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ALLUVIAL LANDSCAPES OF THE MARONAN AREA, CLONCURRY-McKINLAY DISTRICT, QUEENSLAND

M.R. Jones

CRC LEME OPEN FILE REPORT 129

March 2002

(CSIRO Exploration and Mining Report 374R/CRC LEME Report 45R, 1997.
Second impression 2002)

CRC LEME is an unincorporated joint venture between CSIRO-Exploration & Mining, and Land & Water, The Australian National University, Curtin University of Technology, University of Adelaide, University of Canberra, Geoscience Australia, Bureau of Rural Sciences, Primary Industries and Resources SA, NSW Department of Mineral Resources-Geological Survey and Minerals Council of Australia, established and supported under the Australian Government's Cooperative Research Centres Program.

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

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

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

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

This report (CRC LEME Open File Report 129) is a second impression (second printing) of CSIRO, Division of Exploration and Mining Restricted Report 374R, first issued in 1997, which formed part of the CSIRO/AMIRA Project P417.

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PREFACE

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

The Maronan area covers the junction between exposed metamorphic rocks of the Selwyn Range of the Eastern Succession of the Mt Isa Inlier and plains occupied by the Carpentaria-Eromanga Basin. Proterozoic rocks, which have considerable potential for Au and base metal deposits, continue beneath this basin which has since been filled with a thick layer (40-100 m) of Mesozoic sediments and then covered by a comparatively thin veneer (<10 m) of Tertiary-Quaternary alluvial materials. This report deals with drainage systems which are sourced in the hill belts on the Proterozoic rocks and flow northeast onto the plains towards the Gulf of Carpentaria. It describes the dynamics of the streams, their sediments and their sources within the various geomorphic regimes, and the characteristics and evolution of the resultant alluvial landscapes.

This report is one of three covering the Eloise-Maronan area. The others deal with regolith-landform mapping, landform development and investigations into geochemical dispersion in Mesozoic and Tertiary-Quaternary alluvial sediments from buried Cu-Au mineralisations.

R.R. Anand
Project Leader

I.D.M. Robertson
Deputy Project Leader

22nd April, 1997.

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1. SUMMARY

1.1 Location

The Maronan area extends approximately 70 km northwest of McKinlay and includes the slopes of the Selwyn Range and the adjacent plains to the east (Figures 1, 2). In the north, drainage is provided by the Williams and Fullarton Rivers, which have upper catchments incised in the Selwyn Range. Most of the numerous minor streams in the south only drain the foothills along the range's eastern margin. The McKinlay River and its tributary Boorama Creek are the other major streams in the south. Braided channels are common on the plains.

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

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

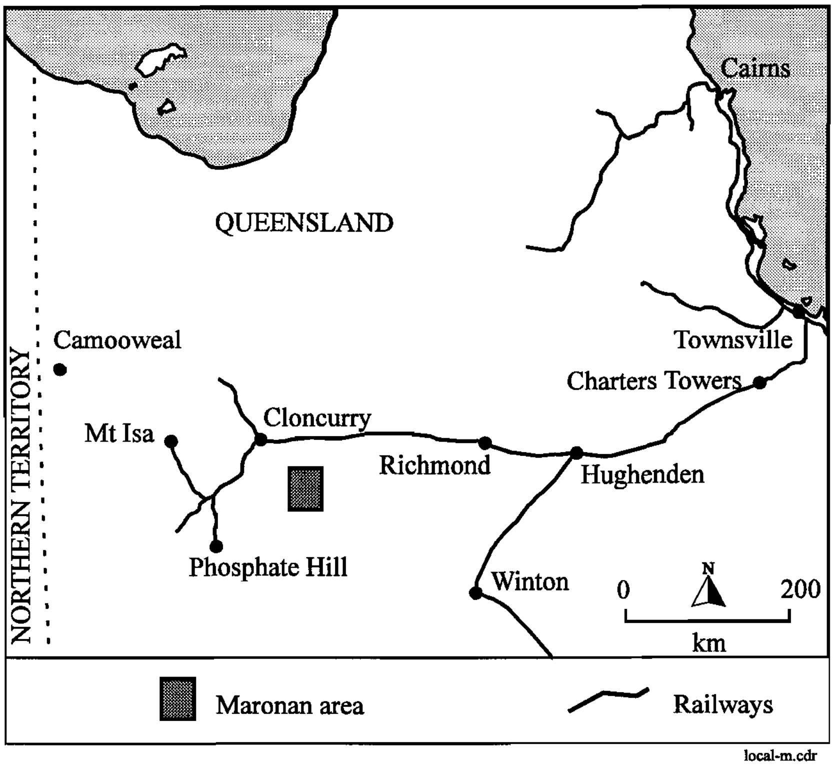

Figure 1: Location of the Maronan study area.

1.2 Landscape Studies

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

1.2.1 Geomorphology and Landscape Evolution

The main geomorphic units are:

- **Isa Highlands** - the Selwyn Range.
- **Cloncurry Plain** - the narrow foothills zone along the base of the Selwyn Range.
- **Wondoola Plain** - the extensive plain east of the ranges and north of the McKinlay River.
- **Julia Plain** - the plain southeast of the McKinlay River; this plain is slightly higher than the Wondoola Plain.

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

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

1.2.2 Age and distribution of regolith

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

1.3 Implications for Mineral Exploration

1.3.1 Hydromorphic dispersion of trace elements

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

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

1.3.2 Mechanical dispersion of trace elements

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

1.3.3 TM Interpretations

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

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

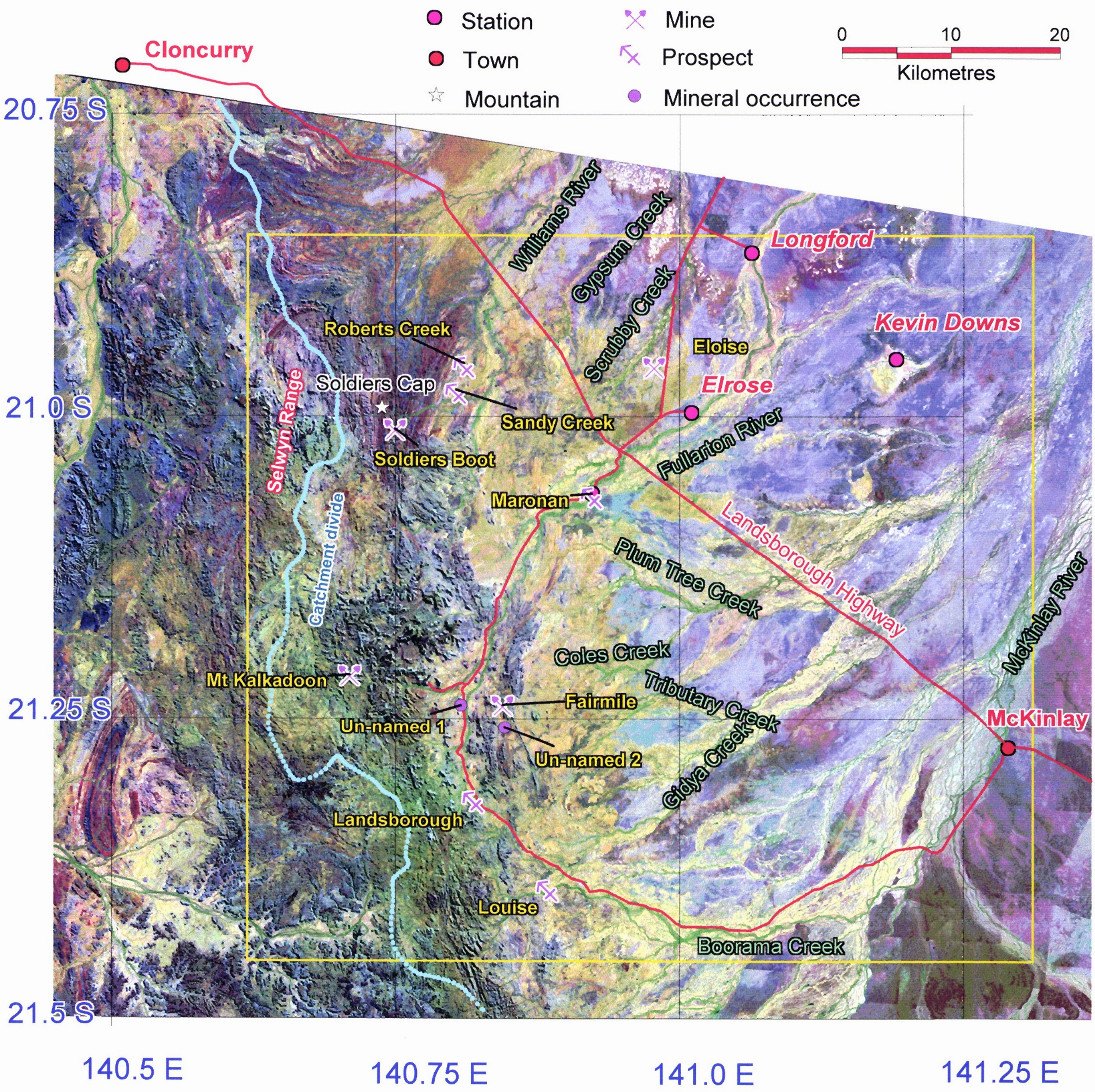

Figure 2: Landsat TM image of the Maronan study area (yellow square). Mineral localities from the Kuridala 1:100 000 geology sheet (Donchak et al, 1983), Amalg Resources NL (1996), and Dunstan (1913). See Table 1 for further details.

2. INTRODUCTION

This study contributes to AMIRA Project 417 - "Geochemical Exploration in Regolith Dominated Terrain of North Queensland". The area under investigation covers about 4750 km^2, and lies between Cloncurry and McKinlay (Figures 2, 3). The investigations have concentrated on the geology of the largely unconsolidated surficial deposits. These deposits are inferred to result from Quaternary processes of landscape evolution. Much of the area is covered by alluvial deposits. The study has identified the sources of these deposits, the transport pathways across the plains, the depositional areas, and areas where older deposits are being reactivated through erosion. The implications of Quaternary landscape changes for mineral exploration have also been assessed.

This report compliments similar investigations of Quaternary landscape evolution on the western side of the Mt Isa Inlier on the northern part of the Kennedy Gap 1:100 000 sheet (Jones, 1997).

2.1 Geological Setting

Since the Cretaceous, the marine basin on the eastern side of the Mt Isa Inlier has contracted northwards and is now the 70 m deep Gulf of Carpentaria. Holocene terrigenous sediments have accumulated around the fringes of the Gulf in a wide but shallow area where water depths are generally less than about 20 m (Jones and Torgersen, 1988). These sediments are supplied by streams draining the onshore areas, referred to collectively as the Carpentaria Plains (Twidale, 1956), which extend from the Northern Territory border around the Gulf almost as far as Weipa.

The investigation area is on the southern margin of the Carpentaria Plains in the upper catchments of the Williams, Fullarton, and McKinlay Rivers. These streams rise in the Selwyn Range and flow across a wide and flat lying plain now covered with Tertiary and Quaternary fluvial deposits (Donchak et al, 1983; Wilson et al 1983).

Beneath the surficial deposits on the plains is a Cretaceous sequence of mainly marine sediments up to 100 m thick overlying Proterozoic bedrock (Wilson et al, 1983). Cretaceous mudstone also outcrops on the plain northeast of Eloise. During the Cretaceous, extensive marine deposition occurred, interspersed with episodes of subaerial exposure and fluvial deposition.

In the Selwyn Range, fluvial deposits include the Late Jurassic to Early Cretaceous Gilbert River Formation. This Formation ranges from 3-40 m thick and consist of a basal conglomerate overlain by cross bedded quartzose sandstone, and mudstone (Donchak et al, 1983). In the study area, remnants of the Gilbert River Formation are confined to the Selwyn Range east of the Cloncurry Fault in the Williams and Fullarton River catchments. Here, sandstone remnants cap ridges of Proterozoic bedrock, 50-100 m above the adjacent plains.

The Proterozoic rocks includes the steeply dipping and folded Soldiers Cap Group which contains meta-sediments and meta-volcanics. As well as the outcrops in the Selwyn Range, "islands" of Proterozoic bedrock protrude through the alluvial cover in a zone as much as 10 km wide bordering the eastern margin of the range between Eloise and McKinlay. Isolated windows of Proterozoic rocks occur further to the east including those at Kevin Downs approximately 30 km from the foothills (Vine, 1964) (Figure 2). The area's major structural feature is the Cloncurry Fault (Donchak et al, 1983); it is readily seen on the TM image, extending north-northeast for about 70 km in the Selwyn Range (Figure 4).

