MUNDUBBERA 1:250 000 SHEET, QUEENSLAND

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INTRODUCTION

The MUNDUBBERA 1:250 000 map sheet area extends from latitude 25° to 26°S and longitude 150° to 151°30'E, in southeastern Queensland. The region contains a range of landform types, and has a history of successful gold exploration with significant discoveries at Cracow and Eidsvold (Figure 1). The area is also well covered by airborne and satellite datasets suitable for interpreting landforms and regolith.

REGIONAL LANDSCAPE AND DRAINAGE

The Mundubbera region comprises a continental landscape of hills, valleys, plateaux and plains. The climate is subtropical without a distinct dry season, although most rain falls during the summer. The average annual rainfall is about 670 mm (Bureau of Meteorology, 2000). Stream erosion has been a major factor in the evolution of the landscape and has produced incised topography over much of the area.

The region includes two major drainage networks; the Dawson River with its system of westward and northward tributaries in the west, and the Burnett River with its system of southward and eastward tributaries in the east (Figure 1). The drainage divide between the two drainage networks runs approximately north–south, with the Dawson River draining the western third of the region, and the Burnett draining the eastern two thirds of the region. The drainage divide is principally at 400–450 m above sea level (ASL). The valley floors in the east are at about 150–250 m ASL, whereas in the west they are at about 200–250 m ASL. The landscape attains its lowest elevation (~150 m ASL) on the Burnett River east of Mundubbera. The maximum elevation is 568 m ASL at Mt Mungungal in the north–central part of the region (Figure 1). Hence the elevation range within MUNDUBBERA is about 400 m, although most of the landscape lies between 200 and 400 m.

BEDROCK GEOLOGY

The bedrock geology (Whitaker *et al*., 1975) comprises a series of north-trending zones (Figure 2). Progressing from east to west, these are as follows:

- Steeply dipping Devonian to Carboniferous rocks in the east of the region are related to a former subduction zone and forearc basin. Also in this area are a number of Permian to Triassic intrusions and several Tertiary basalt flows.
- Immediately to the west is a narrow zone of Jurassic sediments (Mulgildie Basin in the north; Surat Basin in the south).
- Permian to Triassic intrusive rocks of the Rawbelle Batholith dominate the central part of the region. The batholith comprises granite, granodiorite, adamellite and gabbro. The Eidsvold Complex also forms part of the Rawbelle Batholith, and is the host for gold mined in the Eidsvold area.
- Carboniferous intrusions fringe the Rawbelle Batholith in the west. These comprise granodiorite and adamellite.
- Upper Carboniferous and Permian volcanic rocks occur west of the Carboniferous intrusions, and also along the eastern

