67	9.82	68.08	.03	.05	.016	.01
Irregular reddish-orange mega-mottling								
Quartz vein	Qtz, Kao							
Bleached saprolite with patchy, pale diffuse iron staining.								
	Mi,Qtz, Hm, Gt	55.12	24.83	9.11	.04	.08	.049	.10
Saprock								

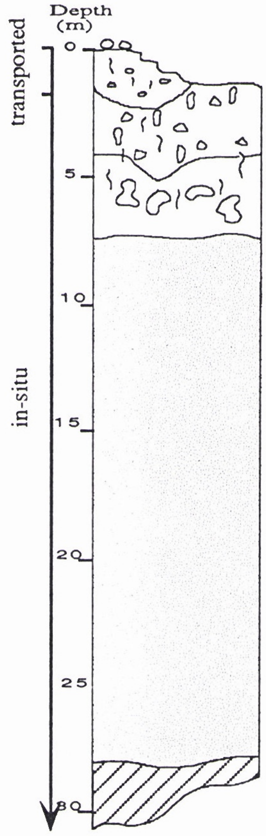
Hm Hematite
Gt Goethite
Kao Kaolinite
Sm Smectite
Ca Calcite
Qtz Quartz
Fp Feldspar
Mi Mica



Regolith	Mineralogy	Cu	Zn	Ni	Pb	Cr	V	Zr
		Elements in ppm						
Ferruginous saprolitic breccia, consisting of angular lithic fragments cemented by iron and silica	Gt, Ht, Kao	83	15	28	14	315	1039	188
Irregular reddish-orange mega-mottling								
Quartz vein	Qtz, Kao							
Bleached saprolite with patchy, pale diffuse iron staining.								
	Mi,Qtz, Hm, Gt	26	5	27	14	55	82	272
Saprock								

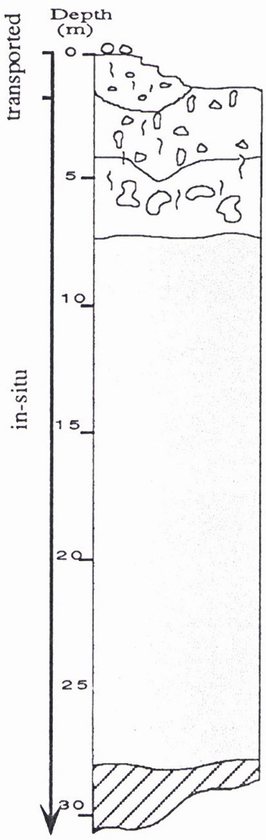
Figure 12B. Vertical distribution of major minerals and some major and trace elements in the weathering profile over Proterozoic phyllite and schist. Profile developed on mesas and low hills.

448394E 7614340N - Ferruginous breccia and mottled saprolite over Proterozoic bedrock (Phyllite)



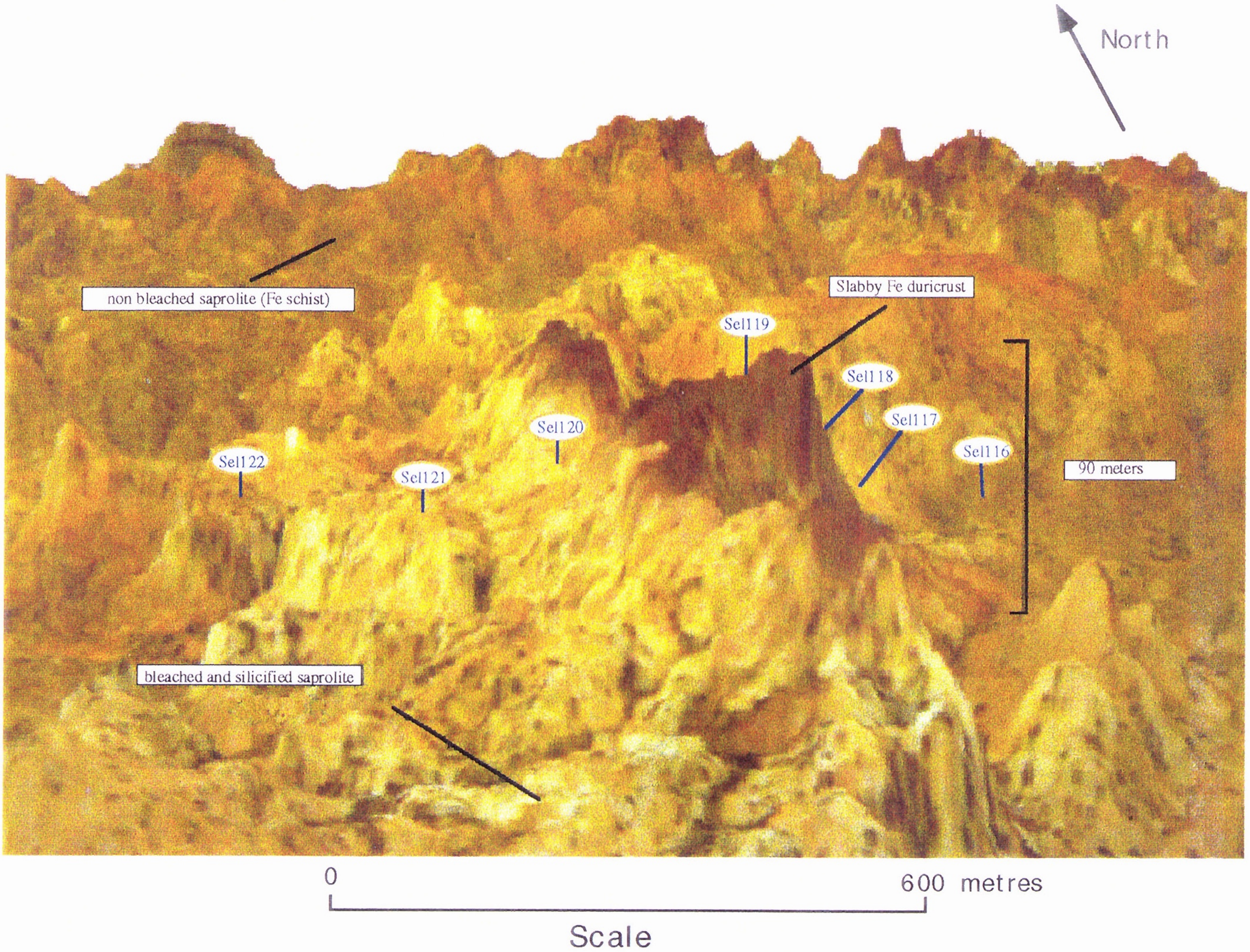
Regolith	Mineralogy	SiO2	Al2O3	Fe2O3	CaO	MgO	MnO	K2O
		Elements in %						
Silicified Mesozoic sediments	Gt, Ht, Kao							
Siliceous saprolitic breccia, consisting of angular fragments cemented by silica		73.79	15.78	1.5	.14	.49	.007	.29
		80.2	13.04	.61	.03	.13	.009	1.28
Irregular and diffuse reddish-orange mottling		72.72	17.5	.74	.02	.33	.005	3.62
Bleached saprolite with patchy, pale diffuse iron staining.	Qtz, Kao	81.34	12.18	.59	.03	.19	.007	1.75
	Mi,Qtz, Hm, Gt							
Saprock		66.26	16.4	6.97	.03	.76	.02	4.12

Hm Hematite
Gt Goethite
Kao Kaolinite
Sm Smectite
Ca Calcite
Qtz Quartz
Fp Feldspar
Mi Mica



Regolith	Mineralogy	Cu	Zn	Ni	Pb	Cr	V	Zr
		Elements in ppm						
Silicified Mesozoic sediments								
Siliceous saprolitic breccia, consisting of angular fragments cemented by silica	Gt, Ht, Kao, Qtz	13	11	14	20	36	72	226
		4	3	0	13	24	47	221
Irregular and diffuse reddish-orange mottling		0	6	12	18	59	89	223
Bleached saprolite with patchy, pale diffuse iron staining.	Qtz, Kao	5	3	-4	21	39	62	287
Saprock	Mi,Qtz, Hm, Gt, Kao	233	39	60	19	77	89	211

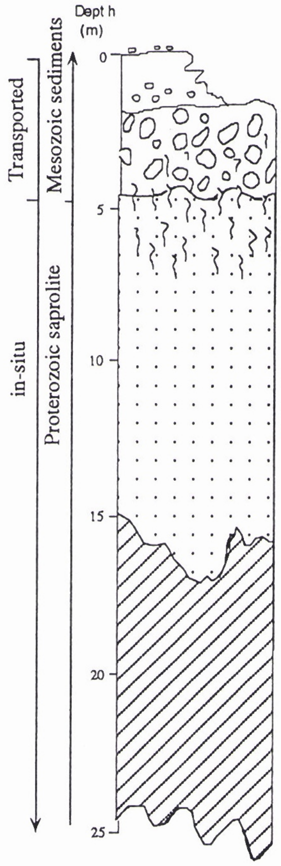
Figure 12C. Vertical distribution of major minerals and some major and trace elements in the weathering profile over Proterozoic phyllite and schist. Profile developed on mesas and low hills.



	SiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5
sel 116	61.61	18.87	6.61	0.031	2.27	0.29	0.36	5.96	0.62	0.207
sel 117	76.08	10.8	5.69	0.016	0.77	0.05	0.08	1.95	0.41	0.051
sel 118	69.12	18.56	1.79	0.005	0.37	0.05	0.17	3.47	0.63	0.125
sel 119	3.88	3.31	79.42	0.005	0.08	0.01	-0.02	0.13	0.14	0.404
sel 120	72.98	16.56	1.36	0.005	0.27	0.03	0.17	2.78	0.65	0.01
sel 121	62.25	23.36	2.22	0.007	0.51	0.04	0.39	6.06	0.64	0.038
sel 122	57.53	21.43	7.31	0.038	1.87	0.24	0.42	6.84	0.59	0.163
	Ba	Cr	Cu	Ga	Ni	Nb	Pb	Rb	Zn	Zr
sel 116	589	86	18	25	85	11	12	290	24	140
sel 117	537	77	51	15	65	7	16	222	16	299
sel 118	1359	72	3	23	8	14	20	109	4	126
sel 119	30	85	79	12	529	-1	8	4	15	23
sel 120	643	57	14	21	3	14	11	86	4	163
sel 121	1109	97	0	31	-1	12	12	208	3	130
sel 122	901	99	88	31	523	12	15	289	17	114

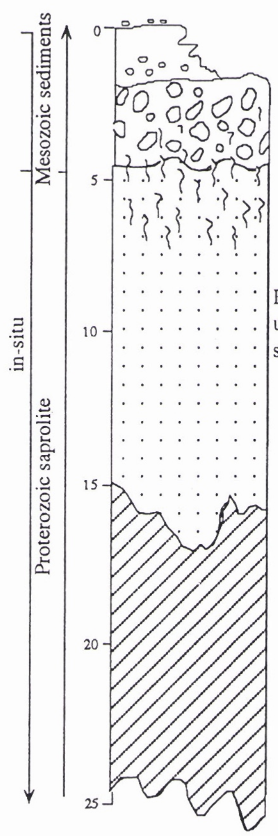
Figure 12D. Distribution of some major and minor trace elements across a palaeochannel (see section 9.4). The old river channel floor correlates to the zone of bleached and silicified saprolite. Slide of the image above is shown in Figure 11B.

455427E 7586354N - Ferruginous duricrust (Mesozoic) over Proterozoic schist and slate



Regolith	Mineralogy	SiO2	Al2O3	Fe2O3	CaO	MgO	MnO	K2O
		Elements in %						
Loose iron nodules and gravels. Massive duricrust contains alluvial gravels	Gt, Ht	4.65	4.53	79.28	.01	.07	.005	.14
Mottled, partly silicified and poorly sorted conglomerate. Clasts supported in a silicified clay matrix.		73.39	15.67	2.28	.06	.21	.006	2.09
Bleached structural saprolite, upper part tends to be partly silicified	Qtz, Kao	64.65	21.91	2.18	.03	.51	.006	5.68
Saprock	Mi,Qtz, Hm, Gt	65.33	17.38	7.29	.04	.33	.012	3.38

Hm Hematite
Gt Goethite
Kao Kaolinite
Sm Smectite
Ca Calcite
Qtz Quartz
Fp Feldspar
Mi Mica



Regolith	Mineralogy	Cu	Zn	Ni	Pb	Cr	V	Zr
		Elements in ppm						
Loose iron nodules and gravels. Massive duricrust contains alluvial gravels	Gt, Ht	32	11	-12	12	195	69	43
		4	3	-2	13	55	62	207
Bleached structural saprolite, upper part tends to be partly silicified	Qtz, Kao	23	2	51	10	79	64	110
Saprock	Mi,Qtz, Hm, Gt	102	2	13	22	-4	24	169

Figure 12E. Vertical distribution of major minerals and some major and trace elements in the weathering profile over Mesozoic and Proterozoic slate. Profile developed on mesas and rises.

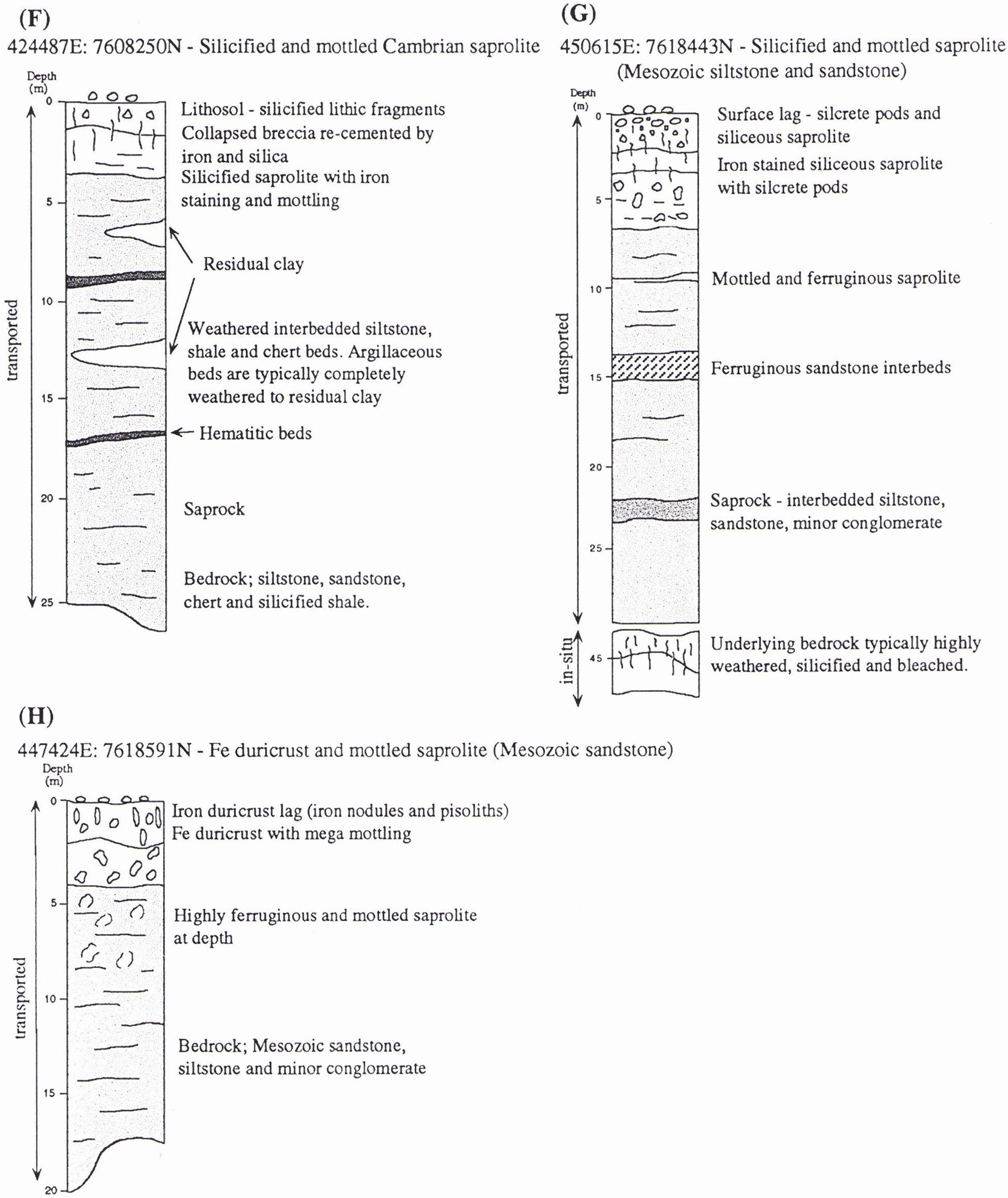


Figure 12F, G and H. Vertical distribution of major regolith materials in weathering profiles over Cambrian (F) and Mesozoic (G & H) sediments.

Silcretes and silicified Proterozoic bedrock are typically impregnated by Fe to varying degrees in the form of hematitic mottling and diffuse staining. The silcretes are typically covered by a veneer of ferruginised silcrete and silicified saprolite gravel lags. They consist of massive, grey, indurated crusts which typically exhibit columnar jointing patterns. They can also form as pods 0.2-1.0 metres wide which are typically surrounded by gritty sands which are partly cemented together by iron and silica. Silcretes may be fine-grained with a micro-crystalline textures or coarse grained where silica has cemented quartzose sand and gravel. Mottled saprolite beneath the silcrete is often also silicified. Silicification is also associated with ferruginous duricrusts described above where Si has cemented the mottled and kaolinised zone beneath the duricrust. An example of a silcreted weathering profile developed on granite is shown in Figure 11 Q.

8.2 Cambrian and Mesozoic bedrock

Cambrian and Mesozoic profiles were not considered for geochemistry or mineralogy. However 'typical' weathering profiles developed on these lithologies are shown in Figures 11F, G and H. The most deeply weathered profiles are now preserved on remnant plateaux and mesas. Profiles developed on Cambrian sediments consist of lithosols partly covering a brecciated saprolitic layer (Figure 11F and 10). The breccia is typically stained by Fe, mottled and partly silicified. The degree of weathering beneath the breccia zone is largely controlled by lithological variation within the sedimentary sequence. Argillaceous units are typically completely weathered to residual clays whereas more siliceous units are generally only moderately to slightly weathered.

Mesozoic sediments are typically very highly weathered with either ferruginous or siliceous duricrusts overlying ferruginous and mottled saprolite (Figure 11J and K). Ferruginous duricrust are typically massive and partly covered by Fe stone lags, nodules and pisoliths. Siliceous duricrusts appear as either silicified saprolite or as silcrete pods in the silicified and ferruginous matrix (Figure 11N). Mottling varies from irregular and diffuse to clearly delineated mega mottles. Weathering of the sediments is largely controlled by variation in lithologies. Siliceous units (siltstone, sandstone) are often silicified whereas clays rich sediments (mudstone) are often highly ferruginous. The contact with the underlying Proterozoic bedrock is commonly bleached and silicified (Figure 11K).

9. REGOLITH-LANDFORM EVOLUTION

A number of regolith materials, landform and drainage features contain important information when developing an understanding regolith-landform evolution in the Selwyn area. These are discussed before a summary of landscape evolution is presented.