The Maronan area contains a copper/gold mine at Eloise on the northeastern side of the Landsborough Highway (Amalg Resources NL, 1996). The MPI owned lead-zinc prospect at Maronan is located to the southwest of the Landsborough Highway. Other mineral localities are included in Table 1.

Table 1: Mineral occurrences in the Maronan area:

Name	*AMG E (Zone 54 K)*	*AMG N*	*Minerals*	*Geology*	*Lithology*
Eloise (1)	497700	7682500	Copper, gold, silver	Soldiers Cap Group (Early to Middle Proterozoic)	Metasediments
Maronan (2)	491969	7670852	Lead, zinc	?Soldiers Cap Group	Metasediments
Fairmile (3)	483880	7651500	Lead, zinc, copper	Soldiers Cap Group	Gneiss, schist, quartzite, some banded iron
Mt Kalkadoon (3)	469900	7654250	Copper	Williams Batholith, Mt Angelay Granite	Biotite and hornblende-biotite granite, porphyritic and non-porphyritic
Glen Idol (4)	480000	764750	Gold in quartz	Soldiers Cap Group	Metasediments
Louise (5)	487950	7634700	Copper	Soldiers Cap Group	Silicified fault zone
Landsborough (5)	481200	7642800	Copper	Soldiers Cap Group	Amphibolite
Soldiers Boot (5)	474000	7676700	Copper	Soldiers Cap Group, Toole Creek Volcanics	Metavolcanics
Un-named 1 (5)	480050	7651440	Copper	Soldiers Cap Group	Mica schist
Un-named 2 (5)	484060	7649340	Copper	Soldiers Cap Group	Mica schist
Roberts Creek (6)	480306	7682778	Copper, gold	Soldiers Cap Group	Quartz lode
Sandy Creek (6)	479568	7680317	Copper, gold	Soldiers Cap Group	Quartz veins, mica schist

Refs:
(1) Brescianini et al, 1992.
(2) Mining Project Investors Pty Ltd, pers comm.
(3) Blake et al, 1983.
(4) after Dunstan, 1913.
(5) Donchak et al, 1983.
(6) Amalg Resources NL, 1996.

2.2 Geomorphic Units

The geomorphic units in the Maronan area (Figure 4) are:

1. Isa Highlands - mostly Proterozoic outcrops of the Selwyn Range.
2. Cloncurry Plain - the foothills bordering the eastern margin of the Selwyn Range.
3. Wondoola Plain - the flat to undulating plain with braided channels, east of the Selwyn foothills.
4. Julia Plain - the flat to undulating plain extending to the southeast of McKinlay; the land surface is slightly higher than the Wondoola Plain.

(after Grimes and Doutch, 1978; Ryburn et al, 1988.) The Isa Highlands are included in the Hill belts geomorphic province of Anand et al, 1996. The Cloncurry, Wondoola, and Julia Plains are included in the Undulating to rolling plains unit of the Plains geomorphic province of Anand et al, 1996.

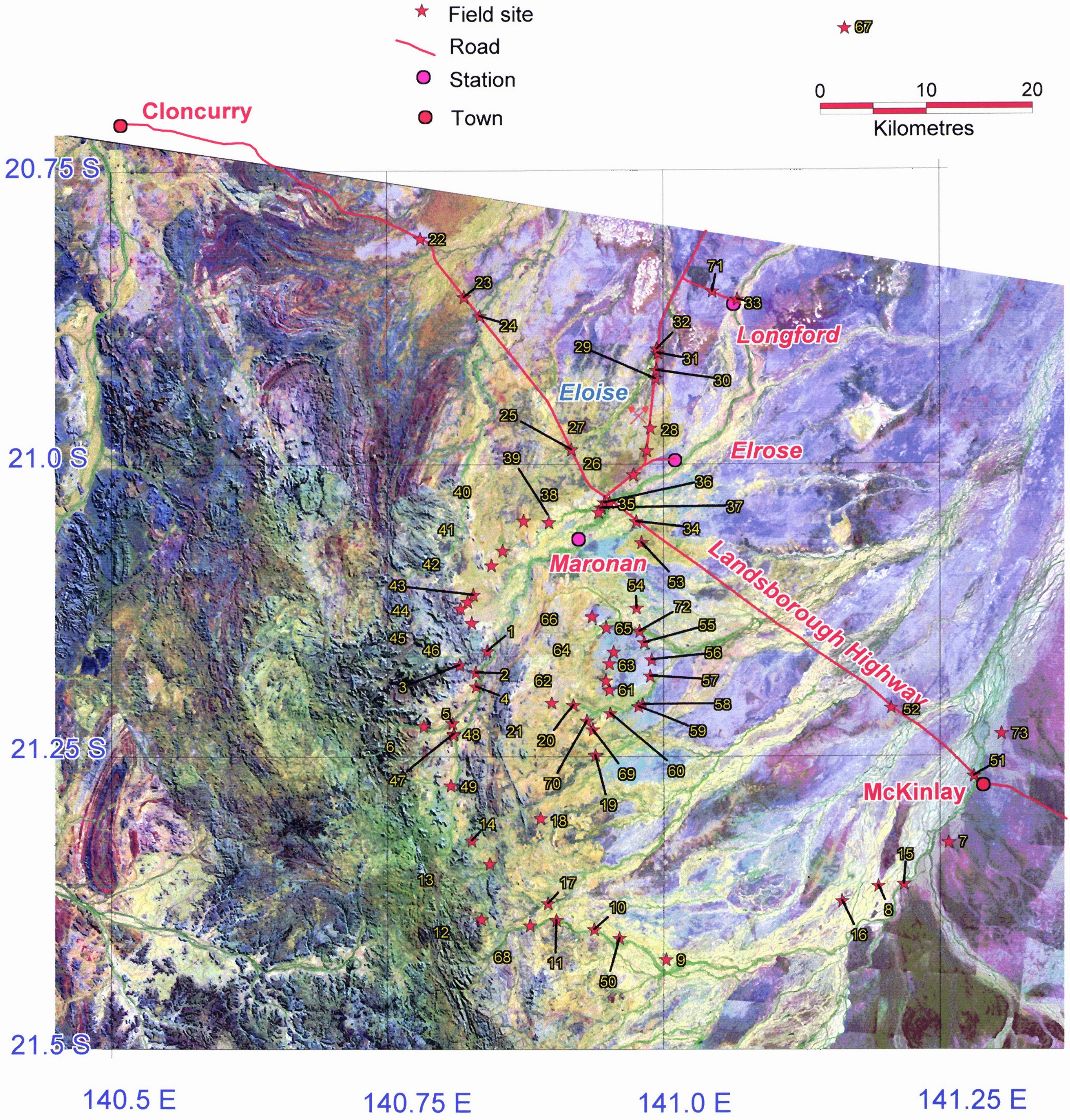

Figure 3: Landsat TM image of the Maronan study area and locations of field sites.

3. STUDY METHODS AND RESULTS

3.1 Field Inspections

The study involved inspections at 73 field sites, extending from upper catchments in the Selwyn Range to the plains in the east (Figure 3). Locations were determined using a hand-held GPS unit. Many sites were in creek beds where exposures of the regolith could be observed. The observations included the types of sediment in the stream bed and banks, stratigraphy, stream dimensions, surface deposits and evidence of evolutionary processes. Informal notes on the landscape between field sites were also made. Example observations at several field sites, grouped according to the geomorphic units of Figure 4, are presented in Appendix 1.

3.2 Landsat TM Interpretations

The field site locations were overlaid on the regional Landsat TM image (Bands 1, 4, 7 - blue, green, red) and further interpretations were made, based on image patterns, drainage networks, and outcrop style and extent.

The Landsat TM image enabled interpretation of numerous landscape features including:

- Distribution of bedrock and inferences on continuation beneath cover deposits.
- Identification of bedrock - the Proterozoic metamorphics could be distinguished from the Proterozoic granite, and from Jurassic-Cretaceous deposits.
- Qualitative estimation of regolith thickness over bedrock.
- Variations in styles of channels and valleys in the Selwyn Range.
- Comparison of channel styles on the plains - braided or meandering channels in wide corridors; braided or meandering channels in narrow corridors; location and style of former channels.
- Identification of landform units - boundaries for the main geomorphic units were interpreted from the TM image. The boundaries were digitised "on-screen" in MapInfo using the Landsat TM image as a background layer (Figure 4).
- Identification of interfluves with cracking clays - these appear on the TM image as shades of purple.
- Interpretation of past channel evolution - abandoned channels in flood corridors were identified; several generations of point bars are evident in the Fullarton River.
- Interpretation of sediment distribution across the plains - sediments in the channels have a similar colour/pattern to inferred source areas upstream; a contrasting colour/pattern to adjacent interfluves suggests different processes are influencing interfluves and channels.
- Interpretation of regional patterns of landscape evolution - eg. "Island" remnants of the Julia Plain are present in the McKinlay River corridor, indicating that the plain extended further north in the past.

3.3 Additional data

The geological maps of the area, including the Kuridala 1:100 000 sheet (Donchak et al 1983), the 1:250 000 sheets (Vine, 1963, 1964) and the 1:250 000 topographic sheets (Division of National Mapping, 1977; Royal Australian Survey Corps, 1988a, 1988b, 1990) provided additional information to assist interpretations of landscape evolution.

3.4 Data storage

All field data are stored in a database in MS-Access, which is linked to map displays in MapInfo. The results of queries run in MS-Access can be exported to MapInfo to display results such as the distribution of bedrock, calcrete, and iron-rich gravels at the field inspection sites. Interpretation of the significance of observations are displayed as thematic layers in MapInfo, showing for example the boundaries of geomorphic units, and the patterns of modern sediment distribution across the landscape.

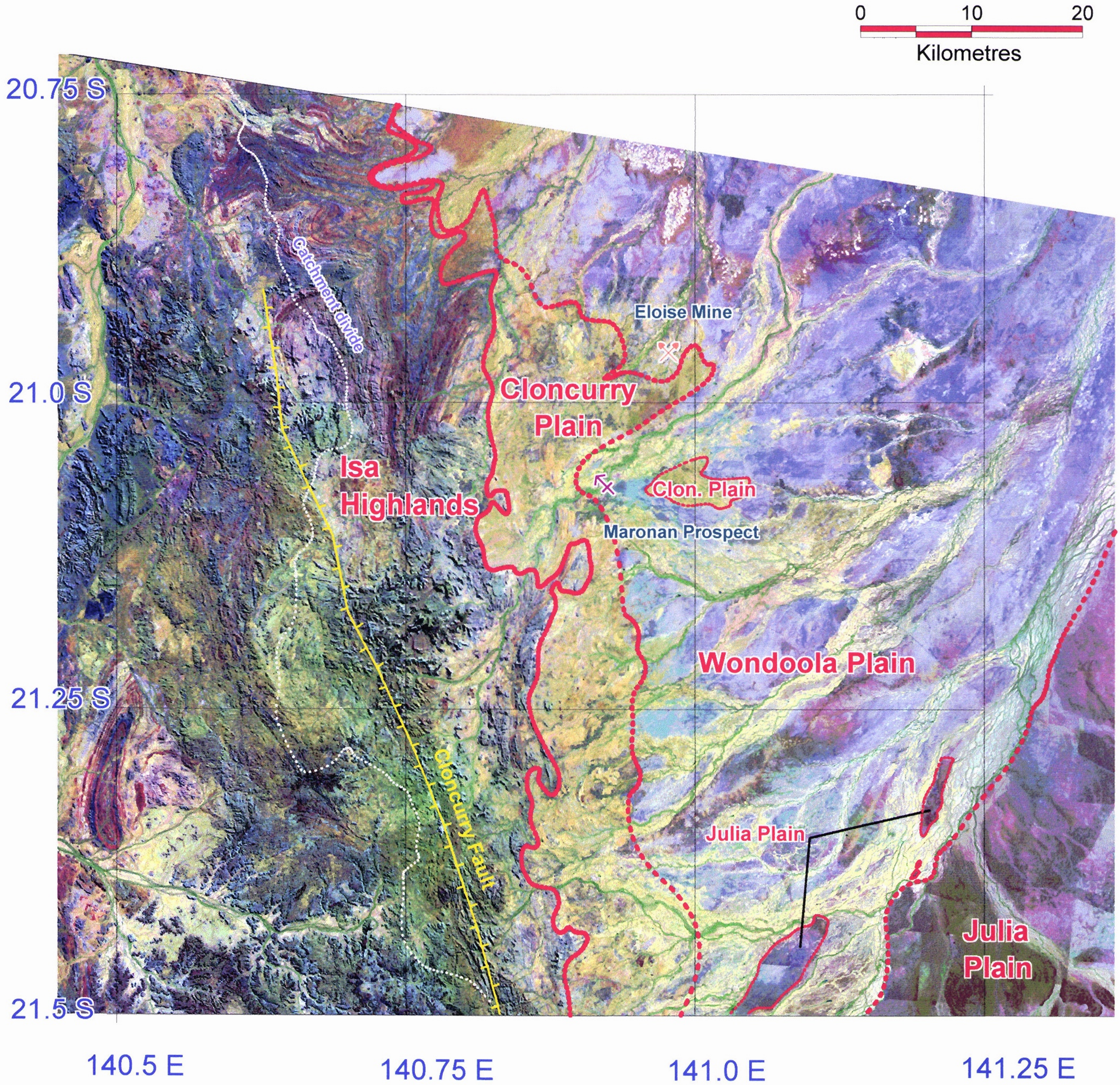

Figure 4: Landsat TM image and geomorphic units in the Maronan area (boundaries in red).