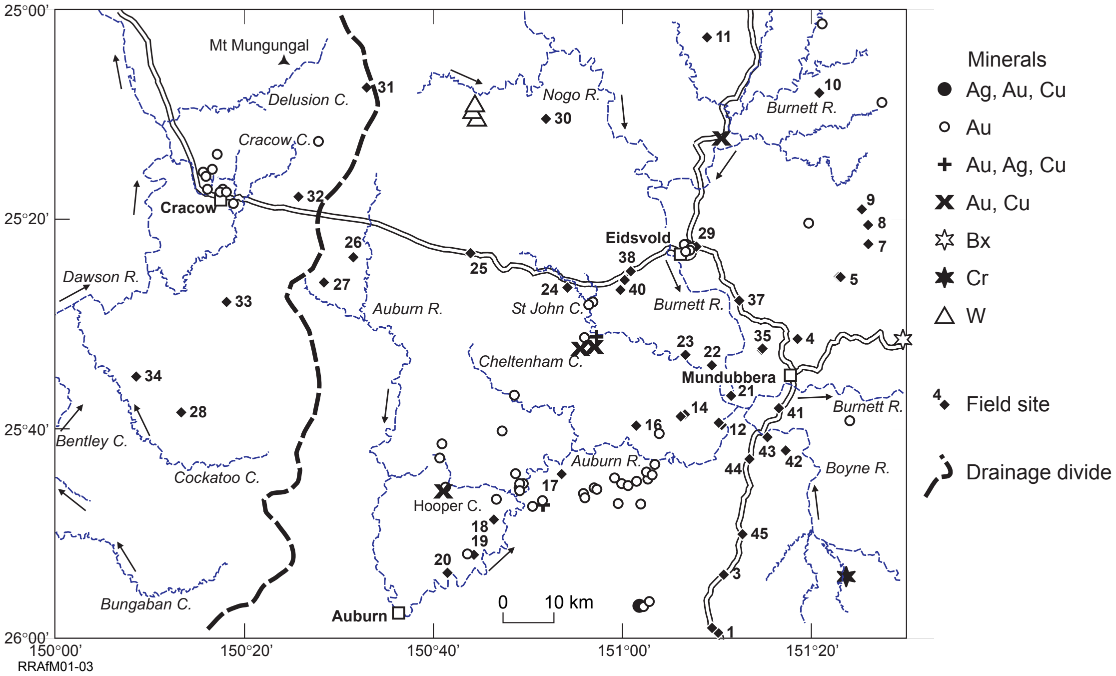

Figure 1. Roads, towns, drainage, mineralisation, and field sites. Dashed line marks drainage divide and arrows show drainage direction.

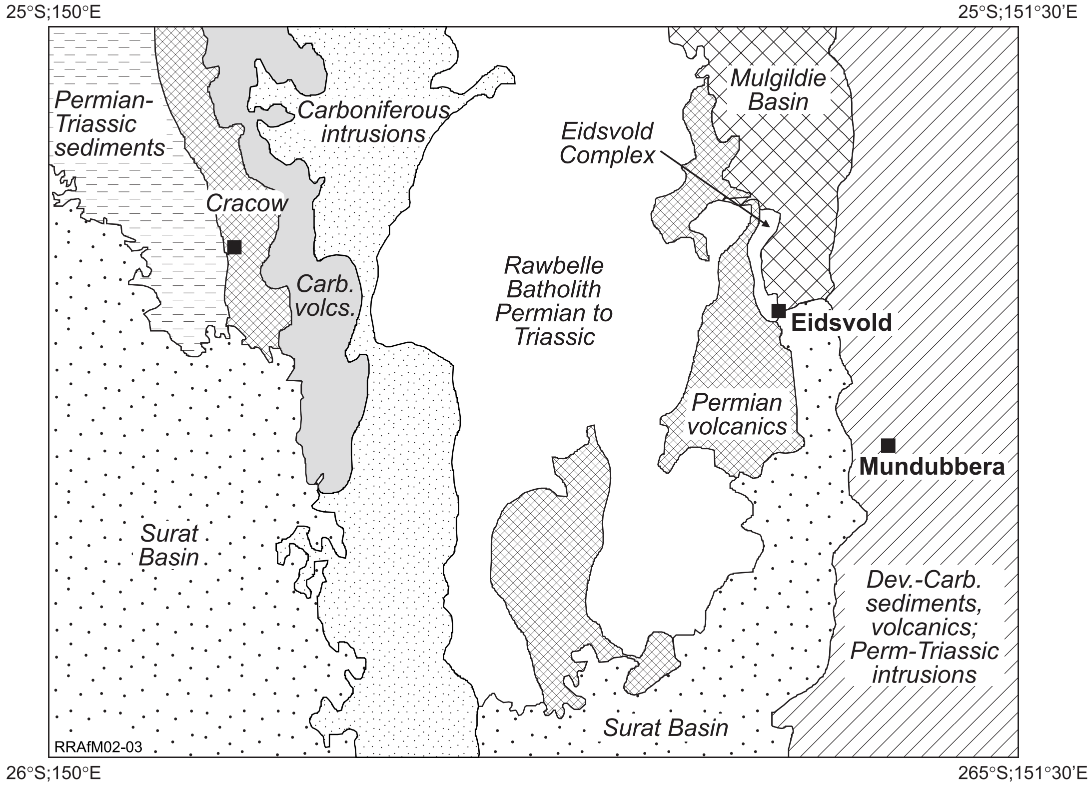

Figure 2. Major structural elements and simplified geology, MUNDUBBERA 1:250 000 sheet. (modified after Whitaker *et al*., 1975)

margin of the Rawbelle Batholith, near Eidsvold. In the west they comprise the Camboon Volcanics (Bowen Basin), which host the Cracow gold deposits.