9.1 Duricrusts and associated deep weathering

Duricrusts have cemented *in situ* materials (saprolite) and sediments. They generally have a scattered distribution in the landscape. The distribution of ferruginous and siliceous duricrusts are shown on map 5.2 (Appendix 5). Duricrusts are divided on whether the major cementing agent is Fe or Si and on their physical characteristics.

9.1.1 Ferruginous duricrusts

Iron cemented materials are divided into three main categories based largely on textural differences. They are:

1) Massive ferruginous duricrust (duricrust has little or no internal differentiation);

2) Slabby ferruginous duricrust (duricrust has a partly layered or slabby appearance); and

3) Ferruginous/brecciated saprolite (Fe oxides cementing a typically brecciated saprolite which grades into mottled saprolite at depth).

Massive and slabby duricrust also occur on Mesozoic sediments and probably reflect a long history of weathering from sub-aerial exposure of the sediments in the Late Cretaceous through to the present day.

Massive duricrusts form an extensive plateau surfaces over the northeast corner of the Selwyn study area. Slabby duricrusts in comparison are less common and generally occur along the edges of plateaux and mesas. The ferruginous and highly weathered nature of the Mesozoic sediments in the Selwyn area and elsewhere over the Mt Isa inlier may relate to the abundance of water in the sedimentary sequence. Water would have been associated with the initial deposition of the shallow marine/terrestrial sediments and then later with groundwater flow while the sediments still occupied lower parts of the landscape (i.e. valley floors, coastal inlets). Water would have accelerated the weathering process, particularly with regard to the movement of Fe and Si in the sedimentary sequence.

Massive, brecciated and slabby duricrust occur on Proterozoic rocks. These duricrusts show clear evidence (quartz veining) that they have developed largely *in situ*. In many cases, there is clear field evidence of a gradual transition between Fe segregations in the mottled zone and the overlying massive ferruginous duricrust. Mottling has formed by segregation of clay and Fe oxides in the saprolite. As mottling proceeds more iron and clay species are separated and concentrated in the mottled zone. This eventually leads to the formation of Fe segregations in the upper part of the weathering profile. Iron segregations are then progressively exposed and hardened due to surface weathering and erosion. The Fe segregations may either collapse and be re-worked at the surface to form gravels consisting of ferruginous saprolite, duricrust, nodules and pisoliths, or, cement together to form massive duricrust. Iron in the upper part of the profile is likely to have been sourced from the mottled zone and the underlying saprolite zone. In addition, some Fe was probable sourced laterally from up-slope. However lateral sourcing of Fe is thought to be a more important process in the development of slabby ferruginous duricrusts (see section 9.2).

Brecciated duricrusts (Figure 11S) are less consolidated than the massive or slabby duricrusts. They consist of angular-kaolinised saprolite fragments which are cemented by Fe oxides to form an indurated brecciated duricrust. In addition to saprolite fragments the breccia contains ferruginous nodules and pisoliths which are partly cemented in a ferruginous earthy clay matrix. The indurated breccia grades into a well developed mottled zone (mega-mottling common) and kaolinsed saprolite. The breccia fabric has probably developed from the removal of clays - causing the saprolite to collapse. Reworking due to bioturbation would also contribute to surface mixing and brecciation. Mobilisation and precipitation of Fe has subsequently partly cemented the saprolite fragments and formed ferruginous nodules and pisoliths in the upper part of the weathering profile.

Slabby Fe duricrusts (Figure 11A) in comparison to the massive ferruginous duricrusts exhibit sub-horizontal to horizontal layering. The top of the slabby duricrust typically consists of lithosols which consist of ferruginous duricrust gravels, pisoliths and nodules. Slabby duricrusts have a sharp contact with the underlying mottled zone and are typically associated with a well developed bleached zone which is invariable silicified. Quartz veining through the duricrusts although discontinuous in places indicates that the profile has largely formed *in situ*. The origin of the layers within these slabby duricrusts is uncertain but is thought to have developed from lateral movement/accumulation of Fe and partial collapsing of the upper part of the weathering profile.

Massive or slabby duricrusts have not been dated. However they have more than likely formed from continual weathering during the Tertiary with periods of active and less active formation depending on changing climatic conditions (i.e. humid and arid). The brecciated duricrusts have however many similarities with the Canaway weathering profile in the Eromanga Basin described by Idnurm and Senior (1978). The Canaway profile has a palaeomagnetic age of Late Oligocene.

9.1.3 Siliceous duricrusts

Silica-cemented materials consists of:

1) Silcrete (completely silica-cemented microcrystalline duricrust);

2) Silicified sand and gravel; and

3) Silicified saprolite (silica cementing saprolite).

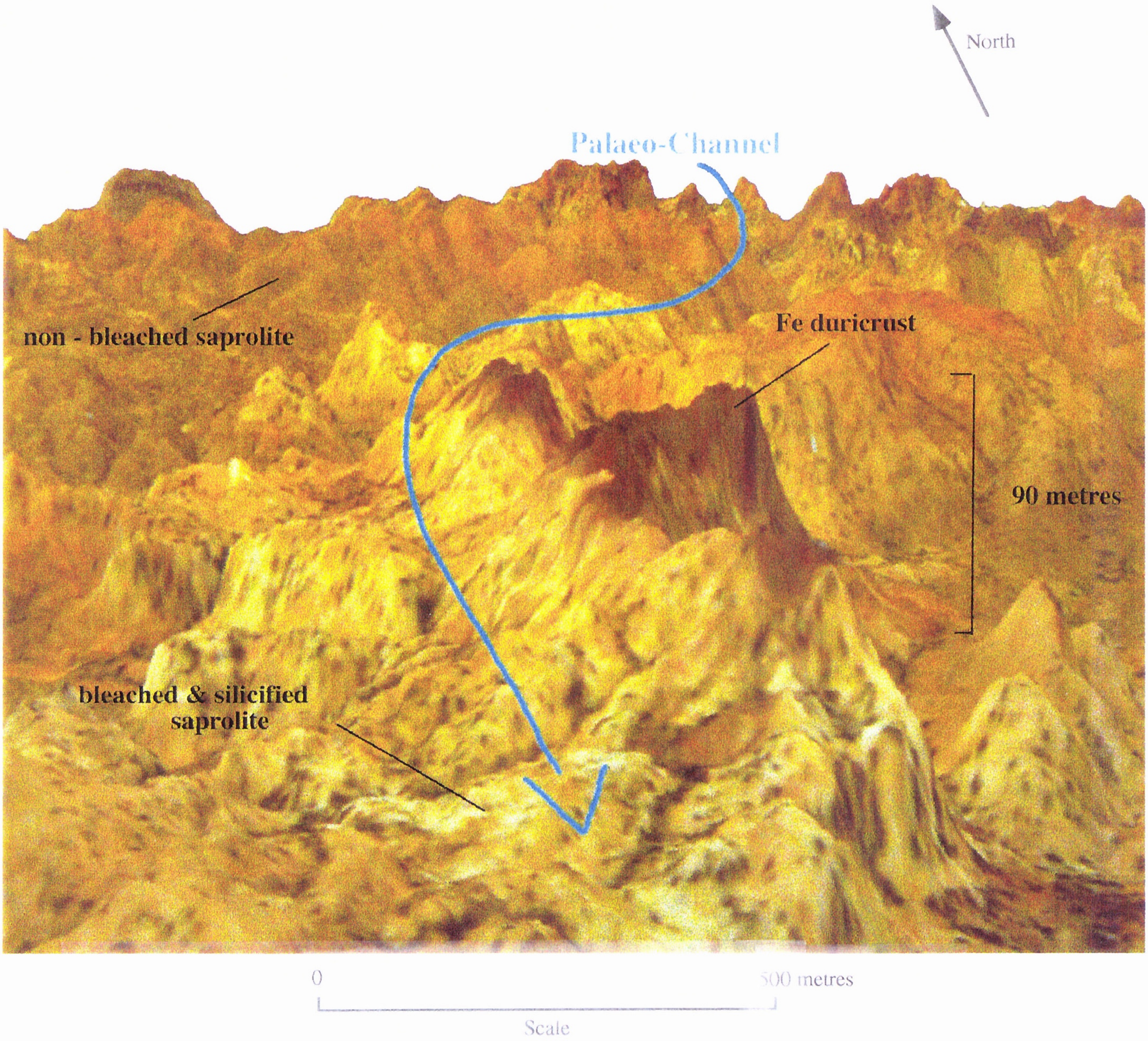


Figure 13. Some of the most intense weathering is associated with Pre-Mesozoic valley floors as shown by the enhanced colour photographic/digital elevation model drape. In places, Mesozoic sediments have been removed leaving behind silicified and bleached Proterozoic saprolite. This intense weathering is likely to be due to groundwaters removing Fe and precipitating silica within the saprolite beneath the old valley floor. Slabby Fe duricrusts probably delineate the edge of the old river valley and have formed from the lateral movement of Fe oxides down palaeo slope.

Silica-cemented materials are associated with the ferruginous duricrusts (see map 5.2 - Appendix 5) and appear to have formed on a variety of different materials. Iron and Si cementing can occur within the same weathering profile. In many places Si overprints ferruginous materials suggesting that conditions more favourable for silicification may have occurred more recently. Silicification of the bleached or kaolinised zone of the deeply weathered profiles is common. This suggests that weathering and kaolinisation of the bedrock occurred prior to silicification. Linking the origin of some of these silicified materials with palaeaochannels best explains their distribution, association with ferruginous duricrusts, composition and texture. A model for the origin of these silcretes and slabby ferruginous duricrusts is explained in section 9.2.1.

Silicification of saprolite is not restricted to palaeochannels but also occurs on erosional plains and rises. It is possible that silicification has been occuring more or less continously throuthout the Cainozoic and earlier, cementing saprolite in different parts of the landscape at different times.

9.2 Drainage features

9.2.1 Palaeodrainage, duricrust development and relief inversion

Drainage evolution in the Selwyn region has had a long and complex history. It is thought that palaeo-river systems are intrinsically related to some of most highly weathered regolith in the landscape. Palaeohydrology is also likely to have had a major influence in the formation and distribution of indurated materials (ferruginous duricrusts and silcrete).

Sinuous, silicified concordant plateaux or dissected plateaux with either cemented quartz sands and pebbles and/or silicified saprolite occur approximately 4 km west of the Selwyn mine. The cemented quartz sands and pebbles represent old valley floor alluvium, whereas the silicified saprolite is associated with subsurface water flow beneath the old valley floor (Figure 11O). Silicification and hardening of the valley floor has led to differential erosion and relief inversion.

Slabby ferruginous duricrusts are often associated with these old valley silcretes and zones of silicification. These relationships are shown in a 3-D colour photograph/digital elevation drape across an interpreted palaeo-channel (Figure 13). The old palaeochannel (depicted in Figure 13) is delineated by intense bleaching and silicification of Proterozoic bedrock which was once a Fe-rich schist. Geochemical variation for selected elements across the palaeochannel is shown in Figure 12D. Bleaching of the bedrock is thought to be due to groundwaters removing Fe and precipitating silica within the saprolite beneath the old valley floor. Slabby duricrusts are likely to have formed on the valley sides adjacent to the palaeochannel by vertical and probably more importantly by lateral movement of Fe oxides down slope to the valley sides. Therefore slabby ferruginous duricrusts may mark the edge of the old valley wall. This would explain why many of the slabby duricrusts are inclined or dipping (Figure 11A). The palaeochannel was probably once filled with Mesozoic sediments which have since been eroded, what remains is cemented (Si) saprolite associated with the old valley floor (Figure 14). A diagrammatic model for the formation of silcretes and slabby ferruginous duricrusts is shown in Figure 14.

9.2.2 Drainage superimposition

There is clear evidence of drainage superimposition in the north-west part of the map sheet. Limestone Creek and other rivers flowing predominantly east-west are likely to have been inherited from a flat-lying Mesozoic sedimentary cover which blanketed most of the region during the early Cretaceous (see Appendix 5). The older eastwest palaeoflow direction is now superimposed over the predominantly northsouth structural fabric of the underlying Proterozoic rocks. In the north-east corner of the map sheet large areas of Mesozoic sediment remain. Irregular thicknesses of Mesozoic sediments and undulating contacts with the underlying Proterozoic rocks in this area are best explained by sediments infilling valley and ridge palaeotopography. This suggests that there was quite substantial pre-Mesozoic relief prior to sedimentation. The underlying Proterozoic rocks along these now partly exhumed valleys are typically very highly weathered and koalinised. This probably relates to deep weathering associated with ground waters along and beneath the palaeovalley floors.

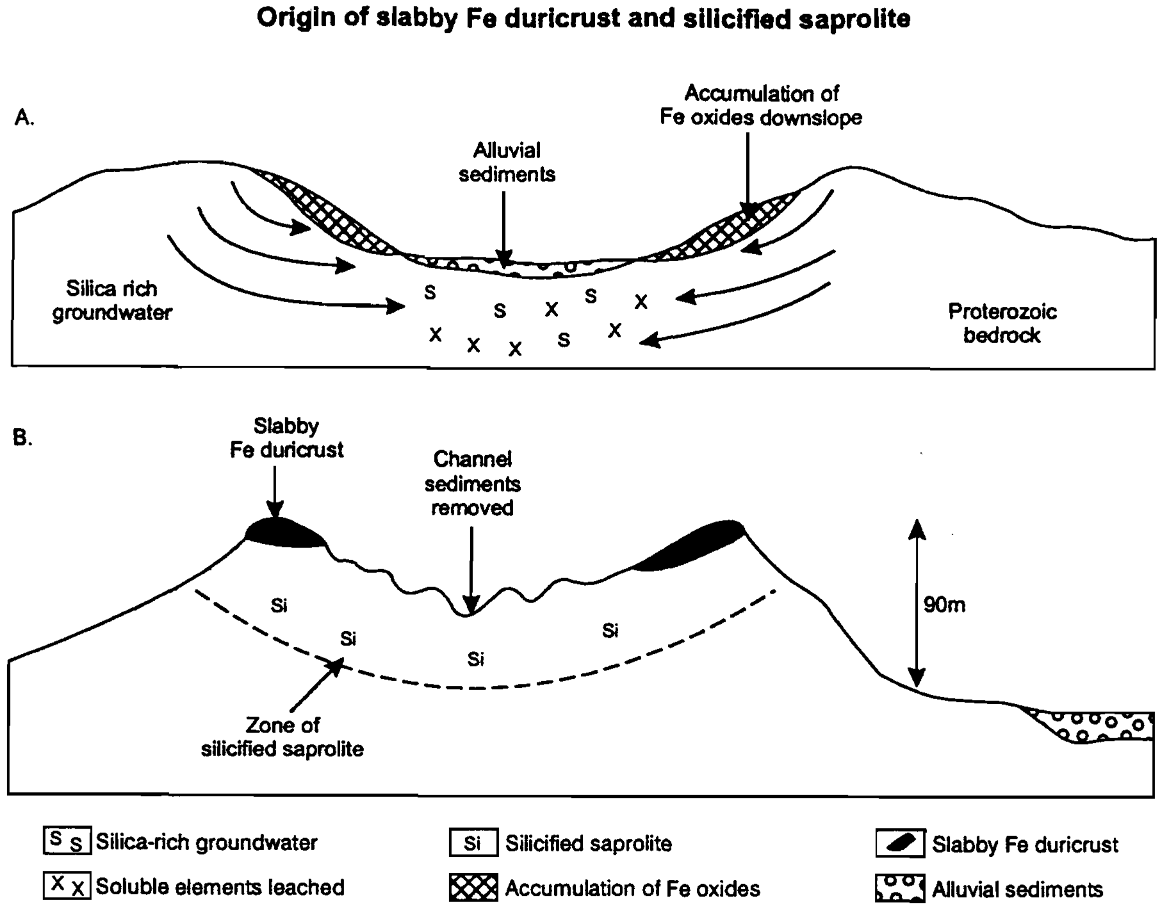


Figure 14. Showing the development of slabby Fe duricrusts and silicified saprolite associated with palaeochannels. (A) - silicification of valley floor and accumulation of Fe oxides along valley sides.
(B) - differential erosion and relief inversion caused by induration by Si and Fe associated with the palaeochannel.

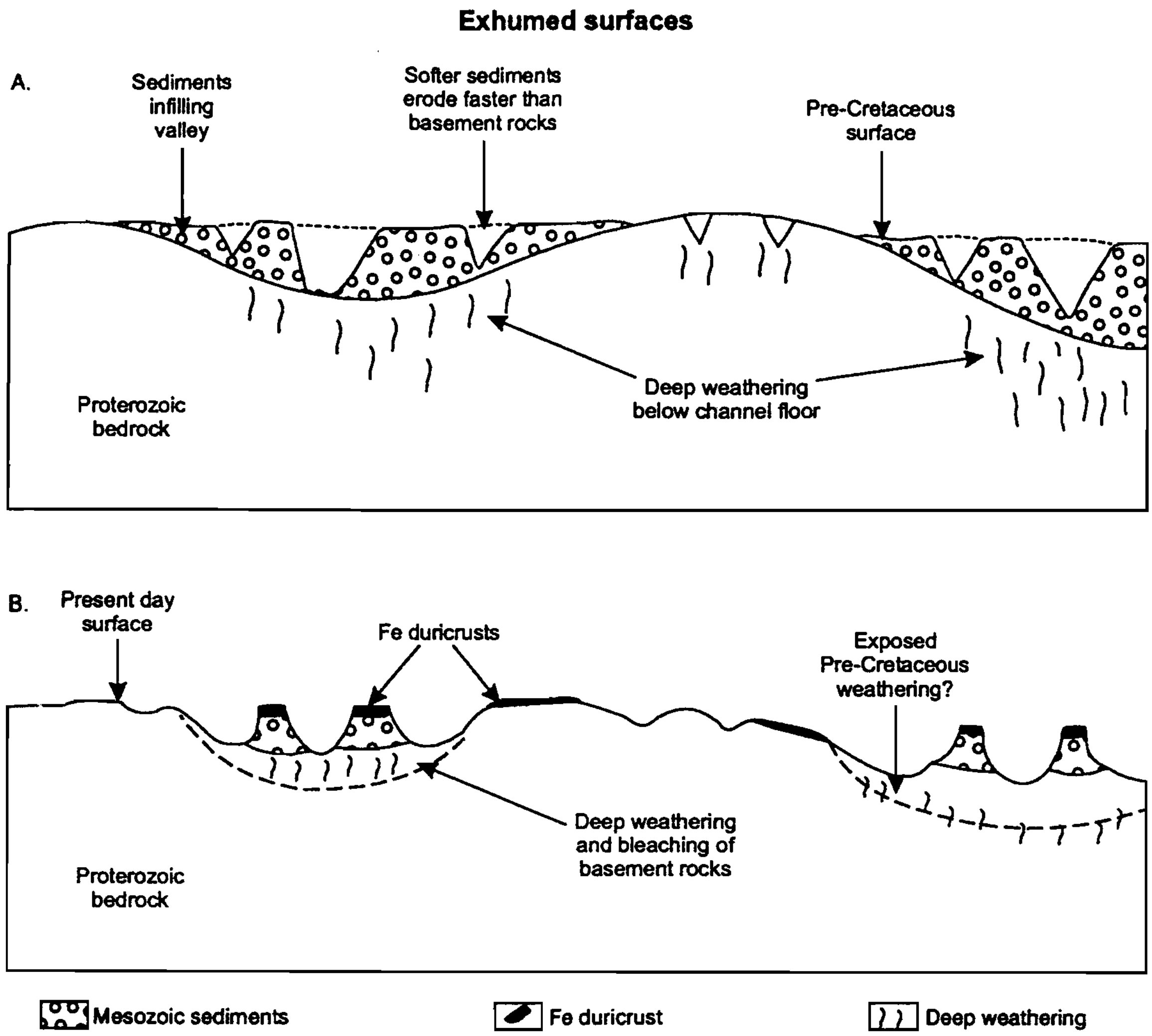


Figure 15. Stages of exhumation exposing pre-Cretaceous weathering. (A) - most of the Cretaceous sediment preserved. (B) - Cretaceous sediments largely exhumed revealing the pre-Cretaceous weathered Proterozoic bedrock.