3.5 Estimating the age of the deposits

The degree of compaction provides a qualitative indication of the age of parts of the regolith. This approach is based on investigations of the nearshore zone along the coastline (eg. Jones and Hekel, 1979; Jones and Stephens, 1984). Here the influence of sea level change is well documented by facies changes, and provides an indisputable time frame for comparative age estimation. Even in shallow areas, it is typical to have a sequence of unconsolidated marine sediments overlying a cohesive plastic clay. The marine mud is of Holocene age, having been deposited during the last ~6 000 years of comparatively stable high sea level. The underlying clay relates to the preceding period of subaerial exposure during which dewatering, consolidation, and weathering of former marine deposits (mid to late Pleistocene) took place. The cohesive clays may contain ferruginous mottles and incipient ferruginous nodules, and are clearly of late Pleistocene age.

The cohesion of the coastal Pleistocene clays is similar to or greater than the mottled clays found in some areas at the base of the alluvium in the Maronan district. Therefore, these mottled alluvial clays are inferred to be of Pleistocene age, and the overlying unconsolidated deposits are likely to be of late Pleistocene to Holocene age.

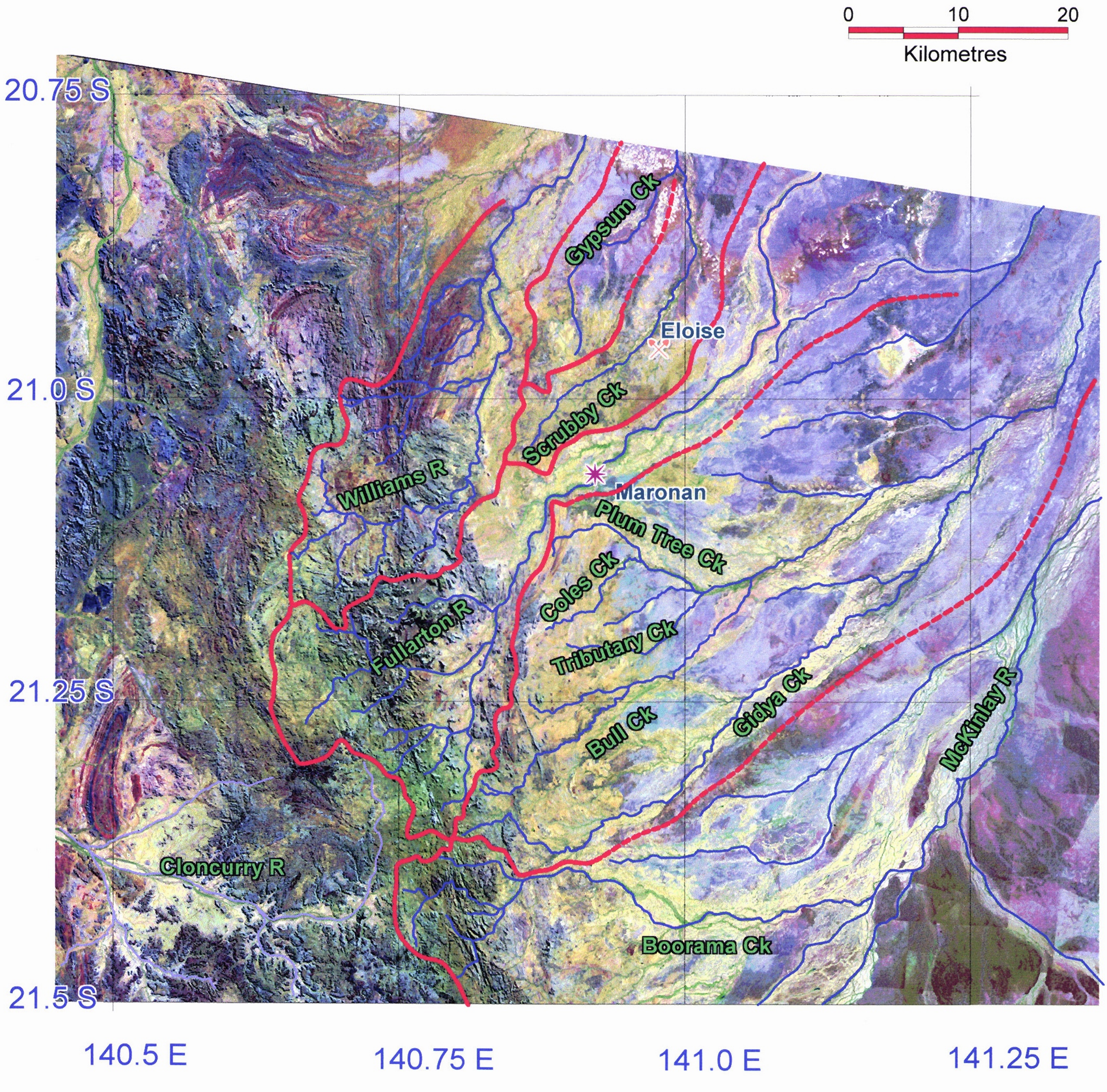

Figure 5: Landsat TM image of the Maronan area, showing streams and major catchments (boundaries in red).

4. DISCUSSION OF DRAINAGE PATTERNS

4.1 The Catchments

The main northeastward draining catchments (Figure 5) from north to south are as follows:

- Williams River.
- Gypsum and Scrubby Creeks.
- Fullarton River.
- a series of braided streams including Coles, Tributary, Bull, Garnet, and Gidya Creeks, which flow into McKinlay River.
- Boorama Creek (a major tributary of the McKinlay River).

4.1.1 Williams River

The upper 40 km of the catchment is contained in the Selwyn Range where the rocks are mainly Soldiers Cap Group metamorphics and Saxby Granite. There are also remnants of the Gilbert River Formation near the southern rim. Williams River and its tributaries incise the bedrock, with channels in places cutting across the north-south geological grain of the metamorphics, and in others being coincident with it. The streams generally skirt around the intrusions of Saxby Granite. The catchment extends northeastwards onto the Cloncurry Plain north of Eloise. The stream alignment changes from north to northeast in the vicinity of the highway, influenced by an inferred shallow bedrock high beneath the northern interfluve.

The Williams River enters the plains about 4 km upstream of where it crosses the Landsborough Highway. On the plains, the stream has developed a flood corridor about 4 km wide (Figure 6). There is no evidence that the river has occupied any other entry point to the plains for a considerable time. The evolution of the river, as interpreted from the TM image, has involved channel development only within the flood corridor. Here, the stream has occupied a number of channels through cycles of avulsion - the rapid development of a new channel and abandonment of the former. The channel switching has meant that the pre-existing deposits have not been entirely reworked, and islands of older deposits with similar TM patterns to the interfluves are present in the flood corridor. The corridor represents only shallow incision into the interfluves. Bedrock outcrops are also present, indicating that the surficial deposits are thin.

The neighbouring interfluves have been unaffected by the Williams River. They contain fluvial mud, sand and gravel, but their accumulation can only be visualised with the land at a higher level than it is today. Under these circumstances, the Williams River would have been able to supply the interfluves through distributaries having greater mobility than the present channel. Since deposition of the interfluves, the river has formed the flood corridor it now occupies.

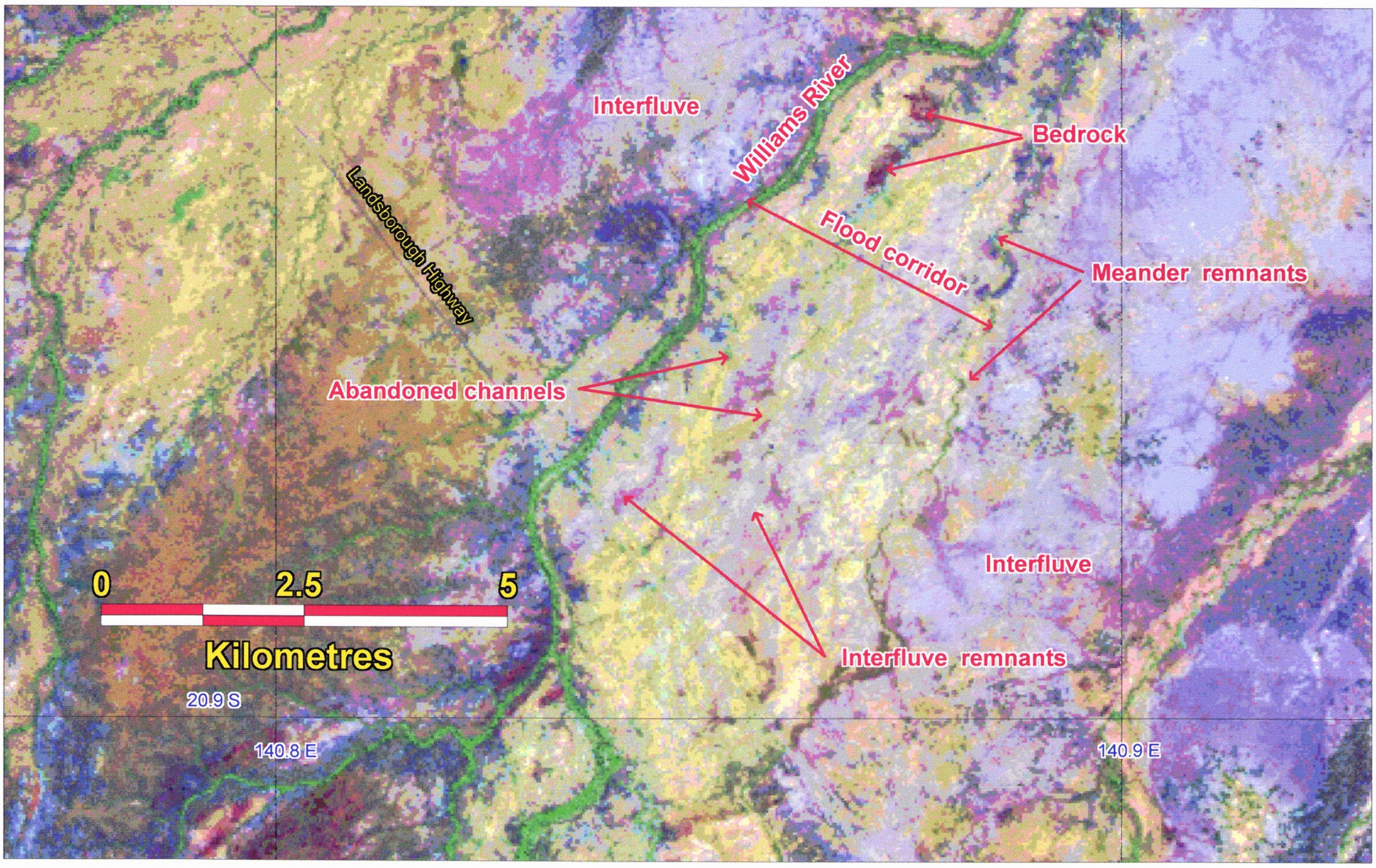

Figure 6: The Williams River has an incised channel on the northern side of a shallow flood corridor. The corridor contains remnants of interfluves, meanders, channels and bedrock (TM image).

4.1.2 Scrubby Creek

Scrubby Creek drains the northern margin of the interfluve on which the Eloise mine is located. Further to the southwest, the upper reaches of the creek have incised low lying Proterozoic bedrock near the base of the Selwyn Range. Approximately six upper catchment tributaries drain bedrock which is sparsely covered by regolith; the tributaries converge into a comparatively narrow alluvial corridor 6-800 m wide. In this corridor, the alluvial deposits are incised by a single, or in places, dual main channel. In the vicinity of Eloise, the main channel is straight to slightly meandering in the confined alluvial corridor.