- Lower to Middle Jurassic sediments of the Surat Basin are exposed in the western and southwestern parts of the MUNDUBBERA sheet area. These rocks dip very gently to the southwest and include the Precipice Sandstone at the base of the sequence, overlain firstly by the Evergreen Formation, then the Hutton Sandstone, and then the Injune Creek Group.
- Westerly dipping sedimentary rocks of the Bowen Basin are present in the northwest of the region. These comprise the Permian Back Creek Group (mudstone, sandstone, limestone), and the Lower Triassic Rewan Formation (sandstone and finer grained rocks).
- Overlying the Permian to Triassic intrusive rocks in the centre of the region is an extensive but thin Cenozoic sandstone with a variably preserved ferruginous cap. An erosional scarp commonly marks the perimeter of the Cenozoic sandstone thereby forming the "Central Plateau", and a pediment of mottled saprolite extends from its base. To the east of the Central Plateau are numerous knolls and mesas of sandstone resulting from incomplete erosion of a formerly more extensive sand sheet.

LANDFORMS

There are virtually no landforms in the MUNDUBBERA sheet area with a relief of more than 300 m, the value of which is used to distinguish between hills and mountains (Pain *et al*., 1991).

Landforms can be placed in one of three categories: erosional, depositional and residual (Anand *et al*., 1989, 1993). These categories arise from a generic landform model which views the landscape as a dynamic system involving:

- Regolith production by weathering; during this process, the landform may be slightly erosional.
- Regolith transport by erosional processes; weathering of bedrock may continue during erosion.
- Regolith deposition, commonly by streams; deposition may be either short-term or long-term, and weathering may continue to affect these deposits.

Over time, these three processes affect all of the landscape, and over long time periods, repetition of the evolutionary processes leads to cycles of landform development. Various intermediate landforms are produced as the landscape evolves:

- Incomplete erosion may produce residual landforms. For example, as the erosion scarp along the eastern margin of the Central Plateau (Figures 3 and 4) moved westwards, parts of the plateau were not completely removed and these now remain as plateau remnants.
- Multi-stage transport of regolith may produce short-term accumulations of deposits 'in transit' to depositional areas, such as the alluvial plains of the Dawson and Burnett rivers.
- Deposition may bury older landforms, such as buried regolith surfaces in alluvium 30 km northeast of Mundubbera (Figure 1, site 8).
- Erosion may re-expose former landforms, such as the