9.3 Exhumed surfaces

In many places the pre-Cretaceous land surface or a derivation similar to it has been re-exposed or exhumed. The term exhumation refers to a process relating to the exposure by denudation of a land surface that has in the past been buried. The exposed pre-Cretaceous surface may be highly weathered. bleached and in places silicified. The age of exhumation is younger than the Proterozoic basement affected by the erosion and older than the Cretaceous sediments which once covered the basement rocks. Several stages of exhumation or degrees of uncovering can be recognised in the Selwyn region depending on the relative rates of erosion and the original thickness of the Cretaceous sediments (Figure 15).

Exhumation has probably developed by a combination of deep weathering, competency contrast between Cretaceous sediments and underlying Proterozoic sediments and, uplift and associated active erosion. In many places exhumation has exposed highly weathered (typically bleached) possible pre-Cretaceous weathering (Figure 11 K). Exhumed landscapes in the Selwyn region are part of broader scale preferential stripping of the Cretaceous cover and exposure of basement rocks across the Carpentaria Basin (Twidale and Campbell, 1993). How closely the exhumed surface will reflect the original pre-Cretaceous topography will largely depend upon post-Cretaceous tectonism in the area.

9.4 Erosional scarps and uplift

Several active scarps occur over the western part of the Selwyn map. They flank Mesozoic and Cambrian sediments. The scarps separate relatively older landforms and regolith above from predominantly younger landforms and regolith below the scarp edge. Active erosion together with low angle dips of the sedimentary beds may relate to local warping and uplift in this region. This tectonism may be associated with the Selwyn Uplift described by Twidale (1966). Warping may also be associated with the re-activation of the Pilgrim Fault near Mt Birnie (west of the map sheet boundary) during the Cainozoic as evident by diping (3 degrees) silcrete mesas (de Keyser and Cook, 1972). Changes of river patterns to the east of the study area was attributed by Twidale (1966) to Late Pleistocene and Early to Middle Holocene uplift. This might also explain why the highest elevations in the Selwyn study area occur along the east to north eastern margin of the map. Scarps are also associated with highly ferruginous and silicified saprolite which resist erosion due to their hardness (see maps - Appendix 5.0).

9.5 Summary of Regolith-landform history

A summary of the regolith-landform events from the Late Jurassic to the present day are outlined below. However, due to the lack of regolith dating around the Selwyn area age relationships and correlations are at best speculative. The stages of regolith-landform evolution are show diagrammatically in Figure 16.

9.5.1 Late Jurassic - Early Cretaceous

Rising sea level in the early Cretaceous caused sedimentation in the lower stretches of the main drainages and, eventually, sediments drowned all but the highest parts of the local topography. Irregular thicknesses of Mesozoic sediments and undulating contacts with the underlying Proterozoic rocks indicate that sediments infilled valley and ridge palaeotopography. Highly weathered Proterozoic bedrock beneath the Mesozoic sediments indicates either pre-Mesozoic kaolinisation prior to valley infilling or deep weathering after sedimentation. Ferruginous Proterozoic rock fragments were in places incorporated in the basal units of these sediments.

9.5.2 Late Cretaceous

As the sea fell during the Late Cretaceous the sea floor was exposed. Drainages were initiated on the sea bed sediments, flowing generally north to the subsiding Carpentaria Basin and south southwest to the Eromange Basin. north-east drainage superimposition across the predominantly north south structural grain of the Proterozoic rocks reflects an early drainage pattern inherited from the exposed sea floor cover. This inheritance strongly suggests that the Mesozoic cover extended over a large part if not all of the Selwyn region. Resistant strata may have protruded as islands surrounded by a Mesozoic sea. Immediately after emergence the area was relatively flat with early Cainozoic weathering and erosion bevelling Proterozoic rock which protruded through the sedimentary cover. Most of the soft Mesozoic sediments had been eroded by the end of the Cretaceous uncovering the basement of the Mt Isa Inlier. Regional uplift of the inlier and modest down warping of the Carpentaria and Eromanga basins would appear to be the primary driving forces behind regional erosion and aggradation. Differential erosion following emergence left the Proterozoic rocks basement rocks high in the landscape, particularly over the central and eastern half of the Selwyn map sheet area.

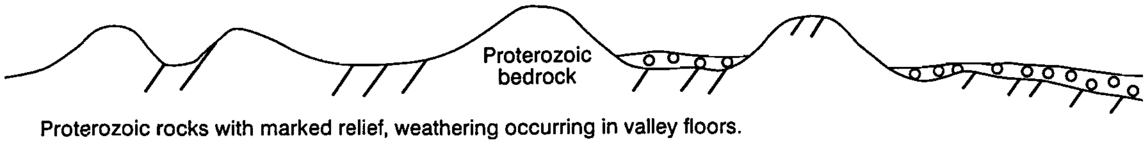
9.5.3 Cainozoic

By the early Cainozoic the Mesozoic sediments had been largely eroded except in the northeast, southeast and southwest corners of the Selwyn area. In places pre-Cretaceous weathered Proterozoic rocks have been exposed. Weathering and differential erosion from the Late Cretaceous and during the Cainozoic has formed most of the present day landforms and drainage divide. Up-warping of the Selwyn highlands was active in the Late Cainozoic (Twidale, 1966). In places valley floors and sides became cemented by iron and silica. Subsequent erosion has left these very resistant siliceous and ferruginous duricrusts as mesas and plateaux, some of which now form relief inverted landscape elements. These resistant landforms have developed on Proterozoic and Mesozoic and to a lesser extent on Cambrian sediments. Some of the best examples are approximately 4km west of the Selwyn mine and over the southeast corner of the map sheet (Figure 11Q).

Weathering continued during the Tertiary with periods of active and less active formation depending on changing climatic conditions (e.g. humid or arid conditions). Deep weathering and duricrusts developed on exposed stable parts of the landscape. Duricrusts also developed in response to lateral water flow associated with valley floors and valley sides. Silicification of weathering profiles became more common as climatic conditions became more arid from the Late Miocene to the present day.

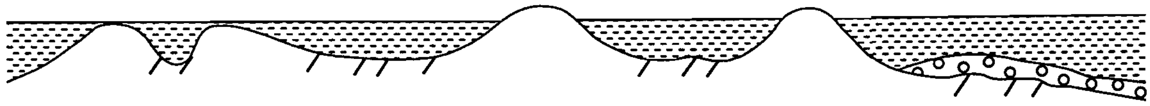
Landscape evolution in the Selwyn Region

1. Late Jurassic



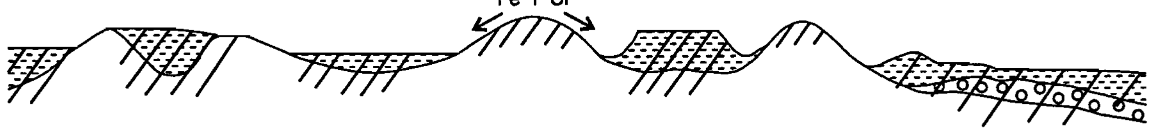
Proterozoic rocks with marked relief, weathering occurring in valley floors.

2. Early Cretaceous



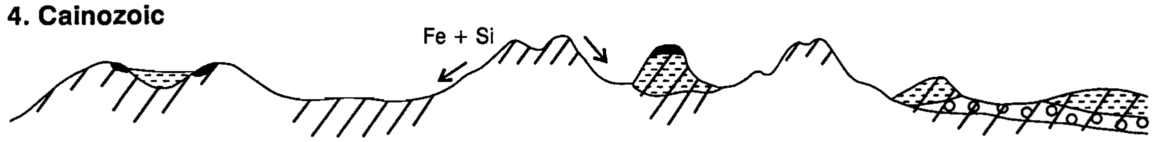
Highest hills protrude above Mesozoic sea. Mesozoic sediments (conglomerates, sandstone and siltstones) infills valleys within Proterozoic rocks. Local relief is reduced due to valley infilling and bevelling of hills by deposition and erosion.

3. Late Cretaceous



Weathering and erosion of Mesozoic and Proterozoic rocks. Weathering products retained where rate of weathering is greater than rate of erosion.

4. Cainozoic



Differential rates of erosion and weathering form a variety of different weathering styles on Mesozoic, Cambrian and Proterozoic rocks. Ferruginisation and silicification of Mesozoic and Cambrian Proterozoic rocks form Mesas and resistant rises and hills. Relief inversion occur on some of the indurated surfaces. Colluvium develops down slope from adjacent hills. Alluvial sediments accumulates in floodplains, alluvial plains and sheetwash plains. Valley widening and pediment development takes place.

5. Present Day

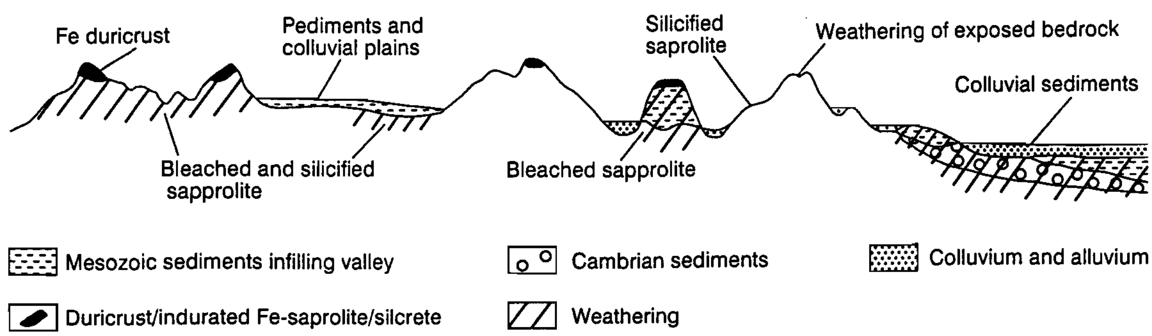


Figure 16. Stages of regolith-landform evolution over the Selwyn region of the Mt Isa Inlier.

10. DISCUSSION AND IMPLICATIONS FOR MINERAL EXPLORATION

The Selwyn region has a highly variable regolith cover which reflects weathering processes from the Jurassic to the present day and variable degrees of erosion and exhumation. In addition relief inversion processes add to the complexity of the present day landscape. Standard geochemical sampling methods are unlikely to be effective across the whole study area. Different regolith materials will require different approaches when sampling and interpreting surface and drill hole geochemistry. For geochemical surveys to be effective, an understanding of the origin of the sampling media, style of weathering, geomorphic processes and regolith-landform relationships are necessary.

10.1 Geochemical sampling strategy map

To provide a direct tool for the interpretation of surface geochemistry and drilling, regolith-landform units have been classified to generate a interpretative geochemical sampling strategy map. The strategy map divides the landscape into major geochemical sampling groups as outlined below;

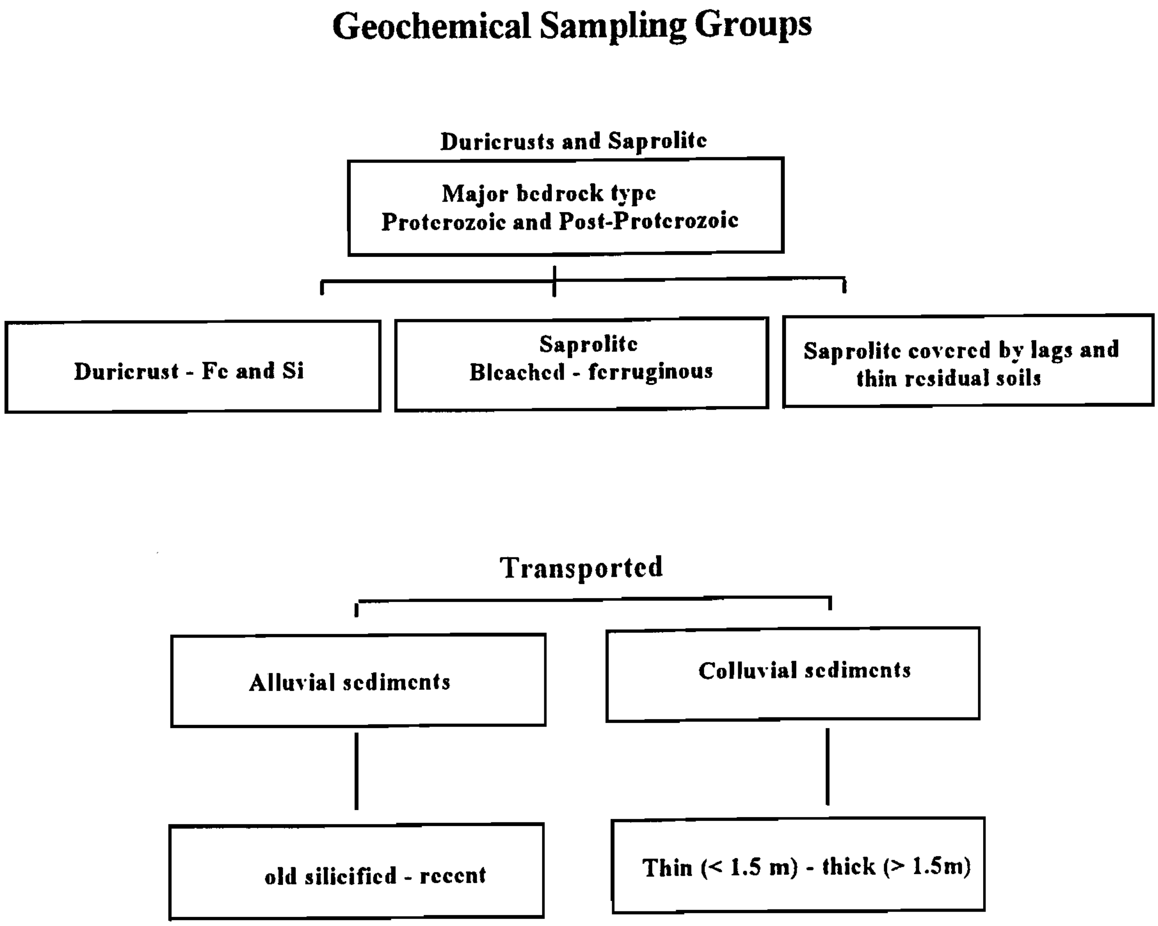


Figure 17. Shows the major geochemical sampling groups which are used in the geochemical sampling strategy map (Appendix 5.4).

Each of these groups with the exception of the alluvium and colluvium are divided into Proterozoic and Post-Proterozoic bedrock types. Subdividing regolith materials on whether the bedrock is Proterozoic or Post-Proterozoic is essential since they have a completely different geochemical significance and regolith derived from these rocks require different interpretations. Each unit within these groups describe regolith properties in a geochemical context. For example highly weathered bleached regolith is separated from ferruginous saprock, and thick (> 1.5m) colluvial cover which is likely to have a more dilute geochemical response is separated from thin colluvium over bedrock. Recommended sampling approaches are also described for each unit. Clustering regolith-landform units into major regolith-geochemical groups is an interpretative process. Although the subdivision have been largely based on the physical and chemical characteristics of the regolith, genetic landscape models are also involved in the decision making process. Therefore the geochemical strategy map (Appendix 5.4) is a interpretive thematic layer which has been generated from the original descriptive regolith-landform map (Appendix 5.1). Separating factual from interpretative information allows the user to generate new interpretative maps based on different landscape and geochemical models from the original factual data.

Several major regolith-landform associations which are highlighted on the sampling strategy map should be considered carefully when interpreting surface and drill hole geochemistry. These associations are described below.

10.2 Weathering profiles on Proterozoic bedrock with or without thin cover

Regolith materials in this category include a range of materials from relatively unweathered saprock to highly weathered zoned profiles which are often capped with either ferruginous or siliceous duricrusts. Areas of saprock correspond to actively eroding parts of the landscape. Soil/rock geochemical sampling is recommended in this type of terrain. Ferruginous and siliceous materials require more careful and selective sampling. Massive and brecciated ferruginous duricrusts develope largely *in situ* and are likely to be useful indicators of geochemistry at depth. The duricrust, ferruginous saprolite, ferruginous nodules and pisoliths are all useful sampling materials. However, slabby Fe duricrusts may give false anomalies due to lateral movement of iron oxides and associated metals. Slabby duricrust probably once developed along valley sides or in topographic lows where groundwaters precipitated Fe oxides. Therefore, slabby duricrusts can be sampled to give broad geochemical indications. In siliceous landscapes mottling and ferruginous granules derived from the weathering of the silcretes can be used as a indicator of geochemistry at depth. Silcretes, however, should be interpreted independently from ferruginous duricrusts since they invariably show much lower metal concentrations.

Some of the most deeply weathered bedrock is associated with palaeochannels and exhumed landscapes. Metal concentrations within leached kaolinised bedrock associated with these features are anomalously low compared with the surrounding saprock.

10.3 Weathering profiles on Cambrian and Mesozoic sediments

Regolith developed on Mesozoic sediments are most common over the northern end of the map sheet where they form ferruginous duricrust plateaux. Sampling of these duricrusts are unlikely to directly relate to mineralisation at depth. The use of ferruginous duricrusts as sample media requires an appropriate orientation study. However, re-worked Proterozoic bedrock and metals precipitated from groundwaters in the sediments may provide regional dispersion indicators. Since Mesozoic sediments largely infilled old valleys, anomalies in the sediments may relate to mineralisation higher up in the palaeochannel.

10.4 Saprolite covered by colluvial and alluvial deposits

Colluvial deposits consisting mainly of sheetwash sands, clays and gravels are best developed over low relief areas of the Selwyn study area. Sampling of ferruginous materials including lithic fragments, pisoliths and nodules can be useful in reconnaissance geochemical interpretations. Alluvial sediments consisting of clays, sands and conglomerates form relatively narrow floodplains associated with sandy Creek, Mort River, Mistake Creek and Limestone Creek. Rotary air blast (RAB) and stratigraphic drilling is recommended to sample and characterise saprolitic materials beneath the sediments. Sediments can be used to give reconnaissance stream sediments geochemical indicators.

11. ACKNOWLEDGMENTS

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APPENDIX 1

Definitions and glossary

In this section terms used to describe mapping units and regolith units of the weathering profile are defined. They are largely derived from Terminology and classification of laterites and associated ferruginous materials (Anand et al., August, 1989), Classification and Atlas of regolith-landform mapping units (Anand et al., 1993) and RTMAP regolithdatabase field handbook (Pain et al, 1991).

Regolith Stratigraphy

Duricrust
Mass of hard material formed within the regolith by either relative or absolute accumulations of natural cements in sediment (which may be variably weathered), saprolite or partially weathered rock.