On the plains to the northeast of Eloise, Scrubby Creek becomes a meandering channel in the flood corridor. Here, the corridor contains abandoned meanders in close proximity to the modern channel (Figure 7). On the plains, the width of the corridor remains fairly constant at about 750 m, which is much narrower than the Williams River corridor, influenced by smaller catchment area and runoff volumes.

Proterozoic-sourced sediments are present in the stream bed. These are supplied by erosion of the regolith on the Proterozoic bedrock in the upper catchment. Although the coarse bedload sediments in Scrubby Creek could be quite erosive during transport, the lateral deposits are sufficiently cohesive to restrict channel movement. The volume of runoff from the comparatively small catchment limits the erosive power of the creek. However, flows are sufficient for Scrubby Creek to produce meander cut-offs and flood-formed bars of sand and gravel. The corridor appears to have been stable for some time, as the interfluves do not contain evidence of slow lateral migration.

On the interfluves, the surficial pale brown and orange-red soils are interpreted as *in-situ* weathering of transported fluvial deposits. Cracking clays at the surface are associated with young water-transported deposits. These clays are associated with minor surface wash eroding the orange-red soils. There is a somewhat radial drainage pattern from the interfluves, indicating a flat surface unaffected by tectonics. These short streams supply local runoff to the creek. There is minimal erosion on the interfluve tops, indicated by the thin layer of gravel at the surface (commonly a single grain thick). Stream bank erosion around the edge of the interfluves is the main process of landscape degradation operating at present. Erosion along the banks of Scrubby Creek north of Eloise has exposed calcrete and mottled clays in the interfluve deposits, indicating that *in-situ* weathering has occurred.

In contrast with Williams River, the Scrubby Creek catchment does not extend into the Selwyn Range. Hence the catchment has low slopes throughout, providing low erosion potential. The channel has developed to drain sheet wash from the gently sloping surface of the Cloncurry Plain, and Wondoola Plain further downstream.

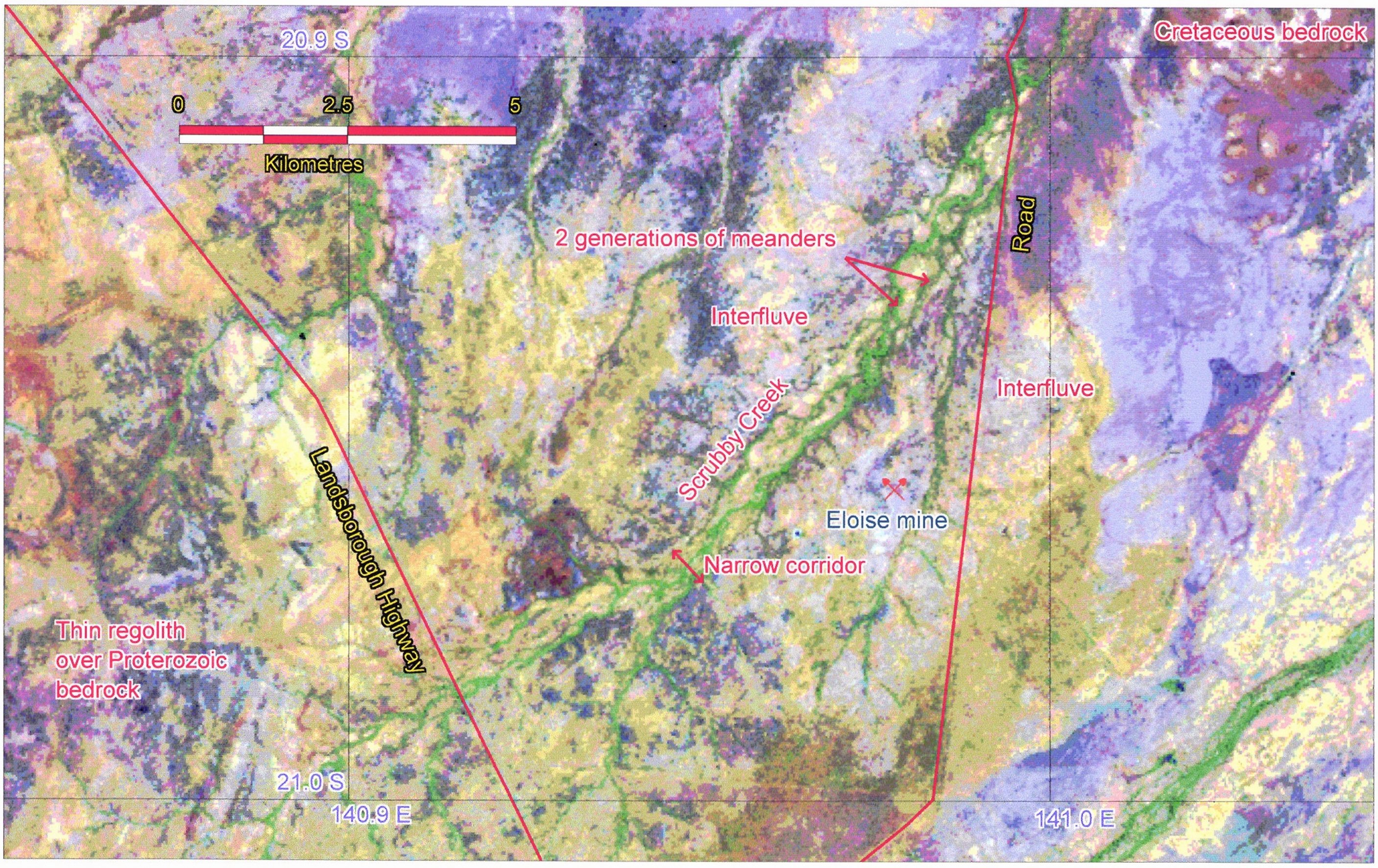

Figure 7: TM image of the Scrubby Creek catchment shows a narrow, relatively straight flood corridor with two generations of meanders. The interfluves are covered with cracking clays (pale purple on the image), and orange-red soils (shown as olive green and pale yellow areas).

4.1.3 Fullarton River

The Mt Angelay Granite is exposed in the Fullarton River catchment adjacent to the drainage divide between east and west flowing streams. On the TM image, the granite appears more resistant to erosion than the metamorphics to the east. Streams on the granite terrain are less incised than on the metamorphic rocks. Because of the more gentle slopes, the granite has retained a shallow regolith cover. Further downstream, the Fullarton River has a narrow incised channel in the metamorphics of the Doherty Formation (calc-silicate banded granofels). The stream and its tributaries occupy V-shaped valleys which retain little alluvium. In the metamorphic terrain, the rate of sediment supply through weathering is less than the rate of removal and there is little *in-situ* or transported regolith preserved (Figure 8).

The Fullarton River catchment contains most of the Gilbert River Formation present in the study area. Even so, the area of outcrop is small, and comprises ridge-top layers with cliffed edges, the remnants of retreating scarps on the incised valley rims. Erosion of the Gilbert River Formation over a long period has supplied a declining contribution to the fluvial accumulations on the Wondoola Plain.

In the upper catchment about 20 km upstream of Maronan station is a bedrock-confined valley about 4 km wide. Some alluvial sediments are retained on the flat valley floor where the main channel occupies a flood corridor about 250 m wide. The bedrock substrate is shallow, and bedrock islands protrude through the alluvial deposits. The shallow bedrock restricts lateral movement of the channel. There are minimal colluvial aprons along the bedrock margins of the valley floor. Erosion of the limited regolith produced in the incised upper catchment, is likely to yield mainly gravelly sediments. Fine grain size components are released partly with the coarse debris from the source areas on the ridges, and additional amounts are produced by abrasion during transport. As the valley opens out downstream, the coarse sediments from the valley sides form channel floor gravels, and the fine grain sizes are laid down as blanketing deposits from overbank flows.

Colluvial aprons are virtually absent at the base of bedrock slopes along the valley margin. It is inferred that colluvial sediments are produced rather slowly, and flooding across the valley floors rapidly incorporates them into the alluvial deposits. The unconsolidated valley floor deposits are reworked by streams, resulting in only limited soil profile development, mainly iron staining.

The Fullarton River changes character where the stream enters the plains. The gentle slopes on the plains allow the main channel to migrate sideways and develop a flood corridor. Surface patterns show that through avulsion, the stream has occupied different channels in the past. Meander cut-offs are also preserved, indicating that the channel changed its position gradually for a time. Later, the channel was abandoned and re-developed elsewhere in the flood corridor.

Near Maronan station, the TM image shows that the flood corridor is now directed to the northeast, whereas at some time in the past it flowed to the southeast. The channel to the southeast is now occupied by Plum Tree Creek, which swings to the northeast further downstream and links with the McKinlay River. The two flood corridors record past episodes of channel switching by the Fullarton River.

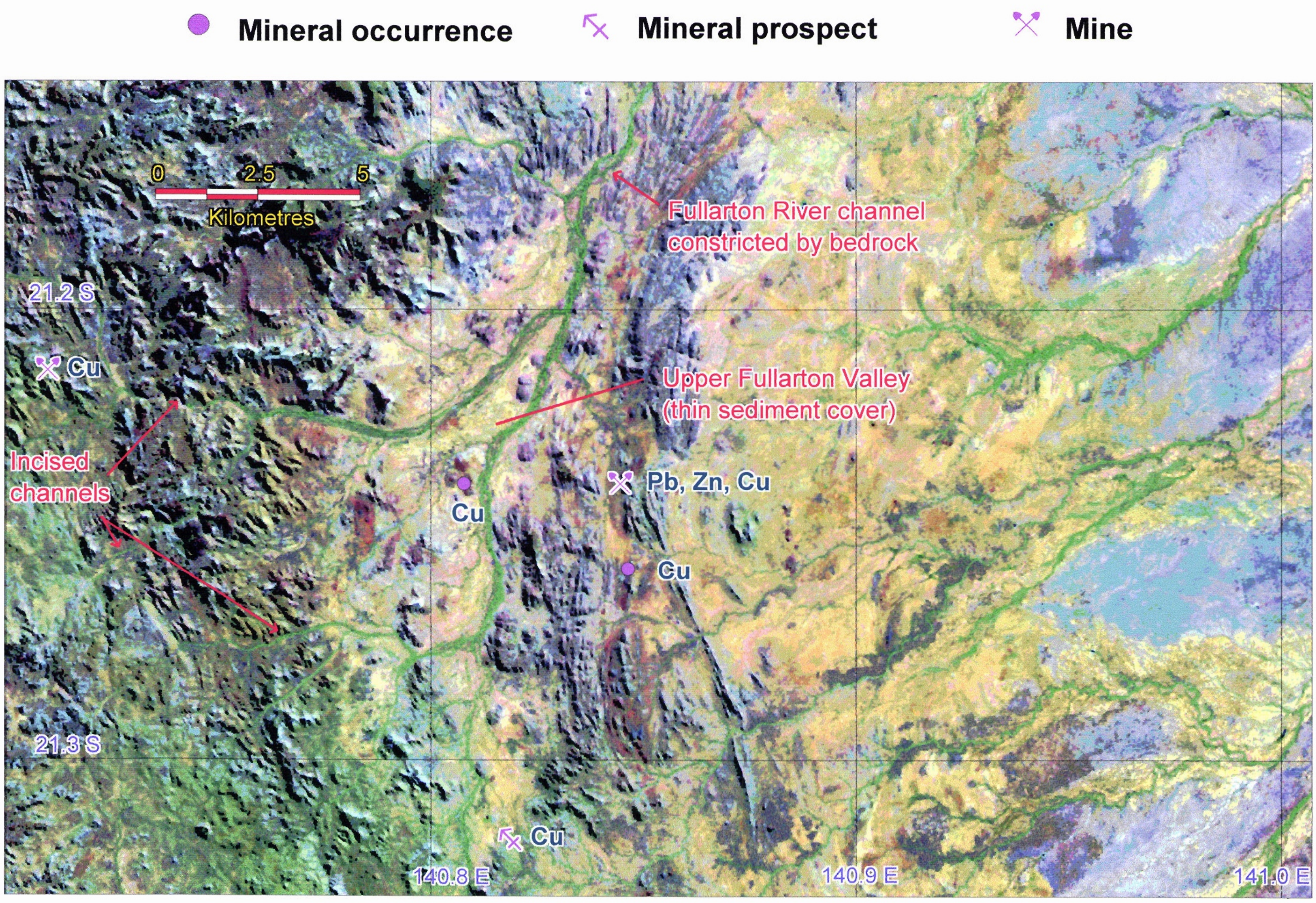

Figure 8: Fullarton River has scoured a confined valley in its upper reaches. The valley may represents a zone of structural weakness in the Proterozoic bedrock. Mineral occurrences are also shown.

