Progress report on regolith mapping on the Mingary 1:100 000 map area

Alistair F Crooks

Report Book 2002/003

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Alistair F. Crooks

Geological Survey Branch
Mineral Resources Group

January 2002

Report Book 2002/003

PRIMARY INDUSTRIES AND RESOURCES SA

MINERALS & ENERGY RESOURCES

Government of South Australia

Office of Minerals and Energy Resources
Primary Industries and Resources South Australia
4th floor, 101 Grenfell Street, Adelaide
GPO Box 1671, Adelaide SA 5001

Phone	National	(08) 8463 3204
	International	+61 8 8463 3204
Fax	National	(08) 8463 3229
	International	+61 8 8463 3229
Email	pirsa.minerals@saugov.sa.gov.au	
Website	www.minerals.pir.sa.gov.au	

Preferred way to cite this publication
Crooks, A.F., 2002. Progress report on regolith mapping on the Mingary 1:100 000 map area. *South Australia. Department of Primary Industries and Resources. Report Book,* 2002/003.

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Alistair F. Crooks

ABSTRACT

Regolith mapping over the Mingary 1:100 000 map area in the northeast of the State is in progress. To date, the Cockburn North, Cockburn South, Mutooroo North, Mutooroo South and Radium Hill South 1:25 000 maps have been completed. A well-developed weathering profile is present on basement rocks. Subsequent erosion has removed the weathered materials from the highest parts of the ranges, which form a major drainage divide, and transported these into the Murray-Darling Basin to the south and the Lake Eyre Basin to the north. Remnants of the old residual land surface are preserved along the northern flank of the ranges. The ability to recognise the residual, erosional and depositional regimes is critical to the design of good geochemical sampling programs as each will affect element dispersion haloes in significant ways.

INTRODUCTION

The Broken Hill Exploration Initiative (BHEI) is a joint program of data acquisition and interpretation by Primary Industry and Resources South Australia (PIRSA), New South Wales Department of Mineral Resources (NSWDMR) and the Australian Geological Survey Organisation (AGSO). The aim of the BHEI is to raise the level of geological knowledge and thereby improve the effectiveness of exploration in the region.

As part of the BHEI in South Australia, Palaeo- and Mesoproterozoic basement rocks of the Mingary 1:100 000 map area, part of the OLARY 1:250 000 map area on the SA–NSW border, are being mapped (Fig. 1). Maps of regolith have also been assembled in the course of mapping these typically poorly exposed and widely scattered basement outcrops. The identification of different regolith regimes was considered important for the design of geochemical sampling programs which could reliably test for anomalous trace elements. Currently, regolith maps of five of the eight 1:25 000 scale (25K) map areas, which comprise the Mingary 1:100 000 map area, are available in draft form as hardcopy of digital output. These are Cockburn North, Cockburn South, Mutooroo North, Mutooroo South and Radium Hill South maps. Additional geomorphic and geophysical data are also being compiled and added to the maps by the authors. The remaining 25K scale maps are currently being compiled.

This report book has been prepared as an accompaniment to the mapping to further explain map unit subdivisions.