Ferruginous Saprolite
Ferruginous saprolite is commonly developed over Fe-rich bedrocks. It is firm to hard, massive to mottled, and is dominated by goethite and kaolinite. Fragments of ferruginous saprolite are yellowish-brown to reddish-brown, non-magnetic, and may have an incipient nodular structure. Ferruginous saprolite may form a continuous blanket and is generally overlain by collapsed ferruginous saprolite where soft, soluble, less ferruginised material has been removed by leaching, causing the whole structure to collapse.

Ferruginous Granules
Fragments of Fe-rich (hematite, goethite, and maghemite) material, somewhat rounded, between 2 and 4 mm in diameter, generally having no cutans, and comprised of a mixture of magnetic and non-magnetic iron oxides. Commonly occur in soils or as surface lag.

Lag
Lag covers much of the surface in the Mt Isa region and consists of a variety of clast types, including lithic fragments, ferruginous granules, pebbles and cobbles, lateritic pisoliths, nodules, and quartz clasts. Lag reaches the surface by deflation of the soil by wind and water, by root plucking and by eluviation. The various clast types are commonly mixed but their distribution may be related to source material, such as regolith substrate, and to the regolith-landform framework.

Lateritic Residuum
Lateritic residuum is a collective term for certain ferruginous units of the laterite profile. It is formed by weathering, precipitation of minerals, and residual accumulation in the upper part of a lateritic weathering profile. Lateritic residuum includes units consisting of loose lateritic pisoliths and nodules (forming lateritic gravel) as well as lateritic duricrust. The colour of this regolith unit varies from yellowish-brown, through dark reddish-brown to very dark brown. The mineralogy is mainly kaolinite, hematite, goethite, with or without subordinate and variable amounts of gibbsite, quartz, maghemite, muscovite, zircon, ilmenite, and anatase. Lateritic residuum may occur at surface or subsurface when the weathering profile has been buried.

Lateritic Duricrust
Lateritic duricrust is indurated lateritic residuum, consisting of various secondary structures such as nodules, pisoliths, and ooliths, set in a matrix of kaolinite and Fe-oxides. Both magnetic and non-magnetic varieties of nodules and pisoliths occur in lateritic duricrust. The magnetic properties are due to maghemite.

Lateritic Gravels
Lateritic gravels consist of loose lateritic nodules, pisoliths, and hardened mottles. Lateritic pisoliths and nodules typically have 1-2 mm thick, yellowish-brown to greenish cutans around hematite-rich, black to red nuclei. Both lithic and non-lithic nodules are common in this unit.

Lateritic Nodule
A ferruginous lateritic particle with an irregular shape, usually with rounded edges, in the 2 to 64-mm diameter range, and which may have a cutan around a nucleus or core. As sphericity increases, the term pisolith becomes appropriate. The core can be of a variety of materials, such as hardened, variably ferruginised sandy grit, lithorelics, etc. Lateritic nodules commonly occur as loose aggregates, as a lag, in soil, and in lateritic duricrusts.

Lateritic Pisolith
A ferruginous lateritic particle resembling a pea in shape, by definition of 2 mm or more in diameter. Pisoliths can have a concentric internal structure, but concentric lamination is not diagnostic; however, most pisoliths have a cutan. Lateritic pisoliths and nodules commonly occur together, but the former rarely exceed 20 mm in diameter.

Massive Fe duricrust
Duricrust which has little or no internal differentiation.

Massive Silcrete
Completely silica cemented duricrust which has little or no internal differentiation and consist largely of micro-crystalline silica.

Mottled Zone
The mottled zone differs from the lateritic residuum above by lesser accumulation of Fe-oxides and lacks induration. The mottled zone has contrasting kaolinite-rich bleached domains and Fe-mottles, which may be distinguished easily in outcrops and in samples on a centimetre scale.

Nodular Fe duricrust
Duricrust which is differentiated internally and gives the appearance of cemented nodules.

Nodules
Nodules are irregular to spherical units of regolith material that occur enclosed within the regolith, as lag or soils. They typically have a greater concentration of some constituent (ie , carbonate, silica, iron or clay) difference in internal fabric or a distinct boundary with the surrounding material. They may contain pisoliths and/or concretions.

Pisoliths
Small round or ellipsoidal accretions resembling a pea is shape and size. Typically composed of either iron or carbonate. They may have radial or concentric structures.

Residual sand
A deposit of sand sized material, commonly composed largely of quartz, covering the land surface, and derived from the removal of finer material either in solution or suspension in subsurface water. It includes the sandy top of some soil types.

Residual clay
Clay material that remains behind after weathering has removed part of the original rock. A common example is the clay soil material found on limestone after solution has removed the calcareous part of the rock.

Shallow soil on fresh bedrock or lithosols
In some areas, particularly on steep slopes, or on young surfaces, the regolith consists of soil material up to 2 m thick formed directly on the underlying bedrock. Commonly the soil has a skeletal profile, and is less than 1 m thick.

Slabby Fe duricrust
Duricrust which is has a partly layered or slabby apperance

Silcrete pods
Silcrete which forms discrete pods or lumps, sometimes up to a metre across. Commonly found in alluvial sediments, it may also be found in other locations.

Siliceous saprolite
Where secondary silica is abundant (>50%) and partly or completely cements the saprolite. It often has a grany texture and may be mottled. In many cases the type of bedrock can be identified.

Saprolite
Saprolite is weathered rock that retains much of the fabric and structure of the parent bedrock. Saprolite can be firm (rather than hard), soft, or friable. Isovolumetric weathering is commonly envisaged. Saprolite may become more massive upwards as the proportion of clay increases and cementation by secondary silica, carbonates, and especially Fe-oxides is common. Saprolite is lighter in colour than the overlying mottled zone and lateritic residuum. Its mineralogy is variable, depending upon the nature of the parent bedrock.

Saprock
Saprock is a compact, slightly-weathered rock of low porosity, with less than 20% of the weatherable minerals altered. The boundary between bedrock and saprock is not generally a plane, but is very irregular and corestones of fresh rock may occur in the saprock and saprolite.

Stratigraphic ironstones
In situ weathering products of Fe-rich lithologies

Degree of bedrock Weathering (saprolite)

Slightly weathered
Slightly weathered rock has traces of alteration, including weak iron staining, and some earth material. Corestones, if present, are interlocked, there is slight decay of feldspars, and a few microfractures. Slightly weathered rock is easily broken with a hammer.

Slightly weathered sediments have traces of alteration on the surfaces of sedimentary particles, including weak iron staining. Some earth material may be present, filling voids between coarse particles.

Moderately weathered
Moderately weathered rock has strong iron staining, and up to 50 % earth material. Corestones, if present, are rectangular and interlocked. Most feldspars have decayed, and there are microfractures throughout. Moderately weathered rock can be broken by a kick (with boots on), but not by hand. Moderately weathered sediments have strong iron staining, and up to 50 % earth material. Labile particles up to gravel size are completely weathered. Larger particles have thick weathering skins. Most feldspars in larger particles have decayed.

Highly weathered
Highly weathered rock has strong iron staining, and more than 50% earth material. Core stones, if present, are free and rounded. Nearly all feldspars are decayed, and there are numerous microfractures. The material can be broken apart in the hands with difficulty.Highly weathered sediment has strong iron staining. and more than 50% earth material. All except the largest particles are weathered right through. Boulders have thick weathering skins.

Very highly weathered
Very highly weathered rock is produced by the thorough decomposition of rock masses due to exposure to land surface processes. The material retains structures from the original rock. It may be pallid in colour. and is composed completely of earth material. Corestones, if present, are rare and rounded. All feldspars have decayed. It can easily be broken by hand.Very highly weathered sediment is thoroughly decomposed. but still retains the shapes of the original sediment particles, as well as laminations and bedding. It is composed completely of earth material.

Completely weathered
Completely weathered rock retains no structures from the original rock. There are no corestones, but there may be mottling. It is composed completely of earth material.

Completely weathered sediment retains no structures from the original sediment. It is composed completely of earth material. There may be mottling.

Sedimentary Deposits

Alluvium
A general term for clay, silt, sand, and gravel deposited as a sorted or semi-sorted sediment during comparatively recent geological time on the bed or flood plain of a river or stream.

Channel deposits
Alluvium which is deposited in an alluvial channel. It is commonly coarser than surrounding deposits, and is found in both active and relict channels. It includes deposits in cut-off meanders, and point bar deposits.

Colluvial Deposits
Colluvial deposits, generally less than 5 m thick, occur as footslope deposits adjacent to steeper ridges and hills. The deposits are typically poorly sorted and consist largely of sheet flow deposits and fanglomerates overlain by stony soils. Near valley floors, these deposits typically inter finger with alluvial sediments.

Lacustrine sediments
Sediments deposited from transport by waves and from solution and suspension in still water in a closed depression on land.

Over bank deposits
Alluvium which is deposited outside an alluvial channel from flowing water which has overflowed from the channel. It includes levees and back swamp deposits.

Sheet flow deposit
Colluvium deposited from transport by a very shallow flow of water as a sheet, or network of rills on the land surface. Sheet flow deposits are very thin except at the foot of a slope and beneath sheet flood fans.

Landforms

Alluvial terrace
Former flood plain on which erosion and aggradation by channelled and over-bank stream flow is slightly active or inactive because of deepening or enlargement of the stream channel has lowered the level of flooding. A pattern that includes a significant active flood plain, or former flood plains at more than one level, becomes terraced land.

Alluvial swamp
Almost level, closed or almost closed depression with a seasonal or permanent water table at or above the surface, commonly aggraded by over bank stream flow. They typically have a gilgai micro-relief caused by shrinking and swelling of soil (i.e. montmorillonite and mix layered illitic clays).

Breakaways
Erosional scarps usually capped indurated and subindurated parts of the weathered mantle. Breakaways can mark the limits of the erosional destruction of a deeply weathered landsurface.

Colluvial footslope
Very gently to moderately inclined complex landform pattern of extremely low relief with a generally fan-shaped plan form. Divergent stream channels are commonly present, but the dominant process is colluvial deposition of materials. The pattern is usually steeper than an alluvial fan.

Drainage Floors
Flat alluvial tracts having little, if any, stream incision. Major floors are to 0.5 km wide. Small floors are <0.2 km wide.

Depositional plain
Level landform pattern with extremely low relief formed by unspecified depositional processes.

Escarpment
Steep to precipitous landform pattern forming a linearly extensive, straight or sinuous inclined surface which separates terrains at different altitudes, that above the escarpment commonly being a plateau. Relief within the landform pattern may be high (hilly) or low (planar). The upper margin is often marked by an included cliff or scarp.

Erosional plain
Level to undulating or, rarely, rolling landform pattern of extremely low relief (<9 m) eroded by continuously active to slightly active or inactive geomorphic processes.

Flood plain
Level landform pattern with extremely low relief. The shallow to deep alluvial stream channels are sparse to widely spaced, forming aunidirectional integrated network. Alluvial plain characterised by frequently active erosion and aggradation by channelled or over-bank stream flow. Unless otherwise specified, "frequently active" is to mean that flow has an Average Recurrence Interval of 50 years or less.

Hills
Landform pattern of high relief (90-300 m) with gently sloping to precipitous slopes. Fixed, shallow erosional stream channels, closely to very widely spaced, form a dendritic or convergent integrated tributary network. There is continuously active erosion by wash and creep and, in some cases, rarely active erosion by landslides.

Low hills
Landform pattern of low relief (30-90 m) and gentle to very steep slopes, typically with fixed erosional stream channels, closely to very widely spaced, which form a dendritic or convergent integrated tributary pattern. There is continuously active sheet flow, creep, and channelled stream flow.

Pediment
Gently inclined to level (<1% slope) landform pattern of extremely low relief. typically with numerous rapidly migrating, very shallow incipient stream channels which form a centrifugal to diverging integrated reticulated pattern. It is eroded, and locally aggraded, by frequently active channelled stream flow or sheet flow, with subordinate wind erosion. Pediments characteristically lie down-slope from adjacent hills with markedly steeper slopes.

Plateau
Level to rolling landform pattern of plains, rises or low hills standing above a cliff, scarp or escarpment that extends around a large part of its perimeter. A bounding scarp or cliff may be included or excluded; abounding escarpment would be an adjacent landform pattern.

Rises
Landform pattern of very low relief (9-30 m) and very gentle to steep slopes. The fixed erosional stream channels are closely to very widely spaced and form a dendritic to convergent, integrated or interrupted tributary pattern. The pattern is eroded by continuously active to slightly active creep and sheet flow.

Sheet-flood fan
Level (< 1% slope) to very gently inclined landform pattern of extremely low relief with numerous rapidly migrating very shallow incipient stream channels forming a divergent to unidirectional, integrated or interrupted reticulated pattern. The landform pattern is aggraded by frequently active sheet flow and channelled stream flow, with subordinate wind erosion.

Valley Floors
This is applied to valley bottoms when the site, in question, is not on other features that might be present within the valley, such as alluvial or colluvial plains. Alluvial sediments Materials deposited on the landsurface from transport by flowing water confined to a channel or valley floor.

Drainage Definitions

Drainage Pattern
Drainage pattern refers to the plan shapes made by drainage channels on the land surface. It should not be confused with channel pattern, which refers to the plan shape of river reaches. Drainage patterns reflect a number of elements in the landscape. They may reflect underlying rock structures, or the nature of the original surface on which they were developed (Pain et al., 1991) Simple rivers have a dendritic pattern. Complications to a dendritic pattern mean that the drainage has been affected by rock structure or events in its geomorphic history or both. Proper interpretation of drainage patterns contributes to an understanding of the geomorphic history of an area, and so to an understanding of regolith development. Drainage patterns are often one of the oldest features in a landscape, because they are developed very soon after an area is exposed to surface activity, and they can persist through several tectonic and erosional episodes. Drainage patterns described in this report include;

Dendritic
Integrated drainage patterns where small branch channels join, usually at acute angles, to feed a trunk channel. They show no preferred orientation, and are typical of areas where the underlying rock is more or less homogeneous.

Trellis
A drainage pattern where secondary channels flow at right angles to the main channel. The secondary channels are in turn joined at right angles by small tributaries flowing parallel to the main channel. This pattern is common in well bedded rocks, commonly with scarp and dip slopes. Small tributaries on the scarp slopes are short and steep, while those on the dip slopes are longer and more gently sloping.

Drainage Type

Drainage type refers to the relationship between drainage lines and landscape evolution. Currently the following types are recognised.

Superimposed
Superimposed drainage occurs when a river cuts down through rocks of varying hardness from above. Softer rocks are readily removed, but harder rocks remain as higher parts of the landscape. This commonly leads to rivers flowing in gorges right through high areas.

APPENDIX 2

Regolith point attributes

Field site abstract descriptions
Layout;
Site No
Amg coordinates
Abstract description

S1
449981 7603040
Quartz gravel lag and residual red clay (30-40cm) over highly weathered structural saprolite (schist). Landform: Rises (9-30m relief).

S2
451884 7603073
Silicified saprolite (Proterozoic sandstone schist) over mottled bedrock. Landform: Plateau.

S3
451634 7602207
Red clay soils, quartz gravel and ferruginous lithic (40cm) lag over highly weathered saprolite. The saprolite is kaolinised and weakly mottled. Landform: Erosional plains (<9m relief)

S4
452407 7601194
Channel and over bank sediments consisting of sand, silt and clay with lenses of conglomerate. Conglomerate consists of quartz and silicified saprolite and minor Fe nodules in sandy matrix. Landform: Flood plain

S5
453684 7596701
Veneer of sheet wash sand and clays over ferruginous structural saprolite. Gravel lags common. Erosional plain (<9m relief).

S6
453723 7590402
Ferruginous and partly indurated granitic saprolite over mottled bedrock. Forms: local rises and mesas.

S7
455422 7586339
Slabby Fe duricrust and silicified conglomerate over Proterozoic schists and sandstone. The conglomerate is silicified and silicification extends into the Proterozoic basement. Landform: rise

S8
456443 7583571
Ferruginous saprolite over mottled bedrock. Forms local rises surrounded by gravelly pediments. Landform: rises (9-30 metres relief).

S9
458278 7588302
Conglomeritic sandstone (mainly quartz pebbles rounded to sub angular with Fe Oxide staining throughout. Sandstone exhibits reddish orange mottling and is silicified in places (Mesozoic sediments) Landform: low hills and rises.

S10
459221 7589000
Partially silicified sandstone with basal conglomerate over very highly weathered granite (kaolinised, with diffuse reddish orange mottling) Bedrock: granite/Mesozoic sst. Landform: Low hills, plateau top.

S11
459091 7589705
Silicified Mesozoic sandstone over very highly weathered granite. Minerals within the granite have been altered and partially kaolinised with diffuse reddish orange mottling. Bedrock: granite/Mesozoic. Landform: low hills

S12
463415 7596753
Fe duricrust cementing channel sands and gravels forming capping to highly weathered granite. Landform: Plateaux.

S13
463911 7596415
Fe duricrust over highly weathered granite. The granite is strongly bleached (kaolinised) and partially silicified in places. The ironstone exhibits an elongated tubular fabric, mottles infillled with gritty sand and cemented by Fe. Landform mesa. Bedrock granite

S14
461919 7597072
Fe duricrust over ferruginous mottled saprolite. Landform: low hills, ridge.

S15
459762 7591730
Alluvial channel and over bank sediments (5m) consisting of gravel and clay. In places partially indurated by clay and Fe. Landform: Flood plain.

S16
461561 7590893
Slightly weathered granite forming tors. Exfoliated boulders with thin weathering lines. Landform: Rises.

S17
464648 7589911
Partially silicified granite over very highly weathered granite where most minerals have been altered to clay and Fe Oxides. Landform: Low hills.

S18
453310 7585341
Ferruginised structural saprolite surrounded by ferruginous gravel, lithic and sand lags. Landform: Local rise.

S19
445376 7600782
Reddish brown clays over highly weathered saprolite. Carbonate nodules occur within the soil profile and ferruginous lithic lags occur at the surface (derived form haematitic ridges upslope). Landform: footslope

S20
445121 7600709
Ironstone (haematite) forming strike ridges with locally developed Fe scree slopes and footslopes. Landform: Low hills.

S21
442908 7600563
Highly weathered and mottled schist covered in most places by a veneer of residual red clay and ferruginous, lithic and quartz lags. Landform: Erosional plain.

S22
440557 7601078
Sheet wash (10-30cm) and gravel lags (mostly quartz) over granitic saprolite. Landform: Erosional plain.

S23
437760 7602339
Gravel lags and red clay over saprolite (schist, quartzite). Landform: Rise.

S24
436675 7603200
Ferruginous earthy soil over highly weathered schist. Landform: Low hills.

S25
432685 7604466
Highly ferruginous saprolite with a collapsed brecciated fabric over mottled saprolite. Landform: Hill.

S26
431729 7604762
Fe rich gravel lags (amphibolite), residual red clay over saprolite. Patchy outcrop. Swelling cracking clays with Fe nodules. Landform: Erosional plain.

S27
432180 7604838
Ferruginous lithic fragments (siltstone, sandstone) forming gravel lags and swelling calcareous clays. Landform: Erosional plain adjacent to low hills.

S28
424824 7608690
Quartz and ferruginous lithic fragments forming gravel lags over saprolite. Soil: red clay. Landform: erosional plain.

S29
424487 7608250
Silicified siltstone over highly weathered mottled saprolite forming local mesas. Landform: Low hills, plateaux.

S30
422609 7610352
Ferruginous Fe and Quartz lags, red earthy and mottled clays with Fe nodules. Landform: Rises.