Further downstream (north of the Landsborough Highway), flood overflow channels diverge from the main corridor. These overflows may be reactivated periodically during severe floods, and become the main channel, leaving the original channel abandoned. The abandoned channels eventually become filled with fine grained deposits from overbank flow during floods.

4.1.4 Minor streams - Coles, Tributary, Bull, Garnet, and Gidya Creeks

None of these streams to the south of Fullarton River have catchments that extend westwards beyond the foothills of the Selwyn Range. Their upper catchments are part of the Cloncurry Plain, and include Proterozoic bedrock with a shallow regolith cover (approximately 0-2 m thick). On the Cloncurry Plain, the streams are slightly incised whereas downstream on the Wondoola Plain, they occupy incised channels in flood corridors. The corridors are 2-4 km wide and contain a primary incised channel and shallow anastomosing channels in various stages of activity. These streams provide a pathway for draining surface runoff, and distribute sediment derived from the shallow regolith in the upper catchments. Most sediment transport takes place during floods, at which time sand and fine gravels are transported across the entire width of the corridors.

Gidya Creek has cut through 2-2.5 m of regolith in its upper catchment near Boorama Creek (Figure 3, Site 17). The creek exposes a surficial orange-red soil 0.5-1 m thick containing mud, sand and gravel. The coarse sediments were deposited in layers by stream activity. Beneath the orange-red soil is a cohesive iron-stained and mottled clay containing water-laid gravels at its base. This unit is up to 2 m thick. The mottled clays probably represent overbank deposition of fine sediments in an abandoned channel. It is inferred that the fine sediments lay undisturbed for some time enabling compaction and mottling to occur before they were re-exposed by stream erosion. This exposure suggests slow movement of the channels across the land, and is consistent with the area being erosional at present.

4.1.5 McKinlay River / Boorama Creek

Boorama Creek is a major tributary of the McKinlay River, the largest braided stream south of Fullarton River. The upper Boorama Creek catchment extends about 10 km into the Selwyn Range, where it drains a metamorphic substrate of Soldiers Cap Group and Doherty Formation. The bedrock areas are largely free of regolith. The Selwyn foothills include the Cloncurry Plain where shallow regolith is the source of much of the sediment transported to the Wondoola Plain. On the Wondoola Plain, the stream occupies a single or dual channel in a flood corridor containing braided secondary channels. The corridor is initially up to 4 km wide, but widens to as much as 5 km beyond the confluence with the McKinlay River. Downstream, the channel has developed several bifurcating flood overflow corridors that are inactive at present. When reactivated, these channels may take over as the main channel for the stream, enabling channel switching without reworking the interfluves.

In the McKinlay River, the braided streams are contained in a flood corridor about 4 km wide near McKinlay township. The corridor contains a narrow, incised channel, (or perhaps several), occupying a small part of the total width. The main channel is approximately 20 m wide and incised to 5-6 m below the surrounding plain (Figure 9). The bed sediments are dominantly coarse sand to fine gravel, formed into sand waves and ripples by high water velocities. Channel-confined flow during floods provides an effective pathway for the downstream transport of sand and fine gravel. Flood flows maintain an incised channel and expose Cretaceous cone-in-cone limestone in parts of the bed. Despite the low gradient of the land surface, the incised channels show little tendency for meandering. Rather, new channels develop by avulsion. The braided corridor contains evidence of former incised channels either declining in importance or completely abandoned.

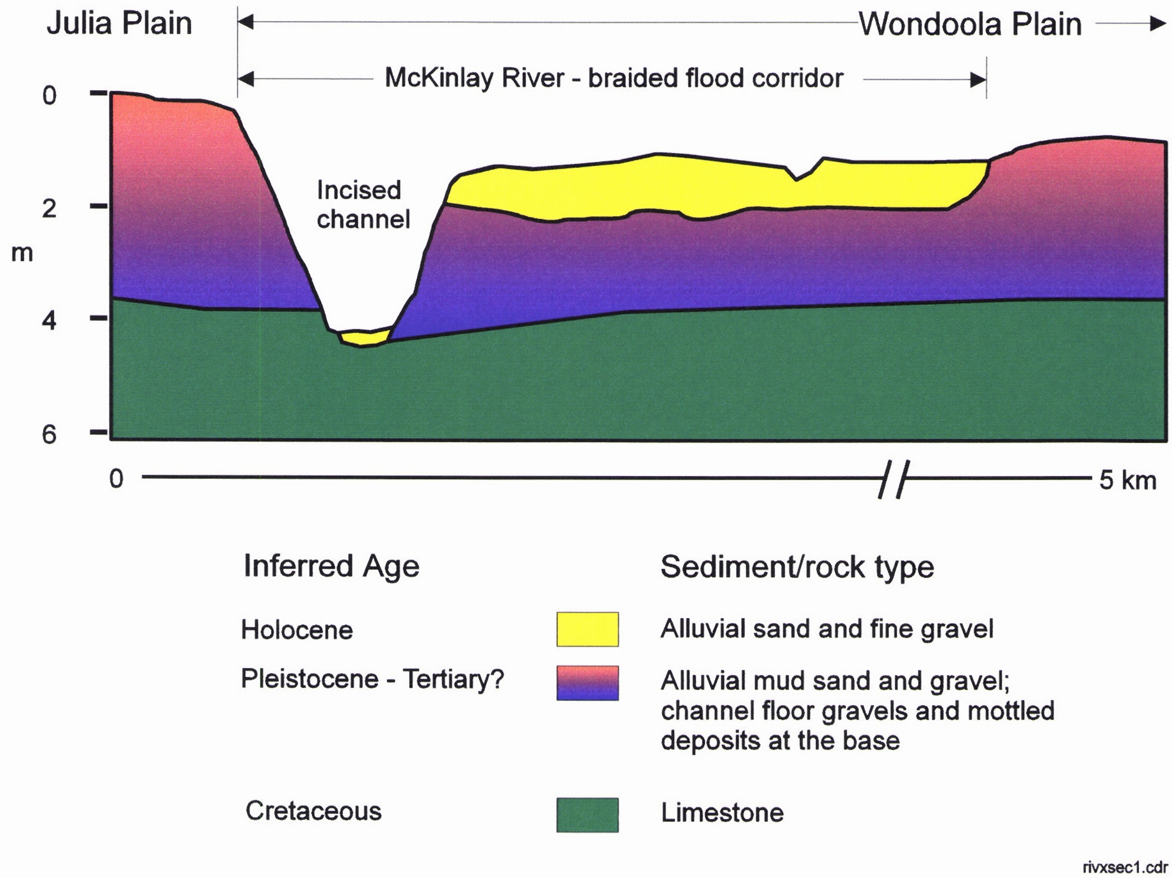

Figure 9: Diagrammatic section across the McKinlay River near McKinlay. The Wondoola Plain is an eroded remnant of the Julia Plain. Braided stream deposits in the McKinlay flood corridor are thin.

4.2 Sediment sources and stream evolution

The main sources of sediments on the plains are the upper catchments where steep slopes assist bedrock and regolith erosion. In the Selwyn Range, the Williams and Fullarton Rivers have incised channels that cannot have moved laterally very far during a considerable time (TM image interpretation). Further downstream where the channels emerge on to the plains, there are more opportunities for the channels to move laterally or to take up entirely different courses. However, the interfluves restrict the channels to fairly localised flood corridors.

The channel of the Fullarton River has a similar overall pattern to the Williams River. It is unlikely that either river has entered the plains at any location other than the present one for a considerable time. Hence, the greatest thickness of alluvial channel deposits should occur beneath the modern outflow channels.

The minor shallowly incised streams commencing in the foothills of the Selwyn Range south of Fullarton River have probably moved laterally some distance. However, as the upper catchment has a limited area to source fluvial sediments, thick sequences of sand and gravel from these streams are not expected beneath the Wondoola Plain.

In the south, Boorama Creek and McKinlay River have short upper catchments extending about 10 km into the Selwyn Range. The steep upper catchments are similar to those of Williams and Fullarton Rivers in the north, and are likely to be the main source of sediments in transit in the channels across the plains. On the plains, McKinlay River is fed by numerous tributaries draining the Selwyn Range. In addition to transporting sediments from these sources, the river is eroding the margin of the Julia Plain. These reworked sediments contribute to the sediment load of the McKinlay River.

4.3 Summary of drainage patterns

The Williams and Fullarton Rivers are the two streams that have significant catchments in the Selwyn Range. These catchments provide the main sources of eroded Proterozoic rocks distributed across the plains. On the TM image, their drainage patterns are similar:

In the ranges, both have their main channels aligned slightly east of north on the eastern side of their catchments. Both main channels are supplied by a series of incised tributaries from the west. The rivers occupy narrow incised channels between steep confining bedrock ridges, or form channels incised in unconsolidated alluvium in flat-floored valleys. In their upper catchments, very little alluvial sediments are retained.

On the plains the Williams and Fullarton Rivers flow to the northeast. Different controls on channel alignment exist in the ranges and on the plains. On the plains, the stream orientation is typical of the radial drainage around the periphery of a sedimentary basin. Outcrops of Cretaceous rocks north and northeast of Eloise have had local effects on channel location, causing diversions around erosion-resistant areas. The streams are conduits for sediment transported to the east and north in well-defined flood corridors. In the corridors are incised channels, abandoned meanders, point bars, and shallow braided channels. The fluvial corridors are distinctive landforms separated by slightly higher interfluves.

The interfluves in places have erosion scarps along their boundaries with the flood corridors. Erosion occurs as the streams undercut the interfluves and collapse the deposits into the channel, from where they are washed downstream. Apart from erosion along the edges of the interfluves, the remainder is mostly unaffected by modern stream activity. The major influence on these flat surfaces is sheet wash erosion which develops small drainage channels with a somewhat radial pattern. Sheet wash removes fine sediment, leaving a thin gravel layer. However, at times, the gravel can also be transported into shallow channels, preventing the build-up of thick gravel layers on the interfluve surface. When the gravels are removed, unsorted deposits below are exposed and sheet wash erosion can continue.

Most of the remaining streams commence in the foothills and extend onto the plains. Their upper catchment slopes and surface areas are much less than the rivers, lessening their capacity to remove regolith from the upper catchment. Nevertheless, the braided streams south of Fullarton River transport shallow regolith from the gently sloping Cloncurry Plain. Despite the low slopes, the streams contain

large quantities of coarse sand and fine gravel in transit to the northeast. In the upper reaches, the channels are commonly almost bank-full with sand and fine gravel.

Because the slopes on the present day Wondoola Plain are extremely gentle, many streams, notably in the south, occupy braided corridors which can be up to 5 km wide. These streams include McKinlay River, Gidya Creek, and Bull Creek (formed beyond the confluence of Tributary and Plum Tree Creeks). Their channels contain mica-rich sand and fine gravel from erosion of Proterozoic rocks. Bedforms observed on the stream beds, and channel patterns shown on the TM image indicate episodic transport associated with major floods. Despite the dry environment, water flow is the dominant influence on long term landscape evolution in the district.

Good exposures of Quaternary deposits are found in the upper catchments of the minor streams south of Fullarton River. The physical confinement of these valleys allows several metres of deposition to occur, whereas out on the plains synchronous deposits are spread widely and thinly. In the upper catchment, the minor streams move laterally rather slowly so that deposits are preserved for a longer period before being reworked by the returning channel.

5. INTERPRETATIONS

5.1 Regolith development

Data from the field inspections and interpretations of the TM image show that there is little regolith in the Selwyn Range catchments. Streams remove most regolith as it is produced. Continued throughput of sediments in the upper valleys ensures that there is minimal sediment retained as valley fill. Further downstream, wider valleys enable some sediment to be retained. At two locations in the Fullarton River catchment (Figure 3, Sites 37, 47), iron-stained orange-red alluvium is overlain by brown to brown-orange alluvium. The brown alluvium has a limited extent, and is interpreted as younger short term deposition of alluvium eroded from further upstream.

Bedrock "islands" and outcrops in stream beds in the Fullarton River valley 15 km upstream from Maronan station show that the alluvial deposits are thin - 1.5 m thick at Site 47 (Figure 3). Calcrete, presumed to have formed in the regolith, is exposed in channels. Much of the alluvium is iron-stained producing an orange-red colour. The calcrete, and the iron staining of the regolith, are interpreted as late Quaternary soil profile development.