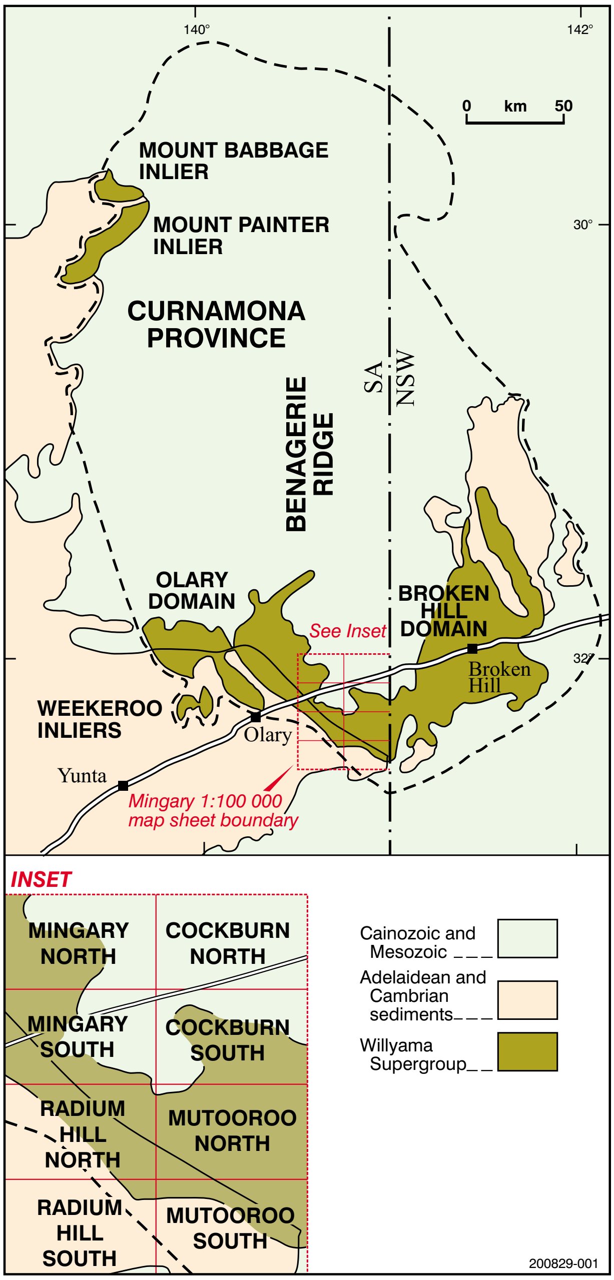

Figure 1 Curnamona Province locality map

The regolith unit boundaries on each of the 25K regolith map series are an amalgamation of the Quaternary subdivision boundaries established by Callen and others, and published on the OLARY 1:250 000 geological map (Forbes, 1989), and recent mapping by the author and P.W. Hill. The style of presentation of these maps also owes some influence to the regolith mapping by Conor (1978) in the northwest of the State.

The subdivisions do not have a strict time stratigraphic significance, many of the boundaries being transitional, and should be interpreted as geomorphic units only.

REGOLITH — GENERAL COMMENTS

Regolith is a general term which collectively includes all weathering products, soils and sedimentary deposits that have accumulated on basement rocks over time. Deep weathering and duricrust development, soil development and transported material all add to the regolith profile. Physical erosion and chemical remobilisation act over time to modify these developing profiles. Regolith formation has been an integral part of geological cycles from the Archaean and has been subjected to the same processes of formation, burial, exhumation and destruction as other rock types. Thus, older rocks have been subjected to earlier regolith-forming events on which later regolith-forming processes act. The modern regolith is therefore a composite, overprinting and modifying past accumulations of regolith materials.

In most geochemical sampling programs, the dominant sampling medium is the regolith. The key to the design of any successful geochemical sampling program is the understanding of the intricate regolith–landform relationships, which control the distribution of targeted elements. Mobilisation and redistribution of metal ions is strongly influenced by processes involved in the formation of regolith. Sampling strategies designed to test for anomalous metal abundances need to take these processes into consideration and require the identification of modern and past sedimentary and hydrological pathways and weathering processes as an aid to interpreting results. In the Curnamona Province, detailed investigations into aspects of metal ion mobilisation has recently been conducted by Swarnecki et al. (2001) in the Olary district and by de Caritat et al. (2000) to the north.

The regolith map differentiates between various landform regimes based on the dominant regolith processes, and shows their distribution. Different sampling strategies are required to accurately test the surface residuum for anomalous trace elements in each of these regimes.

Three major landform regime subdivisions are identified using the scheme recorded by Anand et al. (1993).

Residual regimes exist where there is widespread preservation of relict land surfaces and their associated regolith, notably ancient weathering profiles. The development of a weathering profile results in the partitioning of elements into different parts of the profile at rates dependent on their mobility. Some elements will be enriched in specific horizons while others may be depleted. Certain elements may be removed from the weathering profile altogether. Thus, the process of weathering creates positive and negative geochemical anomalies and dispersion haloes dependent on the geochemical properties of the elements in question, and the weathering environment.

In depositional regimes, the net input of transported material is greater than the rate of erosion. At high rates of input, the influx of externally sourced material may help to preserve older weathering profiles by burial. The development of regolith will be dominated by sedimentation and will result in development of a stratigraphic sequence. At lower rates of input of externally sourced sediment, there may still be dilution and overprinting of any developing dispersion haloes from geochemical anomalies in the underlying basement. Even so, some geochemical sampling techniques may still be able to detect these dispersion haloes from anomalies at depth through up to 100 m of transported cover (Hedger and Dugmore, 2001).