S31
426067 7608414
Red sandy earths with quartz and lithic (sandstone lags) over ferruginous saprolite. Local channel alluvium. Landform: Rises.

S32
427416 7607328
Red earths (40cm) with quartz and lithic (sandstone lags) over ferruginous saprolite. Soils contain scattered Fe nodules. Bedrock: schist/amphibolite? Local channel alluvium. Landform: Rises.

S33
429772 7605950
Gravel and cobble lags surrounded by red earthy soils. Bedrock: amphibolite/metabasalt.
Landform: Erosional plain.

S34
433007 7606823
Ferruginous structured saprolite partially covered by lithosols. Landform: Rises.

S35
434769 7608465
Alluvial clay (1m) and silt over highly weathered saprolite. Adjacent areas: bedrock outcrops surrounded by sheetwash gravel lags. Landform: Flood plain.

S36
436395 7609159
Weathered Cambrian calcareous siltstone with vuggy textures. Partly buried by red sandy clays and quartz gravel lags. Landform: rises.

S37
442542 7615479
Red clay soils and gravel lags consisting of quartz, lithic fragments, Fe nodules and pisolites (<1m) over saprolite. Landform: Rises.

S38
447676 7613534
Highly weathered ferruginous saprolite over mottled saprolite. Lithosols. Landform: Hills.

S39
448047 7613576
Highly weathered saprolite with ferruginous gravelly soils grading into mottled saprolite at depth. Minor Fe duricrust. Landform: Bevelled hills.

S40
444501 7598808
Ferruginous clays and gravels infilling cracks and mottles in highly weathered shales. Landform: Bevelled hills and ridges.

S41
441910 7601804
Very highly weathered granite consisting mainly of kaolinite and Fe Oxides. In places silicified. Landform: Mesas .

S42
444994 7600495
Ferruginous saprolite with cemented gravels and clay infilling cracks and mottles, lithosols. Landform: Hills, ridges.

S43
445562 7601717
Ferruginous colluvial gravels and clay over highly weathered saprolite. Landform: Footslope.

S44
448383 7614302
Fe stained bedrock over higly bleached saprolite. Silicified sandstone is scattered float. Bedrock: Schist. Landform: mesa, bevelled ridge.

S45
448271 7614489
Silicified sandstone and quartz gravels with reddish orange mottling over brecciated and mottled schist. Landform: Plateau top.

S46
448299 7614567
Silicified and mottled conglomerate and sandstones over highly weathered and bleached schist. Bedrock: Mesozoic sandstone/schist. Landform: Plateau surface.

S47
448541 7614766
Fe duricrust developed on sediments (minor quartz gravels) with reddish orange mottling over bleached Proterozoic bedrock. Landform: Plateau surface.

S48
448733 7614662
Ferruginous mottled and in places silicified sediments overlying schist. Mesa edge.

S49
448715 7614408
Mesozoic sandstone and conglomerates with fragments of Proterozoic bedrock. Mesa.

S50
445304 7610932
Gritty quartz lags. Residual red clays over very highly weathered saprolite with carbonate veins and fragments. Erosional plain.

S51
47423 7618591
Ferruginous saprolite over mottled saprolite forming local bluffs and mesas. Secondary silicification in places.

S52
450303 7618128
Silcrete breccia and silicified saprolite (Mesozoic sandstone and siltstone) over mottle bedrock. Fe staining throughout. At the surface old silicified mega mottles are in filled with sand. Landform erosional scarp. Bedrock Mesozoic sandstone.

S53
450528 7617986
Massive iron stone and highly ferruginous saprolite over mottled (reddish orange)saprolite (Mesozoic interbedded sandstone). Mega mottled textures at surface. Landform: mesa.

S54
450523 7618262
1-1.5 metres of red clay and gravel alluvium over mottled sandstone (Mesozoic) Gravels include ferruginous and siliceous lithic fragments and Fe nodules. Landform: alluvial Flood plain.

S55
450615 7618443
Silcrete, sand, clay and Fe nodules cemented by silica over silicified saprolite (Mesozoic sandstone) Fe staining and diffuse mottling throughout. Landform: mesa.

S56
450317 7618587
Silicified sandstone (Mesozoic) and Si breccia (.5-1.5 metres) forming indurated capping to mesa.

S57
449686 7618307
Ferruginous saprolite developed on Proterozoic schist. Landform: low hill - rise.

S58
447429 7621222
Ferruginous and partly silicified sandstone and conglomerate (Mesozoic) over mottled (large reddish orange) and bleached (in places silicified) Proterozoic saprolite (schist and siltstone). Landform: Mesa. Bedrock Mesozoic sandstone.

S59
447856 7621557
Silicified, mottled and ferruginous saprolite (Mesozoic) over highly weathered diffusely mottled granitic saprolite (upper part silicified). Landform: mesa.

S60
447533 7619939
Highly ferruginous brecciated saprolite (lithic fragments in a earth red matrix) over ferruginous and mottled (diffuse reddish orange)saprolite. Landform: local bluff.

S61
447137 7620446
Highly ferruginous brecciated saprolite (lithic fragments in a earth red matrix) over ferruginous and mottled (diffuse reddish orange)saprolite. Landform: mesa.

S62
447173 7620325
Red clay earth with a well developed ferruginous lithic lag (1 meter) over saprolite. Landform erosional plain.

S63
447069 7620316
Red clay earth - mantled by a quartz gravel lag (30cm)over saprolite. Landform erosional plain.

S64
455575 7597666
Slabby iron duricrust over diffusely mottled and bleached saprolite (schist). Ferruginous and Fe nodules form a thin lag over the surface. Landform: mesa.

S65
456235 7601174
Massive iron duricrust and mottled saprolite over bleached saprolite (schist). Landform: mesa.

S66
453645 7601150
Sheetwash sands and minor quartz lags and clay. Typically less than 1 meter deep. Landform: erosional plain - sheet flood plain.

S67
441474 7597793
Red earthy clays - mantled by quartz gravel lags over highly weathered saprolite (schist). Landform: erosional plain.

S68
441207 7595801
Silicified quartz gravels (Mesozoic ?) over silicified ferruginous and mottled granitic saprolite. Landform. mesa.

S69
40976 7595689
Silicified conglomerate, sandstone and silcrete over silicified and mottled granitic saprolite. Paleao-channel, inverted relief?. Landform: mesa.

S70
438835 7598384
Ironstone and quartzite ridge protruding from erosional plain. Surrounding plains are mantled by a veneer of quartz and ferruginous lithic lag over red silty loam and highly weathered saprolite. Landform ridges and hills.

S71
437449 7600598
Ferruginous saprolite in places silicified over structured saprolite with diffuse reddish orange mottling. Landform: mesa.

S72
435085 7597479
Red clay earths and silty earths. Patchy sheet wash colluvium and quartz lags. Landform erosional plains.

S73
432959 7592623
Silicified quartz pebble conglomerate (Mesozoic) with Fe staining throughout. Landform: rise.

S74
430280 7591596
Red earthy clay soils developed on alluvial clay, sand and gravel beds (3 metres). Landform: flood plain.

S75
429616 7592787
Brown swelling-cracking clays, minor gritty lag consisting mainly of quartz, ferruginous nodules and fragments. Landform erosional plain.

S76
429319 7591262
Reddish orange clay (non-cracking) with gritty sands and minor quartz gravel lags. Landform; erosional plains.

S77
429438 7589909
Silicified saprolite (mudstone with chert beds) in places covered with a veneer of fine grained silcrete and ferruginous gravels. Landform: rises.

S78
429689 7589712
Silicified alluvial sands and gravels over mottled saprolite (siltstone). Thin gravel lags consists of silcrete and ferruginous lithic fragments. Landform: erosional plain.

S79
429340 7587975
Red clay loam, minor silicified Fe stained sandstone lag. Buckshot gravels common. Landform: erosional plain.

S80
430013 7585999
Silicified claystone with Fe staining. Lags consists of siliceous lithic fragments, buckshot gravels and minor quartz gravels in and red sandy matrix. Landform: erosional plain.

S81
430004 7585265
Ferruginous sandstone (Mesozoic) with quartz gravels. In places covered with a veneers of quartz and lithic lag. Minor buckshot gravels. Red sandy soils. Landform: minor erosional scarp.

S82
430732 7583145
Silicified and ferruginous sandstone (Mesozoic). Silcrete and ferruginous lithic lags. In places silcrete forms massive blocky outcrops. Landform: rises with stepped topography

S83
423635 7590985
Light grey-brown calcareous silty clay soils (bedrock calcareous siltstone, limestone). Mantled by calcareous lithic lag. Landform: erosional plain.

S84
424246 7591375
Silicified and mottled sandstone grading into mottled (soft) saprolite. Silcrete and ferruginous lithic lags. Well rounded as scattered float. Landform: erosional scarp.

S85
448535 7605102
Ferruginous saprolite in places silicified (granite) forming rocky bluffs and bevelled hill tops.
Landform: hills.

S86
444138 7608806
Ferruginous and mottled saprolite (granite). Landform: mesa.

S87
444968 7609128
Highly ferruginous red clays mantled with a veneer of ferruginous lithic lag. Ferruginous saprolite outcrops in places. Landform: rises.

S88
446184 7617554
Highly ferruginous saprolite (schist and meta sandstones) forming bluffs. Minor Fe duricrust.
Landform: rises and low hills.

S89
445900 7617073
Ferruginous saprolite (2 metres) with diffuse reddish orange mottling at depth over bleached (soft) kaolinised saprolite (3 + metres) (bedrock; schist) Landform: low hills.

S90
430186 7621337
Ferruginous and silicified Mesozoic sandstone and conglomerate over ferruginous and mottled saprolite (schist) Landform: mesa.

S91
431832 7617665
Red residual earthy clay mantled by a veneers of ferruginous lithic and quartz lag. Exposed ferruginous saprolite (amphibolite) in places. Landform: erosional plain.

S92
431759 7617054
Alluvial sediments consisting clay, sand and interbedded gravels. Landform: flood plain.

S93
432977 7618753
20-40cm lithic and quartz lag over very highly weathered and mottled saprolite. Red clay. Bedrock: schist. Landform: erosional plain.

S94
434257 7618820
approx 2 metres of alluvial clay with conglomeratic beds. Landform; flood plain.

S95
438982 7618481
Channel conglomerate (1.5 metres) over very highly weathered saprolite (Phyllite).
Landform river channel.

S96
441443 7618165
Quartz, ferruginous saprolite and lithic lags over ferruginous saprolite (sst and siltstone).
Landform: pediments and erosional plains.

S97
445289 7620054
Ferruginous saprolite and lithic gravel lag and lithosols over very highly weathered and mottled saprolite. Landform: rises.

S98
452182 7619118
Silicified and ferruginous over mottled granitic saprolite. Minor Fe duricrust. Fe segregation's developing in the mottles. Landform: mesa.

S99
451557 7618781
Ferruginous sandstone (Mesozoic) over very highly weathered (kaolinised) granitic saprolite.
Landform: mesa.

S100
438429 7603363
Highly ferruginous and in places silicified saprolite forming indurated capping (duricrust). Bedrock Proterozoic schist, sandstone and phyllite. Landform: Mesa

S101
430284 7604324
Lithic and quartz lags in earthy red matrix over saprolite (Phyllite). Patchy outcrop in places.
Landform; erosional plain.

S102
429944 7601287
Gravel lags (quartz gravels and ferruginous lithic fragments) and residual red ferruginous clay over highly weathered saprolite (amphibolite). Landform: erosional plain.

S103
429383 7597029
Residual red clay and minor alluvial clays and sands. In places veneers of quartz and ferruginous lags over highly weathered saprolite. Landform: erosional plains and pediments.

S104
429667 7595195
Several metres of alluvial sand and clay over mottled saprolite. Landform: Flood plain.

S105
430363 7598718
Ferruginous red clay (30-60cm) over saprolite (silicified sandstone). Surface quartz and lithic lag with minor buckshot gravels. Landform: erosional plain and rises.

S106
429750 7600088
Silicified and ferruginous saprolite over mottled saprolite (Cambrian: sandstone, siltstone and claystone)-forming indurated capping. Landform: rise.

S107
430021 7600291
Cracking clay - reddish orange with a veneer of siliceous and ferruginous gravel lags. Landform: erosional plain

S108
462173 7598690
Massive Fe duricrust over mottled saprolite (schist, sandstone and quartzite). Fe duricrust commonly silicified. Landform: bevelled hill top.

S109
458695 7599384
Fe duricrust (partly silicified) over mottled and bleached saprolite (schist, sandstone, quartz veining). Landform: bevelled hill top.

S110
451937 7603025
Silicified structural saprolite. Bedrock; Proterozoic schist.
Landform: mesa

S111
453931 7590565
Very highly weathered ferruginous, mottled and in places silicified granitic saprolite. Bedrock; granite. Landform: mesa.

S112
453451 7590033
Coarse gritty quartz sands containing feldspathic and micaceous grains over highly weathered granitic and mottled granitic saprolite. Sands are largely locally derived. Bedrock; granite. Landform: erosional plains.

S114
462700 7580197
Silicified sandstone and conglomerate (Mesozoic) over bleached (upper part silicified) Proterozoic saprolite (schist and sandstone). Landform: rise.

S115
462226 7580012
White Mesozoic siltstone with diffuse Fe staining surrounded by gravel lags and sheet wash sands. Landform: rises.

S116
455728 7597672
Moderately weathered Fe saprolite (schist) covered in part by lithosols and sandy pockets. Landform: rise

S117
455662 7597623
Silicified and mottled saprolite below slabby Fe duricrust. Landform: low hills.

S118
455584 7597748
Highly weathered partly mottled and silicified saprolite (schist). Landform: low hills.

S119
455578 7597721
Completely weathered Fe cemented duricrust. Slabby Fe duricrust forming resistant capping over mottled and silicified saprolite (schist). Fe segregrations. Landform: mesa.

S120
455498 7597671
Bleached and partly silicified schist. Landform: low hills.

S121
455284 7597914
Bleached and partly silicified schist. Landform: low hills.

S122
455055 7598160
Fe saprolite, non bleached schist. Landform: low hills.

S123
455193 7596028
Very highly weathered, mottled and silicified saprolite (granite) Fe segregrations developing in mottled zone. In places silicified and fe stained sst and clatstone (Mesozoic ?) overly granitic saprolite.
Landform: mesa edge.

S124
454933 7595442
Silicified, bleached and Fe stained saprolite froming resistant capping. Landform: mesa.

S125
454873 7595442
Fe stained and diffusely mottled saprolite (non silicified). Landform: mesa edge.

S126
441902 7590590
Ferruginous sandstone (Mesozoic). X-bedded conglomeratic sst with numerous quartz gravels forming lags surrounding outcrop Landform: local rise (9-30m relief)

S127
440575 7589080
Quartz gravels cemented by Fe unconformable over highly cleaved schist. Landform: mesa.

S128
440603 7589796
Silicified, ferruginised and mottled saprolite. Fe segregrations developing within the mottled zone. Nearby ferruginous Mesozoic overlying saprolite. Landform: mesa. Bedrock: Proterozoic schist.

S129
440736 7590137
Fe rich conglomerate and sst in places silicified forming a erosional scarp edge to mottled and silicified schist. Fe segregation in mottled zone. Landform: mesa. Bedrock: Mesozoic/Proterozoic.

S130
444233 7590872
Highly ferruginous saprolite with Fe cemented breccia fabric (palaeosol?) over mottled saprolite. Quartz veining to surface. Landform: mesa. Bedrock: Proterozoic siltstone & sst.

S131
455422 7586339
Slabby Fe duricrust and silicified conglomerate over diffusely mottled schists and sandstone. Silicification extends into the Proterozoic basement. Landform rise. Bedrock Proterozoic.

S132
463345 7596684
Massive Fe duricrust, slabby in places and containing quartz grit over mottled and bleached saprolite. Appears to be insitu. Landform: mesa. Bedrock: granite.

S133
463918 7596389
Highly bleached and in places silicified saprolite, approx 80 metres below scarp edge. approx 50% of primary minerals altered to clays, fe oxides and secondary silica. Bedrock granite. Landform: Low hills.

S134
459081 7589724
Silicified Mesozoic siltstone over very highly weathered and mottled granitic saprolite with grades into moderately to slightly weathered granite at depth. Landform Mesa. Bedrock Mesozoic/Proterozoic.

S135
443219 7616726
Polymictic gravel lags (ferruginous saprolite, lithic fragments, quartz, buckshot gravels) and course textured soils over highly weathered and mottled schist. Sheet wash colluvium several metres thick in places. Landform: erosional plain/pediments. Bedrock; Proterozoic schist.

S136
447394 7617999
Fe duricrust and Fe segregation in the mottled zone developed in sandstone with minor quartz pebbles. Landform; mesa/ low flat topped hill. Bedrock Mesozoic sst and siltstone.

S137
447634 7617727
Ferruginous sandstone and claystone containing numerous quartz gravels over intensely weathered highly ferruginous saprolite. Fe segregation developing within the mottled zone. Landform; Low Hill. Bedrock Mesozoic over Proterozoic.

S138
447761 7618192
Ferruginous saprolite with well developed Fe segregation developing within the mottled zone. Saprolite between Fe segregation largely weathered to clay (kaolinite ?) Landform mesa local bluff

S139
447521 7618422
Highly ferruginous saprolite with diffuse reddish orange mottling. Argillaceous units altered to clay. Landform: flat topped hill. Bedrock: Proterozoic schist.

S140
447616 7613134
Ferruginous breccia with Fe segregation over mega mottled saprolite over ferruginous diffusely mottled moderately weathered saprolite. Weathering profile approx 40 metres to moderately weathered saprolite. Landform: mesa - bluff. Bedrock: Proterozoic sediments.

S141

448394 7614340

Silicified sandstone and quartz gravels with reddish orange mottling over brecciated, mottled and highly bleached schist. Landform Plateau top. Bedrock: Proterozoic schist

APPENDIX 3

Polygon unit description summary.

Regolith-landform Unit

	DFls1	DFls2	DFls3
Regolith; Profile desc	Massive & collasped ferruginous saprolite over mottled and bleached saprolite. Minor slabby duricrust	Massive blocky Fe duricrust over ferruginous and mottled saprolite. Duricrust is associated with massive stratigraphic hematitic beds.	Massive and in places slabby Fe duricrust over ferruginous, mottled and bleached saprolite. Bleached zone typically > 20m thick
Soil & lags	Lithosols, lags of lithic fragments, Fe duricrust gravels and pisoliths.	Lithosols; lags of ferruginous lithic gravels, fragments of Fe duricrust and pisoliths.	Lithosols, lags of ferruginous lithic gravels, fragments of Fe duricrust, pisoliths & gritty sands.
Landforms	Plateaux, mesas & buttes	Flat top hills, minor plateaux	Plateaux. mesas & buttes
Bedrock lithology	Proterozoic; meta-siltstone, meta-arenite, gneiss, schist, phyllite and quartzite.	Proterozoic; meta-siltstone, meta-arenite, gneiss, schist, phyllite and quartzite.	Proterozoic; foliated and non-foliated biotite granite, hornblende-biotite granite, tonalite and granodiorite.
Regolith Induration	Massive Fe duricrust & segregations. In places silicification of bleached and mottled zone.	Massive Fe duricrust & segregations. Minor Fe cemented angular colluvial gravels.	Massive Fe duricrust & segregations. Silicification of mottled and bleached zones.