Fluctuating sediment supply ensures that the valleys can only provide temporary storage of transported regolith from the upper catchments. The net erosional environment of the late Holocene has lowered the valley floors. The major drainage channels now control the sediment distribution from the valleys out onto the plains to the east and north.

5.1.1 Wondoola Plain

The surface has a variable scattered cover of gravels supplied from the Selwyn Range. The gravels comprise quartz, ferruginised lithic fragments and siliceous and ferruginous nodules sorted from the interfluve deposits. Sediment throughput to the northeast forms channel bed layers of sand and fine gravel. The interfluves are most likely remnants of a possibly early Pleistocene fluvial blanket deposited by streams draining the Isa Highlands.

5.1.2 Julia Plain

The present day geological environment on the Julia Plain is one of minimal sediment input. Minor reworking occurs by water flow from local run-off. The margins of the Julia Plain are contracting due to erosion by peripheral streams such as the McKinlay River and, in the south, the Diamantina River.

5.2 Fluvial Processes - sediment deposition and sediment budget

The braided channel corridors are a prominent feature on the southern Wondoola Plain. In the McKinlay River, most of the corridor is taken up by shallow branching and rejoining channels separated by linguoid sand (and gravel) bars with downstream directed asymmetry. These areas become active when the incised primary channels can no longer confine the water moving downstream during floods. The excess water spills out of the incised channels and floods across the full width of the corridor.

Water depths over the braided channels and bars during floods may be of the order of 1 m or more. Velocities are lower than in the incised channels. Sand waves and ripples develop more readily in shallow water than deep water under the same flows (Miall, 1977). On the flood corridors, the fall in velocity relative to the incised channel is compensated for by the shallow depth, which enables substantial transport of sand and fine gravel in large sand waves. The bedforms across the corridor and in the incised channel are preserved from one flood to the next.

Despite the width of the braided channels on the Wondoola Plain, the thickness of the sand and fine gravel is not great, estimated from field observations at 1-2 m.

During floods, large quantities of sediment are in transit downstream. This volume can be considered to be the throughput of sediment in the river. In order to maintain the sediments in the channels, the upper catchment must be able to supply new quantities to make up for the volumes transported downstream. If this is not done, the channel becomes erosional and bed levels are lowered. Continued shortfalls in

supply cause depletion of the store of sediment built up in the stream bed during earlier phases when supply exceeded throughput. This leads to thin sequences of sand and gravel in the bed - which is what is seen at present. It is concluded that the plains are now in an erosional phase.

Another influence on catchment evolution in the Selwyn Range and on sediment supply to the Wondoola Plain is the change in sediment sources in the Isa Highlands. The Gilbert River Formation and the Proterozoic rocks have been the main sources of sediments transported by the Williams and Fullarton Rivers. The Gilbert River Formation was previously more extensive than it is at present, and so had a greater role in the past as a sediment source than at present. As more and more Proterozoic bedrock was exposed by the stripping of the Gilbert River Formation, the metamorphics and granites became more important as sediment sources. The notional change in sediment supply through time is shown in Figure 10.

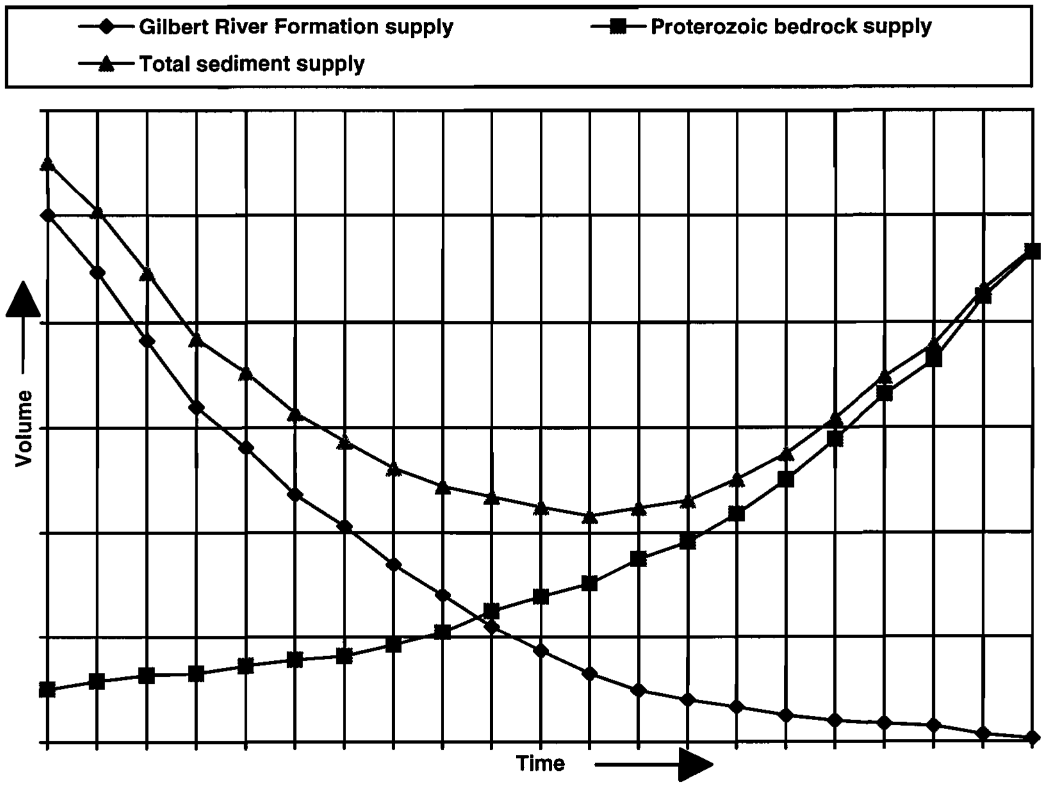

Figure 10: Sediment supply model for the Fullarton and Williams Rivers. The total sediment yield declines and then increases as the Proterozoic bedrock takes over as the principal supplier of sediments. The changes in sediment supply cause episodes of erosion or accretion to pass through the lower catchments.

The total sediment supply gradually declines as the Gilbert River Formation contribution diminishes. It reaches a low point and then rises again as the Proterozoic sources assume greater importance. The decline in sediment supply is likely to cause a pulse of erosion to move through the alluvial plains downstream before an increase in sediment supply follows. The erosional phase may cause the streams to incise more deeply into the plains and erode the existing deposits. This treatment of catchment sediment yield takes no account of other variables such as long term changes to upper catchment slopes and the general lowering of the land from erosion. However it shows that changes in catchment development can be related to changes in sediment supply in the upper catchment rather than linked to other processes such as tectonics, sea level change, or climatic variations.

The sediment budget for the region balances inputs and outputs and identifies transport processes. The main sediment inputs are provided by erosion of the regolith in the upper catchments. Erosion of the bedrock substrate on the plains provides limited localised sediment input. On the Wondoola Plain,

sediment is released where the incised streams cut steep banks into the interfluves. Similarly on the Julia Plain, streams supply mud, sand and gravel through erosion of the existing deposits. Sediments are transported northwards in braided and meandering streams. However, there is a limited capability to retain sediments on the plains, as indicated by the small Cainozoic sediment record. Hence the sediment budget is balanced by long term sediment throughput to the plains to the northeast, beyond the investigation area.

On the plains, lateral stream movement is the main process of erosion. Hence the focus for erosion is along the stream banks where undercutting and collapse releases sediments representing vertical sections of the interfluves. The erosional face may be as high as 5 m. In comparison, on the top of the interfluves, the rate of erosion is much less, and is due to sheet wash which sorts a very thin surface layer. Rain spatter and surface wash removes the mud fraction from the surface, producing the lag layer, which is rarely thicker than a few millimetres. Gradual erosion of the tops of the interfluves may cause planar lowering of the landscape. However, significant erosion is only associated with drainage channel margins.

In the streams, the sediments are coarse sand and gravel, and are largely free of mud sizes. Confined flows in the channels and braided streams produces linear deposits of sand and gravel within the less well sorted interfluve deposits across the plains to the northeast. Lateral channel movement is probably not sufficient to develop continuous sheets of the coarser sediments beneath the plains. The stream deposits are typically dominated by quartz, feldspar, and mica. The pegmatites in the eastern Selwyn Range are also a significant source of stream sediments, as evidenced by gravel sized quartz-feldspar-mica intergrowths. The Cretaceous mudstone and limestone provide sand and gravel to streams such as the Fullarton River but their influence is generally quite localised. For example, the Cretaceous gravels are abundant in Fullarton River at Longford, but 30 km downstream it is the Proterozoic sourced quartz- feldspar-mica component (which at this location has travelled 70 km) that is dominant.

5.3 Evolutionary Processes - sediment transport and deposition

The evolutionary framework for the plains in the Eloise-McKinlay consists of:

- Highland source areas in the west comprising the Isa Highlands. Streams draining to the east provided conduits for sediment transport onto the plains.
- Receiving basin of vast size in the east. This was mainly a marine basin during the Cretaceous.
- Sediment was dispersed into the marginal basin areas in the Cretaceous. Deltaic and nearshore environments were present.
- Alluvial deposition, including alluvial fans in some areas, occurred along the foot of the range and extended onto the plains.

The Proterozoic bedrock windows on the Cloncurry and Wondoola Plains are the tips of outcrops drowned in sediments. Past drainage patterns were influenced by the bedrock distribution and its surface morphology. With alluvial sediments continuing to accumulate in the lower catchments towards the Gulf of Carpentaria, the bedrock influence waned; ridges that in the past may have been drainage divides now provide no obstacle to streams developing new channels (see also Grimes and Doutch, 1978; Twidale, 1966). Near the Selwyn Range however, erosion and incision of the channels restricts lateral stream mobility.

The modern landscape is dominated by fluvial processes. For most of the time, the streams are dry, but during seasonal floods, large volumes of water flow across the landscape in braided channels and incised streams. The sediments entrained in the flood waters are transported to the northeast and north towards the Gulf of Carpentaria.

Sediments are now being transported across the landscape so that transported regolith is common. Further, as a consequence of regional erosion, older regolith deposits are likely to be exposed on parts of the landscape.

Sea level fluctuations in the Gulf of Carpentaria may have influenced stream development from the Gulf coast right through to the bedrock foothills in the Cloncurry - McKinlay area. Quaternary sea levels fell by as much as 150 m during glacial cycles (Chappell, 1983), greatly affecting deposition along many

coastlines. However the full effects of Quaternary sea level changes were not experienced in the Carpentaria and Karumba Basins. This was due to the Gulf of Carpentaria forming a largely land-locked basin during low sea level periods. The basin presently has a base level at about -70 m (Jones and Torgersen, 1988). Further, the nearshore gradients are so slight that exposure of the nearshore zone during low sea level periods may have had negligible impact on continental catchment slopes.

The Holocene evolution of the area appears to be driven by an overall decrease in sediment supply from the upper catchments. This has caused erosion in the upper catchments which has extended on to the Cloncurry Plain and the edges of the Wondoola Plain. The streams have incised the landscape, leaving the interfluves as residual areas. On the Cloncurry Plain, almost all of the interfluves have been removed by erosion, and only their substrates of *in-situ* regolith now mantle the bedrock.

6. IMPLICATIONS FOR MINERAL EXPLORATION

On the Wondoola Plain, the Fullarton and Williams Rivers are more confined by the interfluves than the streams to the south. Lateral channel movement appears to be less active than in the south, and the interfluves may be less disturbed. Stream sampling may provide less diffuse indications of upper catchment minerals than in the braided streams.

The widespread cracking clay soils and iron-stained deposits on the interfluves are not *in-situ*. The interfluves are unlikely to be a useful landform unit for geochemical sampling in the search for underlying mineral deposits. The iron-rich soils may be *in-situ* in the upper parts of the catchments in the Isa Highlands and the Cloncurry Plain, where they are usually quite thin. These thin soils may contain indicators of underlying mineralisation.

On the plains, the iron rich soils commonly include water-laid layers, indicating fluvial transport. An interpretation of their genesis is important in decided whether the deposits are *in-situ* regolith or transported alluvium. If there are alluvial gravels present, the deposits have been transported from source areas in the Selwyn Range. If the regolith is shallow, and or unsorted, it is more likely to be *in-situ*, or at least close to its site of formation.

Geochemical haloes from hidden ore deposits are most likely where well developed *in-situ* regolith overlies the deposit. The base of the regolith overlying bedrock is likely to be the most stable for development of hydromorphic geochemical haloes. In the Maronan area, the exposed bedrock generally has little or no regolith present. The covered Proterozoic bedrock is hidden by a thin layer of regolith, mostly transported, or by Cretaceous sediments that may be as much as 100 m thick. Hence the geological environment is not conducive to developing geochemical haloes from underlying ore bodies. Any trace elements in the regolith are likely to be associated with up-catchment sources in the foothills of the Selwyn Range.