Erosional regimes are those in which all or part of the earlier weathering profile has been removed or substantially reworked, taking key elements with it.

MINGARY REGOLITH

Saprolite development

During the middle Tertiary and perhaps earlier*, the climate of the region was hotter and wetter (Benbow et al., 1995a). This provided conditions for deep weathering of basement and Neoproterozoic rocks in the Mingary area and formation of extensive iron-oxide-rich horizons. A typical regolith profile (Butt, 1981) developed at that time would be (from the base):

- fresh rock
- saprolite with original basement textures preserved
- the saprolite-derived horizon where original textures have been obliterated (the plasmic horizon)
- ferruginous mottled zone (Plate 1)
- ferricrete.

Some silcrete is present in these rock types, either as a result of silicification in areas of groundwater discharge or of pervasive silica cementation due to watertable lowering at the onset of aridity. The deep weathering event and formation of ferricrete and silcrete are the result of a complex history studied by numerous workers, and which has been summarised by Benbow et al. (1995b).

As portrayed in schematic form in Figure 2, the deeply weathered rocks of the ranges extending east–west across the centre of the Mingary 1:100 000 map area formed a more prominent topographic high that separated the Callabonna Sub-basin of the Lake Eyre Basin from the Murray Basin, and which is preserved as the modern, more subdued topographic high of the Barrier Ranges.

Later in the Tertiary, a significant change in base level of the region caused a reactivation of the river systems draining those highlands. During the subsequent erosion event, much of the weathering profile was stripped from the higher parts of the ranges leaving essentially fresh basement. These areas of fresh basement represent the erosional regimes discussed above.

The ferricrete–saprolite weathering profile is preserved in outcrop along the northern margin of the ranges where erosion of the profiles is incomplete.

* Separate periods of iron mobilisation in the Middle Miocene, the latest Cretaceous to Early Paleocene, and Jurassic are inferred from the Cobar region of NSW (McQueen et al., 2001).