Regolith-Landform Unit

	DSls1	DFls4	DFls5
Regolith; Profile desc	Mottled silcrete, silicified and bleached saprolite. Upper part of the profile is iron-stained and mottled. Feldspars and micas weathered to clay (kaolinite) and iron oxides. Bleached zone typically > 20m thick	Massive Fe duricrust and highly ferruginous saprolite over mottled (irregular to mega sub-circular) and in places bleached bedrock. Underlying Proterozoic bedrock is typically very highly weathered.	Ferruginous saprolite with patches of massive Fe duricrust over mottled (irregular to mega sub-circular) and in places bleached bedrock. Underlying Proterozoic bedrock is typically very highly weathered.
Soil & lags	Lithosols, lags of silicified and ferruginous saprolite.	Lithosols, lags of Fe duricrust fragments, lithic and siliceous gravels.	Lithosols, lags of Ferruginous saprolite, lithic and siliceous gravels.
Landforms	Plateaux, mesas & buttes	Plateaux, mesas & buttes	Plateaux, mesas & buttes
Bedrock lithology	Proterozoic; foliated and non-foliated biotite granite, hornblende-biotite granite, tonalite and granodiorite.	Mesozoic sediments; sandstone, siltstone, mudstone & conglomerate	Mesozoic sediments; sandstone, siltstone, mudstone & conglomerate
Regolith Induration	Silrete & silicificied saprolite (bleached zone) Minor Fe duricrust.	Massive Fe duricrust, silicified saprolite and minor silcrete.	Minor Massive Fe duricrust, ferruginous and in places siliceous saprolite. Minor silcrete

	DSls2	Sls1	Sel2
Regolith; Profile desc	Silicified, ferruginous and mottled saprolite. Re-cemented ferruginous and siliceous collasped saprolite common.	Silicified and bleached saprolite. Feldspars and micas weathered to clay (kaolinite) and fe oxides. Bleached zone typically > 10m thick Minor Fe duricrust.	Partly silicified and weakly mottled bleached saprolite (several 10s of metres thick). The upper part of the profile is ferruginous and mottled.
Soil & lags	Lithosols, lags of lithic fragments, silicified and ferruginous saprolite fragments	Lithosols; lags of silicified saprolite, minor fragments of Fe duricrust.	Lithosols consisting of ferruginous/bleached lithic fragments, gravels and minor Fe duricrust nodules and pisoliths.
Landforms	Plateaux, mesas & buttes	Low hills, mesas, plateaux and dissected plateaux.	Low hills, minor scarps and rises.
Bedrock lithology	Cambrian; siltstone, sandstone, limestone, chert. silicified shale and dolomite.	Proterozoic; meta-siltstone, meta-arenite, gneiss, schist, phyllite and quartzite.	Proterozoic; meta-siltstone, meta-arenite, gneiss, schist, phyllite and quartzite.
Regolith Induration	Silicified saprolite	Silicified saprolite, minor Fe duricrust gravels.	Silicified saprolite, minor Fe duricrust gravels.

Regolith-landform Unit

	Sep3	Sep4	Sep5
Regolith; Profile desc	Ferruginous and mottled saprolite. Mottled zone overlies bleached saprolite. Partly covered by	Mottled saprolite partly covered by lithosols and lags.Upper part of the profile typically highly ferruginous.	Highly weathered mottled saprolite covered by extensive veneers of residual soils and lags. Minor alluvium along stream channels.
Soil & lags	Lags of ferruginous and silicified saprolite, quartz and lithic fragments. In places lags overlie bleached saprolite.	Thin soils and lags of highly ferruginous saprolite fragments and lithic gravels.	Residual clay/gravelly soils and lags of ferruginous saprolite, quartz, lithic fragments and minor Fe pisoliths and ferruginous gravels.
Landforms	Erosional plains.	Highly dissected erosional plain (< 9m relief).	Erosional plain (<9m relief)
Bedrock lithology	Proterozoic; meta-siltstone, meta-arenite, gneiss, schist, phyllite and quartzite.	Proterozoic; meta-siltstone, meta-arenite, gneiss, schist, phyllite and quartzite.	Proterozoic; meta-siltstone, meta-arenite, gneiss, schist, phyllite and quartzite.
Regolith Induration	Silicified and ferruginous saprolite	Ferruginous saprolite	Ferruginous saprolite

	Sep6	Ser7	Sel8
Regolith; Profile desc	Mottled saprolite covered by extensive lags.Narrow tracts of alluvium along some stream channels.	Mottled and ferruginous saprolite partly covered by lithosols and lithic lags.	Ferruginous and diffusely mottled saprolite. Colluvial gravels are associated with fans and aprons flanking steeper slopes. Minor river sediment.
Soil & lags	Polymictic gravel lags (generally < 1.0 metres thick) of ferruginous lithic and saprolite fragments, minor quartz, Fe pisoliths and ferruginous gravels.	Lithosols and lags of ferruginous lithic fragments and quartz. Gravelly red silt/clay soils.	Saprolite partly covered gravelly soils and lags.
Landforms	Erosional plains and minor pediments	Rises (9-30m relief).	Low hills (30-90m relief).
Bedrock lithology	Proterozoic; meta-siltstone, meta-arenite, gneiss, schist, phyllite and quartzite.	Proterozoic; meta-siltstone, meta-arenite, gneiss, schist, phyllite and quartzite.	Proterozoic; meta-siltstone, meta-arenite, gneiss, schist, phyllite and quartzite.
Regolith Induration	Ferruginous saprolite	Ferruginous saprolite	Ferruginous saprolite

Regolith-landform Unit

	Seh9	See10	Sel11
Regolith; Profile desc	Saprock	Saprock. Weathering is variable ranging from highly weathered bleached and silicified bedrock to slightly weathered bedrock.	Fe-rich saprolite largely covered by lags.
Soil & lags	Saprolite partly covered by lithosols and colluvium flanking steep hill slopes.	Saprock partly covered by scree and lithosols.	Lags of Fe duricrust fragments and ferruginous lithic gravels. Red clay soils with minor meta-basalt and Fe nodules.
Landforms	Hills (90-120m relief)	Escarpment	Erosional plains, minor pediments (< 9m relief).
Bedrock lithology	Proterozoic; meta-siltstone, meta-arenite, gneiss, schist, phyllite and quartzite.	Proterozoic; meta-siltstone, meta-arenite, gneiss, schist, phyllite and quartzite.	Proterozoic; Amphibolites & meta-basalt
Regolith Induration	nil	In places silicified saprolite	Ferruginous saprolite

	Ser12	Sel13	Sls14
Regolith; Profile desc	Highly ferruginous and diffusely mottled saprolite. Locally developed Fe duricrusts and Fe segregations.	Highly ferruginous bedrock associated with stratigraphic hematitic beds.	Siliceous, ferruginous (fe staining), mottled and bleached saprolite. Feldspars and micas weathered to clay (kaolinite) and iron oxides.
Soil & lags	Saprolite partly covered by highly ferruginous lithic gravel lags and reddish orange clays/fine sands.	Saprolite partly covered by ferruginous gravel lags, beds lithosols and pockets of red clay soil over massive diffusely mottled hematitic bedrock.	Lags of ferruginous and silicified saprolite and quartz gravels. Minor Fe duricrust.
Landforms	Rises, minor low hills (30-90m relief).	Low hills (30-90m relief) and ironstone ridges	Plateaux, mesas
Bedrock lithology	Proterozoic; meta-siltstone, meta-arenite, gneiss, schist, phyllite and quartzite.	Proterozoic; Quartz-hematite beds	Proterozoic; foliated and non-foliated biotite granite, hornblende-biotite granite, tonalite and granodiorite.
Regolith Induration	Minor Fe duricrust and segregations	Ferruginous saprolite	Silicification of bleeached zone

Regolith-landform Unit

	Sel15	Ser16	Sep17
Regolith; Profile desc	Ferruginous saprolite and mottled saprolite over bleached bedrock. Most feldspars and micas weathered to clays and Fe oxides.	Ferruginous and mottled saprolite over bleached saprolite. Most of the soluble minerals in the upper part of the profile have weathered to clays (kaolinite) and Fe oxides.	Bleached granitic saprolite.
Soil & lags	Lithosols and gravel lags over saprolite.	Saprolite partly covered by lithosols and gravel lags	Saprolite partly covered by lithic lags, residual clay and sandy soil.
Landforms	Low hills (30-90m relief) and minor scarps	Rises and mesas (9-30 metres relief).	Erosional plains (< 9m relief).
Bedrock lithology	Proterozoic; foliated and non-foliated biotite granite, hornblende-biotite granite, tonalite and granodiorite.	Proterozoic; foliated and non-foliated biotite granite, hornblende-biotite granite, tonalite and granodiorite.	Proterozoic; foliated and non-foliated biotite granite, hornblende-biotite granite, tonalite and granodiorite.
Regolith Induration	Silicification in mottled and upper part of the bleached zone	In places silicified saprolite	

	Sep18	Ser19	Sel20
Regolith; Profile desc	Granitic saprolite covered by extensive residual sands and lags. Local river channel alluvium and sheet flow sediment of sand and gravel.	Upper part of the profile is ferruginous & diffusely mottled. About half of primary minerals (feldspars and micas) weathered to clays and oxides.	Upper part of the profile is ferruginous and diffusely mottled with most of the primary minerals weathered to clays and oxides. Minor river channel alluvium and sheetflow colluvium.
Soil & lags	Residual sands (generally < 1.0 m) and gravel lags of mica, quartz and feldspar sands; siliceous & ferruginous and bleached saprolite fragments and minor fragments of Fe duricrust.	Partly covered by gritty sands and lithic gravels.	Gravel scree and lithosols on steeper slopes.
Landforms	Erosional plains (< 9m relief).	Rises (9-30m relief).	Low hills (30-90m relief).
Bedrock lithology	Proterozoic; foliated and non-foliated biotite granite, hornblende-biotite granite, tonalite and granodiorite.	Proterozoic; foliated and non-foliated biotite granite, hornblende-biotite granite, tonalite and granodiorite.	Proterozoic; foliated and non-foliated biotite granite, hornblende-biotite granite, tonalite and granodiorite.
Regolith Induration		Ferruginous saprolite	Ferruginous saprolite

Regolith-landform Unit

	See21	Sep22	Ser23
Regolith; Profile desc	Saprock. Weathering is variable ranging from highly weathered mottled, bleached and silicified bedrock to slightly weathered bedrock.	Ferruginous saprolite covered by a veneer of residual soils and lags.	Ferruginous and mottled saprolite, in places silicified,
Soil & lags	Saprolite partly covered by scree and lithosols.	Residual sands, clay and lags. Lags of highly ferruginous saprolite and lithic fragments. Minor siliceous lithic gravel	Saprolite partly covered by lithosols and gravel lags.
Landforms	Escarpment.	Erosional plains (<9m relief).	Rises (9-30m relief).
Bedrock lithology	Proterozoic; foliated and non-foliated biotite granite, hornblende-biotite granite, tonalite and granodiorite.	Mesozoic sediments; sandstone, siltstone, mudstone & conglomerate	Mesozoic sediments; sandstone, siltstone, mudstone & conglomerate
Regolith Induration	Minor silicified saprolite	Ferruginous saprolite	

	Sep24	Sel25	See26
Regolith; Profile desc	Ferruginous saprolite covered by residual sand , clay and lags. Saprolite is typically mottled and partly silicified.	Ferruginous and mottled saprolite and saprock. In places the saprolite is bleached and silicified.	Saprock, Fe-stained and diffusely mottled saprolite.
Soil & lags	Lags of ferruginous lithic & Fe duricrust fragments, quartz pebbles and silcrete gravels in a reddish orange sandy to silty soil matrix.	Saprolite partly covered by lithosols.	Saprolite partly covered by scree and lithosols.
Landforms	Erosional plains (< 9m relief).	Low hills (30-90m relief).	Escarpment
Bedrock lithology	Mesozoic sediments; sandstone, siltstone, mudstone & conglomerate	Mesozoic sediments; sandstone, siltstone, mudstone & conglomerate	Mesozoic sediments; sandstone, siltstone, mudstone & conglomerate
Regolith Induration	minor silicified saprolite	Ferruginous and silicified saprolite	

Regolith-landform Unit

	Sep27	Sel28	Sep29
Regolith; Profile desc Soil & lags	Ferruginous and mottled saprolite. Saprolite mostly covered by thin lithic gravel lags and lithosols.	Mottled and in places ferruginous and silicified saprolite. Saprolite partly covered by gravelly lithosols.	Ferruginous and mottled saprolite. Saprolite is covered by an extensive but thin blanket of gravel lags, of ferruginous, lithic and Fe duricrust fragments, quartz pebbles & silcrete gravels. Residual reddish orange sandy soils.
Landforms	Erosional plains (< 9m relief) minor pediments.	Low hills (30-90m relief).	Erosional plains (< 9m relief).
Bedrock lithology	Cambrian; siltstone, sandstone, limestone, chert, silicified shale and dolomite.	Cambrian; siltstone, sandstone, limestone, chert, silicified shale and dolomite.	Cambrian; siltstone, sandstone, limestone, chert, silicified shale and dolomite.
Regolith Induration	Ferruginous saprolite	Ferruginous saprolite	Ferruginous saprolite

	Sep30	Sep31	Ser32
Regolith; Profile desc Soil & lags	Mottled saprolite largely covered by residual soils and lags. Soils of pale grey to brown silty clays and calcareous clays with minor calcareous lithic and chert lags.	Mottled saprolite covered by extensive soils. Soils; hard setting residual dull green to reddish brown clays, swelling gilgai soils and minor gravel lags.	Ferruginous and in places silicified saprolite. Saprolite mostly covered by thin stoney lithosols, lags and residual soils. Lags of ferruginous saprolite, lithic fragments, chert, silcrete and residual clays.
Landforms	Erosional plains (< 9m relief).	Erosional plains (< 9m relief).	Rises (9-30m relief).
Bedrock lithology	Cambrian; siltstone, sandstone, limestone, chert, silicified shale and dolomite.	Cambrian; siltstone, sandstone, limestone, chert, silicified shale and dolomite.	Mesozoic sediments; sandstone, siltstone, mudstone & conglomerate
Regolith Induration			Ferruginous and silicified saprolite

Regolith-landform Unit

	See33	ACaf	AOao
Regolith; Profile desc Soil & lags	The upper part of the weathering profile typically ferruginous, mottled. Saprolite partly covered by lithosols.	Recent alluvium consisting of interbedded gravel, sand and clay with local lenes of unconsolidated cobble conglomerate. Soils are reddish brown and grey sandy earths.	Overbank and channel overflow deposits consisting mainly of sand, clay and minor gravels. Typically thin and overlie residual sands, clays and saprolite.
Landforms	Escarpment	Flood plains, channel floors.	Flood out and flood plains.
Bedrock lithology	Cambrian; siltstone, sandstone, limestone, chert, silicified shale and dolomite.	unknown	unkown
Regolith Induration	Ferruginous saprolite	In places partly cemented by clay, Fe or silica to form hardpans	

	AAol	Aaf	CHpd1
Regolith; Profile desc Soil & lags	Alluvial terrace sediments consisting of interbedded sand, clay and gravel. In places truncated palaeosols indicate several cycles of deposition, erosion and weathering. Mottled reddish brown earths and duplex soils.	Undifferentiated alluvial channel and overbank sediments consisting of various proportions of clay, sand and gravel. Typically intermixed with minor colluvial footslope deposits adjacent to scarps, low hills and hills.	Sheet flow consisting of silty clay loam, clay and sand. Local cracking clay soils (gilgai micro-relief). Sediments typically > 1.5m thick and overlie very highly weathered and mottled saprolite. Minor alluvium & residual soils. Extensive lags consist of ferruginous saprolite, lithic fragments and quartz with minor Fe duricrust fragments and Fe pisoliths.
Landforms	Alluvial terraces	Flood plains.	Depositional plains
Bedrock lithology	unknown	unknown	unknown
Regolith Induration			

Regolith-landform Unit

	CHpd2	CHei1	CHei2
Regolith; Profile desc	Sheet flow & residual deposits consisting of various proportions of clay, sand & gravel. Local cracking clay soils. Typically < 1.5m thick & overlie very highly weathered & mottled saprolite. Minor alluvium.	Sheet flow colluvial and minor alluvial deposits forming a veneer (generally < 1m thick) of sand, clay and gravel over mottled and typically bleached saprolite.	Sheet flow quartzose feldspathic sand, clay and gravels (generally < 1m thick) derived from granitic saprolite. Minor channel alluvium and residual sand. Protruding tors common.
Soil & lags	Extensive lags consist of ferruginous saprolite, lithic fragments and quartz with minor Fe duricrust fragments and Fe pisoliths.	Gravelly lags are common and consist of ferruginous saprolite, quartz and lithic fragments.	Lags consist of siliceous, ferruginous and bleached saprolite fragments, quartz and Fe duricrust fragments.
Landforms	Depositional/erosional plains	Pediments	Pediments and erosional plains.
Bedrock lithology	unknown	likely to be mainly metamorphic bedrock	likely to be mainly granitic bedrock
Regolith Induration			

	CHei3	CHei4	CFfc1
Regolith; Profile desc Soil & lags	Colluvial and alluvial clay, sand and gravel over ferruginous and mottled saprolite.	Colluvial sheet flow sands and lags consisting of lithic fragments and ferruginous gravels over highly weathered typically mottled and ferruginous saprolite. Minor alluvial sand and gravel.	Colluvial footslope gravelconsisting of quartz, ferruginous saprolite and lithic fragments in a coarse sandy to gravelly earthy matrix.
Landforms	Pediments.	Pediments.	Footslopes.
Bedrock lithology	unknown	Likely to be mainly Cambrian sediments	unknown
Regolith Induration			

Regolith-landform Unit

	CFfc2		
Regolith; Profile desc Soil & lags	Colluvial footslope deposits consisting of highly ferruginous saprolite, Fe duricrust fragments, Fe pisoliths and lithic fragments in a ferruginou matrix.		
Landforms	Footslopes, minor pediments.		
Bedrock lithology	unknown		
Regolith Induration			

APPENDIX 4 - Major and trace element geochemistry of selected regolith materials collected over the Selwyn map sheet area.