In upstream areas of streams such as Boorama Creek, regolith sampling should provide geochemical indications of underlying mineral deposits. Unfortunately in these areas the regolith is typically thin or absent.

The sediments distributed across the modern landscape are derived from the Selwyn Range catchments east of the drainage divide between eastward and westward drainage. The eastward draining streams occupy a highland zone only 10-15 km wide, before emerging onto the Cloncurry and Wondoola Plains. Any placer deposits of trace minerals are likely to be sourced in this narrow zone.

The Cretaceous marine deposits contain limestone units that may be chemical traps for tracer elements derived from Proterozoic rocks below. The Cretaceous rocks have been mechanically stable for a long time, and subjected to ground water percolations which could lead to trace element concentration. Because of their long-term stability, the Cretaceous deposits are more likely to contain geochemical haloes than the overlying transported regolith.

6.1 Sampling media, formation and distribution

Potential media for geochemical analysis include the iron stone gravels, calcrete, and ground water.

The ironstone gravels comprise fragments that have been both ferruginised and silicified. The cementation has affected lithic fragments as well as nodules in the regolith. The iron stone gravels are quite widespread, and are found in the bedrock confined valley of the upper Fullarton River, on the shallow regolith in the upper catchment of the braided streams on the Julia Plain, and on the interfluves. Their presence in the upper catchments where Proterozoic bedrock is at or near exposure suggests that they are formed as part of the regolith developed on these rocks. Fluvial transport away from these source areas has distributed the iron-rich gravels widely across the landscape. In some areas, they are being re-released into the streams as interfluves are eroded. The amount of iron in the soils varies in the region and is shown by colour differences from pale brown to orange-red. The iron rich gravels from the upper catchments are likely to be a source of the iron, indicating that they remain chemically active in the dispersed environment.

Calcrete is also reasonably widespread across the landscape, ranging from *in-situ* horizons in Quaternary / Tertiary sequences to surficial scatters transported from source areas. Calcrete has been related to outcrops of calcareous Corella Formation in other areas (Grimes and Doutch, 1978), but in the investigation area, most of the calcrete is developed as part of the regolith.

The study of landscape evolution has some implications for exploration for hidden metallic mineral deposits, summarised as follows:

> **Williams River Catchment** The portion of the catchment in the Selwyn Range contains little regolith. Most of the regolith developed in this area has been transported on to the plains. On the plains, the catchment comprises two geomorphic units - a flood corridor and the confining interfluves. The likely bedrock geology beneath these units can be inferred by extrapolation of the strike trends of outcropping rocks to the southwest.
>
> The flood corridor contains surficial sands and gravels derived from the Proterozoic bedrock in the upper catchment. Trace elements detected in these deposits represent mechanical dispersion from up-catchment sources. Placer concentrations are possible.
>
> Ghosts of former channels are present on the interfluves but these appear to be substantially older than the modern channels. The interfluves are likely to have remained undisturbed for a considerable time, and may contain hydromorphic dispersion haloes from underlying rocks. These trace elements may be present in regolith components such as calcrete.
>
> **Scrubby Creek Catchment** In the foothills part of the catchment, the regolith is thin and overlies Proterozoic bedrock. Regolith techniques are probably not required in this environment. Stream geochemistry is likely to relate to sources in the Selwyn Range rather than mineral deposits under the Quaternary to Cretaceous cover. On the Wondoola Plain, there is some *in-situ* calcrete exposed by stream erosion of the interfluves. Calcrete has proven potential as a sampling media for trace element geochemistry in gold exploration in South Australia (Lintern and Butt, 1996).
>
> **Fullarton River Catchment** There is no substantial regolith cover in the upper catchment, making it suitable for traditional geochemical approaches such as stream sediment sampling.
>
> In the mid catchment where bedrock confined valleys are present, there is some accumulation of alluvial deposits as shallow valley floor fill. These deposits have sources in the upstream catchment and reflect the mineralogy of those areas. The unconsolidated deposits lie directly on Proterozoic bedrock and it is uncertain whether there has been sufficient time for hydromorphic dispersion to develop recognisable geochemical haloes from underlying sources.
>
> In the lower catchment, stream sediments reflect upstream sources. The interfluves adjoining Fullarton River may be older than those to the south, but are thin and overlie Cretaceous deposits which in turn overlie Proterozoic bedrock. There is little prospect for the regolith to contain geochemical haloes from underlying Proterozoic bedrock.
>
> **Southern Braided Stream Catchments** These catchments comprise shallow alluvial deposits in flood corridors and interfluves concealing Cretaceous bedrock. The sediments moving across the land surface at present are derived from the upper catchment where remnants of regolith partly conceal the Proterozoic bedrock. Although the interfluves are older and more stable than the sediments in the creeks, they too were deposited under fluvial conditions in which erosion in the Selwyn Range was the main sediment source. Hence the transported sediment cover overlying barren Cretaceous rocks does not provide an encouraging setting for regolith techniques of mineral exploration.

Overall, the interfluves may be more stable in the long term than the channels, so in general may be a better prospect for developing geochemical haloes. Thick *in-situ* regolith over Proterozoic bedrock is likely to contain the best indicators of mineral deposits, but this occurrence is not common.

6.2 Distinguishing transported, *in-situ*, and lag deposits

In areas where *in-situ* regolith may be expected - such as in the upper catchments overlying bedrock - there is generally very little present, and what is there is comparatively young. The main indicators of *in-situ* regolith are a matrix supported fabric, angular fragments, poor sorting and no horizontal or sub-horizontal gravel or sand layers. Preserved bedrock structures in the regolith are also useful indicators of *in-situ* regolith.

In fluvial deposits, weak cementing and iron staining of lower horizons indicates little reworking of these sections in the Holocene. These deposits are likely to develop where there is a long return period for streams moving sideways across valley floors.

The main lag deposits in the region are the thin layers of gravel and sand found on the interfluves and even in the braided stream corridors. These deposits have a patchy distribution and are generally only a single layer of sand or gravel in thickness. Slow erosion on the interfluves by surface wash would be sufficient to develop these deposits. The surface scatters in some braided channels indicates that the flood flows are capable of transporting gravel sized fragments. These are deposited during waning flood periods, and are likely to be far from their original site of formation.

7. COMPARISON - EASTERN AND WESTERN MARGINS OF THE MT ISA INLIER

Several neighbouring catchments to the northwest of Mt Isa on the Kennedy Gap 1:100 000 sheet have also been investigated to gain insights into Quaternary history and regolith development (Jones, 1997). The Kennedy Gap and Maronan study areas provide opportunities for comparison.

The sites are on opposite sides of the Mt Isa Inlier. The Maronan area in the southeast lies on the coastal side of the drainage divide where catchment erosion is more dynamic than on the side draining into the centre of Australia. To the northwest of Mt Isa, the drainage divide passes through the Kennedy Gap area where contrasting catchments exist on either side. Here, the northward flowing streams - Gidya and Judenan Creeks - exhibit more erosional activity than the inland-flowing streams of the area. In both areas, the cover deposits are fluvial sediments subject to episodic transport. This works against the development of geochemical haloes from underlying deposits, as the frequency of disturbance is sufficient to disperse any developing geochemical anomalies.

At Kennedy Gap, the bedrock ridges are commonly capped by silcrete. Iron rich bedrock horizons are capped by ferricrete, in places forming mesas. In the Maronan area, duricrusts are not developed on the ridges and rises, and the only mesas are those where remnants of the Gilbert River Formation cap the Proterozoic bedrock ridges. Nevertheless, ironstone gravels are reasonably common across the land surface in the Maronan area. These are partly silicified and partly ferruginised, nodular, and in some areas pisolitic. Rather than forming duricrust horizons as in the Western Succession, the iron and silica mobilisation has formed nodules which have experienced several episodes of exposure and burial, and associated development of desert varnish. Some of these may have been supplied from erosion of the duricrusts associated with the Aurukun Surface, remnants of which are still present in parts of the Cloncurry River catchment on the west side of the Selwyn Range (Ryburn et al, 1988).

In the Maronan area, there is almost no development of the cemented layers at the base of the unconsolidated fluvial sequence as there is at Kennedy Gap. This suggests that the overturning of the fluvial deposits has been more effective in the eastern area than at Kennedy Gap. The cemented fluvial deposits are chiefly associated with the inland flowing streams at Kennedy Gap, and similar streams are not present in the Maronan area.

8. CONCLUSIONS

The McKinlay-Eloise area has a thin surface cover of inferred Tertiary/Quaternary regolith, most of which is transported from sources in the west. The prospects for finding geochemical haloes from hidden ore deposits are doubtful. Below the regolith on the plains, the Cretaceous deposits overlie the potentially mineralised Proterozoic rocks, forming a further barrier to the development of geochemical haloes in the surficial deposits. However, the Cretaceous sequence is in direct contact with the Proterozoic metamorphic rocks, so there is a possibility that some upward geochemical dispersion may have taken place. The Cretaceous deposits could be sampled to investigate whether any haloes can be detected. This would best be done initially at a known deposit such as Eloise.

The Cloncurry Plain consists of eroding, shallow, *in-situ* regolith. The Wondoola Plain consists of fluvial sediments in transit, and older interfluve fluvial deposits, transported from the Selwyn Range and deposited on the plains some time ago. The time of deposition was probably during the Pleistocene or possibly even earlier.

The limited thickness of Cainozoic deposits on the Wondoola Plain indicates a fine balance between accretion and erosion over the long term. Only minor changes in catchment sediment yield, episodicity of flooding or severity of flooding would be needed for the area to switch from an accretionary phase to an erosional one, or the reverse. Under present conditions, the Wondoola Plain appears to be slightly erosional.

Depressions in the top of the Cretaceous sequence are expected to contain fluvial gravels, but for the remainder the cover is thin and composed mainly of poorly sorted fluvial deposits. The upper surface of the exposed Cretaceous deposits is erosional. The rocks are shedding gravels into the modern drainage channels and contribute a substantial proportion of the bed load at places such as Longford on Fullarton River. However in most areas, the main suppliers of the stream sediments are the Proterozoic rocks of the Selwyn Range. The quartz, feldspar and mica from pegmatites and quartz veins in the Proterozoic bedrock are relatively resistant to breakdown in the fluvial transport environment. These components are identifiable in the stream bed even as far north as where the Fullarton River crosses the Flinders Highway west of Julia Creek.

The main difficulties in applying geochemical approaches directly to northwest Queensland arise from the mobility of the regolith cover. Much of the unconsolidated regolith is in transit across the landscape at present (Figure 11). Much of the *in-situ* regolith is in the form of duricrust remnants, commonly at high points on the landscape. Mineral exploration may benefit by investigating the Cretaceous sequences for geochemical haloes sourced from the Proterozoic rocks below.