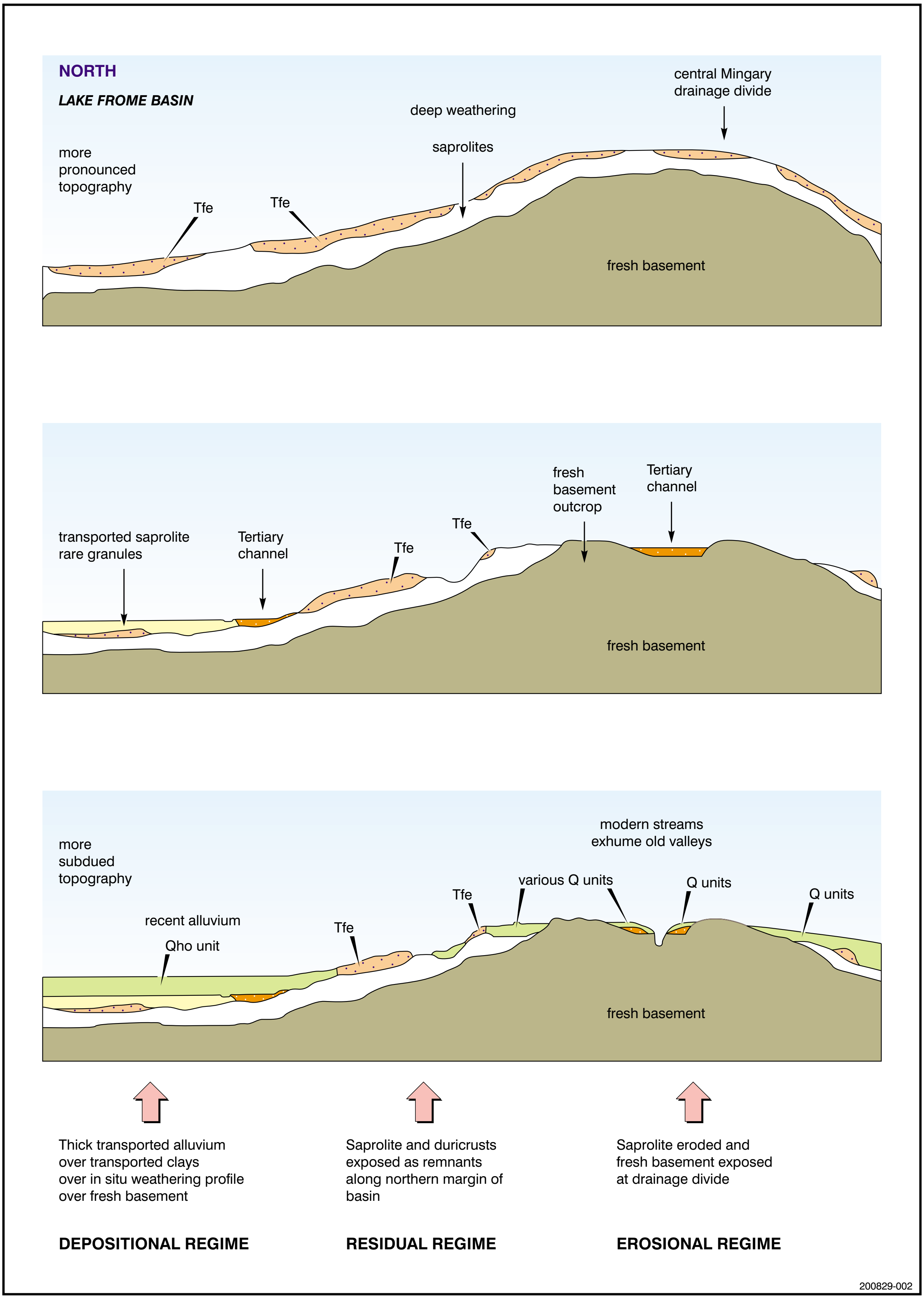

Figure 2 Evolution of the regional regolith zones over time

Plate 1 Mottled zone of weathering profile in Willyama Supergroup rocks. From quarry on Barrier Highway near the turn off to 'Tepco'. (photo 047737)

On the 1:25 000 regolith maps, an attempt has been made to illustrate the degree of saprolitic alteration and duricrust development in the zones where these basement and Neoproterozoic rocks are exposed. Rocks influenced by the Olarian Orogeny are labelled '**W**', while younger rocks postdating the Olarian Orogeny, but which have been folded by the Delamerian Orogeny, are labelled '**N**'. Some intrusives of intermediate or indeterminate age, which fall outside these classifications, have not been differentiated but are grouped under the classification of the rock-types they intrude.

The degree of saprolite development on these rocks has been indicated with a colour grading and a subscript ranging from 1 to 3. Thus, deeply weathered saprolitic rocks of category 3 could be strictly categorised as part of the plasmic horizon. These weathering categories are also modified with an overprint — blue for iron and red for silica — to indicate the degree to which ferruginisation or silicification has been imposed on the profile.

Tertiary sedimentation

Tertiary sediments of the reactivated river systems are commonly preserved in the map area. A lack of carbonaceous material, however, precludes precise biostratigraphic dating. The sediments are generally cross-bedded, coarse to fine, well-rounded to angular, siliceous grits. Kaolinite, transported and deposited from eroding saprolite zones, is also common (Plate 2). The latter clay sediments frequently contain rounded quartz clasts and occasional silcrete granules.

Plate 2 Well-rounded grit grains in transported kaolin from saprolite zone, south of Hartford Dam. (photo 047735)

The Tertiary sediments can be silicified and/or ferruginised, confirming the continuation of weathering during the erosional and depositional events.

Since the sediments occupy topographically low positions within modern valley systems, it can be concluded that the modern rivers occupy, and are exhuming, pre-existing Tertiary river valleys. The coincidence of these modern and Tertiary river systems suggests that the modern basement high through Pinery Hill, which marks the current watershed between the Murray and Lake Eyre Basins, was the site of the earlier Tertiary drainage divide as well.

The Tertiary fluvial sediments are generally exposed as terraces in the modern river valleys (Plate 3), with fresh basement exposed in the base of the channels. This suggests that erosion of the saprolite through the higher parts of the ranges was extensive during Tertiary times while sedimentation was thin and local, and largely confined to the valleys.

Away from the highest parts of the topography, there has been incomplete erosion of the relict land surface and its associated weathering profile. Here, Tertiary ferricrete and silcrete duricrusts have acted as hard pans to preserve parts of this old land surface. These remnants range from the preservation of the complete weathering profile to that of only the lower saprolitic zone (Plate 1). This geographic zone, along the northern face of the ranges, represents the preserved remnants of a residual regime.