Sample no	Eastings	Northings	Regolith & sample depth (m) S= surface	Geology	SiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O
sel13a	463911	7596416	fe duricrust (s)	granite	6.56	3.06	77.34	0.006	0.05	0.01	-0.03
sel13b	463911	7596416	mottled & partly Si saprolite (3.5)	granite	71.37	18.4	1.11	0.005	0.05	0.06	0
sel20	445123	7600711	fe stone hematitic beds (s)	quartz hematite	10.43	1.45	86.46	0.013	0.09	-0.01	0.01
sel109	458695	7599384	fe duricrust (s)	schist	24.61	16.26	48.33	0.026	0.05	0.02	0.02
sel136	447394	7617999	fe duricrust (s)	mesozoic sst	31.28	8.39	51.98	0.008	0.07	0.16	0.03
sel116	455728	7597672	ferruginous saprolite (s)	schist	61.61	18.87	6.61	0.031	2.27	0.29	0.36
sel117	455662	7597623	silicified & mottled saprolite (s)	schist	76.08	10.8	5.69	0.016	0.77	0.05	0.08
sel118	455584	7597748	saprolite (s)	schist	69.12	18.56	1.79	0.005	0.37	0.05	0.17
sel119	455578	7597721	fe duricrust (s)	schist	3.88	3.31	79.42	0.005	0.08	0.01	-0.02
sel120	455498	7597671	bleached saprolite (s)	schist	72.98	16.56	1.36	0.005	0.27	0.03	0.17
sel121	455284	7597914	bleached saprolite (s)	schist	62.25	23.36	2.22	0.007	0.51	0.04	0.39
sel122	455055	7598160	non bleached saprolite (s)	schist	57.53	21.43	7.31	0.038	1.87	0.24	0.42
sel140a	447615	7613120	fe segregations in mottled fabric (.5)	schist and meta-sst	12.67	9.82	68.08	0.016	0.05	0.03	0
sel140b	447615	7613120	white clay between fe segrations (.5)	schist and meta-sst							
sel140c	447615	7613120	white clay mottled zone (5)	schist and meta-sst							
sel140d	447615	7613120	ferruginous mottles (5)	schist and meta-sst							
sel140e	447615	7613120	ferruginous & diffusely mottled saprolite (36)	schist and meta-sst	55.18	24.83	9.11	0.049	0.08	0.04	0.01
sel141a	448394	7614340	ferruginous breccia (s)	schist	73.79	15.78	1.5	0.007	0.49	0.14	0.05
sel141b	448394	7614340	mottled & fe stained saprolite (2)	schist	80.2	13.04	0.61	0.009	0.13	0.03	0.03
sel141c	448394	7614340	bleached saprolite (8)	schist	72.72	17.5	0.74	0.005	0.33	0.02	0.13
sel141d	448394	7614340	bleached saprolite (15)	schist	81.34	12.18	0.59	0.007	0.19	0.03	0.03
sel141e	448394	7614340	ferruginous saprolite (30)	schist	66.26	16.4	6.97	0.02	0.76	0.03	0.19
sel133a	463918	7596387	bleached & silicified saprolite (3)	granite	69.5	19.99	1.36	0.008	0.06	0.05	0.01
sel133b	463918	7596387	bleached & partly silicified saprolite (20)	granite	67.42	19.81	1.34	0.011	0.13	0.04	0.15
sel133c	463918	7596387	moderately weathered saprolite (50)	granite	76.36	13.38	0.45	0.003	0.08	0.08	0.11
sel64a	455575	7597660	fe duricrust (s)	mesozoic sst	4.65	4.53	79.28	0.005	0.07	0.01	-0.01
sel7	455575	7597660	silicified conglomerate (2)	mesozoic conglomerate	80.35	12.74	0.84	0.005	0.13	0.03	0.07
sel64b	455575	7597660	feurruginous & mottled saprolite (3)	schist	73.39	15.67	2.28	0.006	0.21	0.06	0.15
sel64c	455575	7597660	bleached saprolite (5)	schist	64.65	21.91	2.18	0.006	0.51	0.03	0.38
sel131c	455575	7597660	non bleached saprolite (20)	schist	65.33	17.38	7.29	0.012	0.33	0.04	0.38
sel137a	447634	7617727	highly ferruginous sst (1)	mesozoic sst	39.04	12.23	39.36	0.007	0.05	0.02	0.01
sel137b	447634	7617727	fe segregations (25)	calc silicate	22.61	20.24	44.94	0.02	0.13	0.07	0.03

Sample no	K2O	TiO2	P2O5	Ba	Ce	Cl	Cr	Co	Cu	Ga	La	Ni
sel13a	0.03	0.1	0.136	495	24	90	18	-1	61	0	-8	71
sel13b	0.33	0.69	0.033	184	52	20	7	3	14	24	53	9
sel20	0.31	0.15	0.017	27	18	-50	23	17	108	12	-2	48
sel109	0.1	1.46	0.05	15	13	-10	282	2	48	30	-6	78
sel136	0.16	0.37	0.2	253	30	120	170	-7	463	19	2	30
sel116	5.96	0.62	0.207	589	103	450	86	17	18	25	61	85
sel117	1.95	0.41	0.051	537	100	80	77	9	51	15	64	65
sel118	3.47	0.63	0.125	1359	320	-10	72	1	3	23	217	8
sel119	0.13	0.14	0.404	30	33	20	85	-3	79	12	-1	529
sel120	2.78	0.65	0.01	643	25	-40	57	3	14	21	14	3
sel121	6.06	0.64	0.038	1109	145	-30	97	2	0	31	83	-1
sel122	6.84	0.59	0.163	901	104	300	99	11	88	31	57	523
sel140a	0.01	0.82	0.041	175	23	-30	315	-5	83	50	-8	28
sel140b												
sel140c												
sel140d												
sel140e	0.1	0.89	0.02	1415	80	-60	55	2	26	32	18	27
sel141a	0.29	0.99	0.032	350	17	-40	36	4	13	24	19	14
sel141b	1.28	0.57	0.005	84	12	-50	24	1	4	14	2	0
sel141c	3.62	0.71	0.002	440	9	-70	59	4	0	18	-2	12
sel141d	1.75	0.61	0.078	242	144	-70	39	2	5	15	101	-4
sel141e	4.12	0.76	0.043	449	58	270	77	4	233	22	44	60
sel133a	0.55	0.73	0.036	578	91	50	7	1	14	24	102	62
sel133b	3.8	0.66	0.149	1297	462	330	3	-2	14	24	329	13
sel133c	4.59	0.25	0.055	1333	223	210	-4	4	102	13	145	13
sel64a	0.14	0.12	0.15	20	10	160	195	-2	32	8	-13	-12
sel7	0.91	0.39	0.048	149	105	0	31	3	13	10	74	49
sel64b	2.09	0.59	0.013	1111	13	-20	55	0	4	20	2	-2
sel64c	5.68	0.57	0.027	1026	118	-40	79	1	23	29	63	51
sel131c	3.38	0.55	0.096	874	39	90	72	1	93	23	14	38
sel137a	0.08	0.54	0.07	87	72	80	59	-4	630	15	182	8
sel137b	0.02	0.53	0.266	186	158	0	73	19	1375	25	174	48

Sample no	Cr	Co	Cu	Ga	La	Ni	Nb	Pb	Rb	S	Sr	V
sel13a	18	-1	61	0	-8	71	1	5	6	480	11	37
sel13b	7	3	14	24	53	9	29	18	18	40	48	37
sel20	23	17	108	12	-2	48	4	-2	19	-30	3	58
sel109	282	2	48	30	-6	78	6	15	4	370	6	968
sel136	170	-7	463	19	2	30	6	17	3	1410	42	421
sel116	86	17	18	25	61	85	11	12	290	-20	21	80
sel117	77	9	51	15	64	65	7	16	222	60	67	49
sel118	72	1	3	23	217	8	14	20	109	170	167	72
sel119	85	-3	79	12	-1	529	-1	8	4	720	6	53
sel120	57	3	14	21	14	3	14	11	86	110	14	54
sel121	97	2	0	31	83	-1	12	12	208	80	71	86
sel122	99	11	88	31	57	523	12	15	289	-10	26	91
sel140a	315	-5	83	50	-8	28	9	14	0	930	5	1039
sel140b												
sel140c												
sel140d												
sel140e	55	2	26	32	18	27	20	14	10	300	5	82
sel141a	36	4	13	24	19	14	16	20	13	60	37	72
sel141b	24	1	4	14	2	0	6	13	56	0	13	47
sel141c	59	4	0	18	-2	12	13	18	97	-30	22	89
sel141d	39	2	5	15	101	-4	11	21	61	20	116	62
sel141e	77	4	233	22	44	60	12	19	273	40	42	89
sel133a	7	1	14	24	102	62	30	18	37	120	52	44
sel133b	3	-2	14	24	329	13	27	24	175	310	377	66
sel133c	-4	4	102	13	145	13	14	22	136	440	80	24
sel64a	195	-2	32	8	-13	-12	0	12	3	800	8	69
sel7	31	3	13	10	74	49	6	13	31	20	72	33
sel64b	55	0	4	20	2	-2	11	13	57	160	50	62
sel64c	79	1	23	29	63	51	11	10	187	200	53	64
sel131c	72	1	93	23	14	38	11	17	116	160	54	82
sel137a	59	-4	630	15	182	8	7	24	6	160	70	176
sel137b	73	19	1375	25	174	48	16	22	5	200	165	237

Sample no	Y	Zn	Zr	OXIDES	TotalTr	lod	loi	total
sel13a	1	20	40	87.3	1352	0.35	11.91	99.6
sel13b	15	4	354	92	926	1.03	7.22	100.2
sel20	45	13	24	98.9	326	0.13	0.37	99.4
sel109	8	16	148	90.9	1989	0.67	8.93	100.5
sel136	8	18	119	92.7	3126	0.27	7.1	100.1
sel116	27	24	140	96.8	2015	0.16	2.78	99.7
sel117	23	16	299	95.9	1755	0.39	3.5	99.8
sel118	36	4	126	94.3	2715	0.22	4.57	99.1
sel119	2	15	23	87.3	1610	0.4	12.26	100
sel120	16	4	163	94.8	1217	0.55	4.58	99.9
sel121	20	3	130	95.5	2055	0.19	4.06	99.7
sel122	37	17	114	96.4	2712	0.07	3.14	99.6
sel140a	2	15	188	91.5	2834	0.4	8.04	99.9
sel140b								
sel140c								
sel140d								
sel140e	12	5	272	90.3	2318	0.44	9.67	100.4
sel141a	12	11	226	93.1	911	0.55	6.61	100.3
sel141b	10	3	221	95.9	458	0.18	4.02	100.1
sel141c	15	6	223	95.8	931	0.07	3.63	99.5
sel141d	14	3	287	96.8	1064	0.09	3.3	100.2
sel141e	20	39	211	95.6	1959	0.2	3.81	99.6
sel133a	13	7	431	92.3	1681	0.39	7.39	100.1
sel133b	15	6	359	93.5	3831	0.23	6.01	99.7
sel133c	27	2	169	95.4	2952	0.79	3.66	99.9
sel64a	3	11	43	88.9	1352	1.13	10.2	100.2
sel7	14	24	109	95.5	755	0.37	4.18	100
sel64b	18	3	207	94.5	1761	0.53	4.62	99.7
sel64c	28	2	110	95.9	2018	0.31	3.81	100
sel131c	13	49	166	94.8	1916	0.19	4.61	99.6
sel137a	10	12	135	91.4	1731	0.22	8.68	100.3
sel137b	35	48	243	88.9	3025	1.02	10.56	100.5

Appendix 5 - Regolith Landform and GIS thematic maps

A3 copies of the regolith-landform and derivative maps are enclosed. Hradcopy prints of the regolith-landform (Appendix 5.1) and the Geochemical Sampling Strategy map (Appendix 5.4) will be provided to sponsors in two scales;

- poster size plots (non standard scale) with full map surrounds (Appendix 5.1 = regolith-landform map and Appendix 5.4 sampling strategy map), and

- standard plots (1:100 000) with reference only (Appendix 5.1a = regolith-landform map and Appendix 5.4a sampling strategy map)

These maps will be supplied to sponsors in a map tube which will accompany this report. Postscript files of all the maps shown in appendix 5 will be supplied to sponsors on CDrom. These maps include;

- Regolith-Landforms (Appendix 5.1)

- Palaeo surfaces and highly weathered Regolith over Landsat TM (band 5) (Appendix 5.2)

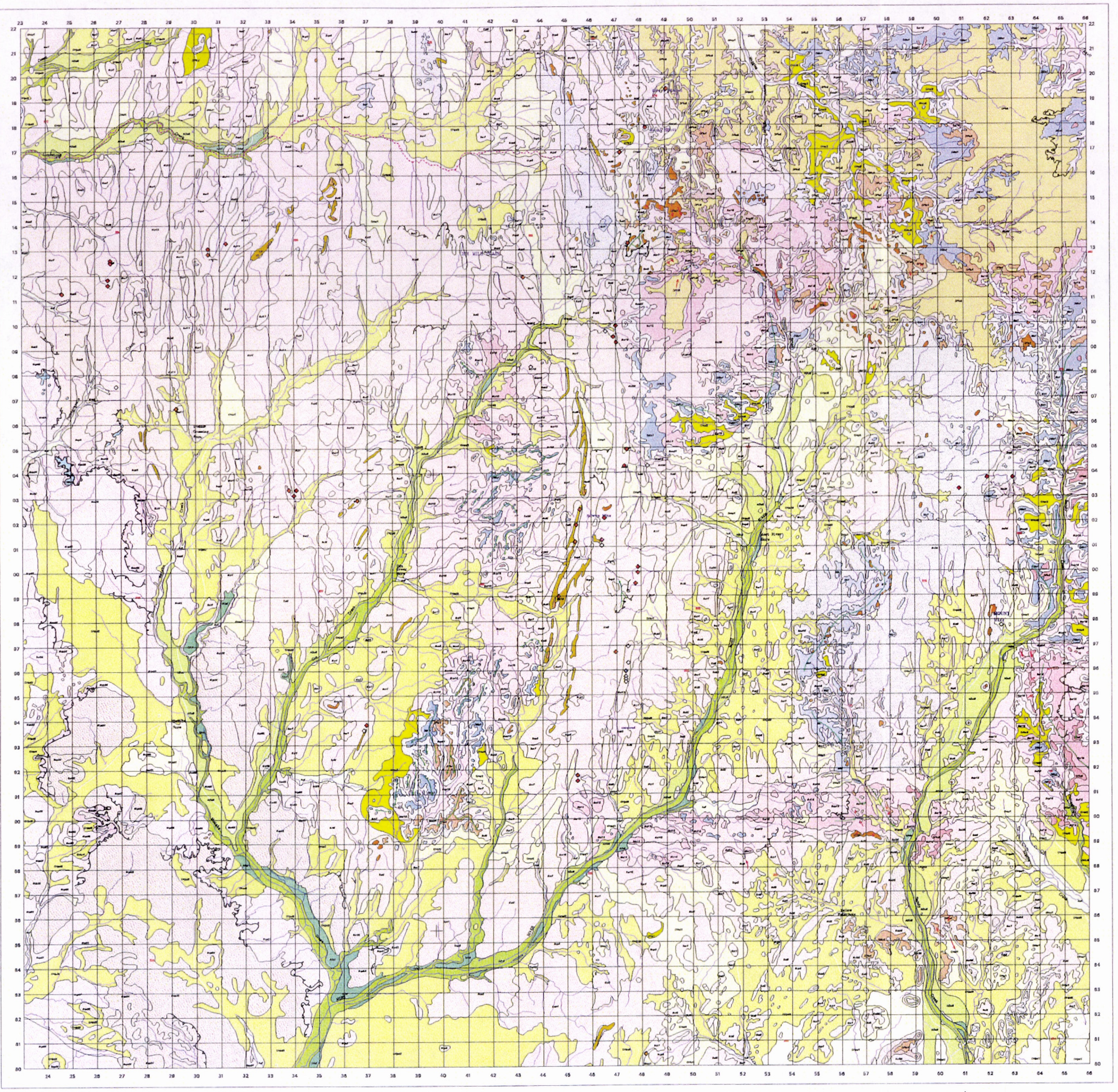
- Regolith-landform Units over 3-Band Landsat TM image, (Appendix 5.3) and

- Interpretative Geochemical Sampling Strategy Map (Appendix 5.4)

Regolith polygons and associated attributes will also be supplied digitally on CDrom in MapInfo format. The CDrom will be supplied when all reports and maps have been sent to sponsors.

Appendix 5.1

SELWYN Regolith - Landforms



REGOLITH TYPES

Major bedrock type

Duricrust

Metamorphics

Granite

Mesozoic sediments

Cambrian sediments

Saprolite

Metamorphics

Granite

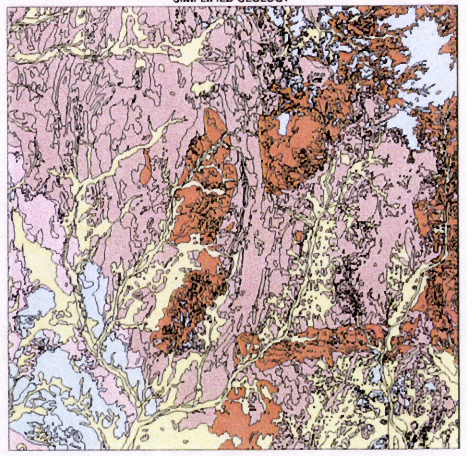
Mesozoic sediments

Cambrian sediments

Alluvial sediments

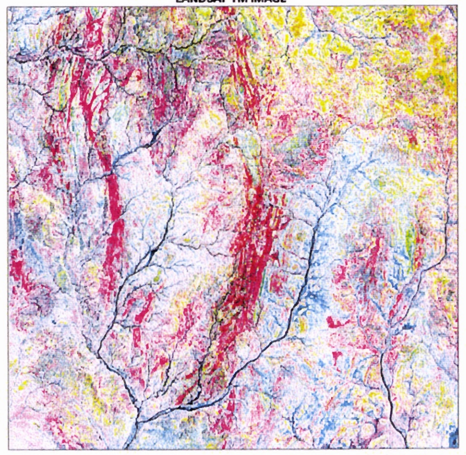
Colluvial sediments

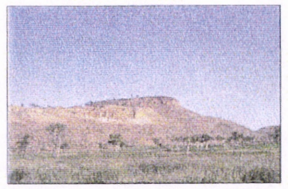
SIMPLIFIED GEOLOGY

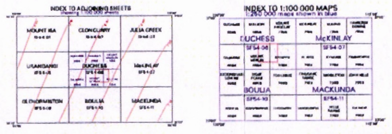


MAJOR LANDFORMS

LANDSAT TM IMAGE





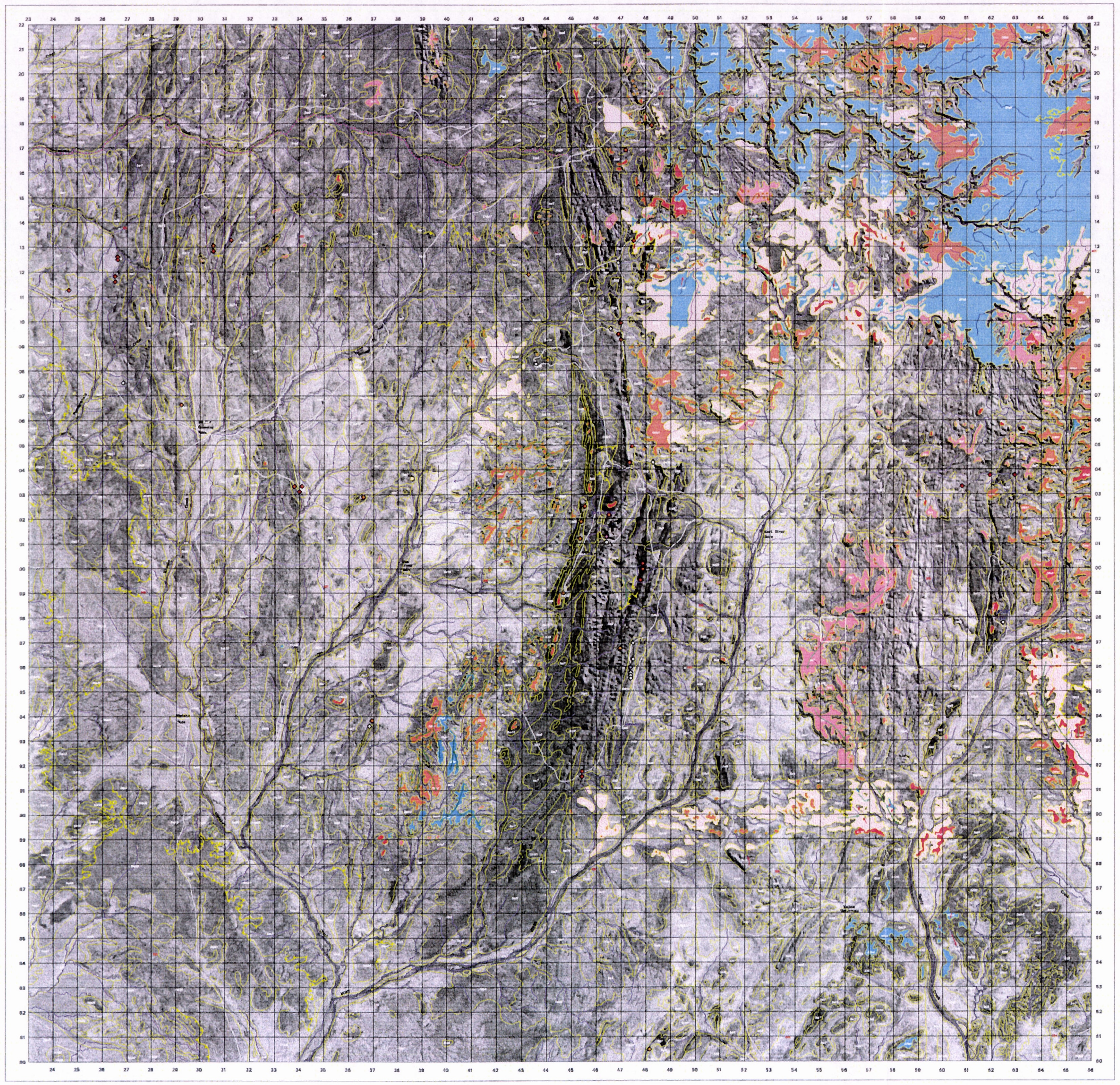


AMIRA

CRCLEME

SELWYN Regolith - Landforms

Deeply weathered regolith over Landsat TM (band 5)