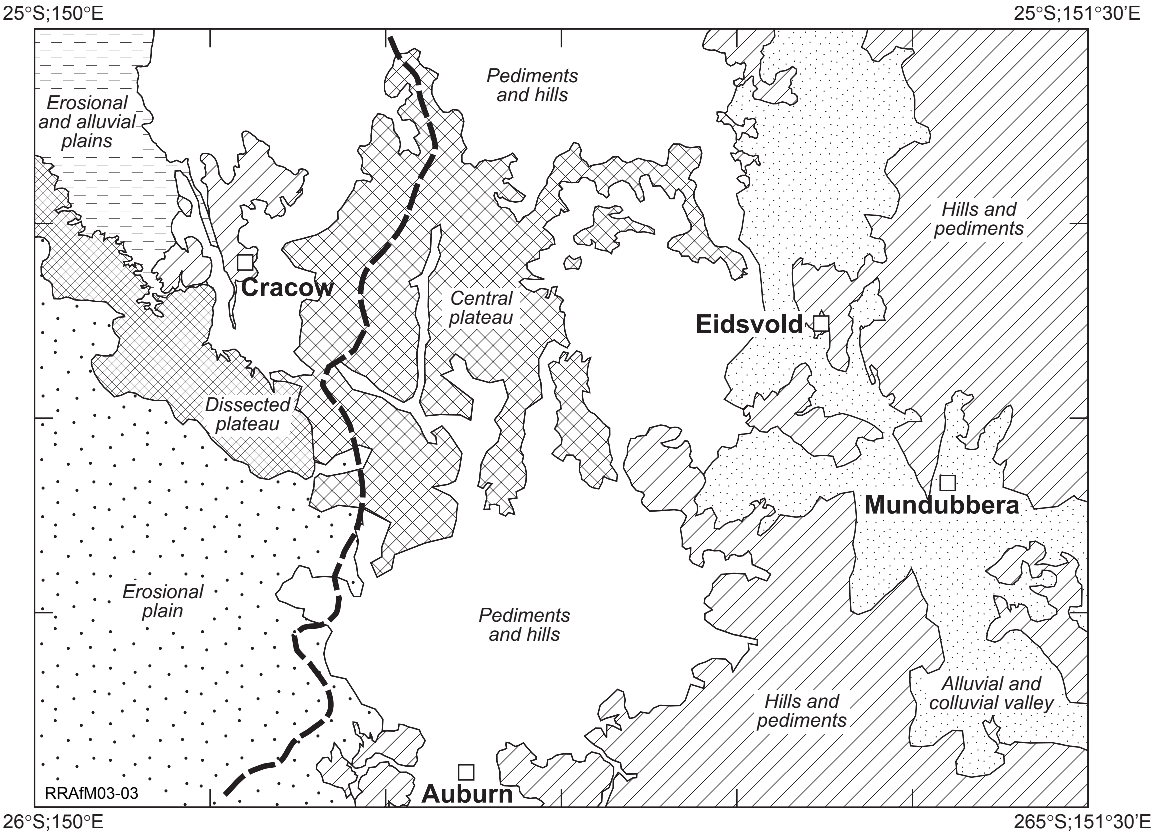

Figure 3. Generalised landforms on the MUNDUBBERA 1:250 000 sheet. Dashed line marks drainage divide.

ferricrete breakaway west–southwest of Mundubbera (Figure 1, site 17).

The balance between weathering and erosion (rate of regolith production versus rate of regolith removal) is an important influence on landform development. Rapid erosion, for example, may prevent the preservation of ferricrete horizons, whereas in other areas, these horizons may form mesas and breakaways.

The main landform types in the Mundubbera region are hills, low hills, pediments, plateaux and plains (Figure 3). The hills include the most elevated areas, are poorly accessible, and retain their original vegetation. Low hills typically have a relief of less than 100 m, and in the southwest of the region low hills form isolated high areas on a subdued landscape. Pediments are primarily the less steeply sloping areas between the hills and the plains or valley floors. In these areas, bedrock is commonly at or near the surface. The pediment landscape may be undulating and weakly to moderately dissected.

Plateaux are generally high areas with flat to undulating surfaces, and have a perimeter escarpment along at least part of their margins. Typically, the amount of stream incision into plateau surfaces is minimal. Isolated plateau remnants (mesas) are also present, particularly in the eastern half of MUNDUBBERA.

The plains are generally flat or weakly incised surfaces in low parts of the landscape. They may be erosional, as in the southwestern part of the region where sedimentary rocks of the Surat Basin are at or near the land surface. Depositional plains are

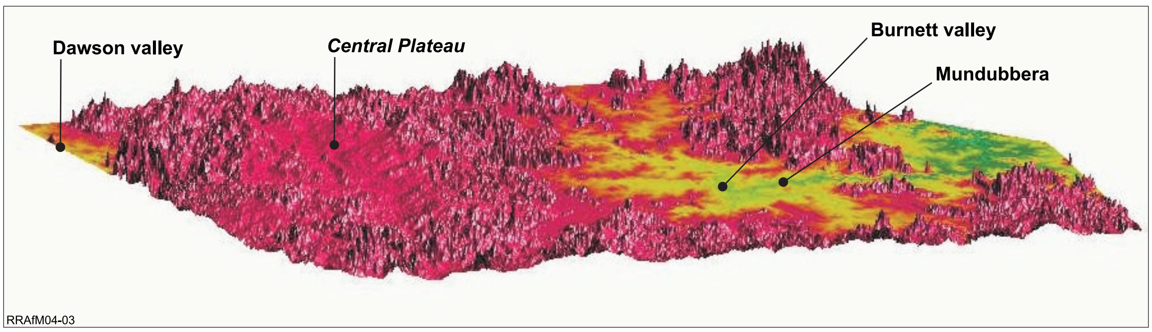

Figure 4. 3D view of the Mundubbera region from the southwest. The distance across the foreground is about 130 km. The *Central Plateau* slopes gently to the south, and contains the upper Auburn River. The low topography of the *Central Plateau* contrasts with the hills along the northern skyline. The Burnett Valley commences in the north and extends south and then east onto the MARYBOROUGH 1:250 000 sheet. Most of the valley floor is a pediment with thin regolith. (Data from Department of Natural Resources & Mines Airdata.)

of limited extent and largely confined to the alluvial plains along the Dawson and Burnett rivers (Figure 4).