Plate 3 Tertiary sediments (white outcrop) exhumed in a modern channel south of Hartford Dam. (photo 047736)

Further to the north of the Mingary 1:100 000 map area is a major region of the depositional regime. Drainage from the northern side of the topographic highs around Pinery Hill was, and still is, to the north. Here, in situ basement weathering profiles have been buried beneath transported kaolin eroded from the exposed saprolite zone in the highlands to the south.

Tertiary clastic sediments are also frequently encountered in dams and bores. It is possible that the upwards coarsening sequence reported by de Caritat et al. (2000) is a result of a change in the available source rocks, with a change from the erosion of kaolinitic–saprolitic weathering products to fresher basement rocks as they became progressively exposed. The Tertiary rivers lead into the network of palaeochannels to the north on CURNAMONA, some of which contain commercial concentrations of uranium leached and transported from the basement highlands (Curtis et al., 1995; Reif, 2000). The potential for both eluvial and alluvial gold has also been noted (Teale, 2001).

Modern sediments are still accumulating in this depositional zone. The palaeochannels themselves have been infilled by subsequent influxes of (transported) sediment.

?Pleistocene channel deposits — Qpa

Near 'Mutooroo' homestead and south of Radium Hill, modern stream valleys also preserve channel deposits that may be intermediate in age between the Tertiary and the modern channel deposits. On the surface they form broad terraces within modern creek systems, with a scattering of exotic cobbles on the surface. Rare sections expose well-rounded, lithic cobble conglomerates cemented by calcrete and gypsum. These have been differentiated on the regolith maps by the label **Qpa**.

Younger quaternary regolith mapping units

On the Mingary map, modern soil and alluvium has been subdivided into five regolith units.

Qhs is aeolian dune sand and is therefore the quintessential transported regolith unit with multiple recycling of the surficial material possible. This unit is not widespread in the region.

Qha, water transported alluvial gravel of the modern river systems, is more widespread. In the higher parts of the drainage divide, these river systems traverse fresh, outcropping basement and so offer the potential for traditional stream sediment sampling techniques to test for anomalous metals.

Qho represents more widespread sediments of the alluvial fans and river flats. A significant component of these sediments may have been transported some distances so dilution may be significant. These thicker, carbonate-poor soils of the **Qho** regolith unit appear to favour the growth of saltbush (*Atriplex* spp.).

Qht occupies the sloping margins and, in places, the tops of the rises. This unit consists of reddish brown clay soils and fan deposits with patterned ground (gilgai) and 'crab holes', and a characteristic armour of angular milky quartz. Although some down-slope movement for this regolith material may have occurred, it may still represent a potential sampling medium for local basement, as this **Qht** unit is generally fairly thin.

Qhi is restricted to the tops of hills adjacent to basement outcrop and is considered to be locally derived. The minerals from the parent bedrock, that are more resistant to weathering (garnet, staurolite, kyanite, hornblende, magnetite, corundum), are locally well represented in the adjacent soils and therefore indicate only limited transportation and dispersion. This unit is generally thin and has a high potential as a sampling medium for fresh basement.

The **Qhi** unit also contains significant earthy carbonate, developing into platy and nodular calcrete. Basement clasts within the soils commonly have calcrete rinds. The presence of the carbonate in the soil profile favours the growth of bluebush (*Maireana* spp.) and this plant can generally be used to indicate in situ soil development.

These regolith units grade transitionally into one another.

RECENT DEVELOPMENTS

In very recent times there has been a significant change in the flow regimes of the modern creek systems. The regular discovery of fencing wire and bottles buried by up to a metre of alluvium and exposed in the walls of deep erosion gutters are evidence of massive local soil movement and active erosion and deposition. This most recent round of channel reactivation is demonstrated along the SA–NSW border fence where the original dog-proof fence has required re-routing following the formation of a 2 m deep erosion gully. These gullies cut back into the existing soil profiles of each of the **Qhi**, **Qho**, **Qht** and **Qha** units.

Where these gutters debouch from the hills, sediment has been locally deposited at the break of slope as alluvial fans. This fan material can choke the broader, older stream valley and in turn is subjected to deep gully erosion. In some gullies, a thick sequence of red-brown alluvium, without a well-developed carbonate profile, is often seen overlying alluvium with an earthy calcrete profile. This could be related, at least in part, to these modern soil movements, with the very recent sediment burying an older **Qho** profile.