Distributary	Source of sediment
Williams River	Isa Highlands - regolith on Proterozoic bedrock, minor Gilbert River Formation
Gypsum/Scrubby Creeks	Cloncurry Plain - regolith on Proterozoic bedrock
Fullarton River	Isa Highlands - regolith on Proterozoic bedrock, minor Gilbert River Formation
Coles-Gidya-Boorama Creeks	Cloncurry Plain - regolith on Proterozoic bedrock
McKinlay River	Isa Highlands, Cloncurry Plain - regolith on Proterozoic bedrock, minor Gilbert River Formation
McKinlay River	Julia Plain - reworked Tertiary/Quaternary alluvium

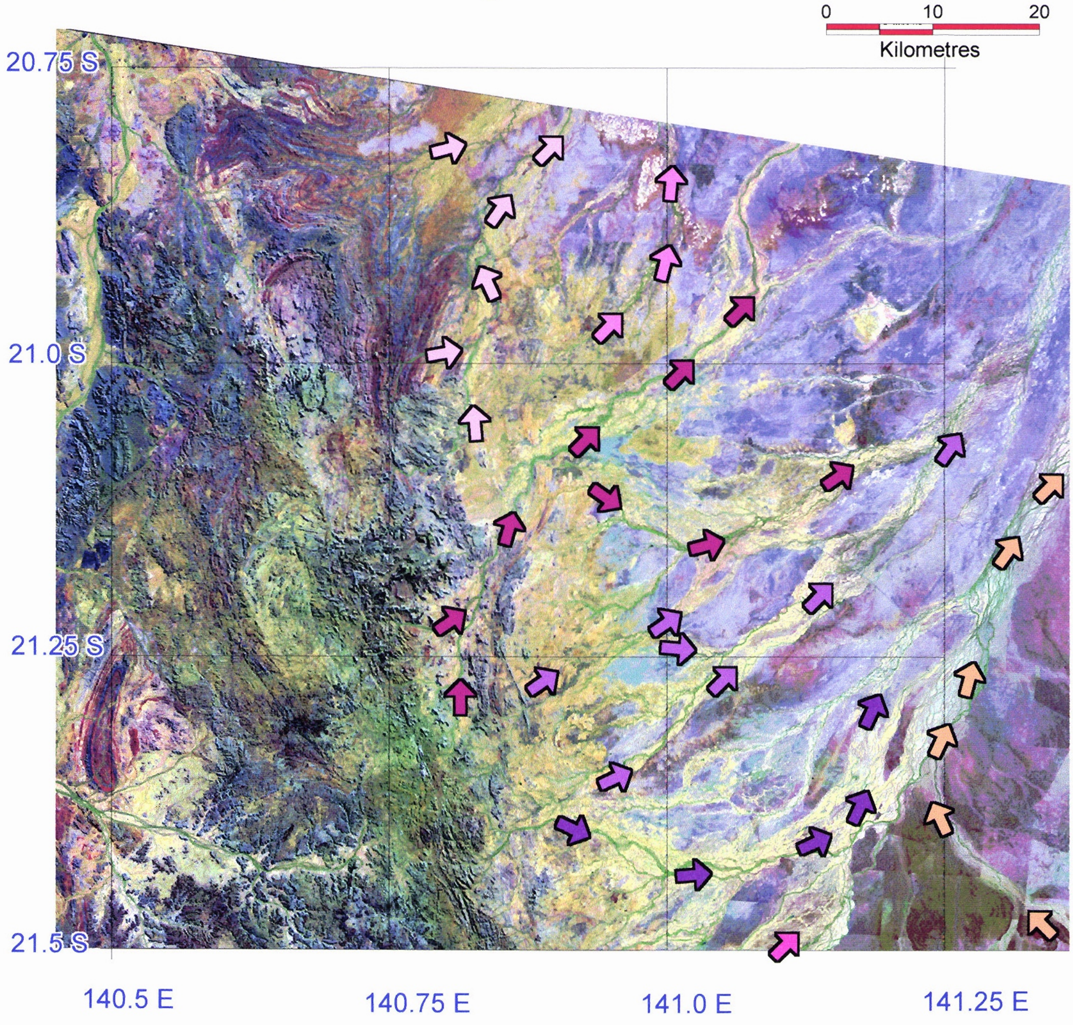

Figure 11: Landsat TM image showing transport of regolith across the landscape during the Quaternary.

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10. APPENDIX 1: EXAMPLE FIELD SITE OBSERVATIONS

Isa Highlands:

Waypoint Number: 1
AMG's (Zone 54): 483425E; 7660362N
Location: Narrow ridge, Selwyn Range, Fullarton River catchment.
TM Pattern: Linear texture of grey, black and light purple.
Description: The site is on the crest of a narrow ridge aligned approximately north-south. The ridge is about 20 m higher than the valley floor nearby. The rock is minimally weathered Proterozoic mica schist with steep eastward-dipping foliations. Quartz is present in veins, and some occurs on the surface as gravel. Garnet crystals are in the metamorphics and some have been released on to the surface. There is no regolith present.

Waypoint Number: 3
AMG's (Zone 54): 480838E; 7659065N
Location: Upper valley of tributary of Fullarton River.
TM Pattern: Linear texture of grey, black and light purple.
Description: The landscape consists of ridges of Proterozoic metamorphics, in places capped by flat lying remnants of Gilbert River Formation sediments. These pale sandstones have erosion scarps around their edges. In the valley, the incised streams have produced a rugged undulating topography with minimal regolith over bedrock. Quartz, mica and feldspar are common in the stream bed sediments, which are predominantly sand and fine gravel. Calcrete nodules up to 50 mm in diameter are present. These nodules are presumed to have formed in the regolith. Their presence in an area where the regolith is now so thin may indicate that erosion of older regolith has occurred.

Waypoint Number: 4
AMG's (Zone 54): 482400E; 7657030N
Location: Upper Fullarton River valley.
TM Pattern: Blotchy texture of olive green, cream, pink.
Description: The flat valley floor consists of orange-red alluvium. On the surface is a veneer of quartzose sand and scattered iron-stained quartz-lithic gravel. A shallow erosion channel is present. Along the edge of the valley nearby, the bedrock slopes steeply down to the valley floor with little development of a colluvial apron. The rate of supply of colluvium is less than the rate of removal by water flow in the valley.

Julia Plain

Waypoint Number: 7
AMG's (Zone 54): 526729E; 7642072N
Location: Julia Plain southwest of McKinlay.
TM Pattern: Light grey, purple.
Description: This is a flat landscape covered with brown to light brown soil composed of cracking clay. Minor fine gravel is scattered across the surface, and includes iron-stained lithic fragments, quartz, iron pisoliths, and haematitic nodules with a siliceous varnish. White mudstone fragments similar to others observed in the upper Fullarton River catchment in the Selwyn Range are present. Stream transport from the ranges is inferred.

Wondoola Plain

Waypoint Number: 51
AMG's (Zone 54): 529114E; 7648290N
Location: Braided channel of the McKinlay River near McKinlay.
TM Pattern: Braided channels are pale green, with the major channel being dark green, reflecting the presence of vegetation. Areas between braided channels are light grey to light blue to white.
Description: The braided channel corridor in this area is approximately 4 km wide. It contains about twelve channels, one of which is a substantial incised channel approximately 20 m wide and 5 m deep. Outcrops of cone-in-cone limestone are exposed in the bank and in the bed. Above the limestone in the eastern bank is 2 m of mottled alluvium and water-laid gravel layers, which is covered by 2 m of brown, unconsolidated fine alluvium. The stream bed deposits are pale orange-brown, coarse sand to fine gravel composed of quartz, feldspar, and mica, and also include iron stained lithics as coarse as 30 mm.

On the surface between the braided channels are iron-stained gravels and pale brown fine alluvium. Many of the gravel fragments have a siliceous varnish. Rounded ferruginous nodules and grapestone are present.

The shallow bedrock indicates that the braided corridor deposits are quite thin. Air photos show that large bedforms with wavelengths of tens of metres are present in the corridor, indicating substantial sediment transport. However the mobile sediment layer is estimated to be only 1-2 m thick. Although erosion of the stream banks is a source of some of the sediments moving downstream, upper catchment sources in the Selwyn Range are also considered to be important.

Waypoint Number: 52
AMG's (Zone 54): 521389E; 7654873N
Location: Interfluve on the Wondoola Plain
TM Pattern: Pale purple, dark blue gradational.
Description: A pale brown cracking-clay soil forms a flat interfluve landscape. Minor ironstone gravel occurs on the surface. Minor surface erosion occurs at present, although this may be related to the use of the land for cattle grazing. This site on the plains is representative of large areas of interfluves that have a similar appearance on the TM image.

Cloncurry Plain

Waypoint Number: 18
AMG's (Zone 54): 488432E; 7644402N
Location: Gentle eastward sloping pediment.
TM Pattern: Grey, olive green, with dark grey linear patterns from shallow bedrock evident.
Description: Incised channels flowing to the east are separated by rolling interfluves where Proterozoic bedrock has a shallow cover of regolith. A trench excavated to 1-1.5 m shows that the regolith is mainly less than 0.5 m thick over mica schist. The bedrock is quite fresh at shallow depth. Variations in the bedrock composition are reflected in variations in the thickness of the orange-red regolith. The regolith is *in-situ*, and demonstrates that the Proterozoic metamorphics are a source of the iron colouring the associated soils.

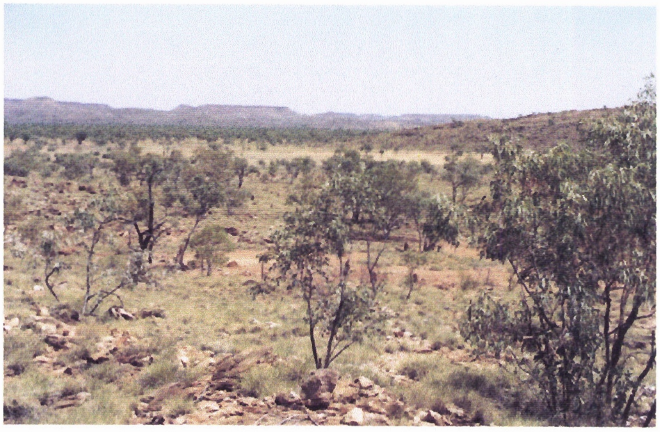
Waypoint Number: 17
AMG's (Zone 54): 489136E; 7636414N
Location: Incised channel of Gidya Creek
TM Pattern: Blotchy cream and olive green; stream associated vegetation shows as a linear green pattern.
Description: The channel is up to 25 m wide and 2.5 m deep. Channel bed sediments include 30-40 mm gravels composed of quartz, quartz-mica intergrowths, quartz-feldspar, quartz-tourmaline, and metamorphic rock fragments. Exposed in the bank is 1.7 m of weakly consolidated to unconsolidated orange-red alluvium, overlying weakly cemented and mottled alluvial gravels. Some calcrete is present in the mottled zone. The TM image shows that this area contains bedrock at shallow depth. However the stream exposure shows that there is at least 2.5 m of alluvium present. There is no evidence of significant *in-situ* regolith overlying Proterozoic bedrock. The differences in compaction and mottling of the alluvium in the bank indicate at least two phases of accumulation.

Waypoint Number: 40
AMG's (Zone 54): 486843E; 7672612N
Location: Crest of low rise
TM Pattern: Olive green and cream
Description: Narrow outcrops of mica schist are oriented north-south. Elongate quartz outcrops are parallel to the metamorphic outcrops. Abundant mica is present on the surface of the orange-red soil. This site confirms that there is minimal regolith cover over bedrock in the foothills of the Selwyn Range.

11. APPENDIX 2 - PHOTOS:

Isa Highlands - Proterozoic bedrock ridges capped with Jurassic-Cretaceous sandstone; orange-red alluvium on flat valley floor of upper Fullarton River (Site 6).

Isa Highlands - Proterozoic bedrock ridges and narrow valley of Fullarton River (Site 1).



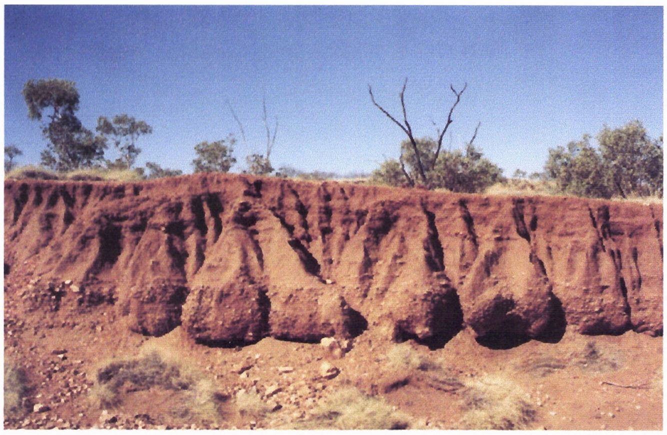
Cloncurry Plain - low bedrock outcrops and thin sediment cover. Isa Highlands in the background with flat ridge-top sandstone of Gilbert River Formation (Site 42).

Wondoola Plain - cracking clay soils on a flat landscape (Site 52).

Cloncurry Plain - trench shows in-situ soils (orange-red) less than 1 m thick over mica schist (Site 18).

Cloncurry Plain - surficial gravel of quartz, iron-rich nodules and lithic fragments (Site 61).

Surficial dark brown alluvium (?Holocene) overlies orange-red alluvium (?Holocene-Pleistocene). Fullarton River (Site 37).



Quaternary sequence over Proterozoic bedrock includes basal channel floor gravels, overlain by alluvium/colluvium. Pauses in accretion marked by thin gravel layers (Site 14).

Fullarton River channel near Maronan is nearly filled with sand and fine gravel. Bedforms are from strong flood flows (Site 35).

Julia Plain - cracking clay soils on a flat landscape; minor surface gravel includes iron-rich nodules (Site 7).

McKinlay River flood corridor contains fine alluvium and surficial iron-rich gravels (Site 51).

Surficial gravel in the McKinlay River flood corridor includes varnished iron-rich nodules, lithic grains, silcrete, and grapestone (Site 51).