REGOLITH

The MUNDUBBERA map sheet area is predominantly an erosional region. In many areas, the regolith consists of thin stony soils on bedrock (Figure 1, sites 25, 28, 29, 35). In granitic areas of the Rawbelle Batholith, thin colluvium partially conceals fresh bedrock to form a landscape of hills and pediments with isolated boulders and whalebacks. In other areas, colluvium directly overlies fresh or slightly weathered bedrock at shallow depth (Figure 1, sites 42, 45). Ferruginous regolith profiles only a few metres deep are common. These profiles are typically rich in iron oxides and hydroxides at the top, grading downwards into a zone of iron-rich and iron-poor mottles, which overlies a pallid zone grading to saprolite, saprock, and fresh bedrock at depth.

Truncated regolith profiles are common as a result of differential erosion in the region. Surficial ironstone lag gravels result from the erosion of ferruginous profiles. The gravels comprise goethitic and hematitic pisoliths and nodules, which typically overlie ferruginous mottled zones and pallid zones just below the surface (Figure 1, site 18, 22; Figure 5).

The thickest regolith profiles are found in unconsolidated and semi-consolidated alluvial deposits close to major streams, such as the Burnett River (Figure 1, sites 12, 21). Exposures of as much as 10–20 m of sand and mud, and lesser gravel, represent several phases of channel bed and overbank deposition (Figure 1, Site 38). Ferruginous staining of the older examples of these deposits is common (Figure 1, Site 43). Several thin weathered sequences of alluvium and colluvium are also present in some stream valleys (Figure 1, Site 8).

Distinctive iron-stained regolith has developed on the Tertiary basalts on the Gurgeena and Binjour plateaux about 15 km northeast of Mundubbera (Figure 1, Site 5). Ferruginous and bauxitic duricrusts are found in these areas (Whitaker *et al*., 1975) and ferruginous soils have been dispersed onto low areas of the plateau.

Ferruginous regolith components

Ferruginous components of the regolith in the Mundubbera region include:

- Pisoliths; these are generally hematitic, but also have goethitic cutans. The pisoliths occur *in situ* within iron-rich areas of the mottled zone, as exposed in a road cutting between Mundubbera and Eidsvold (Figure 6). Pisolitic lag gravels are also common.
- Slabs and sheets of ferricrete; these are only of patchy extent and commonly 0.5–1.0 m thick. Ferricrete slabs occur at or near the surface, overlying the mottled and pallid zones. They also occur within the pallid zone (Figure 5), suggesting that water percolation may be important in their formation.
- Ferruginous nodules; these are generally hematitic, but also have goethitic cutans. The cutans are probably related to the secondary chemical transport of iron, and its deposition on older regolith components. Ferruginous nodules are also released by erosion of the upper ferruginous zones and the underlying mottled zones in the regolith. The mottled zones vary from broadly yellow- and orange-stained regolith to intensely weathered regolith in which black to dark red ferruginous masses are separated by areas of white kaolinitic clays.


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Figure 5. Washout at Site 22 (14 km NW of Mundubbera) exposes regolith comprising a thin (<1 m) unconsolidated ferruginous cap overlying a white pallid zone. Ferricrete sheets (foreground) consist of goethite-cemented hematitic pisoliths and nodules. These sheets may extend along fractures into the pallid zone. Bedrock here is mapped as volcanics and sedimentary rocks of the Nogo Beds (Lower Permian) (Whitaker *et al*., 1975).