CONCLUSIONS

Mingary is a regolith-dominated area with evidence of extensive Tertiary–Quaternary residual, erosional and depositional regimes. The evolution of the drainage divide between the Murray and Lake Eyre Basins can be inferred from the development and erosion of the regolith during this time.

The variation in regolith and landform style needs to be factored into the planning of any exploration program and interpretation of results. Regolith maps over part of the Mingary 1:100 000 map area are now available in preliminary digital or hardcopy format. These will assist in the design of geochemical sampling programs that need to be tailored to the specific regolith regimes.

APPENDIX

REGOLITH LEGEND

Quaternary soil units

Qhs	Modern aeolian quartz sand spreads and dunes. Vegetated. Characterised by native pine (*Callitris columellaris?*) and *Acacia carnei*. Sand usually red or pale yellow.
Qhl	Modern deposits in claypans. Characterised by samphire vegetation. Grades into **Qho**.
Qha	Alluvial sand to coarse lithic gravel of Recent watercourses. Includes modern reworking due to local changes in water runoff.
Qho	Reddish clay–sand soil, non-calcareous at the surface but with mottled earthy carbonate at depth. May contain well-rounded gravel horizons with calcrete rinds on individual clasts. Generally transported alluvial material, characterised by salt bush (*Atriplex* spp.).
Qht	Reddish brown clay soils and fan deposits with patterned ground (gilgai) and 'crab holes' with characteristic armour of angular milky quartz. Commonly lacks shrubs and trees. Basement outcrop is common, particularly of resistant lithologies, but soils may have been transported down slope by mass movement.
Qhi	Reddish clay soils with earthy, nodular or laminated calcrete common. Generally considered to be a soil developed in situ on local basement topographic highs. Float rock-types and grit component (e.g. feldspar, garnet, kyanite, staurolite, hornblende) frequently reflect underlying basement lithologies but preferentially preserve most durable minerals. Characterised by blue bush (*Maireana* spp.) spreads. Grades into Qho and Qht.
Qpa	Poorly vegetated terraces, banks and flats, usually associated with modern river systems but incised by them. Commonly has surface scree of well-rounded exotic cobbles. In rare cases, incision exposes a cross-section of these terraces showing calcrete-cemented, and rarely gypsum-cemented, cobblebeds and ?cross-bedded sandstone. Suggests that older river channel deposits are being incised by modern rivers, rather like the Tertiary channels are today. Shown in part on OLARY 1:250 000 map as Qca. So far these have only been seen in the south near Radium Hill and east of 'Mutooroo' homestead on the northern margin of the Murray Basin.

Tertiary

T	Transported Tertiary sediments including sand and grit, cross-bedded grit, transported kaolinite, and kaolinite with granules. Grit clasts can be well rounded to angular. Largely unaffected by silicification or ferruginisation.
Tfe/T	Ferruginous profile developed in Tertiary sediments.
Tsi/T	Siliceous profile developed in Tertiary sediments.
Tfe	Ferricrete profile of Tertiary age developed on undetermined substrate.
Tsi	Silcrete profile of Tertiary age developed on undetermined substrate.

Tsi-Tfe Silicified and ferruginised profile developed on undetermined substrate.

Basement units

fe Overprint indicates that unit has ferruginous weathering profile.

si Overprint indicates that unit has siliceous weathering profile.

N Neoproterozoic sediments folded by the Delamerian Orogeny. Includes some Delamerian intrusive rocks.

N_1 Fresh outcropping Neoproterozoic sediments.

N_2 Weathered outcropping Neoproterozoic sediments — original lithology still recognisable.

N_3 Deep saprolitic alteration of Neoproterozoic sedimentary rocks — original lithologies totally erased.

W Willyama Supergroup and associated rocks. Largely Palaeoproterozoic to Mesoproterozoic basement rocks affected by the Olarian Orogeny. Includes younger intrusive dykes where they intrude pre-Neoproterozoic rocks.

W_1 Fresh outcropping Willyama Supergroup rocks.

W_2 Weathered outcropping Willyama Supergroup rocks — original lithology still recognisable.

W_3 Deep saprolitic alteration of Willyama Supergroup rocks — original lithologies totally erased.

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