REGOLITH TYPES

Major bedrock type

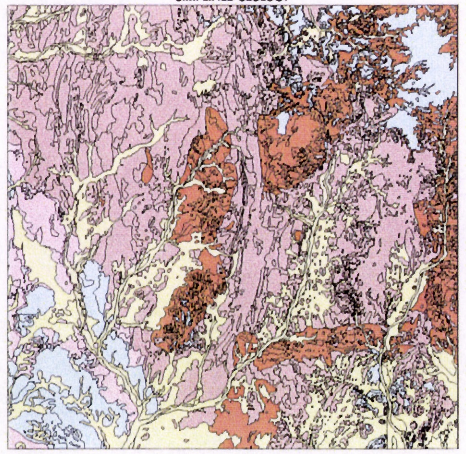
Duricrust

Saprolite

Alluvial sediments

Colluvial sediments

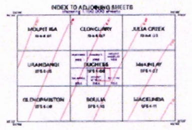
SIMPLIFIED GEOLOGY

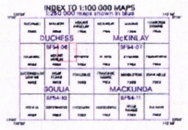


3-D AIR-PHOTO/DIGITAL ELEVATION DRAPE

LANDSAT TM-5 IMAGE

SCALE 1:100,000



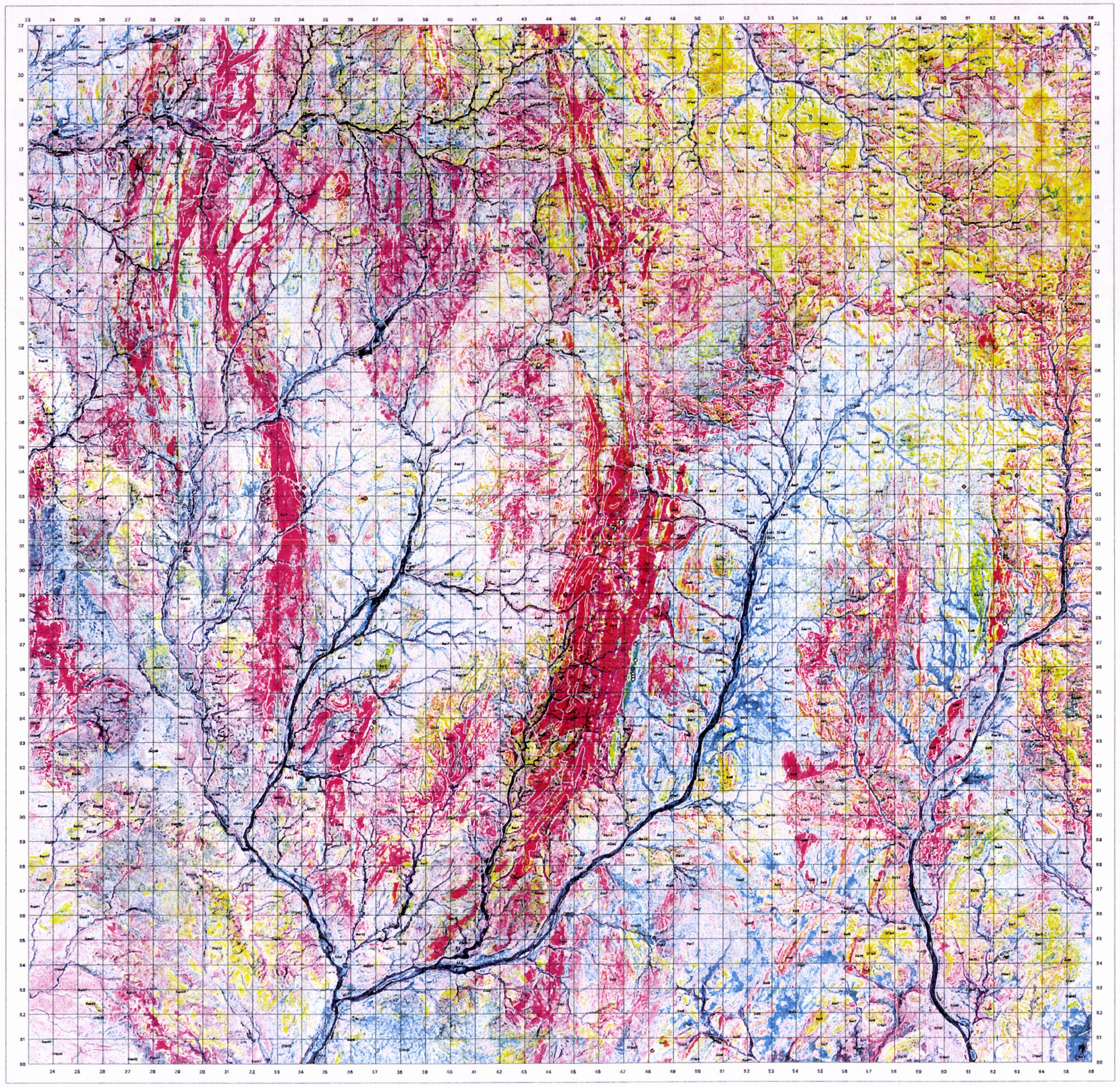


AMIRA

CRCLEME

SELWYN Regolith - Landforms

Regolith-landform units over 3-band Landsat TM



REGOLITH TYPES

Major bedrock type

Duricrust

Proterozoic bedrock

Ferruginous

Metamorphics — DFe1

DFe2

Granite — DFe3

Siliceous

DSi1

Post-Proterozoic bedrock

Ferruginous

Mesozoic sediments — DFe4

DFe5

Siliceous

Cambrian sediments — DSi2

Saprolite

Proterozoic bedrock

Metamorphics

Granite

Post-Proterozoic bedrock

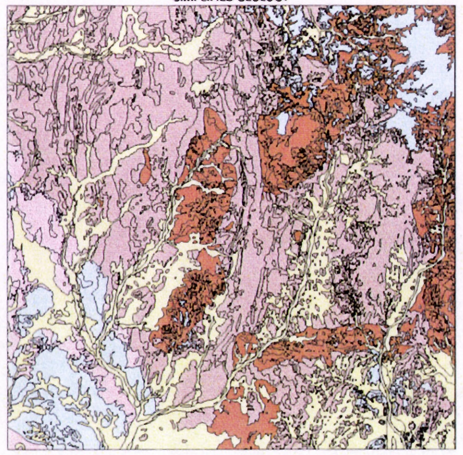
Mesozoic sediments

Cambrian sediments

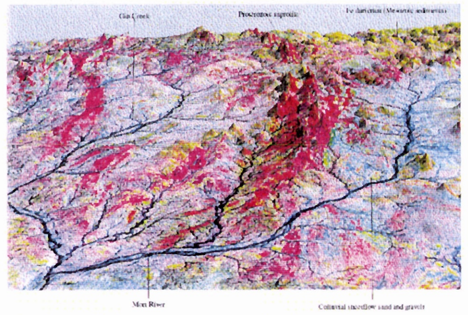
Alluvial sediments

Colluvial sediments

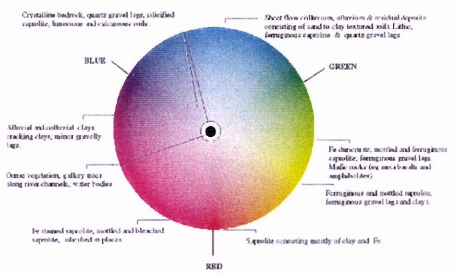
SIMPLIFIED GEOLOGY



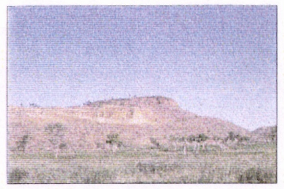
LANDSAT TM

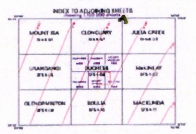


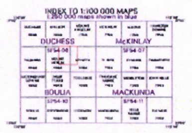
LANDSAT TM INTERPRETATIVE KEY



Compiled by J.R.Wilford (CRC LEME/AGSO), 1998



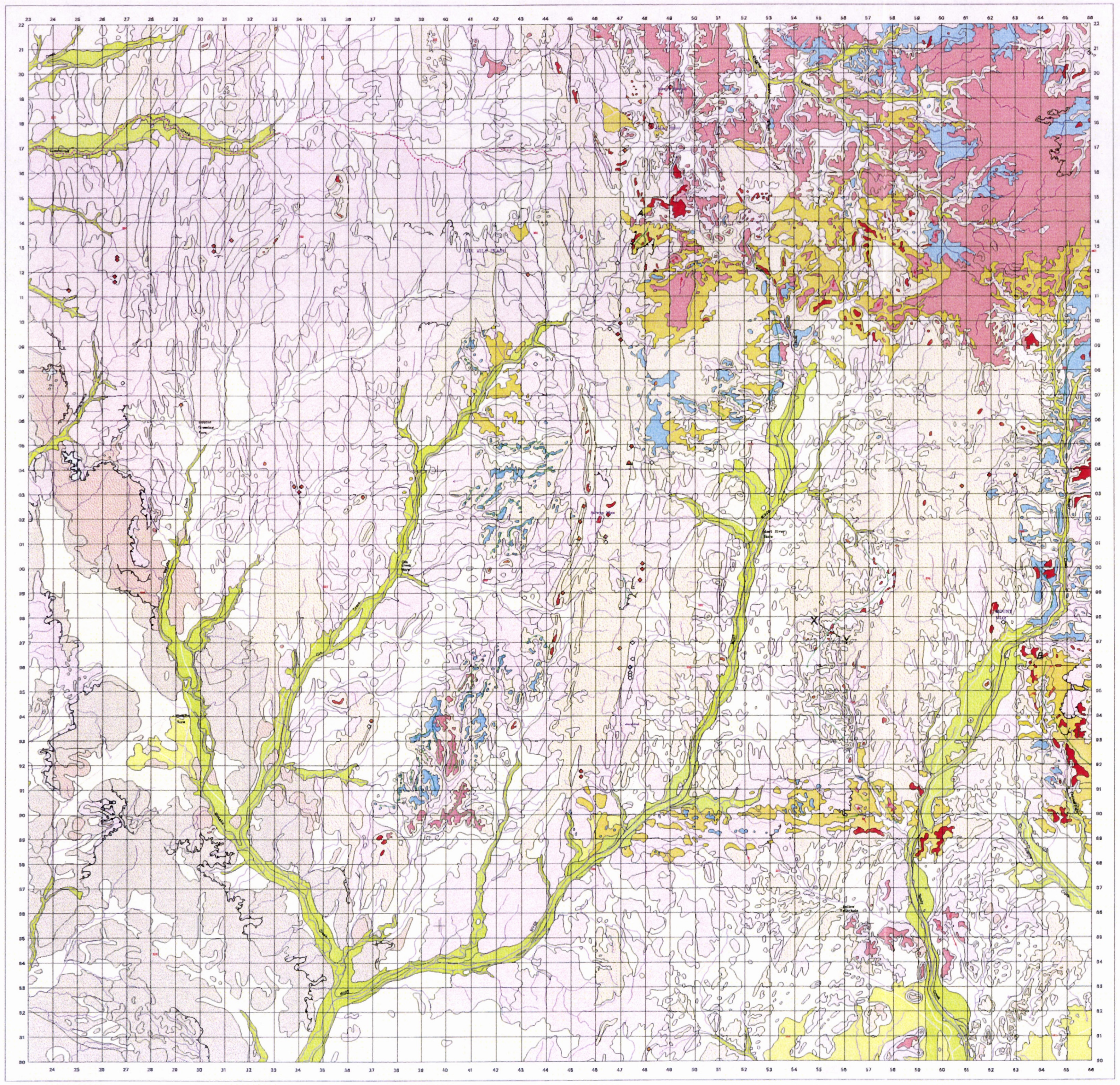




CRCLEME

SELWYN Regolith - Landforms

Interpretative Geochemical Sampling Strategy Map



SCALE 1:50,000

UNIVERSAL TRANSVERSE MERCATOR

REGOLITH/GEOCHEMICAL SAMPLING GUIDE *

Duricrust

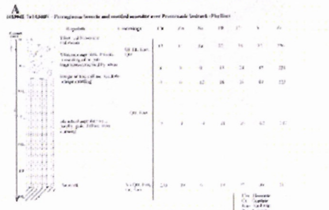
Saprolite and skeletal soils

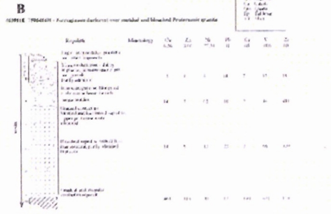
Saprolite covered by extensive lags and thin residual soils

Alluvium

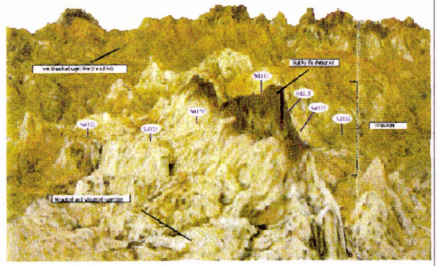
Colluvium

REGOLITH/GEOCHEMICAL PROFILES





REGOLITH/GEOCHEMICAL TRANSECT



	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5
Sel 116	61.61	18.87	6.61	0.031	2.27	0.29	0.36	3.96	0.62	0.207
Sel 117	76.08	10.8	5.69	0.016	0.77	0.05	0.08	1.95	0.41	0.051
Sel 118	69.12	18.56	1.79	0.005	0.37	0.05	0.17	3.47	0.63	0.125
Sel 119	3.88	3.31	79.42	0.005	0.08	0.01	0.02	0.13	0.14	0.404
Sel 120	72.98	16.56	1.36	0.003	0.27	0.03	0.17	2.78	0.65	0.01
Sel 121	62.25	23.36	2.22	0.007	0.51	0.04	0.39	6.06	0.64	0.038
Sel 122	57.50	21.43	7.31	0.008	1.87	0.34	0.42	6.84	0.59	0.163
	Ba	Cr	Cu	Ga	Sr	Nb	Pb	Rb	Zn	Zr
Sel 116	949	86	18	25	85	11	12	290	34	140
Sel 117	537	77	51	15	65	7	16	222	16	299
Sel 118	1359	72	3	23	8	14	30	109	4	126
Sel 119	80	85	79	12	529	-1	8	4	15	23
Sel 120	643	57	14	21	3	14	11	86	4	163
Sel 121	1109	97	0	31	-1	12	12	208	3	130
Sel 122	901	99	88	31	523	12	15	289	17	114

Distribution of some major and minor trace elements across a palaeo-channel. Transect X-Y is shown on the map. The old river channel floor correlates to the zone of bleached and silicified saprolite.

Regolith landform unit boundary

Erosional scarp

Palaeo-drainage

Palaeo-landform slope

Superimposed drainage

MINERAL OCCURRENCES (DEPOSITS) *

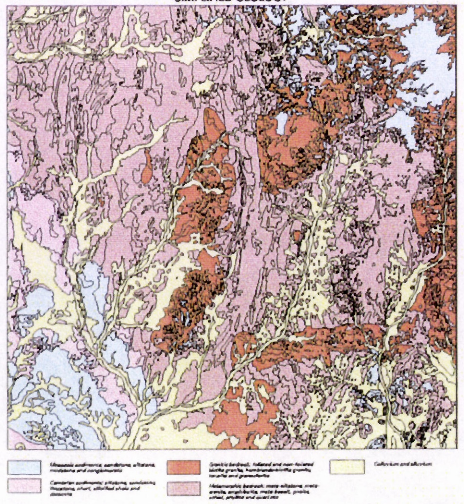
Gold

Silver

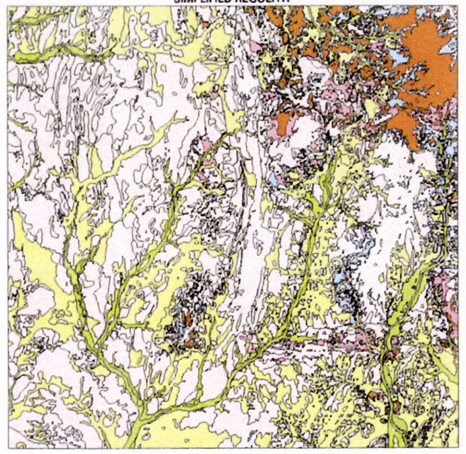
Copper

Cobalt

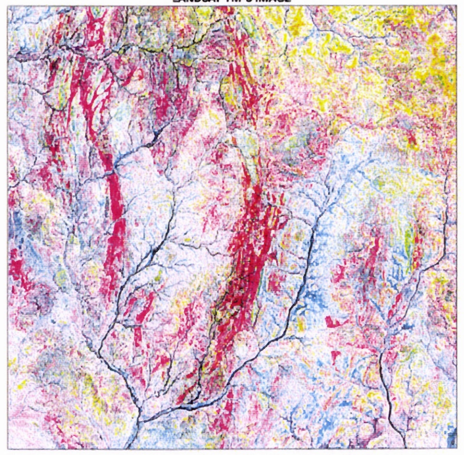
SIMPLIFIED GEOLOGY



SIMPLIFIED REGOLITH



LANDSAT TM-5 IMAGE



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