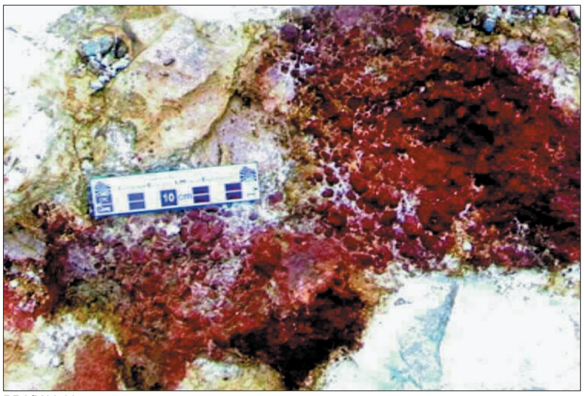
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Figure 6. Ferruginous pisoliths and nodules have developed as part of the mottled zone associated with a palaeochannel at Site 37, 16 km NW of Mundubbera.

Pedogenic carbonate

Pedogenic calcium carbonate is present in the region, and is commonly associated with Holocene alluvium. The calcium carbonate occurs as tubular root casts, vertical sheets, and scattered nodules. Some of the nodules are *in situ*, whereas others have been incorporated into layers of alluvial gravel representing former streambeds. Pedogenic carbonate also occurs as irregular nodules and tubular root casts in saprolite.

Silcrete

Jensen *et al*. (1964) identified silcrete in the Cracow area as being part of a Late Triassic weathering surface exposed by removal of the overlying Jurassic sediments.

Alluvium

In addition to the sediments in the channels and banks of the Burnett and Boyne rivers, alluvium of at least two ages is recognised in their valleys. The younger alluvium is uniformly grey and fine-grained, and occurs as a flood terrace adjacent to the incised river channel. An older iron-stained alluvium is also preserved within the terrace, and is exposed in narrow channels which cross the terrace and extend to the river (Figure 1, Site 43). Preservation of the iron-stained alluvium is due to the river having a limited ability to rework the store of alluvial sediments in its valley. In other areas, channel-fill deposits on alluvial plains are darker coloured (humic rich) than their confining poorly consolidated alluvial deposits (Figure 1, Site 38).

Erosional landforms in the regolith

The main erosional landforms in the regolith are breakaways and mini/micro-towers. Breakaways occur around the edge of ferruginised horizons in the regolith, due to their greater resistance to erosion. The mini- and micro-tower landforms are very localised features caused by differential erosion. The mini-towers occur in the Cenozoic quartzose sandstone (Figure 1, Site 9) where irregular stacks 0.5–1.0 m high are preserved. Micro-towers (<0.3 m high) are formed from erosion of incompletely cemented ferruginous duricrust or mottled zone at Site 31.

Regolith styles

Regolith in the MUNDUBBERA 1:250 000 sheet area occurs in several styles including transported, *in situ*, eroded, and intensely weathered.

Transported regolith occurs as alluvium and colluvium, and can be recognised by:

- the presence of sand and/or gravel layers related to water-borne transport;
- a sharp boundary with underlying bedrock, or with underlying or laterally confining regolith;
- channel-fill morphology; and
- repeated weathering profiles present in a regolith sequence.

In situ regolith can be recognised by:

- a continuous transition from bedrock to saprock to saprolite to regolith mantle in which the bedrock fabric is no longer preserved; and
- regolith containing corestones of the same rock type as the underlying bedrock.

Eroded regolith can be recognised by:

- mini/micro-tower morphology;
- breakaways;
- thin surficial gravel (lag deposits produced by erosion of the iron-rich upper parts of profile); and
- pallid or mottled zones exposed at surface.

Intensely weathered regolith is characterised by:

- a well-developed cemented ferruginous zone;
- mega mottles, possibly indicating Pleistocene or older palaeochannels;
- strong segregation of iron-rich and iron-poor regolith in the mottled zone; and
- a surficial indurated zone which may form a ferricrete up to 1–3 m thick (McNally, 1995).

LANDFORM EVOLUTION

Long-term landform evolution in the Mundubbera region has been dominated by fluvial erosion, which has acted on bedrock substrates of variable resistance. East of the drainage divide, extensive erosion in the Burnett River catchment has produced hills and pediments, which retain only a thin cover of regolith (Figures 3, 4 and 7). West of the drainage divide extensive erosion has also occurred, but the streams are generally fewer and less incised (Figures 4 and 7). The main exception is in the northwest of the region where the Dawson River and other streams have deeply incised the Precipice Sandstone to form the Nathan Gorge, which is flanked by cliffs up to 150 m high.

Incision produces less sediment than widespread landscape lowering, as has occurred on the plains in the southwest of the region. In this part of the Surat Basin, lateral stream migration appears to have been the dominant process of erosion. Most of the eroded regolith has been removed by the drainage system, ensuring that the Surat Basin rocks are at or near the land surface over wide areas.

The area east of the drainage divide appears to have been eroded more rapidly than the area to the west. This is indicated by much denser drainage networks, and more numerous and larger streams in the eastern area. Topographic variation is also more pronounced in the east (Figures 4 and 7). The drainage pattern also indicates that the Auburn River has captured the upper reaches of a southward flowing stream (Figure 1).

The youngest regionally significant depositional rock unit is the Cenozoic sandstone, which occupies an elevation range of about 200 m. On the Central Plateau (Figure 3), the sandstone is chiefly between 400 and 450 m ASL, whereas south of Eidsvold at about 25°30'S, remnants are present at an elevation of around 250 m ASL. These elevation differences equate to slopes of less than 1° across the region, and so suggest a gently sloping landscape at the time of deposition. It appears that the sandstone was draped over a pre-existing landscape of somewhat similar relief to the present one.

The origin of the Cenozoic sandstone is uncertain. However, its widespread extent, gentle slope, and minimal thickness (estimated by Whitaker *et al.* (1975) to be less than 15 m), suggest that it includes both *in situ* and transported components. The *in situ* component was probably formed by weathering of granular basement rocks, such as the granites of the Rawbelle Batholith, whereas the transported component was probably formed by erosion of weathered rocks and transport of the detritus through a network of streams flowing across a low-gradient landscape.

Formation of the Central Plateau occurred largely by perimeter

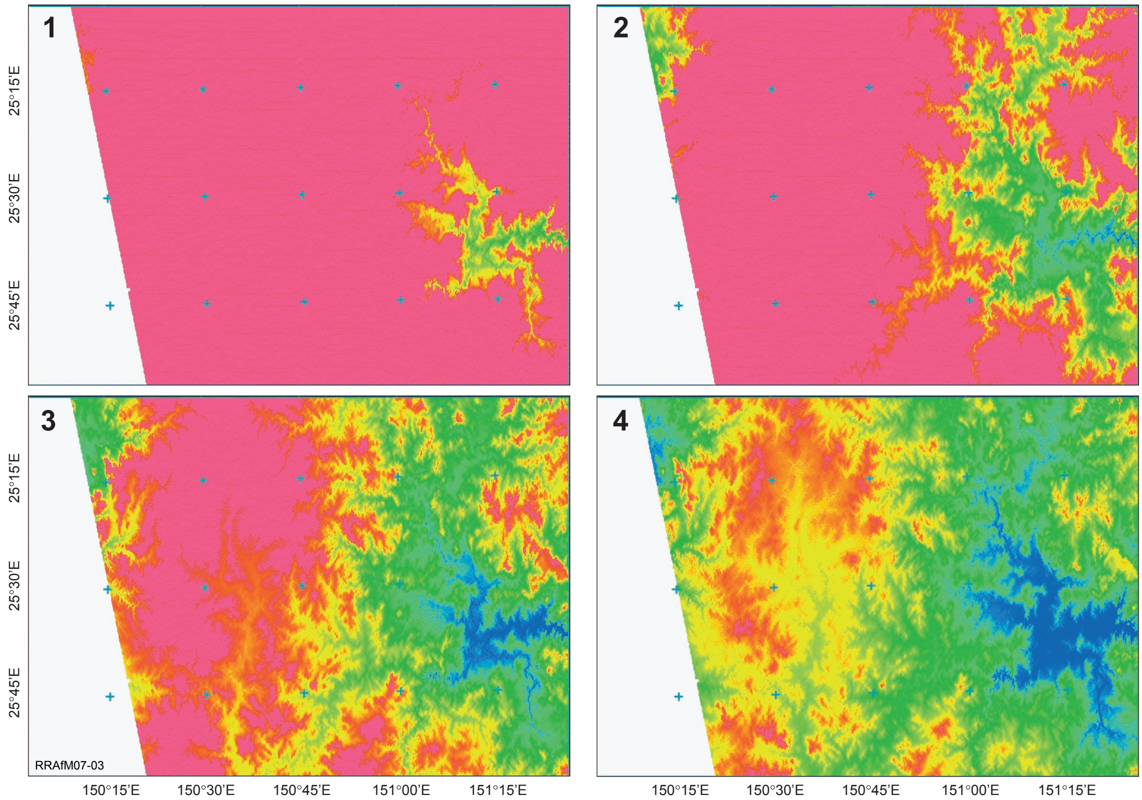

Figure 7. Model of landscape evolution in the Mundubbera district based on elevation data from Department of Natural Resources & Mines airborne surveys (no data along the western margin of the MUNDUBBERA sheet). **1** Following the deposition of an extensive sheet of sandstone in the Cenozoic (dark grey (or red) shaded area), the Burnett catchment commenced development in the east (light grey (or yellow–orange) shaded area). **2** Expansion of the Burnett catchment eroded the Cenozoic sandstone, which retreated westwards by scarp retreat. **3** Aggressive development of the Burnett catchment resulted in erosion of the pre-Cenozoic bedrock in the east and formation of incised valleys (medium grey (or green) shaded area); remnants of Cenozoic sandstone were left as knolls and mesas as the erosional scarp moved westwards; the Auburn River developed an incipient catchment on the Central Plateau and drained southwards; in the northwest, Dawson River tributaries eroded the western margin of the Cenozoic sandstone. **4** The modern landscape features a much reduced area of Cenozoic sandstone, with scarp retreat continuing to be active around its perimeter; drainage southwards by the Auburn River has developed a shallow basin on the Central Plateau; catchments on the western margin have also expanded.

scarp retreat caused by expanding catchments of the incised streams in the east (Figures 4 and 7). The landscape in central and eastern areas was erosional during the late Cenozoic, as indicated by the incised streams and the restricted occurrence or absence of alluvial plains. The streams removed most of the sediment produced by erosion; hence the streams' ability to remove the products of weathering has exceeded the rate of production (by weathering and erosion).

MINERAL OCCURRENCES AND EXPLORATION OPPORTUNITIES

There are 55 gold occurrences marked as prospects or abandoned mines on the MUNDUBBERA 1: 250 000 map sheet (Whitaker *et al*., 1975; Murphy, 1979; Lam, 1998). There are also isolated occurrences of copper, silver, chrome, bauxite and tungsten (Figure 1). In an environment where erosion is a major feature, it may be expected that transported regolith would be a major hindrance to mineral exploration using geochemical sampling. However, erosion within the Mundubbera region has not completely stripped the regolith from many areas. Neither has the eroded regolith been deposited as extensive blankets over the bedrock. Incompletely stripped regolith profiles are present in many places, and these profiles may contain dispersion haloes from concealed mineral deposits. Hence regolith geochemistry is a potentially useful tool for mineral exploration in the region.

The Department of Natural Resources and Mines has acquired airborne geophysical data over about 85% of the MUNDUBBERA sheet area. The potassium distribution highlights the intrusions of the Rawbelle Batholith in the central part of the region, as well as other intrusions in the southeast. Most of the remaining region is low in potassium, although there are numerous small occurrences of high potassium concentration in the southwest (Surat Basin). These may indicate chemical diffusion from rocks beneath the Surat Basin sequence. As the area also has iron oxides concentrated in the regolith, geochemistry using ferruginous regolith components may be a useful technique for mineral exploration.

CONCLUSIONS

The Mundubbera region has a history of successful gold exploration, providing good prospects for new discoveries. Landform and regolith studies can assist new mineral exploration. Potentially prospective areas with a widespread sedimentary cover include the Mulgildie and Surat basins and the Central Plateau. Along marginal areas of the basins, regolith geochemistry may be useful in distinguishing dispersion haloes in the thin sequences concealing prospective bedrock, particularly in the vicinity of Eidsvold. Indications of shallow bedrock beneath the basin deposits are provided by magnetic features and potassium concentrations (Jones, 1999a, b). The widespread occurrence of ferruginous regolith in the region is encouraging for mineral exploration, given the success of geochemical exploration using ferruginous regolith in Western Australia (Anand, 1998).

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